Chignecto Isthmus Climate Change Adaptation Comprehensive Engineering and Feasibility Study – Final Report

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1.0 Study Overview

1.1 Introduction

The Chignecto (can mean "great marsh district" or "drainage place" in Mi'kmaq) Isthmus refers to the land that physically connects the provinces of New Brunswick and Nova Scotia. This narrow land bridge is approximately 21-kilometres (kms) wide and separates the waters of the Bay of Fundy from those of the Northumberland Strait (**Figure 1.1**).

Critical transportation and utility infrastructure crossing the Chignecto Isthmus is primarily protected from the high energy Bay of Fundy tides by historic earthen dykes originating in the 1600s. The isthmus landscape is dominated by private lands including numerous land trusts, conservation organizations, and rights holders, agriculture, and forestry.

Figure 1.1 Chignecto Isthmus Location
Source: Canadian Press, 2019

The combination of effects by climate change such as sea-level-rise, and increased intensity of weather events and land subsidence are increasing the risk that the important transportation infrastructure crossing the Isthmus could be compromised resulting in significant negative socio-economic impacts to the Atlantic Provinces and the rest of Canada. Situated in the Upper Bay of Fundy, the exposure of transportation infrastructure within the study Area to the tidal and climatic conditions leaves the Chignecto Isthmus particularly vulnerable to climatic change impacts given the Isthmus is only slightly above sea level. Currently, there are areas of the Isthmus that are protected by these existing earthen dykes, without which, the Isthmus would be inundated by existing sea levels.

This combination of climate induced sea level rise and coastal subsidence is forecasted to threaten most coastal infrastructure in Atlantic Canada before the year 2100. The Chignecto Isthmus dykes are at risk and so is the infrastructure they protect. The New Brunswick Department of Transportation Infrastructure (NBDTI) and Nova Scotia Transportation Infrastructure Renewal (NSTIR) have worked together with Transport Canada to identify the need to complete a comprehensive engineering and feasibility study to identify potential solutions/options for the protection of the Trade Corridor located within the Isthmus. Members of multiple government agencies, representing both provinces have formed a Project Steering Committee (PSC).

While there have been various studies on the impacts of climate change and rising sea levels, previously, there had been no engineering analysis or feasibility assessment of potential options to provide protection to the Chignecto Isthmus and the existing transportation network along with its infrastructure system/components. At the request of the PSC, this study focuses on the critical infrastructure located within the Sackville (New Brunswick)-Amherst (Nova Scotia) Trade Corridor.

Within the study area (**Figure 1.2**), approximately 35 kms of dykes (shown in red) protect the transportation and utility infrastructure (shown in yellow and in white – colors used throughout the Report). The value-generating assets in the Trade Corridor include the TransCanada Highway, CN Rail, 138 kV and 345 kV electricity transmission lines, fibre optical cables, a wind farm, agricultural cropland activities, and various other utilities.

Figure 1.2 Study Infrastructure Components

The estimated value of goods and merchandise transported through the corridor as well as revenues generated by in-corridor economic activity is estimated at approximately $35 billion per annum. This does not include the monetization of local government services, infrastructure, and lands. The monetization for individual assets cannot be divulged publicly as the information was obtained subject to non-disclosure agreements and confidentiality agreements with the participants of the current study.

1.2 Study Goal

Wood was commissioned to complete a Comprehensive Engineering and Feasibility study to identify three (3) viable options to protect and sustain the Trade Corridor as defined above. An elevation of 10.6 m CGVD2013, (11.2 m CGVD1928) was prescribed by the PSC and adopted for the purpose of this study for the protection from extreme water levels in the estuary. The current dykes and aboiteaux provide protection to approximately 7.5 to 8.5 m CGVD2013. The water level in the estuary is the combined results of tide, storm surge and projected Sea Level Rise (SLR).

To aid in development of protective solutions, a series of steps were undertaken as detailed in subsequent sections. Existing studies and reports were reviewed to identify data gaps and inform the next steps, all required in the process of identifying potential measures to protect critical infrastructure within the study area.

Once the options for protection of the study Area were identified, a set of comparative studies was completed to review the environmental and financial impacts as well as the infrastructure resiliency for each option.

A description of each of the identified options is presented in detail. In addition, the capital and annual operating costs have been estimated for each option, based on information currently available.

Also included in the study are recommendations for further studies or field investigation to better refine any of the uncertainties and estimating accuracy.

While the 10.6 m elevation was used to: 1) Develop preliminary options **(Section 5.0)**; 2) complete the option comparison **(Section 6.0);** and 3) prepare the option costing (**Section 10.0**), this protection elevation could be revised during preliminary/ detailed design, should the level of protection change, and the resulting design and costing of the options may then require further review.

1.3 Statement of Work (SoW)

During the proposal stage for this study, the Study Team developed a project methodology in response to the Request for Proposal 0670007-20 for Chignecto Isthmus Climate Change Adaptation Comprehensive Engineering and Feasibility study, (RFP). Further to the review of available background reports and initial gathering of information, the Study Team then developed a Statement of Work (SoW) to assist in outlining the study goal and reviewed with the PSC to align on the objectives. The overall study approach and Work Breakdown Structure (WBS) is presented in **Figure 1.3**. Following approval by the PSC, the study Team put forward a plan to execute the work. This study is structured to present and include a description of each Task in detail, while a summary of each section is outlined below in **Table 1.1**.

The work breakdown structure was first developed during the Proposal/RFP stage and modified slightly following the Study Team's review of available information. Since the onset of the study, the overall work breakdown structure has only been revised once and resubmitted to the PSC with updates to the project management plan.

Table 1.1 Summary of Tasks in the Work Breakdown Structure

Task	Overview
Task 1: Gather and Organize Key Documents	Presents the document review process and document review register, detailing the information that has been collected and circulated to the Study Team's respective disciplines for this study. The document review register is included in **Appendix A**.
Task 2: Prepare Project Management Plan	Outlines the processes and controls that are in place to see that each task, milestone, request, activity, etc. are well defined in advance of execution with enough budget allocated to complete.
Task 3: Develop Preliminary Options	Describes the process undertaken and considerations in developing the options for protection that would be further examined throughout the Study.
Task 4: Rights Holders & Stakeholder Engagement	Included consultation and communication plan development throughout the Study and the development of the options.
Task 5: Legislative & Regulatory Framework	Identifies requirement for both access and permitting in conjunction with field work and other investigative studies.
Task 6: Archaeological Assessment Initiation	Identified as a requirement within the RFP and was completed for all three of the selected options.

Task	Overview
Task 7: Option Comparison (Pairwise)	Describes the criteria that were developed in conjunction with the Project Steering Committee to evaluate the preliminary proposed options.
Task 8: Field Program	Developed to collect additional information for each of the three proposed options following the option comparison.
Task 9: Option Refinement	Describes the advancement of each of the selected options following the completion of the field program and geotechnical investigation.
Tasks 10, 11, and 12: Comparative Studies	Studies that compare potential environmental and financial outcomes an infrastructure resiliency risk review among the options. Comparative studies will be presented as a single chapter.
Tasks 13, 14, and 15: Report Preparation	Includes iterations of the drafts and final report submission as well as client presentation.

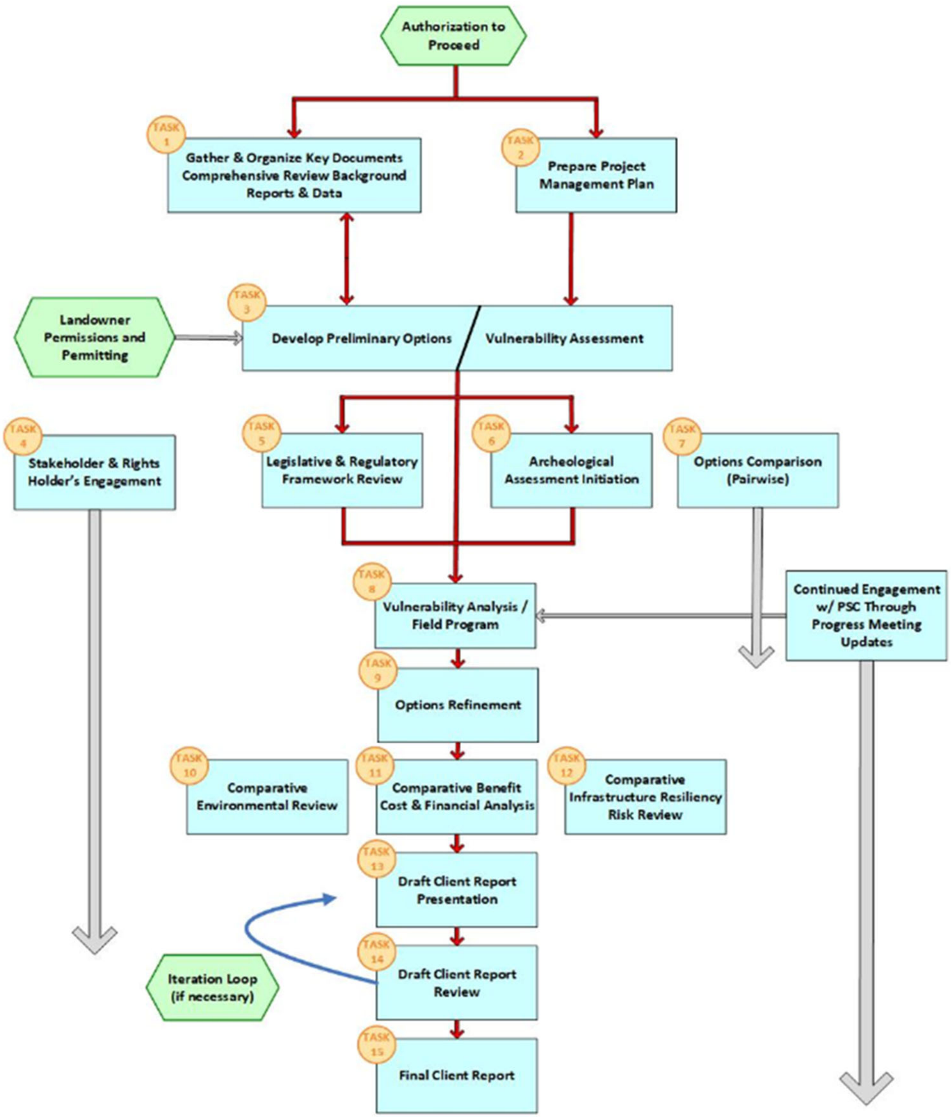


Figure 1.3 Work Breakdown Structure

1.4 COVID-19

Near the middle of March 2020, it became evident that State of Emergency implemented by the provinces of New Brunswick and Nova Scotia, and many of the protective measures put in place by health officials to mitigate the spread of COVID-19 would likely affect the execution of the study. The COVID-19 pandemic is a wide-ranging phenomenon which impacted the ability to complete field work (restricted movement), stakeholder engagement (no collective gatherings), and communications (transfer of information). The study team developed numerous COVID-19 related policies and guidelines, aligned with those of federal and provincial governments. In addition, the Project Specific Health and Safety Plan was updated to include consideration of COVID-19.

It is anticipated that COVID-19 could also impact the delivery of a final presentation in person with the PSC, and as such, accommodations will be made to host the meeting virtually to optimize the delivery of the presentation and the interaction between the Study Team with PSC members.

2.0 Gather and Organize Key Documents for Comprehensive Review

2.1 Purpose

The purpose of the Document Review was to identify and collect relevant documents and investigative engineering information currently available for the study area. The Document Review assisted the Study Team to ensure that valuable information relevant to the Transportation Corridor was maximized in developing options and thereby potentially reducing the need for additional investigative efforts.

2.2 General Approach

The focus of the Document Review was to identify, collect and compile factual documents, drawings and reports to assist with assessing key elements and related conditions within the study area ahead of developing the PMP, SoW and performing the Infrastructure Vulnerability Assessment. There is substantial information available regarding Climate Change and the impact on Chignecto Isthmus and the Transportation Corridor. Meanwhile, information on the existing infrastructure within the study area, was less readily available, therefore required a separate effort to collect, compile and review.

To begin the Document Review, the information related to the study that was identified in *Project Background Information* Section 6.2 of the RFP for the study was used to create the DRR, referenced above. The DRR is an excel spreadsheet organized like a catalogue that includes a brief description of the document as well as the file location, document type (i.e., published journal, as-built drawing, borehole log, etc.), source, and the relevant engineering/technical discipline. The catalog permits for expedited sorting or searching of the information available to the Study Team members. The DRR (**Appendix A**) contains 114 records that provide access to approximately 600 separate documents collected and reviewed for this study.

Sources for information were identified in consultation with the PSC and Discipline Leads and through the Technical Briefing presentation(s) that occurred on March 5th and 11th, 2020 – subsequently, requests for information were made through the Wood Project Manager and the PSC. Items identified and requested included, but were not limited to as-built drawings, inspection reports (dykes, bridges, etc.), property and topographic surveys, photographs, geotechnical logs and investigative information.

In addition, a thorough search of the information available in the public domain of the websites for the provinces of New Brunswick and Nova Scotia was carried out using specific key words and phrases relevant to the study area and scope of the study. The information/data returned through requests or queries was checked for relevance and completeness prior to being added to the DRR by the Project Document Controller or PM Assistant. This provided reliable, ongoing, and efficient control of documents, as well as facilitated distribution of new information to the relevant Discipline Lead(s)s and their respective teams to assist in the development of the PMP.

3.0 Project Management Plan

3.1 Introduction

The Project Management Plan (PMP) document is organized in accordance with the content of *Part B – Work Requirements/Expected Deliverables of Section 6.3* of the RFP for this study. The PMP is one of several documents detailing the management processes the Study Team had in place to ensure successful execution of the SoW. The PMP summarizes the actions and processes the Study Team has followed as the work was carried out, and outlines the methodology used to monitor, measure, and adjust the flow of work as appropriate during the progress of the work.

3.2 General Approach

Following the initial review of available background reports and data, the Study Team developed a PMP, affirming the components listed in the RFP section, although presented in a slightly different sequence, in reflection of our planned approach to carrying out the SoW.

The PMP document has been submitted separately to the PSC throughout the course of this study and has not been appended to this report given the size of the document. At the time of this report the latest version of the PMP is Revision 2, dated January 8th, 2021 which includes a detailed list of the changes noted in the document since its' initiation.

4.0 Stakeholder & Rights Holder's Engagement

4.1 Introduction

In compliance with the RFP, as part of the PMP, the Study Team prepared a Communication Plan, a Rights Holders Consultation and Engagement Plan, and a Stakeholder Management Plan. The Study Team also developed a list of contact coordinates for First Nations, Rights Holders, landowners, organizations, stakeholders, and individuals. A high-level analysis was conducted to:

- Identify parties that are dependent on the trade corridor for their economic well-being, or who may be socially or economically impacted by changes in the bio-physical environment within the study area. It is anticipated that this list will evolve as new stakeholders come to the fore while existing stakeholders may discontinue their interest.
- Analyze relevance, perspective, issues and concerns.
- Map positions and dynamics to determine the level at which they should be consulted.
- Prioritize whom to engage, and why.

All activities were conducted in compliance with the New Brunswick *Right to Information and Protection of Privacy Act* (RTIPPA) and the Nova Scotia *Freedom of Information and Protection of Privacy Act* (FOIPPA).

All communication activities were conducted in strict compliance with COVID-19 guidelines, health and safety and risk management protocols.

4.2 Communication Plan

The Communication Plan (Wood, 2021) describes the formal internal communication protocol to ensure the Study Team is informed of work plan status, issues, and risks. The Communication Plan identifies planned and typical methods of exchanging information between the PSC and the Study Team, internally within the Study Team as well as with media and other interested parties. The Communication Plan documents the tools and methods required to ensure timely and appropriate generation, collection, dissemination, storage, and ultimate disposition of study information. The Communication Plan was aimed at assisting the implementation of the study and was not intended to supersede current Province of New Brunswick, Province of Nova Scotia, NBDTI or NSTIR policies related to communications protocol, public affairs, government services, or community relations.

4.3 Rights Holders Consultation and Engagement

The objective of the Rights Holders Consultation and Engagement Plan (Wood, 2021) was to inform Indigenous people, who may have Aboriginal or treaty rights or interests that may be affected by the study as well as facilitate the exchange of information that may be pertinent to the study. Meetings and correspondence were conducted with the leadership of the Indigenous communities, or through delegated Tribal Councils and organizations.

The Study Team ensured Rights Holders were meaningfully engaged in planning, development, and delivery of study activities. NBDTI and NSTIR established open and transparent communications with Rights Holders relative to the study progression. Contact was initiated and continued over the course of the study in accordance with guidance from the New Brunswick Aboriginal Affairs Secretariat (NBAAS), and the Nova Scotia Office of Aboriginal Affairs (NSOAA).

To that end, correspondence and virtual meetings were convened over the period July 2018 to March 2021 with the following groups / individuals:

- New Brunswick First Nation (FN) Chiefs - Eel Ground FN, Eel River Bar FN, Pabineau FN, Esgenoopetjtj FN, Elsipogtog FN, Bouctouche FN, Indian Island FN, Metepenagiag Mi'kmaq Nation, Amlamgog FN.
- Mi'gmawe'l Tplu'taqnn Inc. (MTI) and Kopit Lodge.
- Sipekne'katik First Nation Chief.
- Stephen Gray, Consultation Advisor Aboriginal Affairs Secretariat.

Communication activities consisted primarily of virtual meetings, emails and written correspondence between NBDTI and NSTIR and Rights Holders as related to the development of viable options to protect and sustain the Chignecto Isthmus Trade Corridor. Updates were also provided on the progress of field activities such as:

- Archaeological investigations completed in compliance with regulatory requirements although at the desktop research level with non-intrusive visual field surveys. Numerous email exchanges and discussions with MTI KMKNO took place regarding fieldwork plans and reports from prior work that might inform current study work, timing and location of fieldwork, research sources and details of ongoing research, a commitment to sharing results once investigations are complete, as well as options to retain MikMa technicians. The investigations concluded that no Indigenous archaeological resources were identified.
- Geotechnical Investigations, completed in compliance with permitting requirements, to confirm the soil characterization and condition at selected drilling sites.

4.4 Stakeholder Engagement

Wood developed a Stakeholder Management Plan (Wood, 2021) to: identify stakeholder concerns and explore solutions that focus on meeting the objectives of managing expectations; understand issues and concerns as these arise; build relationships; and facilitate the exchange of information that may be pertinent to the study. The Stakeholder Management Plan describes the means to build a positive relationship with all stakeholders and deploy multiple consultation tools to ensure effective and fulsome participation by all stakeholders.

Over the course of the study there has been ongoing communication with stakeholders, non-government organizations, local governments, and landowners. These activities have included:

- Information meetings convened in Sackville, New Brunswick on March 5th and March 11th, 2019;
- Requests for information from the Town of Sackville, Town of Amherst, Municipality of the County of Cumberland, Parish of Sackville, and the Southeast Regional Service Commission-Tantramar District;
- Virtual meetings and information exchanges with utilities within the study area;
- Virtual meetings and information exchanges with CN Rail;
- Requests for permission to access properties for archeological and geotechnical investigations; and
- Ongoing correspondence with organizations such as Ducks Unlimited, EOS Eco-Energy Inc., Nature Conservancy of Canada in Nova Scotia, Ecology Action Centre, Conservation Council of New Brunswick, Nova Scotia Nature Trust, and the Nature Trust of New Brunswick.

The main themes resulting from the stakeholder meetings include the following:

- There is strong support for, and interest in, the study as well as an appetite for detailed and technical information.
- There is a desire to discuss potential solutions.
- There is a desire for enhanced engagement / consultation.
- The development of the options should consider specific issues such as *Species at Risk Act*, (SARA), blue carbon, saltmarsh, hurricanes, etc.
- There is a desire for clear communication of assumptions and uncertainties.
- There is concern for protection of the communities not just the trade corridor.
- There is a need to provide justification for the design elevation of 10.6 m CGVD2013.

5.0 Development of Preliminary Options & Vulnerability Assessment

5.1 Introduction

Following the initial assembly and review of the information within the DRR, the Study Team turned their attention towards the development of the preliminary options to provide protection to the Trade Corridor. The objective of this Task was to identify and assess several possible solutions for protecting critical infrastructure identified within the study area (**Figure 5.1**) to the specified elevation, 10.6 m (CGVD 2013).

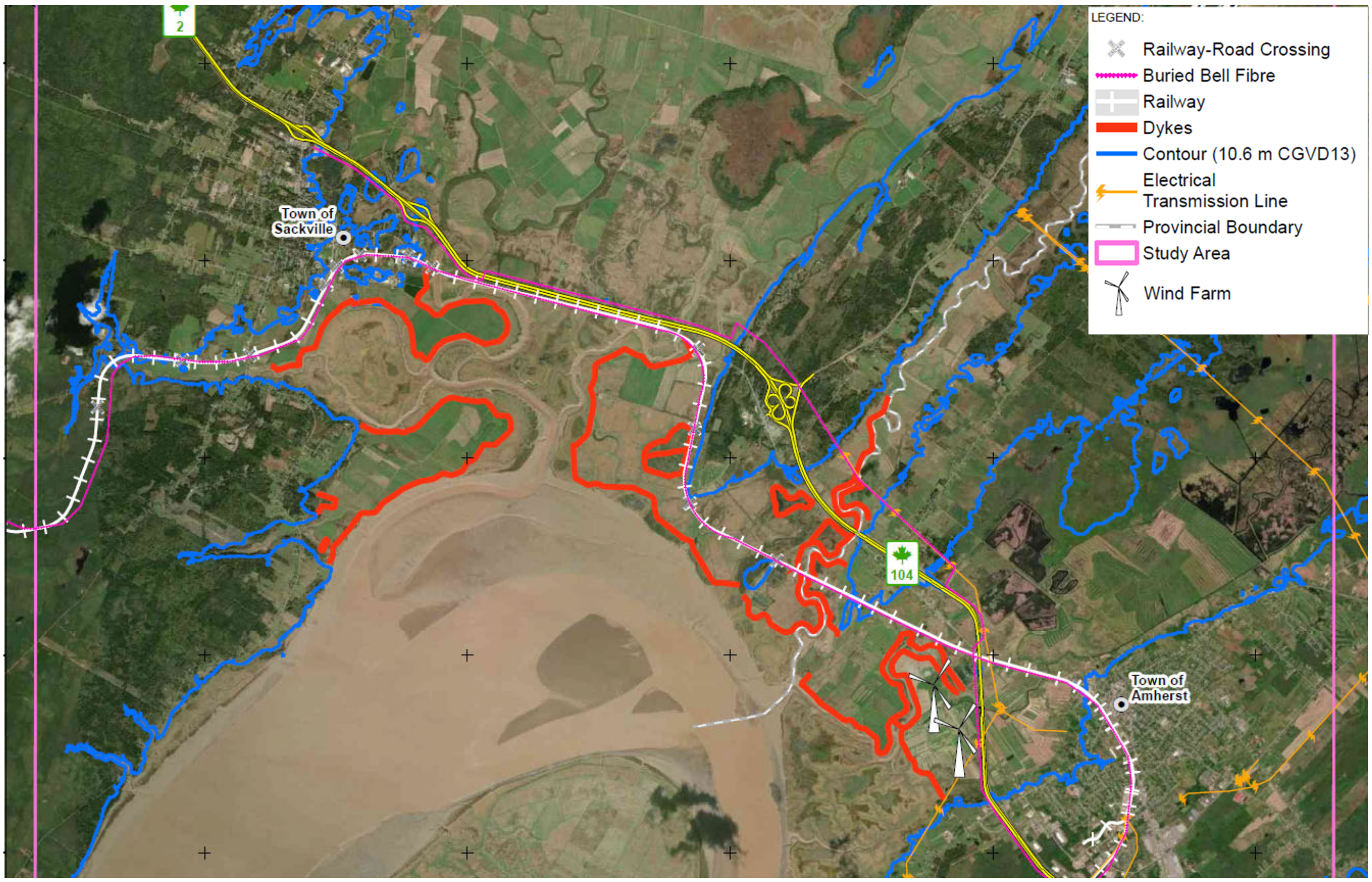


Figure 5.1 Critical Infrastructure for Chignecto Study Area

At this stage, no significant design constraints or limiting factors were imposed for the consideration of the preliminary options, except for the overarching protection of infrastructure to a geodetic elevation of 10.6 m (CGVD2013) high water mark and that the proposed solutions, in part or in whole, must include a dyke/aboiteaux system. As identified in the RFP, a protection elevation of 10.6 m (CGVD2013) or 11.2 m (CGVD1928) has been adopted for the purpose of this study for the protection of the Trade Corridor from sea level rise or other climate change factors within the general isthmus region. It is understood that this level of protection represents the combined results of tide, storm surge and projected Sea Level Rise (SLR). Throughout the report and associated figures, the geodetic reference is inferred to be CGVD2013, unless otherwise stated. Similarly, the design level of protection of a given option is inferred to be 10.6 m to complete the option comparison and refinement and the comparative studies, as referenced in the SoW provided in **Section 1.3**.

5.2 Development of Options

The main objective of this Task was to develop preliminary options for the protection of the Trade Corridor up to the specified elevation of protection. Initially, the study area and overall project footprint was first divided into three distinct project segments described below (**Figure 5.2**). The segment boundaries were defined as follows:

- Segment 1 – east on the Trans-Canada Hwy (TCH Hwy 2)/ Sackville, NB interchange to the Etteridge Road, in Aulac, NB. Shown in **Figure 5.3**.
- Segment 2 - east on the Trans-Canada (Hwy 2) from the Etteridge Road, in Aulac, NB to the New Brunswick/ Nova Scotia border. Shown in **Figure 5.4**.
- Segment 3 - east on the Trans-Canada from the New Brunswick/Nova Scotia border through to the TransCanada (Hwy 104)/ McDonald Road crossing in Amherst, NS. This segment captures some New Brunswick land where it extends north of highway border. Shown in **Figure 5.5**.

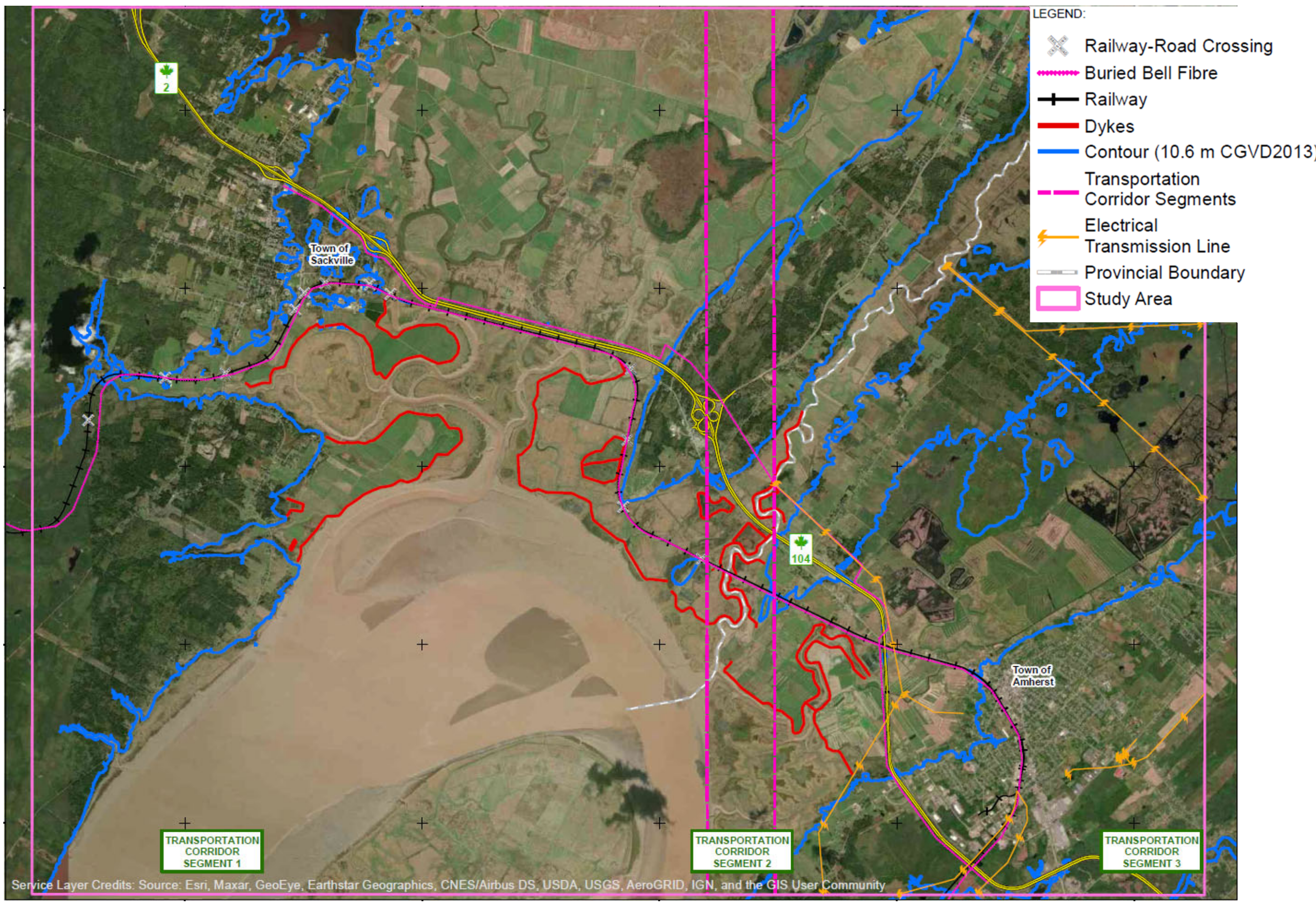
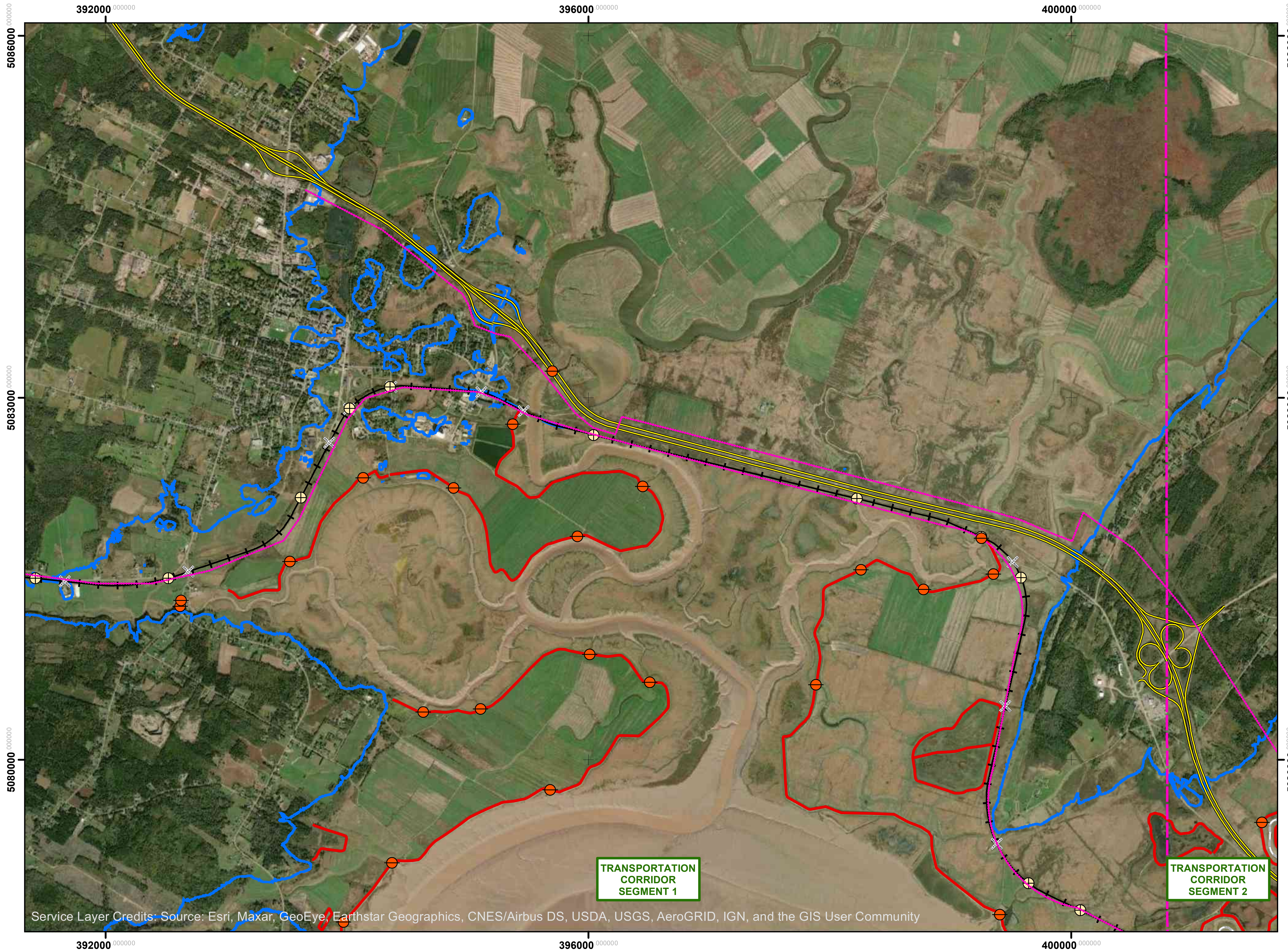


Figure 5.2 Chignecto Study Area Segment Boundaries

These segments were loosely defined by the Study Team, using geotechnical condition, ground surface elevations and access to infrastructure as general criteria. Segments 1 and 3 having similar marsh conditions and roadway elevations, while Segment 2 is defined as a low-lying area where the Missaguash River flows and is bounded by the higher elevation land areas of Aulac in New Brunswick and Fort Lawrence in Nova Scotia.



LEGEND:

- Aboiteaux
- Culvert
- Railway-Road Crossing
- Buried Bell Fibre
- Railway
- Dykes
- Contour (10.6 m CGVD2013)
- Transportation Corridor Segments
- Provincial Boundary
- Study Area

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wood.

TITLE:

FIGURE 5.3 - CHIGNECTO STUDY AREA SEGMENT 1 BOUNDARY

PROJECT:

CHIGNECTO ISTMUS CLIMATE CHANGE ADAPTATION COMPREHENSIVE ENGINEERING AND FEASIBILITY STUDY

PROJECT NO:	DATE:
TAE1949362	APRIL 2021
REV NO: 5	DWN/CHK'D BY: CM/TL
HORIZ. DATUM/PROJ: NAD83 CSRS 2010 UTM ZONE 20 N	VERTICAL DATUM: CGVD2013

FIGURE: **FIGURE 5.3 - SEGMENT 1**

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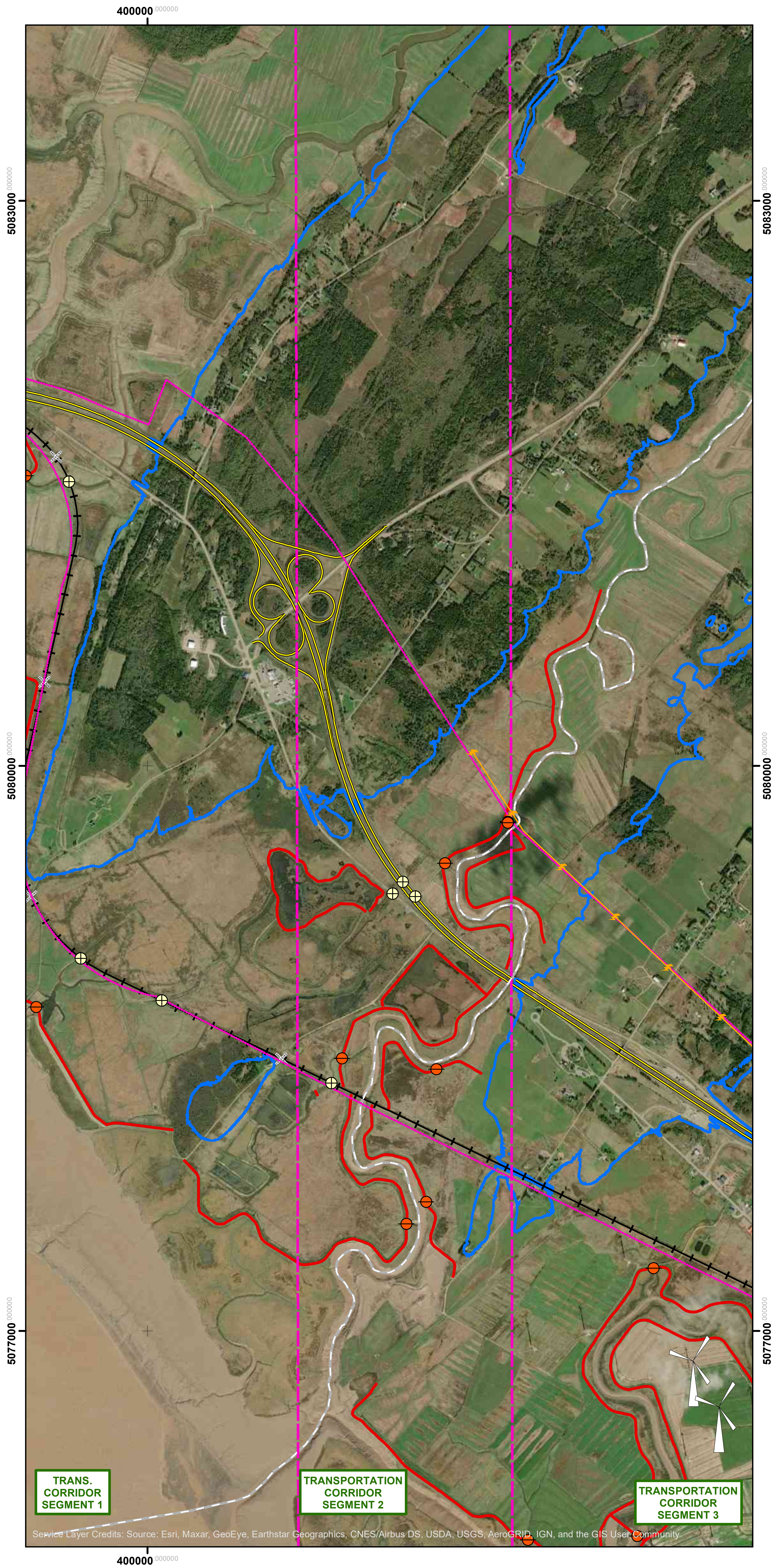

LEGEND:

- Aboiteaux
- Culvert
- Railway-Road Crossing
- Buried Bell Fibre
- Railway
- Dykes
- Contour (10.6 m CGVD2013)
- Transportation Corridor Segments
- Electrical Transmission Line
- Provincial Boundary
- Study Area
- Wind Farm

CLIENT:

NEW BRUNSWICK DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE

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TITLE:

FIGURE 5.4 - CHIGNECTO STUDY AREA SEGMENT 2 BOUNDARY T

PROJECT:

CHIGNECTO ISTMUS CLIMATE CHANGE ADAPTATION COMPREHENSIVE ENGINEERING AND FEASIBILITY STUDY

PROJECT NO:	DATE:
TAE1949362	APRIL 2021
REV NO: 4	DWN/CHK'D BY: CM/TL
HORIZ. DATUM/PROJ: NAD83 CSRS 2010 UTM ZONE 20 N	VERTICAL DATUM: CGVD2013

FIGURE:

FIGURE 5.4 - SEGMENT 2

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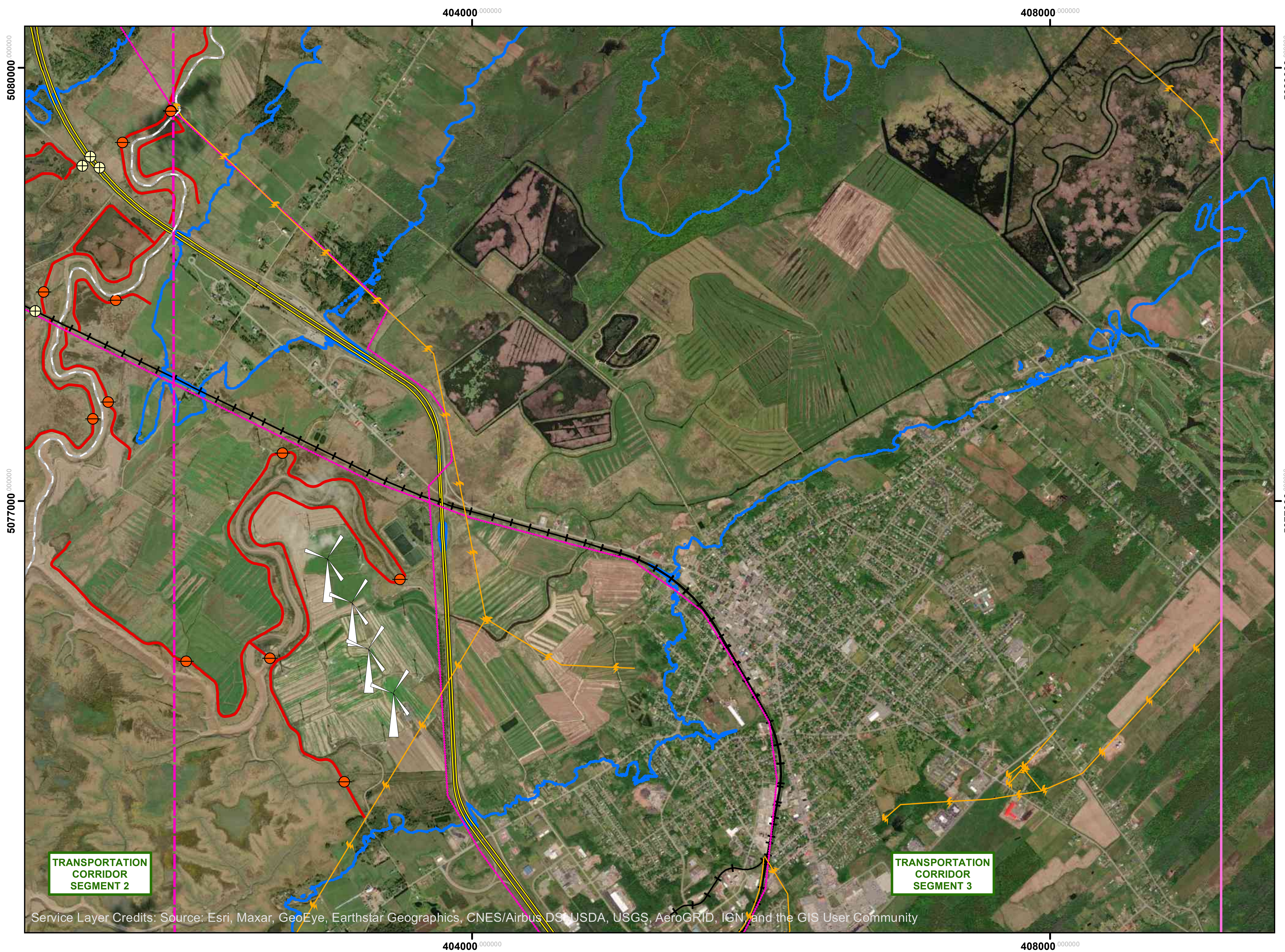

LEGEND:

- Aboiteaux
- Culvert
- Buried Bell Fibre
- Railway
- Dykes
- Contour (10.6 m CGVD2013)
- Transportation Corridor Segments
- Electrical Transmission Line
- Provincial Boundary
- Study Area
- Wind Farm

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NEW BRUNSWICK DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE

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TITLE:

FIGURE 5.5 - CHIGNECTO STUDY AREA SEGMENT 3 BOUNDARY

PROJECT:

CHIGNECTO ISTMUS CLIMATE CHANGE ADAPTATION COMPREHENSIVE ENGINEERING AND FEASIBILITY STUDY

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TAE1949362	APRIL 2021
REV NO: 4	DWN/CHK'D BY: CM/TL
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FIGURE 5.5 - SEGMENT 3

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5.2.1 Conceptual Preliminary Options

Once the three study area segments were defined, the first iteration of preliminary options was applied to each of the three segments.

Table 5.1 defines the conceptual preliminary list of eight options that were reviewed for each of the three segments:

Table 5.1 Original Eight (8) Conceptual Preliminary Options

Preliminary Options	Overview
Option 1	Dykes being raised to 10.6 m and used to control water within the Trade Corridor.
Option 2	Dykes being raised to 10.6 m and used to control water from within the Trade Corridor with a new rail line being constructed.
Option 3	Raise only the eastbound lane of Trans-Canada highway to protect upstream infrastructure.
Option 4	Build a new rail line parallel to the existing rail line, to 10.6 m in elevation.
Option 5	Raise both lanes of the Trans-Canada Highway to 10.6 m in same alignment. Build a new rail line parallel to the existing rail line, to 10.6 m in elevation.
Option 6	Build new Trans-Canada Highway to 10.6 m in a new corridor, which would incorporate a new rail line to 10.6 m in elevation.
Option 7	Raise Trans-Canada Highway to 10.6 m, new rail line to 10.6 m, raise new dykes to 10.6 m in elevation.
Option 8	Build a new Bridge that spans above elevation 10.6 m and incorporate rail from the Sackville/ Trans-Canada Highway interchange to the Trans-Canada Highway (Hwy 104) / Victoria Street West interchange in Amherst, Nova Scotia.

Each of the preliminary options identified in Segments 1, 2 and 3 were then reviewed to determine their effect or impact on each of the following infrastructure components: highways, bridges, railway, dykes, and utilities.

To facilitate the review of the conceptual preliminary options a matrix was developed, a tool used by the Study Team to populate information in defining preliminary options for subsequent consideration and evaluation. The segment boundaries were used initially to ensure that the specific site conditions were considered and that a conceptual preliminary option was not overlooked. While there were some differences, the Study Team identified that, in general, there was little difference in the preliminary options identified relative to the Segment being protected, i. e. an option related to the railway or TCH required the same elevation considerations from segment to segment. Based on these infrastructure constraints, it would not be possible to provide augmented protection by addressing only a portion of the rail or TCH that was below 10.6 m.

The conceptual preliminary options matrix was then revised to remove any reference to the individual Segments and the preliminary options were reviewed and expanded to the study area. The impacts and interactions between a given protection option and a particular infrastructure component were then added in tabular form to populate the preliminary options evaluation matrix.

This preliminary options matrix was then distributed to the study discipline leads for their review and comments. **Table 5.2** below provides a summary of the eight (8) conceptual preliminary options review including potential impacts on each infrastructure component and the comments received.

Table 5.2 Summary of the Conceptual Preliminary Options

Preliminary Option Information		Discipline Component					General		
		Highways	Bridges	Railway	Dykes	Utilities			
Conceptual Option Being Considered	**Option Number**	**Constraints: N/A**	**Constraints: Will have to match Highway Options.**	**Constraints: Existing rail system will have to remain in operation**	**Constraints: New aboiteaux required under bridges where dykes are currently on either side? Dykes with adjacent rail will have to remain in operation until rail is relocated.**	**Constraints: Existing FiberOp in rail bed, will have to remain in operation**	**Comments**	**Challenges/Concerns**	**Benefits/Advantages**
Dykes being raised to 10.6m and used to prevent water from entering the Segment	1	Leave highways at existing elevations and use elevated dyke system to protect the road system.	Leave bridges at existing elevations and use elevated dyke system to protect the bridge/road system.	Rail and dykes to be separated so the rail can be maintained at existing elevation. Aboiteaux is required downstream to protect existing rail bridge.	Top up the existing dykes to 10.6m and leave infrastructure and build aboiteaux under existing bridges	Leave as is.	In areas where existing dykes and rail are shared, a new rail alignment would be required. Would have to review the length of dykes to be raised. We need to protect the west Sackville area below 10.6m, this has to be done with dyke system.	- Performance of existing dykes will need to be understood and risk assessed, Potential Failure Modes (PFM's) need to be assessed - Additional geotechnical investigations required. - Heterogeneous nature of dykes may result in additional boreholes - Relying on existing dyke infrastructure may be difficult to bring to new code/design requirements - The site is underlain by complex soft/loose soil conditions, which will impact all design aspects of the project - Does 10.6m represent the flood elevation or the design crest elevation? Consideration for storm surge, runup, wind velocities, etc. would need to be considered in the freeboard calculation. - Is land based flooding a design consideration?	- Use existing dykes/foundations - Expected settlements should be less than new structures as the existing soil foundations are partially preloaded - Rail/Highway maintenance will not impact dyke performance - Dyke issues/failure and maintenance will have lower impact to rail/highways - Dyke settlement and possible raising would easier to address - Reduced dyke construction materials required
Dykes being raised to 10.6m and used to prevent water from entering the Segment, New rail	2	Leave highways at existing elevations and use elevated dyke system to protect the road system.	Leave bridges at existing elevations and use elevated dyke system to protect the bridge/road system.	Build new bridge and new rail line at 10.6m and tie into existing rail system. No downstream aboiteaux required.	Top up the existing dykes to 10.6m and leave infrastructure and build aboiteaux under existing bridges. Not required at new rail bridge location	Leave as is.		- See ID 1-1 above regarding use of existing dykes - Rail embankments will need to be designed as dyke. A more robust dyke design would be required to accommodate rail loading - Additional geotechnical investigations required. - Soil characteristics and potential for excessive settlements would have to be well understood. - What would be the impact of possible ice loading and accumulation - Rail maintenance after post flooding/ice events or rail/dyke raising would be more challenging - Consideration of including major linear infrastructure along a dyke/water retaining structures should be carefully reviewed.	- See ID 1-1 above regarding use of existing dykes - Using rail embankment as a dyke may reduce construction materials and effort - New dyke/rail structure would reduce risk associated with using existing infrastructure - Rail/dyke structure would be built to current code/design requirements
Raise only the eastbound lane of highway to protect upstream infrastructure	3	Raise only the eastbound lane to the 10.6m and leave the second lane at the existing elevation. In the event of flooding event westbound lane would flood and traffic routed on eastbound.	Raise only the eastbound lane to the 10.6m and leave the second lane at the existing elevation. In the event of flooding event westbound lane would flood and traffic routed on eastbound.	Build a new rail line parallel to the existing rail line, but to 10.6 m in elevation. On the upstream side.	New aboiteaux required where existing rail bridge is now.	Combination of constructing new dykes and raising elevation of existing poles/ lines/ etc.	Impacts on traffic flow only using one section (eastbound lane). Can one lane be raised with out impacts to the other/ space available. May have impacts on roads bridges and civil works/ and utilities	- See ID 1-1 & 1-2 above regarding use of existing dykes and rail embankments - Impacts and stability of highway embankments will need to be assessed, i.e.. soil filter design, risk of piping, seismic, etc. - Existing highway embankment slopes would likely need to be flattened and protected with riprap - Additional highway settlements would be expected and would need to be considered in design - Maintenance of highway after post flooding events would be more challenging - The impact of flooding to bridge structures would need to be carefully reviewed	- See ID 1-1 & 1-2 above regarding use of existing dykes and rail embankments - Using highway embankments may reduce construction materials and effort - Less dependence on existing dyke infrastructure, the condition of which is unknown
Build a new rail line parallel to the existing rail line, but to 10.6 m in elevation.	4	Roadways remains at existing elevations.	Road Bridges remains at existing elevations.	Build a new rail line parallel to the existing rail line, but to 10.6 m in elevation. On the upstream side. The rail system acts as a dyke	No change required- obsolete	Existing utilities behind existing dykes may require relocation depending on the offset distance from the existing rail line.	Lands downstream of the new rail line would be subjected to flooding	- See ID 1-1 & 1-2 above regarding construction of rail embankments and dykes	- New dyke/rail structure would reduce risk associated with using existing infrastructure - Rail/dyke structure would be built to current code/design requirements
Raise both lanes on highway to 10.6m in same alignment. Build a new rail line parallel to the existing rail line, but to 10.6 m in elevation.	5	Raise both east and westbound lanes up in the existing locations to elevation 10.6m.	Bridges would be required to meet new road elevations.	Build a new rail line parallel to the existing rail line, but to 10.6 m in elevation. On the upstream side. The rail system acts as a dyke and requires aboiteaux.	No change required- obsolete	Existing utilities behind existing dykes may require location depending on the offset distance from the existing rail line.	Lands downstream of the new rail line would be subjected to flooding. If rail line/ dam is breached then the roadway is still above the 10.6m.	- See ID 1-2 & 1-3 above regarding use of existing rail and highway embankments	- See ID 1-2 & 1-3 above regarding use of existing rail and highway embankments
Build new highway to 10.6m in new corridor which will incorportate a new rail line to 10.6 m in elevation.	6	Build new highways (East and West bound) in a new alignment.	Bridges would be required to meet new hwy elevations.	New rail line would be constructed in the new highway corridor.	No change required- obsolete	Utilities would have to be moved to new corridor	Options for new alignments will require a north bypass of the existing road to an elevation 10.6. With dykes unchanged, land below 10.6 will be unprotected. Significant land acquisitions and cost would be required.	- Additional geotechnical investigation required - The site may be underlain by complex/soft/loose soil conditions which will impact all design aspects of the project - Soil characteristics and potential for excessive settlements must be well understood - What is potential impact of ice loading and accumulation - Maintenance after post flooding/ice events or rail/highway raising in future may be challenging - Consideration of including major linear infrastructure along a dyke/water retaining structures should be carefully reviewed	- New highway/rail embankment would reduce risk associated with using existing infrastructure - Highway/rail embankment would be built to current code/design requirements
Raise highway to 10.6m, new rail line to 10.6 m, raise/ new Dykes to 10.6m in elevation.	7	Use combination of raised roadways to 10.6m and new dykes at 10.6 for sections of the corridor	Bridges would be required to meet new hwy elevations.	Build a new rail line parallel to the existing rail line, but to 10.6 m in elevation. On the upstream side. The rail system acts as a dyke and requires aboiteaux.	No change required- obsolete	Utilities would have to be moved to new corridor based on roadway modifications	Issues with downstream lands. Assumes that we can have rail and the new dyke system in shared embankment.	- See ID 1-1, 1-2 & 1-3 above regarding use of existing dykes, rail and highway embankments	- See ID 1-1, 1-2 & 1-3 above regarding use of existing dykes, rail and highway embankments
Build a new Bridge that spans above elevation 10.6m.	8		Construct 7.4 km of new bridge to carry rail and traffic in both directions		No change required- obsolete	Raise all utility infrastructure, poles, lines, stations to the 10.6m elevation	- will result in less usable land due to permanent flooding	- requires additional geotechnical investigation - less adaptable if projected flood levels change	- Eliminate requirement for water retaining structures, reduce risk to populations and infrastructure

The Study Team also included any challenges/concerns as well as potential benefits/advantages to the matrix for further discussion. This information was used to refine and better define the preliminary options. In addition, the preliminary conceptual options were reviewed and provided to the members of the Study Team for consideration both in terms of Legislative & Regulatory Framework **(Section 7.0**) and developing the Geotechnical assessment and subsequent Field Program (**Task 8**).

5.2.2 Finalized Preliminary Options for Comparison

With the review of **Table 5.2** completed by the Team Leads, refinements and adjustments were made to individual options. In addition, two (2) additional preliminary options were added to the matrix for further examination.

Refinements included revising proposed option(s) to protect a specific infrastructure component, rather than relocation, due to design constraints (i.e rail). The two additional options added included construction of a new dyke system via a new alignment as well as examining a more selective option to provide protection via a combination of dykes, raising the TCH and potentially rerouting a portion of the CN rail.

These refinements and additions to the original eight (8) conceptual preliminary options resulted in the final ten (10) preliminary options to be further evaluated during the options comparison **(Section 6.0**) are shown in **Table 5.3**.

Table 5.3 Final Ten (10) Preliminary Options

Preliminary Options	Overview
Option 1	Raise existing dyke alignment to 10.6 m and new dykes to join them at river crossings required. Dyke protects corridor assets.
Option 2	Construct new dykes adjacent or inland of existing dyke alignment to protect corridor assets.
Option 3	Raise existing dyke alignment to 10.6 m and new dykes to join them at river crossings, additionally move, and construct new sheet pile adjacent to rail to CN requirements.
Option 4	Construct new dyke alignment to protect corridor assets and additionally move and construct rail to CN requirements.
Option 5	Raise the eastbound lane of TCH and additionally move and construct new rail to CN requirements.
Option 6	Use rail line to protect the corridor: Build a new rail line immediately adjacent and parallel to the existing rail line, but to 10.6 m in elevation.
Option 7	Use rail line to protect: Build a new rail line parallel to the existing rail line, but to 10.6 m in elevation and raise both lanes of highway to 10.6 m.
Option 8	Build new TCH to 10.6 m in new corridor which will incorporate a new rail line to 10.6 m in elevation on an entirely New footprint.
Option 9	Selective protection of corridor using a combination of raising TCH to 10.6 m, new rail line to 10.6 m, raise existing dykes and/or construct new Dykes to 10.6 m in elevation.
Option 10	Build a Bridge that includes the TCH and rail bridge spanning above elevation 10.6 m.

5.3 Vulnerability Assessment

The effects by climate change such as sea-level-rise and increased intensity of weather events, combined with land subsidence, are increasing the risk of temporary and permanent damage to the existing infrastructure, and impacting the function of the Trade Corridor. With the increase in rising sea level as predicted, the existing infrastructure below contour elevation 10.6 m, is vulnerable and requires protection. The main goal of this assessment was to review the vulnerability of existing infrastructure along the overall study area footprint.

Several factors were considered in completing this assessment, such as:

- The nature of the soils is poor along the study area footprint and may be susceptible to excessive settlement. For example, in the 1990s when building the 4-lane highway, wick drains were installed to reduce the time required for the poor soils to settle.
- The need to understand the impact on the existing infrastructure due to soil erosion, flooding, maintenance, and longevity.
- The need to understand the economic impact due to the loss of the transportation corridor.
- The need to focus on a new protected zone at elevation of 10.6 m. What are the impacts on design, cost, and safety of the existing infrastructure?
- A design elevation of 10.6 m - interpretation is that infrastructure does not need to be constructed to the 10.6 m elevation but be able to withstand a storm surge event without loss of its integrity. As an example:
  - A new dyke could be built which would protect to 10.6 m but built only to 10 m. This would allow the dyke to temporarily overtop (in the event of a high-tide event or storm surge) but it would still be intact after the water subsides.
  - The Isthmus could close to traffic a few times a year, but newer roads could still be intact.
- The transport of sediment, which is indicative of where the existing dykes are seeing the most impacts.
- The existing drainage systems located along and under the CN right of way.
- A review of the existing large diameter culverts, roads and existing bridges (road and rail) and the potential impacts.

This assessment was carried out by a combination of field observations and reviews of existing data provided by the provinces of New Brunswick and Nova Scotia, CN Rail and other Stakeholders and was completed by senior Study Team members.

This information was communicated to the Study Team members and was incorporated into the Pairwise Evaluation and the option refinement, **Sections 6.0** and **10.0**, respectively.

6.0 Option Comparison

6.1 Introduction

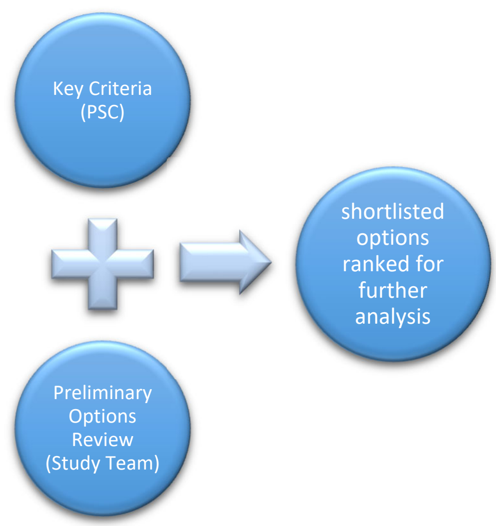
During the RFP preparation, the Study Team identified the need to utilize a structured approach to evaluate the preliminary options, an approach that provides a means to evaluate or rank preliminary options based on the same agreed criterion. Upon award of this work, the Study Team proposed a comparison process known as Pairwise Comparison, also known as the Pairwise Comparison Method to evaluate the preliminary options. Pairwise Comparison is a proven procedural approach used in engineering studies to compare and scale options, choices and preferences. The Pairwise Comparison was used as a method to objectively evaluate preliminary options developed by the Study Team and select the three most viable and resilient options for protecting the infrastructure in the Trade Corridor to elevation 10.6 m.

The process used to develop the evaluation criteria, the application of Pairwise Comparison and the ranking of the preliminary options is summarized below.

6.2 Pairwise Comparison

The Pairwise Comparison process first involves clearly defining "what" is to be considered during the evaluation of a particular option to allow for consistent interpretation by those doing the evaluating. This definitive criterion facilitates discussion on potential merits and impacts during evaluation of a particular option. This can assist to reduce bias or influence and forms a quantitative means for comparison to provide the framework for ranking individual preliminary options. Once the scoring of each option is complete, this comparison will identify those options which scored well for further evaluation.

Concurrently with development of the preliminary options, (**Task 5),** the Study Team worked with the PSC members to identify and define the criteria that would be used to evaluate the preliminary options via the Pairwise Comparison process.



The process of establishing and defining the option evaluation criteria and determining the weighting of the defined criteria was completed through several meetings and two virtual workshops with the PSC. This was completed ahead of presenting or discussing any of the preliminary options with the PSC. The process provided for a clear and concise method to evaluate the various preliminary options as objectively as possible, while still addressing concerns over the options and need for consultation with stakeholders. The process also provided clarity with respect to the potential of add-ons and scope creep later in the process.

6.2.1 Establishing Criteria

The Study Team worked to identify an appropriate number of criteria that both included and represented concerns and priorities as understood from PSC members and Stakeholders. This input was compiled and used to develop and define a total of nine (9) criteria. The final list of criteria was presented to the PSC for approval. These criteria include *Climate Adaptability, Infrastructure Resilience, Trade Corridor Efficiency, Regional Impacts, Constructability, Lifecycle Maintenance, Environmental Impacts, Access/Land Usage, and Implementation (Budget and Timing*). Based on the input from the PSC, clear definitions were developed for each of the nine criteria to support the Study Team during the process of evaluating options.

Once the criteria were clearly defined, the next step was to determine the weighting, or "importance" of each. PSC members provided individual input, to develop this weighting (or ranking) by scoring each of each of the nine criteria against one and other, one at a time while completing a Criteria Comparison worksheet to record the scoring. Each member of the PSC completed this worksheet, and the data was returned to the Study Team and compiled, with each criteria given a percentage score. The average (of all submissions) weighting results of each of the nine criteria are presented in the **Figure 6.1**.

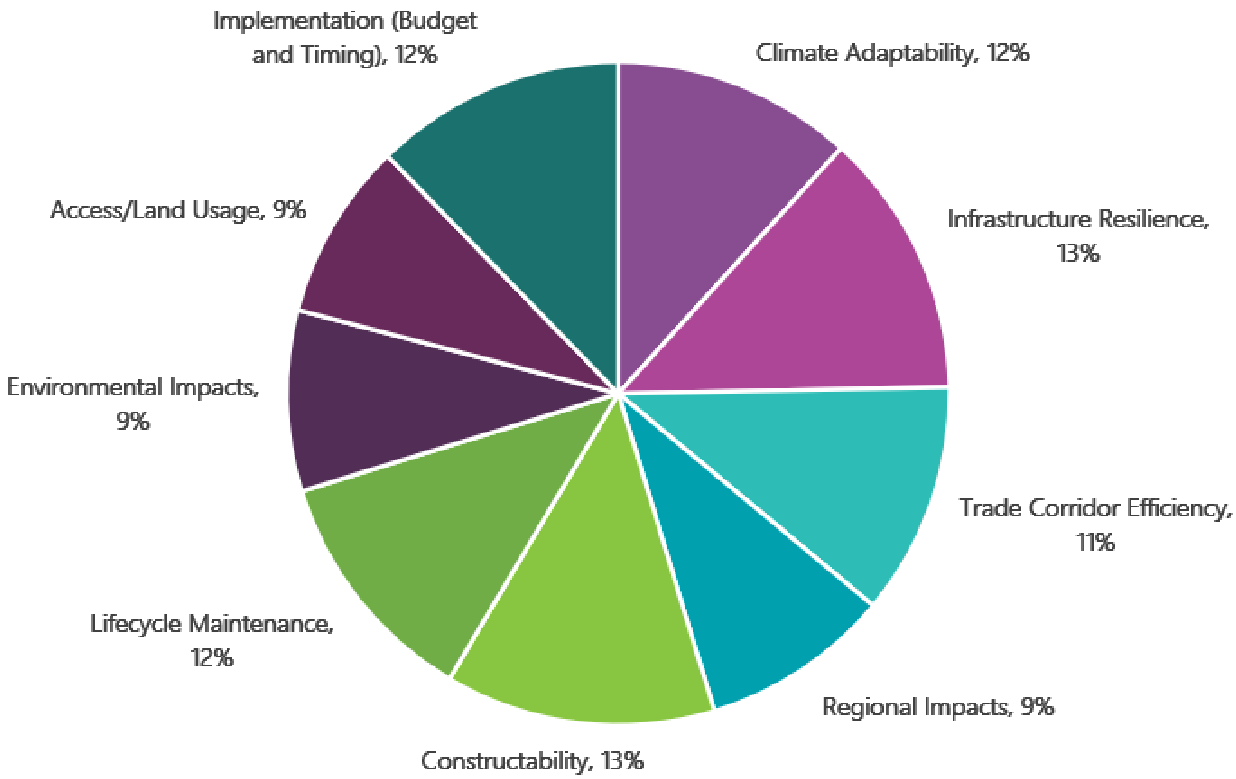


Figure 6.1 Preliminary Option Evaluation Criteria – Average Weighting, %

The percentage (**Figure 6.1**) of a given criteria indicates the weighted representation of that criteria in terms of how to apply the scoring a particular option, which will be discussed in more detail in the next section. What is generally important to note in **Figure 6.1**, is that overall, there is an even distribution of the weighting of the criteria. The evaluation criteria which were weighted the highest are within a few percent of those that scored the lowest weightings, which confirms that there is alignment within the PSC and no overly skewed importance of one criterion to be considered over another.

With the priorities and concerns of the PSC and Stakeholders now clearly identified, defined as criteria, and assigned a numerical weighted importance for evaluating, the Study Team was ready to move the Pairwise Comparison process into the next stage: evaluation of preliminary options.

6.2.2 Evaluation of Preliminary Options

Each of the nine criteria were assigned a "team" to facilitate and participate in the evaluation and ranking of the preliminary options. Each of the nine evaluation teams consisted of three or four Study Team members representing the applicable disciplines specific to that criteria. Each evaluation team worked through the 10 preliminary options to determine if a given option met the definition of the criteria it was being evaluated against. Each team worked collectively to determine if a particular option was considered "Favourable", "Neutral and/or Undetermined" or "Unfavourable" based on the defined criteria. If a particular option was deemed Favorable in relation to that criteria definition (i.e., Climate Adaptability), a score of 3 was used, Neutral and/or Undetermined was assigned a score of 2 and Unfavorable a score of 1. This part of the evaluation is critical, and it is most important during this process that the evaluation team continuously refer to the criteria definition to ensure the evaluation and assessment of a given option stays within the prescribed definition of that specific evaluation criteria.

Each of the nine evaluation teams completed a numerical ranking for the 10 preliminary options based on whether a given option is suitable as defined by the criteria their team was assigned: the results were compiled into a working version of preliminary option matrix, as defined in **Section 5.0**, for tabulation and discussion.

6.2.3 Compiling Results

Once all the information was compiled, the accompanying comments from each evaluation team were reviewed in conjunction with the numerical scores to ensure there were no omissions or errors in reviewing the preliminary option information. Any options identified as Neutral and/or Undetermined was revisited to determine if any additional information could be available at present. All comments were assembled and reviewed in detail and in conjunction with individual evaluation team members.

The result is a comparison matrix outlining the ten (10) preliminary options by nine (9) Evaluation Criteria. Once finalized, the weighting of each of nine criteria, discussed in **Section 6.2.1**, was then applied to the numerical scores assigned to each preliminary option, as outlined above.

The numerical score for each option relates to its favorability (i.e., 3, 2, 1,) in relation to the weighted criteria (shown in **Table 6.1**) which is then tallied. The result is that each of the preliminary options then receives a numerical score, with the best possible score being 3. The preliminary options with the top scores were reviewed in more detail and prepared for discussion with the PSC.

The preliminary option evaluation scores from the Pairwise Comparison are shown in **Table 6.1**.

Table 6.1 only presents the final weighted score of the option with the complete Pairwise Comparison matrix included in Appendix B.

Table 6.1 Preliminary Option Ranking from Pairwise Comparison

Option Description	Option I.D	Pairwise Score
Raise existing dyke alignment to 10.6 m and new dykes to join them at river crossings required. Dyke protects corridor assets.	1	2.87
Construct new dykes adjacent or inland of existing dyke alignment to protect corridor assets.	2	2.42
Raise existing dyke alignment to 10.6 m and new dykes to join them at river crossings, additionally move, and construct new sheet pile adjacent to rail to CN requirements.	3	1.90
Construct new dyke alignment to protect corridor assets and additionally move and construct rail to CN requirements.	4	1.81
Raise the eastbound lane of TCH and additionally move and construct new rail to CN requirements.	5	1.00
Use rail line to protect the corridor: Build a new rail line immediately adjacent and parallel to the existing rail line, but to 10.6 m in elevation.	6	1.35

Option Description	Option I.D	Pairwise Score
Use rail line to protect: Build a new rail line parallel to the existing rail line, but to 10.6 m in elevation and raise both lanes of highway to 10.6 m.	7	1.36
Build new TCH to 10.6 m in new corridor which will incorporate a new rail line to 10.6 m in elevation on an entirely new footprint.	8	1.22
Selective protection of corridor using a combination of raising TCH to 10.6 m, new rail line to 10.6 m, raise existing dykes and/or construct new Dykes to 10.6 m in elevation.	9	1.23
Build a Bridge that includes the TCH and rail bridge spanning above elevation 10.6 m.	10	1.18

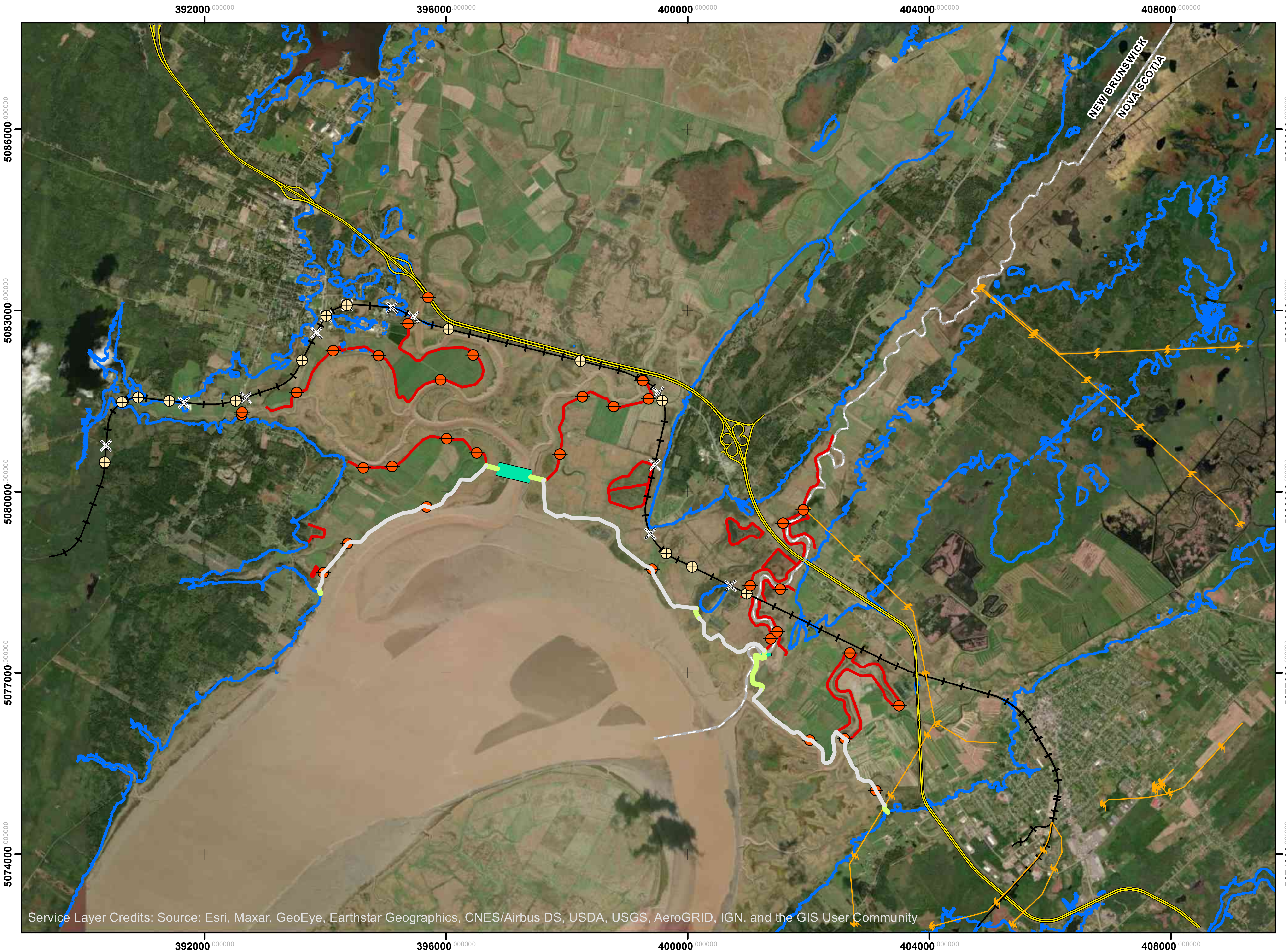
6.2.4 Option Selection

The results of the Pairwise Comparison, as shown in **Table 6.1,** were presented to the PSC for discussion and review before proceeding with further option refinement. The Study Team prepared generic option descriptions and high-level conceptual figures to better illustrate the three highest scoring options, which are identified by the letters A, B and C, in order of ranking: Option A (Raise Existing Dyke), scored 2.87; Option B (Build New Dyke), scored 2.41; and Option C (Raise Existing Dyke + Steel Sheet Pile), scored 1.90. The descriptions are shown in **Table 6.2** and correspond to **Figure 6.2**, **Figure 6.3** and **Figure 6.4**, respectively.

Table 6.2 Highest-Scoring Options

Shortlisted Options	Overview
OPTION A: Raise Existing Dykes	Raise existing dykes, as required, to 10.6 m to protect Trade Corridor (highways, railway, bridges, etc.) and existing infrastructure to remain at present elevation. Where required, existing dykes will be connected by new alignments. Water level control structures required downstream to existing bridges. As previously described, the existing dyke alignment is shown in red while the new alignment is shown in white.
OPTION B: Build New Dykes	New dyke system to be constructed to 10.6 m on inland (Trans-Canada Highway) side of existing alignment, (approximate alignment location to be determined). Existing infrastructure will remain at current elevation, protection will be provided via new dyke system. Water level control structures required downstream to existing bridges. The proposed new dyke alignment is shown in green and white.
OPTION C: Raise Existing Dyke + Steel Sheet Pile	Raise existing dyke along existing alignment, as required, to 10.6 m to protect Trade Corridor (highways, railway, bridges, etc.). Where required, existing dykes will be connected by new alignments. Tidal dam and new aboiteaux in rivers. Install approximately 800 m of steel sheet pile walls at selection locations. Existing dyke alignment is shown in red, the proposed new alignment is shown in white, while the location of the steel sheet pile is shown in purple.

The Study Team worked with the PSC to outline as many of the considerations of each of the options that was available, based on the information available. The PSC approved the top three (3) preliminary options, A, B and C to be advanced for further refinement by the Study Team. Further development and refinement of the Options included items such as the general option alignment, approximate locations of structures, temporary and permanent access, permitting considerations, etc. These considerations and the development of the option descriptions are detailed in option refinement **(Section 10)**.



LEGEND:

- Abiteaux
- Culvert
- Railway-Road Crossing
- Railway
- Dykes
- 10.6 m Contour
- Electrical Transmission Line
- Provincial Boundary
- Proposed Dyke
- Proposed Dyke Raise
- Propose Water Control Structure

CLIENT:	NEW BRUNSWICK DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE
TITLE:	CHIGNECTO ISTHMUS STUDY AREA
PROJECT:	CHIGNECTO ISTMUS CLIMATE CHANGE ADAPTATION COMPREHENSIVE ENGINEERING AND FEASIBILITY STUDY
PROJECT NO: TAE1949362	DATE: APRIL 2021
REV NO: 1	DWN/CHK'D BY: CM
HORIZONTAL DATUM/PROJ. NAD83 CSRS 2010 UTM ZONE 20 N	VERTICAL DATUM CGVD2013
FIGURE:	FIGURE 6.2 - OPTION A RAISE EXISTING DYKES
SCALE:	1:60,000

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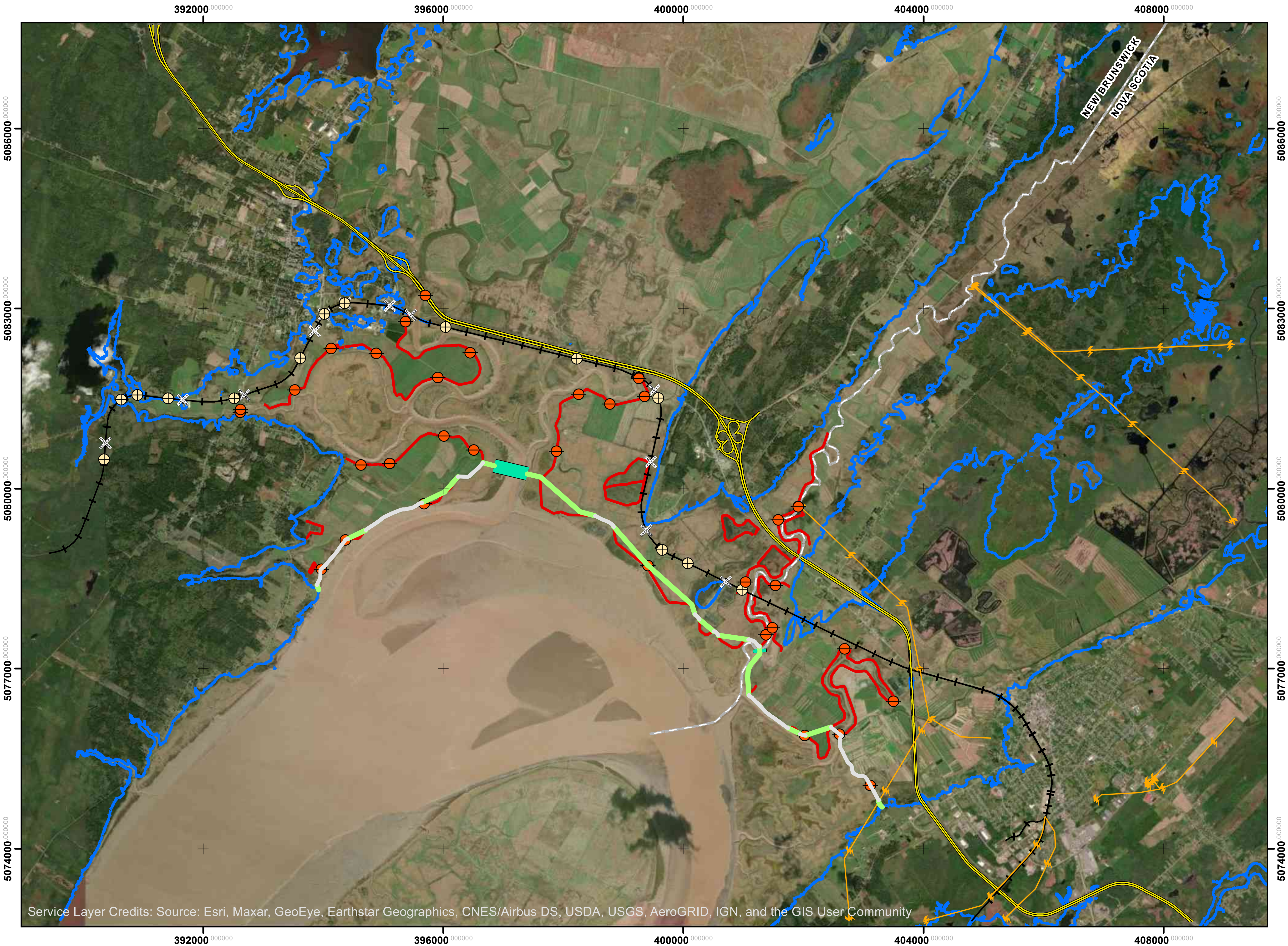


LEGEND:

- Aboiteaux
- Culvert
- Railway-Road Crossing
- Railway
- Dykes
- 10.6 m Contour
- Electrical Transmission Line
- Provincial Boundary
- Proposed Dyke
- Proposed Dyke Raise
- Propose Water Control Structure

CLIENT:

NEW BRUNSWICK DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE

wood.

TITLE:

CHIGNECTO ISTHMUS STUDY AREA

PROJECT:

CHIGNECTO ISTHMUS CLIMATE CHANGE ADAPTATION COMPREHENSIVE ENGINEERING AND FEASIBILITY STUDY

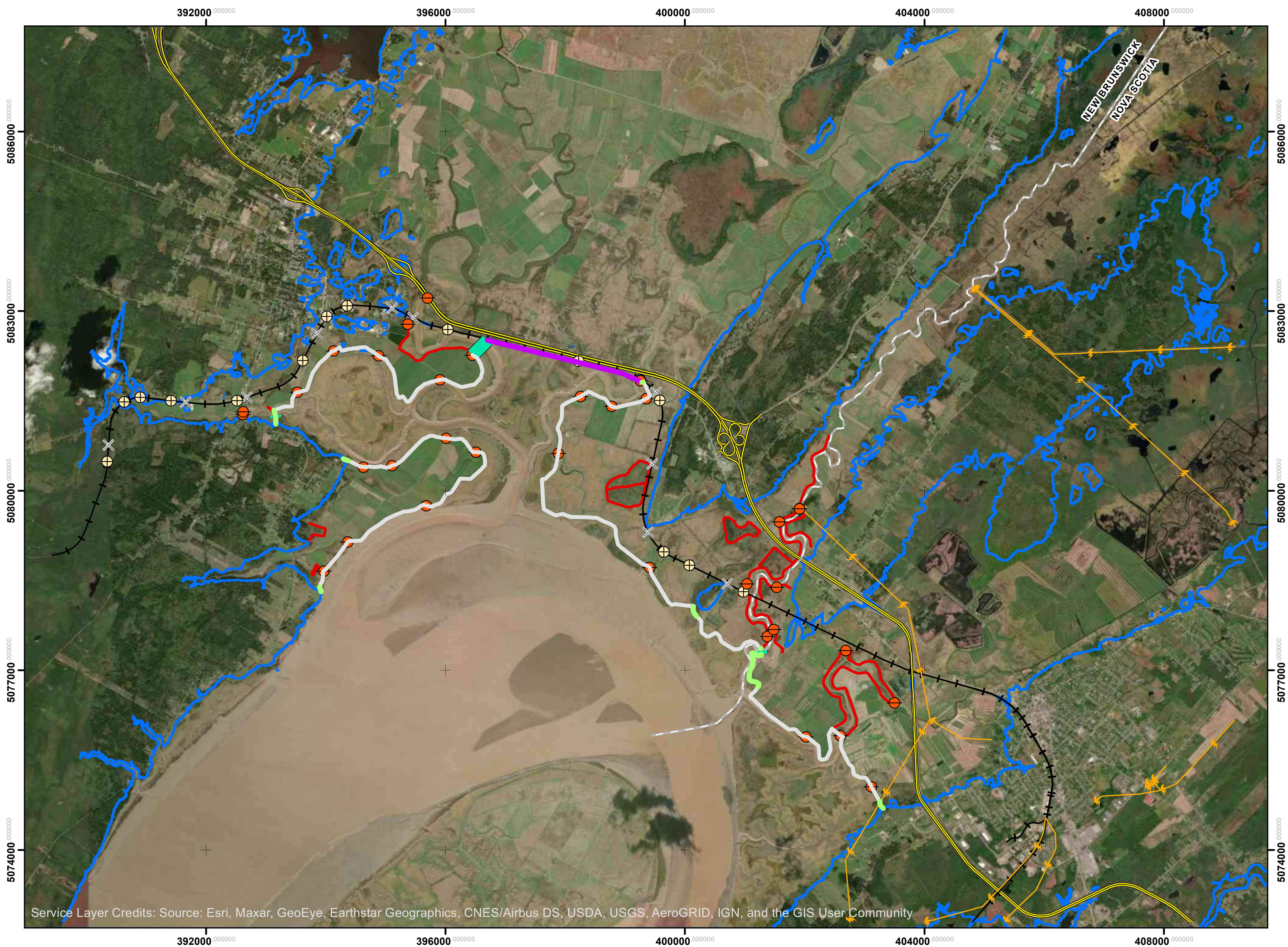
PROJECT NO:	DATE:
TAE1949362	APRIL 2021
REV NO: 1	DWN/CHK'D BY: CM
HORIZONTAL DATUM/PROJ. NAD83 CSRS 2010 UTM ZONE 20 N	VERTICAL DATUM CGVD2013

FIGURE: **FIGURE 6.3 - OPTION B BUILD NEW DYKES**

SCALE: 1:60,000

0 0.75 1.5 3

Kilometres



LEGEND:

- Aboiteaux
- Culvert
- Railway-Road Crossing
- Railway
- Dykes
- 10.6 m Contour
- Electrical Transmission Line
- Provincial Boundary
- Proposed Sheet Pile
- Proposed Dyke
- Proposed Dyke Raise
- Propose Water Control Structure

CLIENT:

NEW BRUNSWICK DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE

wood.

TITLE:

CHIGNECTO ISTHMUS STUDY AREA

PROJECT:

CHIGNECTO ISTMUS CLIMATE CHANGE ADAPTATION COMPREHENSIVE ENGINEERING AND FEASIBILITY STUDY

PROJECT NO:	DATE:
TAE1949362	APRIL 2021
REV NO: 1	DWN/CHK'D BY: CM
HORIZONTAL DATUM/PROJ.: NAD83 CSRS 2010 UTM ZONE 20 N	VERTICAL DATUM: CGVD2013

FIGURE: FIGURE 6.4 - OPTION C RAISE EXISTING DYKES & SHEET PILES

SCALE: 1:60,000

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7.0 Legislative & Regulatory Framework Review

Following the evaluation of the options and following the selection of the highest scoring options, the Study Team reviewed the Legislative and Regulatory Framework applicable to the study area to assist in the option refinement task presented in Section 10.

7.1 Introduction

The Study Team reviewed the potential options to identify potential federal and provincial permitting and approval requirements. This information is intended to be used by the PSC for planning following the selection of an option. These permits and approval requirements are applicable to all options.

The selected option has the potential to require an Environmental Impact Assessment (EIA) Registration in New Brunswick and a Class 1 Environmental Assessment in Nova Scotia (EA), and possibly a federal Impact Assessment, depending on final routing and project funding. The preparation of these assessments will require the field collection of site specific biophysical and socio-economic information, the timing of which may be dictated by biological timing windows (e.g., migratory breeding bird periods). The provincial approval process for NB and NS would likely take approximately 6 to 12 months at minimum following submission to complete, however, due to the spatial extent of the study area, potential for federal involvement, and anticipated requirements for field assessments and consultations, a more realistic timeline would be 18 to 24 months. As it is early in the Project planning process, further clarity will be sought through discussions with federal and provincial regulators as planning and option refinement proceeds (outside the scope of this study).

7.2 Potential Permitting Requirement Framework

An overview of the potential permits and approvals that may be required with the implementation of one or the three options considered is presented in **Table 7.1**. The need for other permits or approvals may be identified as project planning progresses (outside the scope of this study). Additional standalone archaeological approvals and permits may be required to support portions along the alignment of a study option occurring in areas of elevated archaeological potential.

Table 7.1 Potential Environmental Approvals or Permits Required for the Selected Option

Jurisdiction	Permit/Approval	Regulatory Body	Trigger Activity
Federal	*Fisheries Act Authorization*	Fisheries and Oceans Canada (DFO)	Activities which result in a disturbance to fish habitat (salt marsh or watercourse)
Federal	*Canadian Navigable Waters Act* Approval -Navigation Protection Program Screening and Assessment	Transport Canada	Activities in, on, or across a navigable waterbody that interfere with navigation
Federal	Landowner Permission	Public Services and Procurement Canada – Real Properties Branch	Activities on Federal Crown land.
Federal	Impact Assessment	Impact Assessment Agency of Canada	Activities on Federal land, or which receive federal funding.
New Brunswick	Watercourse and Wetland Alteration Permit (Standard Permit)	New Brunswick Department of Environment and Local Government (NBDELG)	Work within 30 m of a watercourse or wetland.

Jurisdiction	Permit/Approval	Regulatory Body	Trigger Activity
	Watercourse and Wetland Alteration Permit (Provisional Permit)		Work within 30 m of a watercourse or wetland which occurs between June 1 to September 30th for alterations with little potential for disturbance to watercourses or wetlands, including geotechnical investigations.
New Brunswick	Archaeological Impact Assessment	New Brunswick Department of Tourism, Heritage and Culture, Archaeological Services Unit	Ground disturbance in areas of high archaeological potential (e.g. dykes)
New Brunswick	License of Occupation for Crown Land	New Brunswick Department of Natural Resources and Energy Development (NBDNRED)	Required for any work conducted on Crown Land under authority and control of the NBDNRED.
New Brunswick	*Quarriable Substances Act*	NBDNRED	A quarry permit is required if material extraction will occur within the designated shore area (defined as 300 m above and 300 m below the ordinary high-water mark).
New Brunswick	Permission to Access New Brunswick Department of Transportation and Infrastructure (NBDTI) Land	NBDTI	Required for any work conducted on land owned by NBDTI.
New Brunswick	Landowner Permission	Provincial Crown (if applicable)	Activities on Provincial Crown land not covered by License of Occupation or owned by NBDTI.
		Municipal	Activities on Municipally owned land.
		Private – Marshland/Agricultural	Activities on privately owned marshland or agricultural land.
		Private - Commercial/Industrial/Other	Activities on privately owned industrial land (e.g., CN)
New Brunswick	Permission from Utility	Various	Required if work is in the vicinity of any utility.
Nova Scotia	*Agricultural Marshland Conservation Act* Approval	Nova Scotia Department of Agriculture	Development in a marshland area designated under the *Agricultural Marshland Conservation Act*.
Nova Scotia	Watercourse Alteration Approval	Nova Scotia Environment	Activities within 5 m of the bed or banks of a watercourse
Nova Scotia	Wetland Alteration Approval	Nova Scotia Environment	Activities that result in a disturbance to a wetland

Jurisdiction	Permit/Approval	Regulatory Body	Trigger Activity
Nova Scotia	Archaeological Resource Impact Assessment	Nova Scotia Department of Communities, Culture, and Heritage, Special Places	Ground disturbance in areas of high archaeological potential (e.g. dykes) *Requirement for separate approval to be determined by regulator.*
Nova Scotia	Permission to access Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR) Land	NSTIR	Required for any work conducted on land owned by NSTIR.
Nova Scotia	Work within Highway Right-of-Way Permit	NSTIR	Required for work within right-of-way of controlled access highway.
Nova Scotia	Landowner Permission	Provincial Crown Lands Act, NS Lands and Forest	Activities on Provincial Crown land.
		Municipal	Activities on Municipally owned land.
		Private – Marshland/agricultural	Activities on privately owned marshland or agricultural land.
		Private - Commercial/Industrial/Other	Activities on privately owned industrial land (e.g. CN)
Nova Scotia	Permission from Utility	Various (Nova Scotia Power)	Required if work is in the vicinity of any utility.

7.3 Enabling Regulatory Considerations

The provinces of New Brunswick and Nova Scotia have specific legislation enabling/authorizing the construction, alteration, and maintenance of works (eg. dykes, aboiteaux, drainage) to protect lands from tidal flooding. In Nova Scotia, the Agricultural Marshland Conservation Act. 2000 is under the mandate of the Minister of Agriculture and in New Brunswick, the *Marshland Infrastructure Maintenance Act* is under the responsibility of the Minister of Transportation and Infrastructure.

Whether on private or public lands, the existing dykes, aboiteaux, the tidal dam on the Tantramar and inland agricultural lands are designated within their respective provincial legislation. The significance of this designation is that it enables the province to access and conduct physical works on privately owned properties.

7.4 Other Specific Approvals

Various other approvals will also be required under federal and/or provincial legislation. These could include for example, approvals for affecting fish habitat under the federal *Fisheries Act*; for effects to species at risk under the *Species at Risk Act* or the New Brunswick *Species at Risk Act* or Nova Scotia *Endangered Species Act*, or effects to wetland habitat under the New Brunswick *Clean Water Act* or Nova Scotia *Environment Act*. The timeline for these permits and approvals will depend on the scope of effects but is anticipated to range from several weeks to several months.

8.0 Geotechnical Assessment and Field Program

Soils characterization was conducted withing the study area, once the three preferred options were identified. Soils conditions at selected locations were investigated at a level of effort, using available information and drilling boreholes, that would help advance geotechnical evaluations at key locations along the proposed alignment(s).

8.1 Introduction

A geotechnical assessment was completed to support the refinement and development of the options presented in this study. There were two main objectives for the geotechnical assessment:

1. Develop an understanding of the subsurface conditions within the study area.
2. Perform geotechnical analyses to support the design of features associated with Option Refinement for the three recommended options.

8.2 Geotechnical Desktop Study and Site Reconnaissance

8.2.1 Geotechnical Desktop Study

A site reconnaissance and geotechnical desktop study was completed to develop an initial understanding of the subsurface conditions with the study area and is presented in Stantec (2020). Stantec completed a desktop study to summarize the existing geotechnical data available within the study area that was available within the geotechnical reports provided by the Project Stakeholders supplemented by the Study Team's internal records (DRR) during the development of preliminary options. The desktop study was used to evaluate and document the range of variability in subsurface conditions, as well as to provide preliminary geotechnical parameters, specific for each Segment. The geotechnical desktop study is provided in **Appendix C**.

Most of the study area is comprised of low-lying areas, former inter-tidal marshes, which are now protected by dykes for agricultural purposes. Typically, the inhabited areas such as towns of Amherst, Sackville, and Aulac are located at higher elevations than the surrounding marshes.

The ground surface in most of the study area is below elevation 10 m (CGVD2013), with higher elevations existing to the east and west portions at elevations in the range of 20 m to 30 m (Nova Scotia Geographic Data Directory, n.d., GeoNB, n.d.).

The surficial geology at the locations of relatively higher elevations is typically glacial till, a heterogenous mixture of gravel, sand, and silt and clay sized particles ranging between less than 1.5 m to upwards of 3 m in thickness, while the lower areas that include the marsh areas are characterized by post-glacial marine sediments comprised of clay, silt, and minor sand (Rampton, 1984 and Stea et. al. 1992).

Available geology mapping indicates that the study area is underlain by variable sedimentary formations including grey-red sandstones, mudstones, and conglomerates characteristic of the Pictou, Mabou, and Cumberland Groups (Johnson, 2005 and Keppie, 2000).

The following descriptions provides a summary of subsurface conditions within the study area based on findings from the desktop study:

- A weathered brown clay crust was encountered immediately below the surficial rootmat at all borehole locations. The brown clay ranged between 1.0 m and 6.1 m in thickness. This material is characterized by firm to stiff consistency and moisture contents typically less than 20%. Grey clay was encountered immediately below the weathered clay crust at most locations and was observed to vary in thickness from approximately 1.3 m to 27.5 m. The consistency of the gray clay was assessed to range between soft and firm, based on

N-values (blow counts per foot as the sampler is advanced in the ground), and determined to be very sensitive to disturbance.

- Loose to compact sand was encountered below the clay at some locations. This sand unit was observed to range between 0.3 m and 14.8 m in thickness and is comprised of variable quantities of gravel and fines. It is possible that this unit may have been documented as glacial till, which was encountered immediately above the surface of bedrock, underlying the clay soils. Glacial till ranging between 0.6 m and 18.9 m in thickness has been documented below the clay unit. The till consisted of sandy, silty clay with gravel. Occasional sand lenses were encountered in the till material.
- Interbedded sandstone, mudstone, and conglomerate has been documented within the study area, which is consistent with the local bedrock geology mapping reviewed as part of the desktop study. The depth to bedrock was documented to be within 1.0 m of the ground surface at localized high spot (Etter Ridge Road/Hwy 2 overpass), however, was typically in the range of 15 m below ground surface and as deep as 34 m below ground surface.

The geotechnical desktop study (Stantec, 2020) was used by the Study Team during the preliminary option Development (**Section 5.0**) to identify potential gaps in the current information, specific to the conceptual Preliminary options. The Study Team assembled and reviewed approximately 150 existing borehole, test pit and CPT records, from approximately 131 locations all within the study area, including for dykes, marsh soil conditions and structures (depth to bedrock).

Based on the initial review of information available, preliminary recommendations for the design of dykes and deep foundations for all structures were included in the geotechnical desktop study, which is provided in **Appendix C**.

8.2.2 Reconnaissance

Following the completion of the review of available existing geotechnical information related to the study area, the Study Team identified the need to visit the study area with the preliminary options in mind, to assess potential locations, including access, for boreholes in advance of a Geotechnical Field Investigation. In addition, reconnaissance of the study area was completed in conjunction with the Vulnerability Assessment (**Section 5.3**) discussed previously. Reconnaissance by senior Study Team members was completed on July 7 and 8, 2020.

The purpose of the Site Reconnaissance was twofold: 1) to conduct a site visit in advance of intrusive geotechnical investigations; and 2) to provide information for the infrastructure Vulnerability Assessment (**Section 5.3**). The tasks performed during the site reconnaissance included: to visually observe the foundations of existing infrastructure for any indicators of excessive deformation or distress; to observe the existing geotechnical condition of the dykes and embankments within the study area; and to evaluate access for future geotechnical drilling investigations. The general observations made during the reconnaissance are shown in **Table 8.1**.

Table 8.1 Visual Observations of Major Infrastructure, July 2020

Infrastructure	General Observations
Bridges	Overall, the bridges and respective approaches did not exhibit obvious signs of excessive settlements, deformation, or slope instability.
Aboiteaux	The aboiteaux at the LaPlanche River and gated structure at the Tantramar River are significantly larger than the smaller, wooden structures observed along the dykes. These structures appear to be performing as intended. There was some localized scouring observed at the Tantramar River structure. Several of the small, wooden aboiteaux observed within the dykes were observed to be in poor condition as the wooden frames were visibility damaged or rotting and will likely need to be replaced in the short-term.

Dykes	Generally observed to be in good condition, particularly the landward (slopes). Most dykes were observed to have toe berms on the landward side and were very heavily vegetated. Vehicle traffic along the crests of the dykes were generally limited to areas where dykes were being used to access agricultural lands as well as to provide access for maintenance equipment. As anticipated, there are locations, particularly where the dykes are exposed to the Tantramar River and the Cumberland Basin, where there has been erosion and scour of the seaward slopes. There is evidence of recent maintenance where sandstone rip rap has been placed on the seaward slope to reduce further erosion.
Highway and Rail Embankments	Although a detailed inspection was not made, where observed, the highway and railway slopes appeared to be stable without problems.

Generally, the study area is readily accessible to vehicle traffic, although there is some agricultural fencing, livestock, and gates restricting access to the windfarms, which was considered during the planning stages for the geotechnical investigation work.

Upon completion of the Site Reconnaissance, the Study Team worked in conjunction with the Legislative and Regulatory Framework Team to identify property and landowners and participated in an iterative review of permitting activities, which would be required based on the potential selected locations for further geotechnical field investigation.

8.2.3 Geotechnical Field Investigation

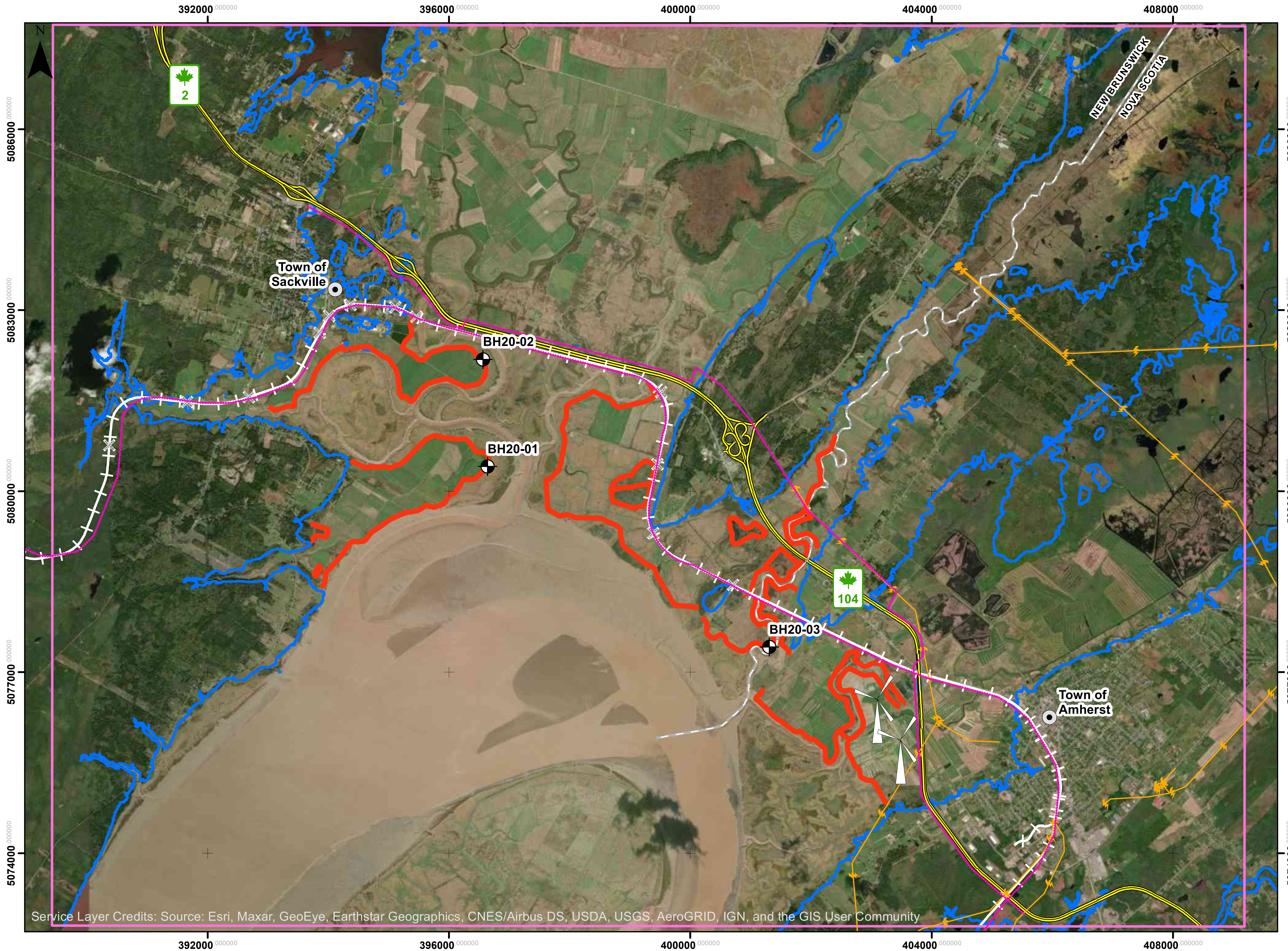
Following the completion of the option comparison (**Section 6.0**) and the selection of the three preferred options, a geotechnical investigation was completed to gather subsurface data at the approximate locations of key structures associated with the options. As documented within the desktop study, the soil conditions are known to vary widely with the study area, therefore it was prudent to obtain preliminary geotechnical data for geotechnical analysis under proposed structures. The information obtained during the geotechnical investigation has been summarized in the Geotechnical Data Report provided in **Appendix C** (Stantec, 2021a).

The fieldwork was completed between November 30 and December 12, 2020. Borehole locations were selected by Stantec based on the proposed locations of water control structures. The approximate locations of the three boreholes are shown in **Figure 8.1**.

Overall, the subsurface conditions encountered during the recent geotechnical investigation are like those documented in the desktop study (Stantec, 2020). Three boreholes, identified as BH20-1, BH20-2 and BH20-3 were drilled at key locations based on the proposed locations of key structures. These are shown in more detail in Figure 1 of the Geotechnical Data Report, (Stantec, 2021a) included in **Appendix C.**

Based on the findings, the following observations and comparisons have been made:

- The thickness of the soft to firm clay, approximately 4 to 8 m, is in the same range as the average thickness reported in the desktop study.
- A sand unit between the clay and the glacial till was not encountered.
- The thickness of glacial till encountered at depths of 26.8 m and 31.4 m was between 6 m and 7 m, slightly thicker than the average thickness of 5 m previously reported for Segment 1 (Stantec, 2020). Glacial till was not encountered at BH20-03.
- The depths to rock, ranging from 16 m to upwards of 38 m below ground surface, were deeper than the previously documented maximum depth of bedrock.



LEGEND:

- Borehole Location
- Railway-Road Crossing
- Buried Bell Fibre
- Railway
- Dykes
- Contour (10.6 m CGVD13)
- Electrical Transmission Line
- Provincial Boundary
- Study Area
- Wind Farm

CLIENT:

NEW BRUNSWICK DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE

wood.

TITLE:

CHIGNECTO ISTHMUS STUDY AREA

PROJECT:

CHIGNECTO ISTMUS CLIMATE CHANGE ADAPTATION COMPREHENSIVE ENGINEERING AND FEASIBILITY STUDY

PROJECT NO: TAE1949362	DATE: APRIL 2021
REV NO: 0	DWN/CHK'D BY: CM/
HORIZONTAL DATUM/PROJ. NAD83 CSRS 2010 UTM ZONE 20 N	VERTICAL DATUM CGVD2013

FIGURE: **FIGURE 8.1 - BOREHOLE LOCATION PLAN**

SCALE: 1:60,000

0 0.75 1.5 3
Kilometres

Path: G:\5300 PROJECTS\2020\TAE1949362_ChignectoIsthmus\MXD\INTERNAL\20210505_TAE1949362_FIGURE 8_1.mxd User: candace.macdonald Date: 5/6/2021

8.3 Geotechnical Design Analyses and Recommendations

The geotechnical desktop study and Geotechnical Data Report (Stantec, 2020 and 2021a) were used to develop the geotechnical parameters for completing the geotechnical analyses and recommendations to support the design of the three selected options. The design of a typical cross-section of dyke for each option was developed including a dyke raise for Options A and C, and construction of a new dyke for Option B. In addition, the Study Team developed a recommended design specification for the steel sheet piling in Option C.

Geotechnical analyses and recommendations completed to support the design of the options include the following:

- Preliminary classification of dykes in accordance with Guidelines for the Design, Construction, and Rehabilitation of Coastal and Estuarine Dykes and Aboiteaux in New Brunswick and Nova Scotia (Amec 2018a) and Safety Guidelines for Coastal and Estuarine Dykes and Aboiteaux in New Brunswick and Nova Scotia (Amec 2018b);
- Seepage analyses of dykes under normal operating tide cycles and storm cycles;
- Slope stability analyses of dykes under several variable loading conditions;
- Riprap sizing for erosion protection; and
- Minimum embedment and steel section for proposed Steel Sheet Pile (SSP) Wall.

The in-situ silty clays that are encountered immediately underlying the surficial root mat within the study area are suitable to be sourced as local borrow for construction of future dyke raises and/or construction of new dykes, particularly within the uppermost weathered crust. It is noted that these materials are moisture and frost sensitive, therefore, care will be required during construction to maintain suitable moisture contents for material placement.

The analyses completed as documented in the Geotechnical Design Memo (Stantec, 2021b) provided in **Appendix C** were used to support the preliminary designs of the three selected options, which are discussed in further detail in **Section 10.0**. In addition to completing preliminary geotechnical analysis, the geotechnical team has also included recommendations for additional studies that will be required to support the advancement of the options as the project proceeds.

9.0 Archaeological Assessment

9.1 Introduction

Archaeological investigations for the study area ("Archaeological Impact Assessment" (AIA) in New Brunswick, "Archaeological Resources Impact Assessment" (ARIA) in Nova Scotia), involved the two preliminary phases of AIA/ARIA investigations: a background desktop review for the general study area and a visual surficial field survey for each of the three study alignment options. The objectives of an AIA/ARIA are to identify, inventory, and evaluate all sites of archaeological and historical significance within the study impact areas and to assess the potential impact on both known and potential archaeological and heritage resources.

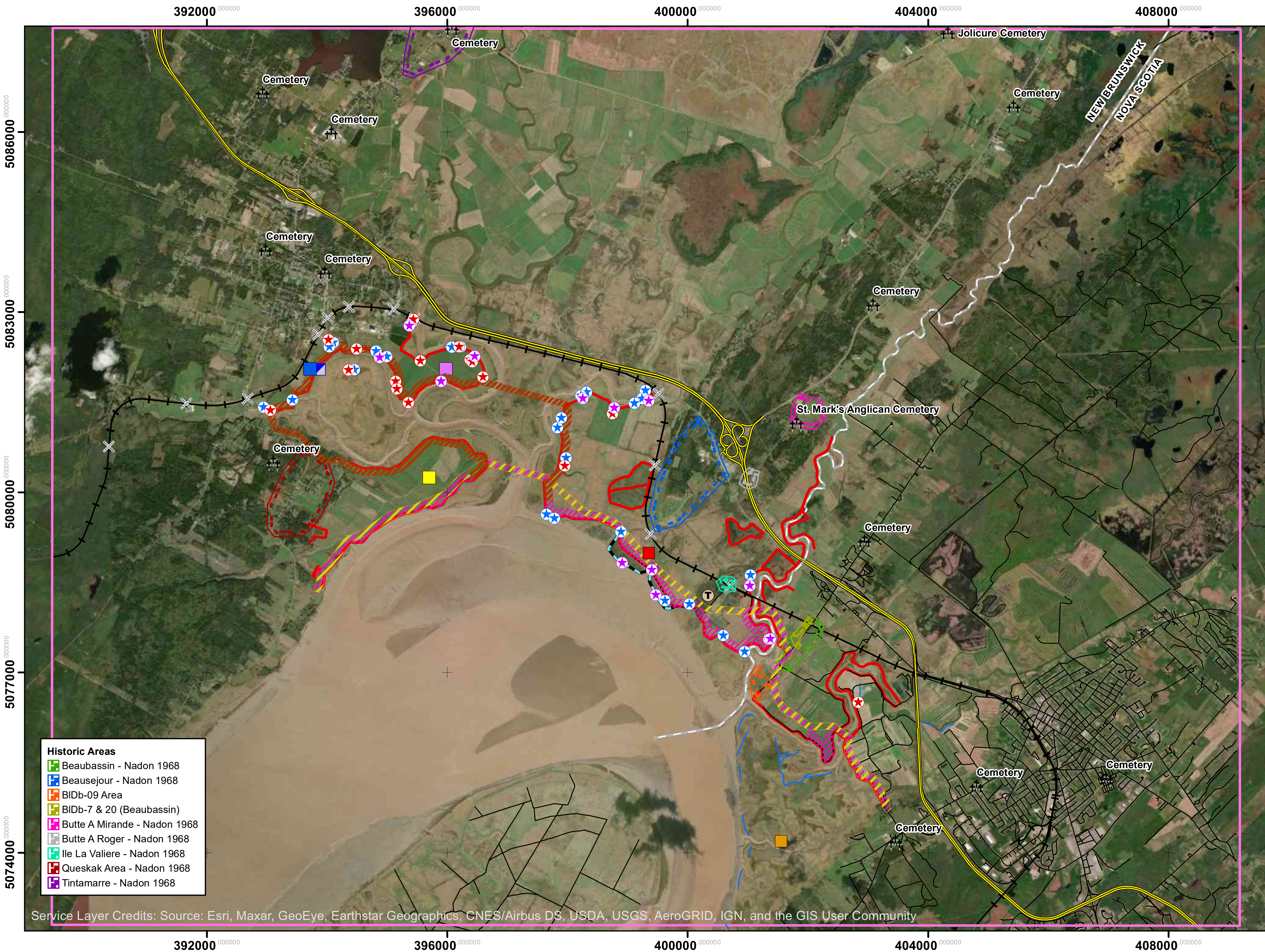
9.1.1 Background Desktop Review

The first phase of the archaeological investigations involved a background desktop review of the general study area to identify and assess the existence of known and/or potential archaeological resources within the footprints of the three proposed options, as well as in the general area around the potential study impact areas. The desktop review for the study included:

- Reviewing present-day and historic aerial photographs and topographic maps;
- Reviewing previous archaeological surveys conducted in the area;
- Reviewing documentation on existing identified heritage sites in the vicinity;
- Conducting a review of archaeological literature sources;
- Identifying any Nationally or Provincially designated historic sites in the area;
- Conducting a review of historical literature sources;
- Reviewing geological surficial and bedrock mapping of the area;
- Procuring and reviewing Archaeology and Heritage Branch New Brunswick (AHBNB) GIS mapping, required for permitting;
- Contacting and consulting with Mi'gmawe'l Tplu'taqnn Inc. (MTI) in New Brunswick and Kwilmu'kw Maw-klusuaqn Negotiation Office (KMKNO) in Nova Scotia; and
- Contacting and consulting with AHBNB and Special Places, Communities, Culture and Heritage Nova Scotia (SP-CCHNS), regarding nearby registered archaeological sites.

9.1.2 Field Examination

The second phase of the archaeological investigations involved a surficial visual survey of the alignments for each of the three proposed options (**Figure 6.2, Figure 6.3, and Figure 6.4**). The survey was conducted by Wood archaeologists Darcy Dignam, Darryl Kelman, and Elissa Atkinson under two New Brunswick permits (2020NB75 (Dignam) and 2020NB76 (Kelman)) and one Nova Scotia permit (A2020NS123 (Dignam)), between November 16 and December 15, 2020. The survey was conducted on foot using hand-held GPS devices and collecting track log GIS data to identify the survey area covered. The linear pedestrian surveys were conducted primarily on the present-day dykes of the five dyked marshes within the study area: Westcock Marsh (NB05), Sackville Marsh (NB37), Dixon Island Marsh (NB16), Aulac Marsh (NB24), and Lusby's Marsh (NS53), as identified in **Figure 9.1**. Rather than conducting the visual surveys of the linear alignments for the three options separately in their individual entirety, the pedestrian surveys were conducted marsh by marsh, ensuring that the sections for each of the three options on that marsh were surveyed.



LEGEND:
- Selected 1950's Dyke & Aboiteaux
- Possible Pre1950's
- Pre1950's Dyking (points)
- Chignecto Cemeteries
- Historic Sackville Wharf
- Tong's Island
- Aulac Marsh (NB24)
- Dixon Island Marsh (NB16)
- Sackville Marsh (NB37)
- Westcock Marsh (NB05)
- Lusby' Marsh (NS53)
- Railway-Road Crossing
- Railway
- NS Roads
- Pre1950's Dykes (lines)
- Selected 1950's Dyke & Aboiteaux
- Dykes
- Provincial Boundary
- Study Area
- Option A
- Option B
- Option C

CLIENT:

NEW BRUNSWICK DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE

TITLE:

DESKTOP IDENTIFIED HERITAGE RESOURCES IN THE PROJECT VICINITY

PROJECT:

CHIGNECTO ISTHMUS CLIMATE CHANGE ADAPTATION COMPREHENSIVE ENGINEERING AND FEASIBILITY STUDY

PROJECT NO:	DATE:
TAE1949362	MAY 2021
REV NO: 1	DWN/CHK'D BY: CM
DATUM: NAD83 CSRS 2010	PROJECTION: UTM ZONE 20 N

FIGURE: **FIGURE 9.1**

SCALE: 1:60,000

0 0.5 1 2 Kilometres

9.2 Findings

9.2.1 Background Desktop Review

Past and present transportation routes and habitation areas are high potential areas for heritage resources. Watercourses lakes, and ocean shorelines were the primary transportation routes in both prehistoric and historic times.

Indigenous peoples and European settlers utilized the river systems and the waterbody shorelines of New Brunswick and Nova Scotia for transportation, settlement, and resource procurement. Therefore, the shorelines of the province's rivers, lakes, and coasts generally have high potential for heritage resources from all time periods. This is the case for the present study area, which runs along the coast of Cumberland Basin and crosses numerous significant watercourses, including the Tantramar, Aulac, Missaguash, and LaPlanche Rivers. In addition, as coastal shorelines and watercourse channels change over time, there remains potential for precontact archaeological resources at locations that today may be high ground or under water. Present-day trails and roads are possible historical transportation routes and indicators for historic habitation locations as well as possible portage routes.

The study area is located within the Chignecto Isthmus. Central to this area is the Missaguash River, which forms the present-day border between New Brunswick and Nova Scotia. The name "Chignecto" is derived from the Mi'kmaw word "Sigunitk"/"Siknikt", which means "foot cloth, alluding to some legend" (Hamilton 1997, Ganong 1896) and/or "at the drainage place", a specific portion of the Mi'kmaw territory (Boreas Heritage 2019). This geographical area has served as an important transportation and trade corridor during both precontact (Indigenous) and post-contact (Historic) times.

The study area falls along an important Indigenous travel route between the Cumberland Basin and Baie Verte, which most likely followed the Missaguash River with an overland portage (Ganong 1899:248–249; Monro 1886:23). Another reported Indigenous portage was located nearby, which connected Memramcook to Westcock (Ganong 1899:248).

Figure 9.1 presents the heritage resources identified during the desktop review, excluding registered archaeological sites. While all registered archaeological sites within the Study area were identified during the desktop review, in accordance with provincial regulatory requirements, the specific locations of these archaeological sites have not been divulged and are not included on Figure 9.1.

9.2.1.1 Indigenous Heritage Resources

A review of the register of archaeological sites for the area indicates that there are 22 registered archaeological sites in New Brunswick and 10 in Nova Scotia, in the vicinity (approximately 7 kilometres (km)) of the study area location. Of these 32 registered sites, 14 have Indigenous components. **Table 9.1** lists these 14 registered Indigenous sites, along with the province they are in and a brief site description. These registered archaeological sites have Indigenous components, ranging from the Archaic period (9,000-3,000 radiocarbon years before present (BP)) through the Woodland (Ceramic) period (2,200-400 BP), and into the Proto-historic period (1,020-360 BP). While there is physical evidence in the archaeological record of an earlier Palaeoindian (11,000-9,000 BP) presence in Baie Verte, this is outside the physical parameters of the study area. The physical evidence within the archaeological record demonstrates the use of this geographic area by the Indigenous peoples over thousands of years.

Table 9.1 Registered Indigenous Archaeological Sites in the Project Vicinity

Site No.	Prov.	Brief Site Description
BlDb-2	NB	Indigenous & Historic site, "Tonge's Island" 1 flake, National Historic Site
BlDb-10	NB	Indigenous site, "Beausejour Bayonet Site", "Late Archaic"
BlDb-12	NB	Indigenous & Historic site, lithic & historic artifacts surface collection

Site No.	Prov.	Brief Site Description
BlDb-17	NS	Indigenous site, single isolated lithic find spot, “celt preform”, “Maritime Woodland”
BlDb-18	NB	Indigenous site, “Beausejour Plummets Site”, lithic plummets, walrus baculum (club)
BlDb-21	NB	Indigenous site, “Black Island”, copper alloy knives, “proto-historic”
BlDb-22	NB	Indigenous site, “Coles Island”, lithic bifaces, surface collected
BlDb-24	NB	Indigenous & Historic site, “Carter Farm”, lithic bifaces, hearth features, gun flint
BlDc-1	NB	Indigenous & Historic site, lithic flakes, English ceramics (Pearlware, Creamware)
BlDc-2	NB	Indigenous site, “Upper Tanramar”, lithic debitage, cultivated field
BlDc-5	NB	Indigenous site, lithic debitage scatter, stone pestle, biface
BlDc-7	NB	Indigenous & Historic site, “Weldon Farm”, lithic scatter, Acadian ceramics (Saintonge)
BkDb-4	NS	Indigenous site, single isolated lithic find spot
BkDb-6	NS	Indigenous site, single isolated lithic find spot

These identified Indigenous sites are associated with the shorelines of the rivers flowing into the Cumberland Basin and the Cumberland Basin shoreline itself. Sites BlDb-10 and BlDb-18 are located offshore of the Aulac Marsh, in the Cumberland Basin; sites BlDb-2, BlDb-17, BlDb-21, and BlDb-24 are within 500 m of the shoreline of the Missaguash River; sites BlDb-12, BlDb-22, BlDc-1, BlDc-2, and BlDc-5 are associated with the shoreline of the Tantramar River; site BlDb-12 is located by the shore of the Aulac River; and sites BkDb-4 and BkDb-6 are associated with the McCan River.

These registered sites with Indigenous components are well inshore of the alignment for the three Options, except for Sites BlDb-10 and BlDb-18, which are offshore of the present-day Aulac Marsh dykes in the Cumberland Basin and sites BkDb-4 and BkDb-6, which are well south of the Project by the McCan River.

9.2.1.2 Historic Heritage Resources

During the early 1670s, Acadian settlers began to move into the Chignecto Isthmus from Port Royal (Ganong 1899:278), whereupon it became an important area both commercially and militarily. In 1676, the isthmus was granted as the Chignitou or Beaubassin Seigneury to Michel Le Neuf La Vallière by Frontenac, Governor General of New France (Ganong 1899:315; Lavoie 1990:14). Several Acadian settlements were established in the area of La Vallière’s Seigneury, including Beauséjour, Beaubassin, Vechcaque (Westcock), Tintemarre, La Coupe, and Le Lac (Ganong 1899:280–281; Surette 2005).

By 1750, it was estimated that approximately 650 Acadians were present along the Missaguash River, Fort Cumberland Ridge, and Aulac (Lavoie 1990:14). La Vallière established a seigneurial manor in the area, probably on Tonge’s Island, which is referred to as Île de La Vallière on early maps (Ganong 1899:278). This location is both registered as an archaeological site (BlDb-2) and as a National Historic Site, because “…it was the capital of Acadia, 1678-1684” (Canadian Register of Historic Places (CRHP) 2021).

In addition to Tonge’s Island, there are two military/fortification National Historic Sites in the Project area, Beaubassin–Fort Lawrence and Fort Beauséjour–Fort Cumberland, which are also registered archaeological sites (BlDb-1 and BlDb-8, respectively). Beaubassin, established in 1672, was one of the most significant Acadian communities on the Isthmus from the late-17th to mid-18th centuries (Parks Canada 2017). The community was razed during the summer of 1750, in an effort to compel the Acadian settlers to move to the French-controlled territory around Beauséjour (Griffiths

2005:392). In the same year (1750), the English established Fort Lawrence on the location of the former community of Beaubassin but was subsequently dismantled in 1756 (Lavoie 1990:15). In 1751, the French constructed a pentagonal, palisaded fort at Beauséjour (Griffiths 2005:395). Following a two-week siege, Fort Beauséjour fell into British hands and was renamed Fort Cumberland, which subsequently played an important role in the Deportation of the Acadians through the 1750s and 1760s (Parks Canada 2018). Following the capture of Fort Beauséjour by the English, Rhode Island settlers came to the Tantramar in 1761 and several families from Yorkshire, England settled on the Chignecto Isthmus, including the Fort Cumberland and Fort Lawrence ridges, in 1772 (Ganong 1899:328). Archaeological traces of both French and English occupation are abundant at and near these sites and consist of surface depressions (indicative of cellars) or other architectural traces which have often been obscured by landscaping activities and other sources of modern disturbance (Nadon 1968; Lavoie 1985, 1990).

In addition to the Tonge’s Island, Beaubassin–Fort Lawrence, and Fort Beauséjour–Fort Cumberland National Historic Sites, two other designated historic sites are located in the Project area: The Fort Lawrence Terminus Provincial Historic Site (archaeological site BlDb-9) and Chapman House National Historic Site (CRHP 2021). The Fort Lawrence Terminus (1888-1891) represents the structural remains of the Chignecto Marine Transport Railway, an ambitious engineering project, which was never completed, to transport ships by rail from the Cumberland Basin to Baie Verte. Chapman House is a two-story Georgian style brick house from the late-eighteenth century, representing an example of a prosperous farmhouse from the period.

Of the 32 registered sites located in the vicinity of the study alignment options, 23 have European Historic components. **Table 9.2** lists these 23 registered sites, along with the province they are in and a brief site description. While five of these sites (BlDb-2, BlDb-12, BlDb-24, BlDc-1, and BlDc-7) also have Indigenous components, the remaining 18 are historic occupation and fortification sites ranging from the 18th to 20th centuries.

Table 9.2 Registered Historic Archaeological Sites in the Project Vicinity

Site No.	Prov.	Brief Site Description
BlDb-1	NB	Historic site, “Fort Beauséjour–Fort Cumberland”, National Historic Site
BlDb-2	NB	Indigenous & Historic site, “Tonge’s Island” 1 flake, National Historic Site
BlDb-3	NB	Historic site, “modern cellar”, 18th Century artifacts
BlDb-4	NB	Historic site, “Beauséjour House 1”, 18th & 19th Century Acadian & English artifacts
BlDb-5	NB	Historic site, “Miner Site”, depression & cellar, 19th Century artifacts
BlDb-6	NB	Historic site, “Trueman Farm” (1)
BlDb-7	NS	Historic site, “Beaubassin” (1), Pre-expulsion Acadian village site
BlDb-8	NS	Historic site, “Beaubassin–Fort Lawrence” National Historic Site
BlDb-9	NS	Historic site, “The Fort Lawrence Terminus” Provincial Historic Site
BlDb-11	NB	Historic site, “South Aulac River”, cellar features & artifacts
BlDb-12	NB	Indigenous & Historic site, lithic & historic artifacts surface collection
BlDb-15	NB	Historic site, “La Coupe”, Acadian artifacts
BlDb-16	NB	Historic site, “Throop”, Acadian & English artifacts, c. 1799-1873
BlDb-20	NS	Historic site, “Beaubassin” (2), Pre-expulsion Acadian village site

Site No.	Prov.	Brief Site Description
BlDb-24	NB	Indigenous & Historic site, “Carter Farm”, lithic bifaces, hearth features, gun flint
BlDb-25	NB	Historic site, “Trueman Farm” (2), Acadian ceramics (Saintonge), clay pipe stems
BlDc-1	NB	Indigenous & Historic site, lithic flakes, English ceramics (Pearlware, Creamware)
BlDc-3	NB	Historic site, depression feature
BlDc-4	NB	Historic site, depression feature with stones
BlDc-7	NB	Indigenous & Historic site, “Weldon Farm”, lithic scatter, Acadian ceramics (Saintonge)
BkDb-3	NS	Historic site, depression features, 19th Century
BkDb-5	NS	Historic site, depressions and artifacts, mid-19th to early 20th Century
BkDc-1	NS	Historic site, depressions and artifacts, mid-19th to early 20th Century

9.2.1.3 Historic Marshlands

The alignments for the three options are all located on the marshlands along the shoreline of the Cumberland Basin. Historically, the five marshlands in this area have been used for agricultural purposes since the late 17th century Acadian habitation of this area. As is the case with the Petitcodiac River saltwater marshlands lands in New Brunswick (AMEC 2011) and the Grand Pre marshlands in Nova Scotia (Fowler 2006), the use of drainage systems to utilize these marshlands for agricultural purposes (dykes and aboiteaux) has continued from the early Acadian use to the present day. A large-scale reclamation of these marshland was conducted in the 1950s by the Maritime Marshland Reclamation Administration (MMRA), through the documentation of existing conditions and the construction of new dykes and aboiteaux to maintain the use of the marshlands for agricultural purposes.

A review of the 1950s MMRA mapping of the marshlands and historic aerial photographs identify the locations of 1950s planned/constructed dyke alignments and aboiteaux, as well as portions/remnants of “pre-1950s” dyking, on the five marshes that are part of the present Project (Westcock, Sackville, Dixon, Aulac, and Lusby’s). While the 1950s dykes and aboiteaux are not considered heritage resources, remnants of earlier drainage systems are considered to be significant heritage resources. As a result of the desktop review of historic and present-day mapping and aerial photography, locations of possible pre-1950s dyking and aboiteaux were mapped in preparation for a field survey of the three Project alignment options (**Figure 9.1**).

9.3 Field Examination

The visual survey of the alignment for the three options resulted in the identification of 27 historic archaeological features, many of which were initially identified during the desktop review of the marshlands. While the majority of these field-identified features are associated with historic, pre-1950s, marshland drainage systems, notable exceptions were historic wharf remnants on the shoreline of Cumberland Basin (Sackville and Lusby’s Marshes) and a grouping of historic building remnants identified by ground depressions, stone walls, a stone well, and artifacts inshore of Lusby’s Marsh. **Table 9.3** lists each archaeological feature identified during the field investigations, the marsh it is located on, and a brief description of the feature. **Figure 9.2** depicts the locations of these field identified features.

Table 9.3 Field Identified Archaeological Features

Feature ID	Marsh Name	Brief Feature Description
2020NB75-1	Dixon Island	Possible inshore pre-1950s dyking. (approx. location).
2020NB75-2	Dixon Island	Possible inshore pre-1950s dyking. (approx. location).
2020NB75-3	Sackville	Possible inshore pre-1950s dyking. (approx. location)
2020NB75-4	Sackville	"Sackville Wharf" – registered Local Historic Place, not yet registered as an archaeological resource. Location of the "old wharf" (c. 1840) and physical remnants of the "new wharf" (c. 1911).
N/A	Westcock	Cultural feature (not archaeological) identified on the 1950s dyke – a recent local "shrine" with a rock enclosure and flowers. meaning unclear.
2020NB75-5	Westcock	Possible pre-1950s "post" dyke facing (Acadian), offshore from 1950s dyke.
2020NB75-6	Westcock	Possible offshore pre-1950s dyking. (approx. location).
N/A	Westcock	Cultural feature (not archaeological) identified on marsh – 20th century barn.
2020NB75-7	Aulac	Possible inshore pre-1950s dyking. (approx. location).
2020NB75-8	Aulac	Possible inshore pre-1950s dyking. (approx. location).
2020NB75-9	Aulac	Possible inshore pre-1950s dyking. (approx. location).
N/A	Aulac	Cultural feature (not archaeological) - Monument identifying the 1953 Aboiteau at this location as an "Historic Civil Engineering Site".
2020NB75-10	Aulac	Possible offshore pre-1950s dyking. (approx. location).
2020NB75-11	Aulac	Possible offshore pre-1950s dyking. (approx. location).
2020NB75-12	Aulac	Possible offshore pre-1950s dyking. (approx. location).
2020NB75-13	Aulac	Possible inshore pre-1950s dyking. (approx. location).
2020NB75-14	Aulac	Possible inshore pre-1950s dyking, associated with location of possible pre-1950s aboiteau. (approx. location).
2020NB75-15	Aulac	Possible offshore pre-1950s dyking. (point taken at railway line).
2020NB75-16	Aulac	Section of decommissioned previous highway alignment, between present alignment and railway line. (point taken at railway line).
2020NB75-17	Aulac	Possible offshore pre-1950s dyking. (point taken at railway line).
2020NB75-18	Aulac	Exposed dyke construction matting. Possibly pre-1950s, but also possibly 1950s.
2020NB75-19	Aulac	1950s Abouteau with possible wood remnants from pre-1950s aboiteau in the immediate vicinity (inshore of the 1950s aboiteau and railway line).
2020NB75-20	Aulac	Possible offshore pre-1950s dyking. (point taken at railway line).
2020NB76-1	Aulac	Possible inshore pre-1950s dyking. (approx. location).

Feature ID	Marsh Name	Brief Feature Description
2020NB76-2	Aulac	Possible inshore pre-1950s dyking. (approx. location).
2020NB76-3	Aulac	Possible inshore pre-1950s dyking. (approx. location). Continuation of 2020NB76-2.
BlDb-9	Lusby's	Identified and documented extent of visible features associated with registered archaeological Site BlDb-9.
A2020NS123-1	Lusby's	Possible historic wharf feature identified by vertical wooden posts (pilings) in a rectangular pattern adjacent and parallel to the shoreline, offshore from the present-day dyke.
A2020NS123-2	Lusby's	Vertical wooden posts aligned along the shoreline. Possible historic dyke facing or a breakwater associated with the nearby historic wharf feature (A2020NS123-1).
A2020NS123-3	Lusby's	A grouping of historic features, including remnants of a road, three stone foundation features, and a stone well feature. A few artifacts observed at the site appeared to be 19th-20th century.

As presented in **Table 9.3**, there were 27 archaeological features and three cultural features (worth noting) observed during the visual field survey of the alignment for the three options. Nineteen of these features are observed possible pre-1950s dykes, 11 inshore of the present-day dyking and 7 offshore. The extent of previously registered site BlDb-9, the Fort Lawrence Terminus Provincial Historic Site, was partially documented in the field because of its proximity to the options alignments. While delineating Site BlDb-9, an unregistered historic site was identified inshore (A2020NS123-3), which included a grouping of historic foundation features, which desktop research identified as a cluster of buildings are visible in a 1931 aerial photograph but were no longer present in the 1945 aerial photograph of the area. In addition to this notable historic site in the Lusby's Marsh area, remnants of an undocumented wooden Wharf (A2020NS123-1) and breakwater (A2020NS123-2) were also identified along the shore of this marsh. Two other archaeological features particularly worthy of note were the remnants of the "Sackville Wharf" (2020NB75-4) not presently registered as an archaeological resource on Sackville Marsh, and apparent pre-1950s dyke facing (2020NB75-5) offshore of Westcock Marsh. Documentation for all the archaeological features will be registered with the respective provincial archaeology regulators, who will assign site numbers accordingly.

In addition to the archaeological features identified, there were three "cultural features" that were observed, which were deemed important enough to mention (for construction purposes) but were not considered to be archaeological resources. These included a shrine and a 20th century barn located on Westcock Marsh and a monument on Aulac Marsh commemorating the construction of the drainage systems in the 1950s as an "Historic Civil Engineering Site".

9.4 Potential Interactions

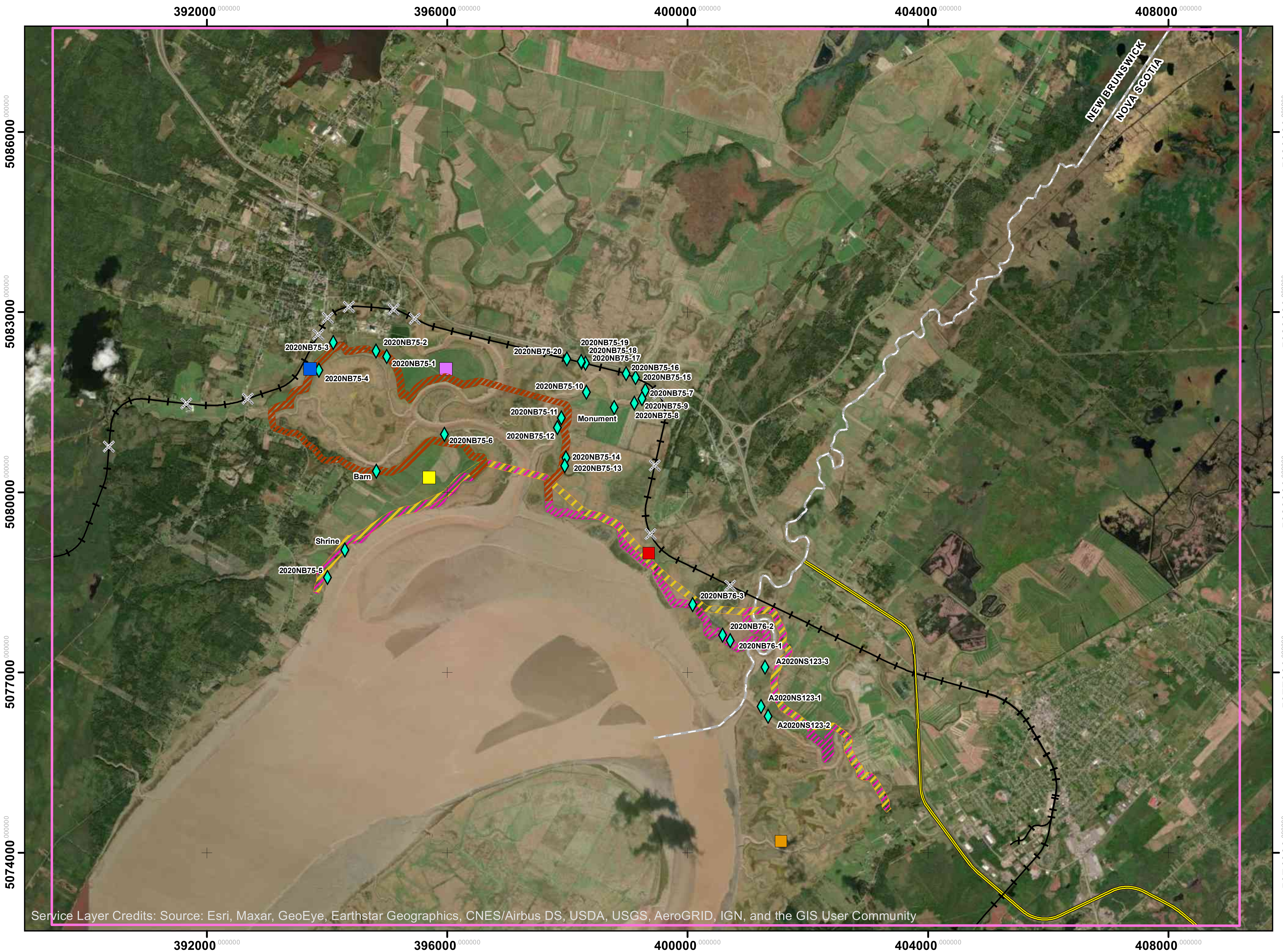
The desktop review of the study area and visual field survey of each of the alignment for the three options identified numerous heritage resources in the vicinity of the study area (**Figure 9.2**). These archaeological features should be avoided in future construction and excavation activities. The one surveyed area of particular sensitivity is the Lusby's Marsh area, where the present-day dyking runs through the centre of registered site BlDb-9, and immediately north of that site is the newly identified historic site with the remnants of a grouping of historic building structures (A2020NS123-3). However, this area has been avoided by all the alignments identified for the three options.

It remains the case that potential options impact areas that are within 100 m of the shoreline of Cumberland Basin, or any watercourse (most notably the Tantramar, Aulac, Missaguash, and LaPlanche Rivers) are considered to have elevated potential for undiscovered archaeological resources. This includes both inshore and offshore of the present-day marsh dyking, as indicated by field identified archaeological resources and the desktop review. It is presently proposed that dyke construction for all three options will use marsh materials excavated within 100 m of the option alignment up to a depth of 1 m. As previously mentioned, archaeological resources, in particular historic resources associated with historic drainage systems dating back to the 1600s, may be present on these marshlands. Should materials be removed from the marshlands to construct dykes, these removal areas (100 m wide) would require archaeological assessment and potentially archaeological monitoring during construction. Should dyke-building materials be procured off-site, only the impact areas (width of the dyke footprint, new or upgraded access roads, and control structures) would likely require archaeological assessments. In addition, archaeological construction monitoring, as determined by the provincial regulator, would likely be required for ground-disturbing activities. Importing off-site materials for construction would significantly reduce potential monitoring requirements.

Regardless of which of the three study options is selected for construction, a full archaeological assessment (AIA/ARIA) must be completed prior to construction. Scheduling and budgeting of dyke modifications must accommodate these considerations.

9.5 Current Traditional Land Use

The Archaeological Research Division (ARD) of the Kwilmu'kw Maw-klusuaqn Negotiation Office (KMKNO) stated that there are "…three recorded traditional use sites within a 1 km radius of the proposed study area…", that is located within the province of Nova Scotia (MacLean pers. comm. 2020). It is presently not known if there are any Traditional land use sites located in the study area the within New Brunswick.



LEGEND:

- Field Identified Archaeology Features
- Aulac Marsh (NB24)
- Dixon Island Marsh (NB16)
- Sackville Marsh (NB37)
- Westcock Marsh (NB05)
- Lusby' Marsh (NS53)
- Railway-Road Crossing
- Railway
- Provincial Boundary
- Study Area
- Option A
- Option B
- Option C

CLIENT:

NEW BRUNSWICK DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE

wood.

TITLE:

FIELD IDENTIFIED FEATURES

PROJECT:

CHIGNECTO ISTHMUS CLIMATE CHANGE ADAPTATION COMPREHENSIVE ENGINEERING AND FEASIBILITY STUDY

PROJECT NO:	DATE:
TAE1949362	MAY 2021
REV NO:	DWN/CHK'D BY:
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DATUM:	PROJECTION:
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FIGURE 9.2

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10.0 Option Refinement - Preliminary Design and Costs

10.1 Introduction

Following the option comparison, as discussed in **Section 6.0**, the top three (3) options were identified for further refinement. The goal of this phase of work was to refine the options and begin to outline preliminary design considerations and costing for each.

The following information was reviewed and considered to augment the option development and preliminary designs specific to the selected options (A to C):

- Existing information provided by NSTIR, NBDTI, CN Rail, NS Agriculture, and other stakeholders; and
- A limited geotechnical investigation field program (Geotechnical Report and Design Memo; **Appendix C)** was executed to provide:
  - supplementary information on the underlying soils in critical locations;
  - to determine the depth of bedrock at the proposed location of the proposed water control structures at the Tantramar and Missiguash Rivers to determine the required lengths of piles that would need to be driven; and
  - associated recommendations required for the preliminary design.

Option A Raise Existing Dyke	• Raise the existing dyke to elevation 10.6 m. • Start south of Sackville at the 10.6 m ground surface contour. • Follow existing dyke alignment up to the mouth of the Tantramar River. • Construct water control structure. • Connect to the existing dyke alignment on the east side of the Tantramar marsh. • Continue to the termination point near Fenton Road.
Option B Build New Dyke	• Construct new dyke to elevation 10.6 m. • Build on landward side, generally following the existing dyke alignment. • Attempt to smooth out new footprint for straightest alignment possible. • Start south of Sackville at the 10.6 m ground surface contour. • Follow existing dyke alignment up to the mouth of the Tantramar River. • Construct water control structure. • Connect to the existing dyke alignment on the east side of the Tantramar marsh. • Continue to the termination point near Fenton Road.
Option C Raise Existing Dyke + SSP	• Raise the existing dyke to elevation 10.6 m. • Follow the existing dyke further up the Tantramar River (than option A and B). • New water control structure will be constructed in the Tantramar River. • East of new structure through Tantramar Marsh to Aulac River, a new Steel Sheet Pile (SSP) wall will be constructed. • New aboiteau structure will be constructed for the Aulac River. • East of Aulac River aboiteau structure, a new dyke will be constructed to tie into the existing dyke until termination point near Fenton Road.

The options are shown in **Figure 10.1**, **Figure 10.2** and **Figure 10.3**, while a summary of the descriptions of the alignment, design, sequence/schedule, assumptions, constructability, and cost are included in this section. The three options are depicted in further design detail in the option design summary document and on the preliminary drawings in **Appendix D**, with the aerial imagery in the background.

10.2 Option Alignment

To simplify the descriptions of each option, the alignments have been broken down into smaller segments using the large water control structures as breakpoints.

As shown on **Figure 10.1**, the Option A dyke alignment follows the existing dyke alignment and crosses the Tantramar River at the mouth of the Bay of Fundy. Reconnection of the existing dyke alignment occurs east of the Tantramar Marsh. Similarly, as shown on **Figure 10.3**, the Option C dyke alignment generally follows the existing dyke alignment as in Option A except that it crosses the Tantramar River further upstream (inland) from the mouth of the Bay of Fundy. East of the new Tantramar River water control structure, the dyke is replaced by the SSP wall to the Aulac River. A new water control structure is required at the Aulac River and east of the structure, the new dyke then rejoins the existing dykes and follows the existing dyke alignment as in Option A.

As shown on **Figure 10.2**, the Option B dyke alignment generally follows parallel along the existing dyke alignment except that it takes a more straight-lined direction (reducing the overall length) and crosses the Tantramar River at the mouth of the Bay of Fundy, like Option A. Once east of the Tantramar Marsh, in general, the Option B alignment follows Option A and the existing dyke alignment, however, Option B does include straightening of sections of the new dyke alignment where possible.

The total length of each proposed alignment is shown in **Table 10.1**.

Table 10.1 Length of Alignment for each Option

Option	Option A – Raise Existing Dyke	Option B - Build New Dyke	Option C – Raise Existing Dyke + SSP
Dyke Length, km	17.0	13.4	27.1

The general plan for the alignment for Option A **(Figure 10.1)** is provided for reference below. An expanded version of this figure can be found in the preliminary drawings for Option A as **Drawings 1 to 12 of 37**, provided in **Appendix D**.

Figure 10.1 General Arrangement Drawing for Option A

The overall plan for Option B is shown in **Figure 10.2**. The location of the dyke alignment to be constructed and the proposed Tantramar River crossing (including a water control structure) is indicated in red. An expanded version of this figure is provided in the preliminary drawings for Option B as **Drawing 13 to 22 of 37**, provided in **Appendix D.**

Figure 10.2 General Arrangement Drawing for Option B

The overall plan for Option C is shown in **Figure 10.3** for reference in this section**.** The location of the dyke alignment to be raised and the proposed Tantramar/Aulcac River crossings (including water control structures) and steel sheet pile is indicated in white. An expanded version of this figure is presented in the detailed preliminary drawings **Drawing 23 to 37 of 37** for Option C in **Appendix D**.

Figure 10.3 General Arrangement Drawing for Option C

10.3 Design

This section summarizes the design components of the options in general terms. Additional detail and information are provided in the option refinement preliminary design memo and drawings included in **Appendix D**.

10.3.1 Dykes

Option A and Option C consist of raising the existing dyke from an elevation of approximately 8 m to an elevation of 10.6 m. Primarily locally sourced material will be used to build up the top and inland (TCH) side of the existing dyke resulting in a top surface 4 m wide with 3 to 1 fore slopes. The seaward side would remain unaffected except in areas where there is limited shoreline in front of the dyke. In these areas the dyke will be protected from storm surge and wave action by the placement of geotextile on the embankment slope topped by a filter blanket and R-500 random riprap. This riprap/armour stone protection will be placed in addition to the standard cross section resulting in a top surface wider than 4 m. Cross sections depicting the typical dyke section are illustrated in **Figure 10.4** and included on **Drawing 32 of 37** in **Appendix D**.

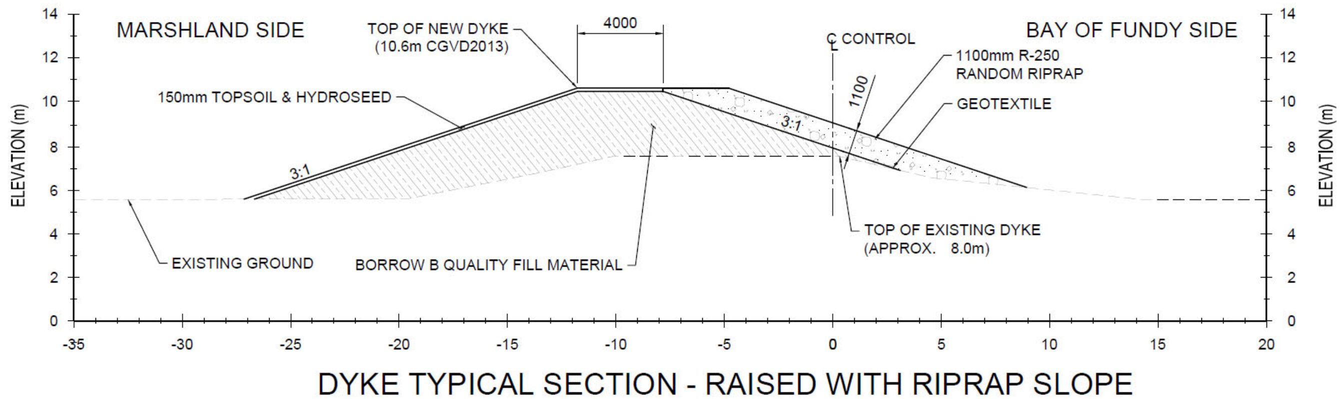


Figure 10.4 Dyke Typical Section for Raising Existing, Options A and C

In areas that may require additional protection, consideration has been given to include armour stone on the Bay of Fundy side. A typical section is shown in **Figure 10.5** and included on **Drawing 32 of 37** in **Appendix D**.

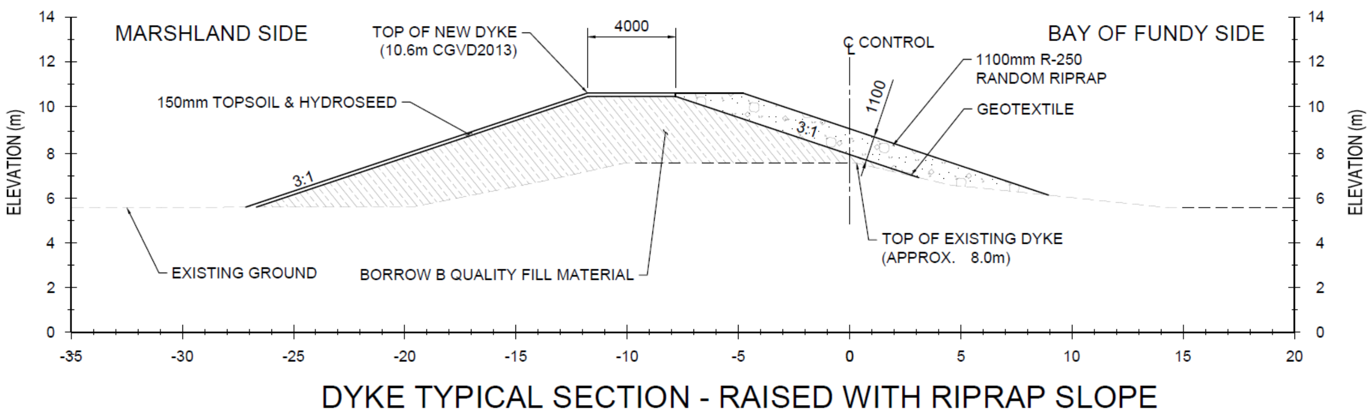


Figure 10.5 Dyke Typical Section for Raising Existing, Options A and C

Option B consists of constructing new dykes using two different construction methods. Portions of the dyke will be built like Option A and Option C by building up the top and inland (TCH) side of the existing dyke, with the other sections being constructed inland of the existing dyke. In addition, construction of the new dyke will include a keyway at the bottom and center of the dyke measuring 2 m by 0.5 m in depth to prevent sliding. Construction would be staged to allow for a period of settlement, as described in Section 10.4. A typical section is shown in **Figure 10.6** and included on **Drawing 32 of 37** in **Appendix D**.

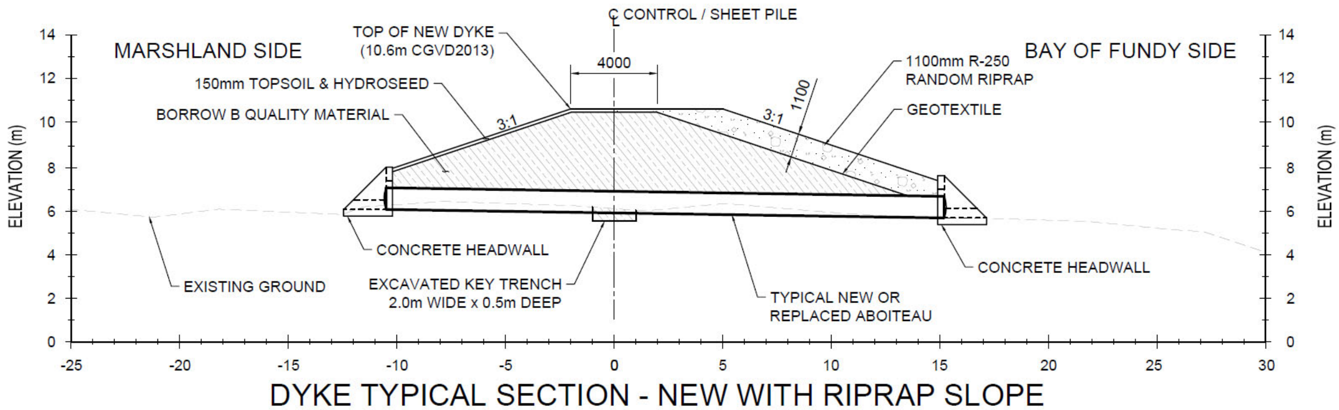


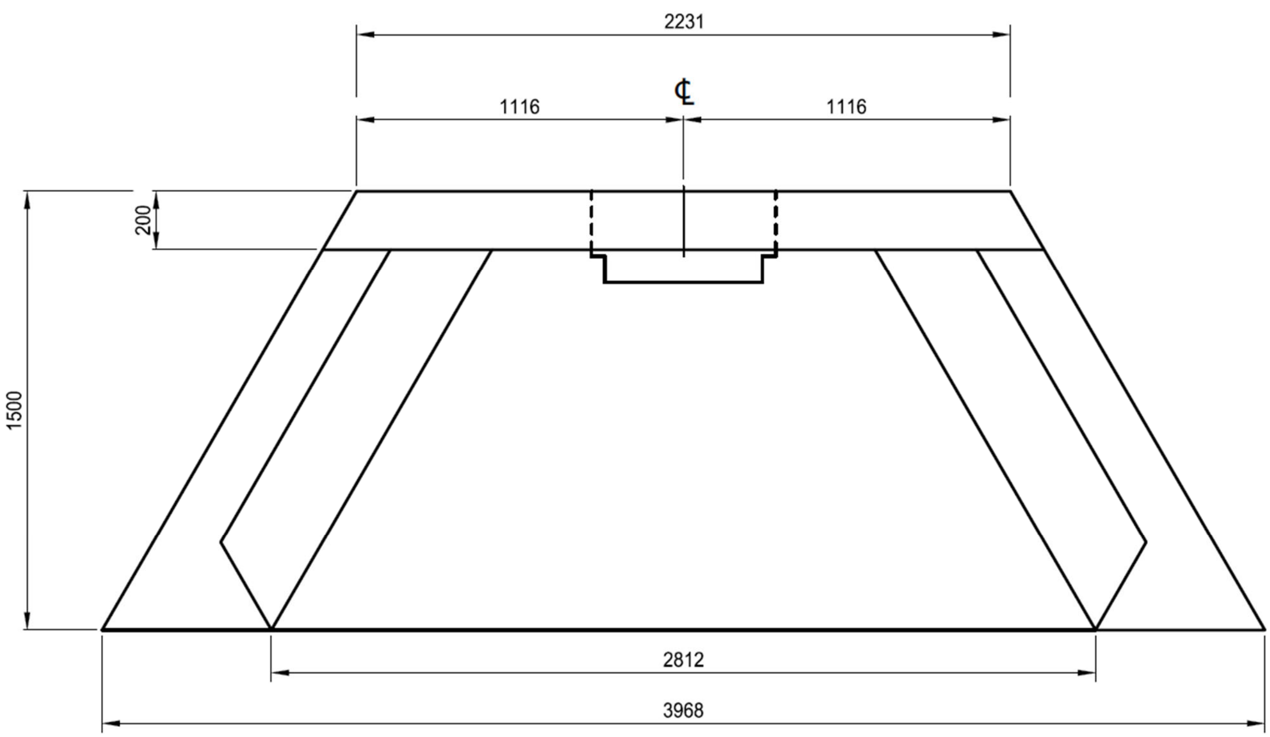
Figure 10.6 Dyke Typical Section for New with Riprap, Option B

As shown in **Figure 10.4** and **Figure 10.5**, both options (raise existing or build new) result in a dyke cross section with a top width of 4 m with 3 to 1 fore slopes covered with topsoil and hydroseed on the marshland side and with riprap on the Bay of Fundy side.

10.3.2 Smaller Aboiteaux

It is assumed that for the three options, the existing smaller aboiteaux will be replaced during construction to raise the elevation of the dykes. Hydraulic studies were not conducted to determine replacement structure sizes for the small aboiteaux at each specific location. Therefore, the hydraulic opening of each existing structure was estimated and compared to standard reinforced concrete pipe sizes. The next nominal size up from the culvert with a matching hydraulic opening was selected for each aboiteaux replacement.

A longitudinal section of each existing culvert was developed using the existing ground surface from available LiDAR information. These sections were used to estimate foundation excavation quantities. New culvert lengths are longer than the existing culverts due to higher dyke elevation (and longer slopes) and larger overall footprint of the dyke. Each culvert will have a flap gate at the outlet end and precast headwalls at both the inlet and outlet ends, appropriately sized for the culvert. Cross-sections depicting the typical detail are illustrated in **Figure 10.7** and included on **Drawing 33 of 37** in **Appendix D.** At each end of the culvert, geotextile type N2 will be placed on the embankment slopes under R-25 random riprap, placed 500 mm thick, and as per the NBDTI and NSTIR Standard Specifications.



TOP VIEW
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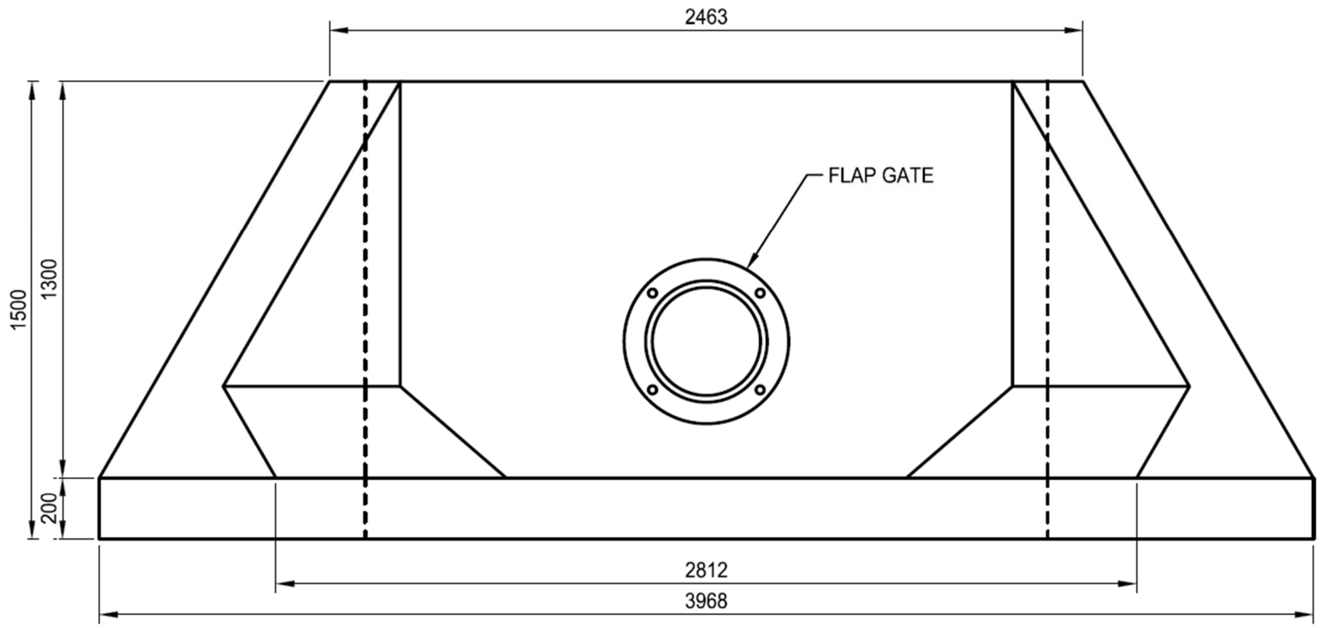

FRONT VIEW
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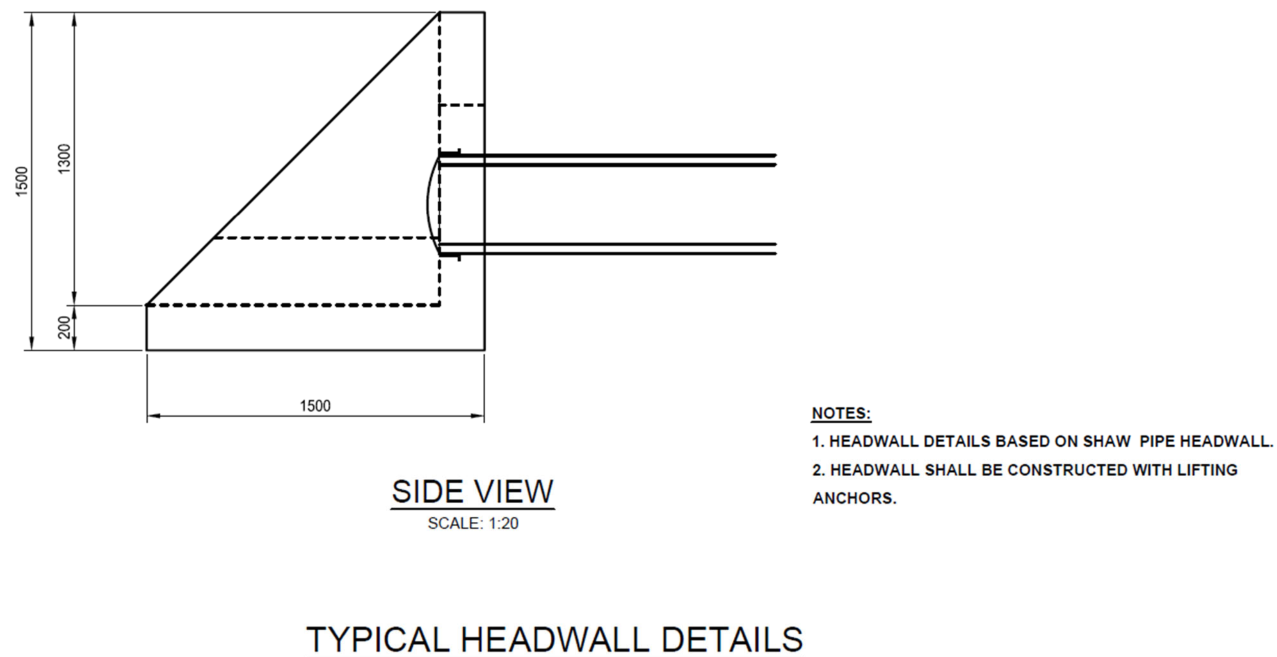

Figure 10.7 Typical Headwall Detail for Options A, B and C

10.3.3 Larger Aboiteaux/Water Control Structures

The large, water control structures are conceptual and based on existing structures in the area. Detailed calculations will require additional hydrotechnical, geotechnical and design for these structures. The three options require large, water control structures at the following locations:

- Tantramar River;
- Missaguash River; and
- LaPlanche River (existing).

Additionally, Option C requires additional water control structures at:

- Carters Brook, and
- Aulac River

In support of the design and operation of these structures, additional hydrotechnical, fish passage studies and potentially fish passage monitoring will be required.

The new proposed structures will need to be designed and operated to allow fish passage. Some of the key options include dedicated fish ways, customized modification to culverts and gates, and proactively managing the water control structures to dampen/clip tidal flow with no complete closure of gates until extreme events. Because the Trade Corridor infrastructure inland of these structures is already protected to approximately el. 7.5 m to 8.5 m and, that currently available state-of-the-art weather forecasting provides sufficient advance warning, some of these water level control structures potentially will only require deployment in extreme circumstances.

10.3.3.1 Tantramar River Water Control Structure

The Tantramar water control structure for Option A and Option B is located near where the Tantramar River discharges into the Bay of Fundy. An existing structure (**Photo 10.1**) upstream at the TCH consists of a twin gated 4.9 m span by 4.6 m wide concrete box culvert structure.

Based on a watershed area of 214 km^2 for the existing structure and 410 km^2 for the location of the new structure, the new structure is assumed to be twice as large as the existing. The new structure consists of four (4) 5 m by 5 m cast-in-place reinforced sluices (open top box), separated with 1.2 m walls in between. Option C (raise existing dykes + SSP), the Tantramar Structure is located further upstream from the Bay of Fundy and does not include the flow from Aulac River, therefore the structure will be similar to the one in Option A and Option B but consist of only three (3) 5 m span by 5 m rise cast-in-place sluices versus the four (4).

Photo 10.1 Existing Tantramar Control Structure

The operation of this water control structure will be used to mitigate flooding by clipping storm surge events when they occur. The water control structure would be closed based on pre-defined high-water elevations in the Bay of Fundy. Once the water recedes, the water control structure would be opened to resume normal water flow. The new water control structure for Option A and Option B is a 4-sluice configuration while Option C is a 3-sluice configuration since it is located further upstream of Options A and Option B and does not include flow from the Aulac River.

The walls are supported on a large slab footing, founded on approximately 30 m deep steel piles with cast-in-place headwalls and flared wingwalls in both designs. At the location of where the dyke abuts with a water control structure, shown in Preliminary **Drawing 32 of 37 (Appendix D),** would include rip rap on both the landward and seaward slopes of the dyke to be protected.

The new structure will be constructed in the dry with either the use of:

1) an adjacent diversion channel and cofferdams upstream and downstream enabling construction in the current channel or;
2) built adjacent to the channel and water diverted to the new structure following construction.

The Tantramar Water Control Structure proposed for Option A (raise existing dyke) and Option B (build new dyke) is shown in **Figure 10.8** and **Drawing 35 of 37** of the Preliminary Drawings in **Appendix D**.

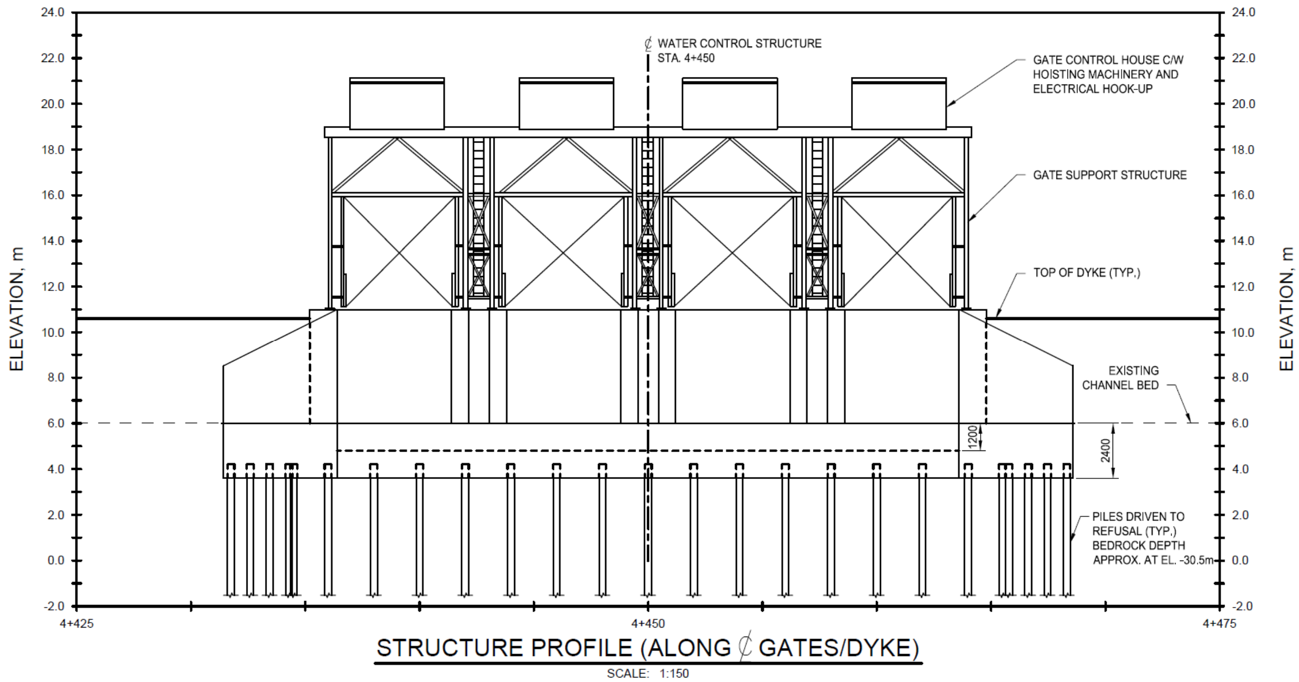

Figure 10.8 **Tantramar River 4 Sluice Water Control Structure for Options A, B**

The Tantramar Water Control Structure proposed for Option C (raise existing dyke + SSP) is shown in **Figure 10.9** and **Drawing 37 of 37** of the Preliminary Drawings in **Appendix D**.

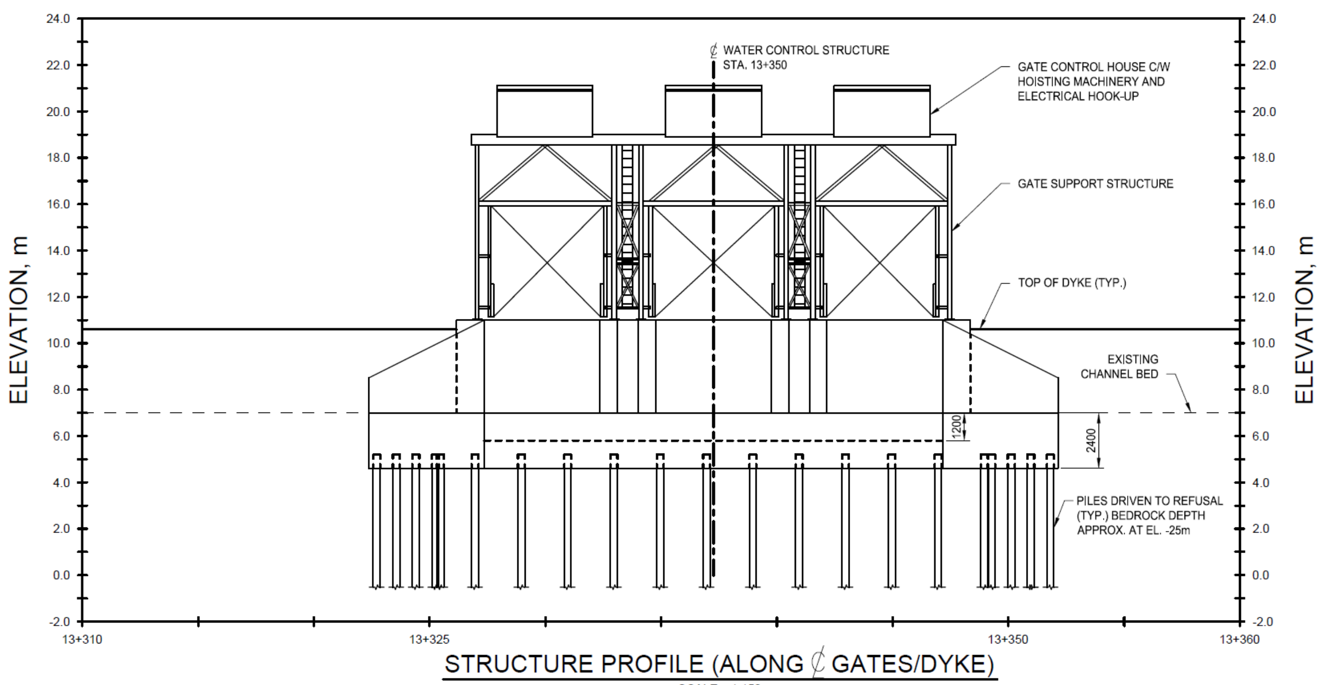

Figure 10.9 **Tantramar River 3 Sluice Water Control Structure for Option C**

10.3.3.2 Missaguash River Water Control Structure

The water control structure design proposed at Missaguash River will be the same for all three (3) options and will be comparable, with improvements, to the existing LaPlanche River structure installed in 2015. This is based on the Missaguash River watershed area of 88 km^2 being smaller than the LaPlanche River watershed area of 143 km^2. The new structure will consist of twin 1824 mm span x 2438 mm rise cast-in-place concrete boxes on steel piles. The structure will be approximately 56 m in length with armour stone protection on the seaward side and riprap on the inland embankment slopes. At the location of where the dyke abuts with to the structure, Preliminary **Drawing 32 of 37 (Appendix D),** would include rip rap on both the landward and seaward slopes of the dyke. The surface of the dyke over the structure will be topped with 300 mm of gravel to facilitate access to the structure for maintenance vehicles, similar to that of the Tantramar Structure.

10.3.3.3 LaPlanche River Water Control Structure

As previously stated above, the LaPlanche River water control structure was recently completed in 2015 and consists of twin 1824 mm span x 2438 mm rise cast-in-place concrete boxes on steel piles. The structure is approximately 56 m in length with armour stone protection on the seaward side and riprap on the inland embankment slopes. The top of the dyke over the structure is topped with 300 mm of gravel surface to facilitate access to the structure for maintenance vehicles.

This structure will be left in place with the earthen portion over the structure raised to elevation 10.6 m by steepening the slopes. Rip rap used for erosion control where the dyke abuts with the structure will be extended as required on both the landward and seaward side slopes. This will be the same for the three options. - the existing structure is shown in **Photo 10.2** for reference.

Photo 10.2 LaPlanche Water Control Structure

10.3.3.4 Carters Brook Water Control Structure

The Carter's Brook structure is only required for Option C and is assumed to be similar to the relatively new existing aboiteau structure that was constructed in 2017 and located immediately upstream where Carter's Brook passes under

Wood Point Road. This new structure will consist of three 1800 mm diameter reinforced concrete pipes approximately 30 m in length, with cast-in-place cut-off walls, headwalls, and flared walls.

10.3.3.5 Aulac River Water Control Structure

Like Carter's Brook, the Aulac River water control structure is only required for Option C and is assumed to be like the existing LaPlanche River structure installed in 2015 (**Photo 10.2**). This is based on the Aulac River watershed area of 127 km^2 being smaller than the LaPlanche River watershed area of 143 km^2.

The structure will consist of twin 1824 mm span x 2438 mm rise cast-in-place concrete boxes on steel piles. The structure will be approximately 56 m in length with armour stone protection on the seaward side and riprap on the inland embankment slopes. The top of the dyke over the structure will be topped with 300 mm of gravel surface to facilitate access to the structure for maintenance vehicles.

10.3.4 Steel Sheet Pile Walls

As shown in **Figure 10.3**, a steel sheet pile (SSP) wall will be constructed south of the existing rail line for Option C. The SSP was designed using methodology detailed in the USS Steel Sheet Design Manual (1984). To ensure the SSP could provide adequate protection, an analysis to estimate the depth of sheet pile embedment and the minimum steel section was necessary for preliminary technical feasibility and cost. The calculations completed provide estimates of sheet pile factor of safety based on soil properties from historical and current soil investigations, assumed ground water and tide levels and approximate existing ground surface elevations. For additional design information refer to the Geotechnical Design Memo (Stantec, 2021b) found in **Appendix C.** A typical sheet pile plan and section are shown in **Drawing 34 of 37** in the Preliminary Drawings in **Appendix D**.

10.4 Sequence/Schedule

As with any large project with significant environmental and ecological sensitivities, there are many requirements that will need to be addressed prior to initiating the detailed design. More specifically, environmental assessments, permitting, land acquisition, detailed geotechnical investigations, hydraulic design, and detailed topographic surveys. Such components are examples of the work to be completed or considered in advance of furthering the design or determining an overall project plan to show how the project will look in terms of design, tendering and construction.

For the purposes of this section, the terms 'phasing', and 'staging' are defined differently.

Staging is defined in terms of the vertical distance of construction whereas phasing is defined as how the project (or projects) will be designed, tendered, and constructed in more of a linear progression in time.

Given the similarity in options in terms of construction, material, etc. – the staging will be relatively similar for each. The staging aspect is driven primarily by the geotechnical conditions of the existing dyke, land adjacent to the dykes and the subsurface soil properties. Based on a preliminary geotechnical investigation and other geotechnical data sources, there are limitations on how much of the dyke can be vertically constructed, while maintaining a factor of safety as it relates to settlement and global stability. As such, the existing dykes are currently constructed to elevations ranging between 7 and 8 m. The Geotechnical Design Memo (**Appendix C)** provides additional details related to the dyke construction and associated findings, assumptions, and recommendations.

For the preliminary design of Option, A (raise existing dykes) and Option C (raise existing dykes + SSP), it was assumed that the existing dykes could be raised to elevation 9.5 m in the first stage to allow for additional settlement. The second stage will include the completion of the dyke to the final design elevation of 10.6 m, based on CGVD 2013 datum. It is understood that other staged approach could be used, however, the two-staged approach is considered in this study for costing purposes.

For the preliminary design of Options B, it was assumed that the new dykes would be constructed to elevation 9.0 – 9.5 m in the first stage to allow for initial settlement. The second stage will include the completion of the dyke to the final design elevation of 10.6 m, based on CGVD 2013 datum.

In terms of phasing, this aspect of the design, tendering and construction is largely influenced by Capital Budgets allocated by each Province.

It would be prudent to begin construction activities as soon as possible because there are locations along the existing dyke that have already been susceptible to breaches and flooding putting the trade corridor at risk.

After the initial project-related tasks have been started, such as the environmental assessment, permitting, and land acquisition, it is reasonable to assume that the design could be completed over a two-to-three-year timeframe. The design of the larger water control structures, such as the Tantramar River structure, will be more involved and complex and will influence the duration of the detailed design. The detailed design associated with the dykes and smaller aboiteaux could be broken up into reasonable pieces, such as in three to five km sections. It is envisioned that the larger aboiteaux structures at the Tantramar River and Missaguash River will be stand-alone design, tender and construction projects, with potentially minimal dyke work that is immediately adjacent to the new structure and within the construction areas defined for the structures. The tendering and construction phases could extend over a longer period and is a function of priorities of each provincial government and their Capital Budgets – priorities for each Province may dictate what portion of the alignment is done first and when.

To achieve a construction timeline of five years or less consolidation enhancements would need to be considered – such as wick drains. Though there are other options to enhance consolidation, for the purpose of the capital cost estimate, the Study Team has considered the inclusion of wick drains. A typical wick drain section is shown in **Drawing 33 of 37** in the Preliminary Drawings in **Appendix D**.

It should be noted that when determining the phasing of the overall project, protection must be always maintained and no breaches in the existing system are permitted. Much of the new construction, such as the smaller aboiteaux and the large, water control structures are on the Bay of Fundy (seaward) side of the existing dyke, and temporary protection against storm surge, wave action and flooding will be required through earthen cofferdams or other physical barriers. These temporary barriers will be required until the new infrastructure can be tied into the existing dyke system and protection can be secured.

Provincial governments and stakeholders will need to collaborate to define an overall project phasing approach as it relates to the design, tendering and construction tasks. Items such as potential federal and provincial funding sources, environmental assessments, permitting, land acquisition and other studies and investigations will need to be considered and discussed, as well as potential budget allocations, projections, and other priorities, to help define how the project should be divided up and phased.

10.5 Assumptions

The following assumptions were made relating to the preliminary design of the dykes, small aboiteaux and large water control structures as part of the Chignecto Isthmus options analysis and unless otherwise noted, are common to all three (3) options discussed to-date.

10.5.1 Dykes

- The 10.6 m protection elevation provided by the PSC for this study is sufficient for protection of existing infrastructure.
- The cross sections of the dykes were derived from the Geotechnical Report and Design Memo in **Appendix C**.

- It is assumed that drainage enhancements such as wick or sand drains would be implemented to accelerate the consolidation and manage the risk of embankment failures due to development of excess pore pressures in foundation soils.
- Filter blanket and riprap/armour stone was assumed for the Bay of Fundy (seaward) side of the dyke along the length of the alignment.
- It was assumed that fill material for the dykes would be sourced locally within 100 m to the landward (TCH side) of the existing dyke and to a depth of 1 m.
- No consideration was given to the number and size of construction contracts or sequencing of the contracts or coordination between the provinces of New Brunswick and Nova Scotia.
- Assumed work to occur within 5 years of provincial funding to align with typical provincial capital budgets.
- Removal of existing dykes in Option B where the new dyke is inland of the existing dyke was not quantified and included in the opinion of probable cost, however, it was considered as a source of material.
- The top of the dyke will provide an driving surface.
- Excavated material sourced locally was assumed to be 100% useable.

10.5.2 Smaller Aboiteaux

- New aboiteaux were assumed to replace all small diameter aboiteaux, including culverts and flap gates.
- New culverts/aboiteaux sizes were increased to the next nominal size up from the existing culvert sizes.
- New cast-in-place concrete box culverts/aboiteaux, like LaPlanche River, were assumed for Aulac River (Option C only) and Missaguash River. Cost for the structures at Aulac River and Missaguash River were derived from the 2014 contract price for LaPlanche River structures as they are all comparable in size.
- The culvert/aboiteau at Carter's Brook for Option C, was assumed to be the same as the culverts and flap gates recently installed upstream, which is a 3-barrel culvert configuration.

10.5.3 Large Aboiteaux/Water Control Structure

- Where appropriate, the operation of water control structures will be used to mitigate flooding by clipping extreme storm surge events when they occur. The gates would close based on pre-defined high-water elevations in the Bay of Fundy. Once the water recedes the gates will open to resume normal water flow.
- Pile depths were assumed based on bedrock depths found during the preliminary geotechnical investigation.
- Structures are conceptual designs and detailed calculations have not been completed.
- Allowance has been included for mud slab (lean concrete) below foundation elevation to provide dry working area.
- Where applicable, allowances were made for power supply (electrical, controls and backup generator), construction access and laydown areas, temporary works, temporary water control, etc.
- Operational, maintenance and rehabilitation costs over the life span of the structures has not been included but are discussed in the Return on Investment/Financial Analysis. **(Section 11.3)**
- Fish passage has been considered however, further hydrotechnical and fish passage studies are required.

10.5.4 Constructability

The preferred options all rank high in terms of constructability and low in negative impacts or interruptions related to the Trade Corridor. Since the three options represent alignments that are all at a considerable offset from the TransCanada Highway and the CN Rail line, there is no discernable impact on traffic within the Trade Corridor such as detours or reduced live loads during structure replacement, and the new dykes, aboiteaux and water control structures can be constructed in isolation and independent from the Trade Corridor operations. Unless otherwise specified, the information as presented will apply to all three options.

10.5.4.1 Source Material

Option A and Option C are defined as raising the existing dyke to elevation 10.6 m. By virtue of this option, the source of material to construct the dyke to the higher elevation cannot be from the existing dyke itself. Rather, it has been assumed that the material will still be sourced locally and within 100 m to the landward side of the existing dyke and up to a depth of 1 m. On this basis, the constructability of Option A and Option C is rated very high, reducing the need for hauling and importing large volumes of borrow material over local roads.

Comparatively, Option B is defined as smoothing out the alignment of the dyke by following a more straight-lined geometry, where possible, constructing new dykes and raising the existing dyke to elevation 10.6 m. By virtue of this option, the source of material to construct the new dyke has been assumed to be a combination of locally-sourced material that is excavated within 100 m to the landward side of the existing dyke and up to a depth of 1 m. The balance of the required dyke fill material will need to be imported from an approved borrow source in the area that meets the specifications. On this basis, the constructability of Option B is rated slightly lower than Option A and Option C due to the need to import borrow material over local roads.

10.5.4.2 Site Access

In terms of site access along the existing dykes, there are multiple properties along the length of the dyke alignment in both New Brunswick and Nova Scotia that provide access to agricultural land and other properties along the dyke system. Similarly, access to construct the large, water control structures at the Tantramar River and Missaguash River, as well as year-round access for maintenance and operation can be achieved by upgrading existing access roads to accommodate construction equipment and delivery of materials. For the Tantramar River water control structure, access can be gained from each side of the river, however, it is envisioned that much of the construction access will be on the east side of the watercourse, which will require crossing the CN Rail line at the existing level crossing near the Aulac Road. Access to the Missaguash River water control structure is via the Fort Lawrence Road, which crosses over the CN Rail line in the form of a grade separated overpass structure.

The construction of the elevated portion of the dyke and the small diameter aboiteau culverts can be completed using standard heavy civil construction equipment that is common to the region, such as excavators, dozers, articulated and tandem dump trucks and rollers/compactors. The large water control structures may require more specialized heavy civil construction equipment such as cranes and concrete pumps, but this equipment is also common to New Brunswick and Nova Scotia and no specialized equipment is foreseen to be required. Upgrade of the existing dyke access roads will be necessary to allow travel of the heavy equipment described, as existing access is meant only for light duty vehicles.

10.5.4.3 Structures

The construction of the smaller aboiteaux culverts will require the existing aboiteaux to be left in place while the new culverts are installed adjacent to them. This will allow for the existing culverts to maintain water control through the dyke, during construction. Following the installation of the new culvert, the existing aboiteaux can be removed. Alternatively, and depending on the flow volume of the watercourse, the new culvert could be installed at the same location as the existing culvert if the flow is such that it can be controlled by pumping. The new culvert installation will require an earthen cofferdam at the outlet end to mitigate high tide influence and the potential of water entering the excavation. Earthen cofferdams can be removed, and riprap and headwalls can be placed at low tide.

The construction of the large water control structures at the Tantramar River and Missaguash River will be in the dry and like the construction of the new structure at the LaPlanche River in Nova Scotia in 2015. This structure was isolated with earthen cofferdams upstream and downstream to protect the construction area. Once the construction is completed, the earthen cofferdams are removed, and the in-water construction work can be completed. There is ample width at the Tantramar River location to construct an earthen cofferdam and not significantly reduce the flow capacity of the river. At the Missaguash River structure location, the river may require limited excavation to widen the watercourse to facilitate the construction of the cofferdam and not restrict the flow of the river.

10.5.4.4 Environmental

From an environmental perspective, the entire dyke alignment for Option A, Option B and Option C is located within an environmentally sensitive ecosystem area consisting of watercourses and wetlands, agricultural land, and historic and archaeological sites. These areas will need to be considered in all aspects of the design and construction of the options so that the impacts are minimized or avoided. Erosion and sediment control and prevention features will need to be integrated into the project such as sediment fencing, use of clean rock fill for construction access roads and laydown areas, filter fabric, mulch, hydroseed, riprap and armour stone.

10.5.5 Cost

For each option, a preliminary option construction cost estimate summary, with related calculations, was prepared based on the NBDTI Standard Specifications for Highway Construction and associated items and units of measure. Items included, but were not limited to grading, structures, environmental and payments divisions, including items for common excavation, borrow, culverts, concrete, reinforcing steel, riprap, armour stone, sediment control fence and mobilization.

Unit pricing was based on recently tendered heavy civil construction contracts in New Brunswick and Nova Scotia, as well as material pricing from vendors for items such as concrete pipe, flap gates for aboiteaux, precast headwalls, etc. A factor of 25% of these supply costs was carried for the installation aspect of the items. Mobilization was calculated on an assumed 5% of the total Contractor Items, however, there was no cap placed on the amount since it was unknown how the construction of the dykes, aboiteaux and large water control structures would be tendered and how many contracts would be issued in each province.

The structural costs related to the larger aboiteau structure at the Missaguash River and the large water control structure at the Tantramar River were calculated separately and include additional site-specific studies which would be required in advance of detailed design. The cost for the large aboiteau structure at the Missaguash River was derived from the construction costs and experience gained from the LaPlanche River aboiteau structure, which was recently completed in Nova Scotia.

For the Tantramar River water control structure, separate detailed preliminary cost and calculations were prepared on a combined unit price, lump sum and contingency basis. Preliminary quantities were derived based on the general arrangement drawings (**Drawing 35 of 37**) included in **Appendix D**, to develop costs for items such as piled foundations, concrete, reinforcing steel, structural steel, steel gates, backup power supply and other related items. A quantities contingency allowance of 10% was included to account for items that could not be quantified or costed for items such as site access and development, laydown area construction, power supply, miscellaneous materials related to the hydraulics, mechanical, and electrical systems, etc.

In addition, the preliminary option construction cost estimate includes a series of allowances and contingency amounts to cover other costs that could not be directly quantified and were based on figures that are typical of the heavy civil industry. Two primary allowances or contingency factors were applied to the preliminary itemized construction cost estimate items amount:

- **Environmental Contingency (5%)**; and
- **General Contingency (10%)**.

The allowance for the Environmental Contingency is to include costs associated with permitting, studies, and other reporting and other environmental measures required for the study area. The General Contingency allowance includes provision for items such as:

- fluctuations in unit pricing;
- construction access and haul roads;
- laydown areas; and
- other unforeseen items not accounted for or quantified under the itemized list.

Once these allowances were applied to the preliminary option construction items cost total, additional allowances were applied to account for the costs for the engineering. Engineering contingencies included:

- **Detailed Design Phase (5%)**; and
- **Tendering and Construction Phase (10%)**.

The allowance for engineering for detailed design also includes geotechnical investigations, topographical surveys, monitoring of settlement and pore pressures, monitoring of wick drain performance, while the construction allowance includes contract administration, project management, inspection and materials testing, etc. These estimates and allowances have been applied to the overall Preliminary Option Construction Cost Estimate; additional allowances specific to some of the larger structures has been captured within the detailed item estimates.

10.6 Summary

The goal of this phase of work was to refine the Options and outline the preliminary design considerations and costing for each option. The major design components have been previously summarized in this section and are further detailed in the option refinement preliminary design and preliminary drawing package, **Appendix D**. **Table 10.2** shows a comparison of each option and the general option characteristics, components, and footprint as well as the associated Preliminary option Construction Cost Estimate for each option as they are described within. For additional detail or information please refer to information contained with **Appendix D** and **Appendix E**.

Table 10.2 Summary of Option Characteristics for Option A, Option B and Option C

Item	Option A - Raise Existing Dykes	Option B – Build New Dykes	Option C – Raise Existing + SSP
Option Capital Construction Cost Estimate	$200.2M	$189.2 M	$300.8 M
Dyke Length	17 km	13.4 km	27.1 km
Estimated Footprint (ha.)	234	206	373
Dyke Construction Material	Local 90% Imported 10%	Local 75% Imported 25%	Local 90% Imported 10%
Sheet Piling (Steel)	None	None	1.038 km
Small Aboiteaux / Culverts (Concrete Pipe)	9	8	18
Major Aboiteaux / Culverts	Missaguash River: Twin Concrete Box	Missaguash River: Twin Concrete Box	Carter's Brook: 3-Barrel Culvert Aulac River: Twin Concrete Box Missaguash River: Twin Concrete Box
Water Control Structures	4 Sluice Tantramar River	4 Sluice Tantramar River	3 Sluice Tantramar River
Dyke Service / Access Roads	Existing	Existing	Existing
Structure Service / Access Roads	On top of new dyke	On top of new dyke	On top of new dyke
Road Construction Method	Combination of locally sourced and imported material	Combination of locally sourced and imported material	Combination of locally sourced and imported material
Buildings	Electrical Service Shed for Tantramar River Control Structure	Electrical Service Shed for Tantramar River Control Structure	Electrical Service Shed for Tantramar River Control Structure

11.0 Comparative Studies

This section includes a comparative review of the potential environmental impacts as well as examines the infrastructure resiliency risk review between the options. Finally, a comparative review of the associated benefits and costs as well as financial implications of the three options. These comparative studies, or the respective summaries will be presented as a single chapter, **Sections 11.1**, **11.2** and **11.3**.

11.1 Comparative Environmental Review

11.1.1 Purpose

To assist in the understanding of environmental, social, and socio-economic issues potentially associated with the three options, a Comparative Environmental Review (CER) has been completed and documented. This section provides a summary of the CER findings. The complete report can be found as **Appendix F**.

The CER will also support the scoping and conduct of any future environmental assessment or other environmental regulatory requirements as may be required in the future if the respective government authorities decide to pursue development of the preferred option.

The CER process contributes to the PSC's selection of a preferred option by comparing, at a high-level, the anticipated environmental, social, or economic outcomes of each of the options, based on current knowledge. The CER does not compare each option to the status quo or "do nothing" scenario, as that is not considered a feasible alternative.

The selection of the preferred option is not part of the CER Process. The CER Report is only one source of information that the PSC will use to select the preferred Option. A wide range of environmental, economic, engineering, energy policy and social issues are considered, as well as the results of other studies being conducted, and input received from Indigenous groups, stakeholders and the public.

The CER is also intended to provide a resource to support Indigenous, public, and stakeholder engagement and to aid in the scoping and conduct of any required future environmental assessment of the selected preferred option.

Environmental assessment is a planning process that is used to predict environmental effects of projects before they are carried out so that adverse effects can be reduced, and positive effects can be enhanced, through project design and planning. An assessment can be required provincially or federally. The CER differs from a typical environmental assessment in the following ways:

- The CER is a planning tool that will help in the selection of a preferred option; it is not a formal regulatory process driven by federal or provincial legislation.
- The CER's intended audience is primarily the PSC as well as the public, stakeholders, and Indigenous groups, rather than regulatory agencies which are the primary authorities for a formal EA.
- The CER generally considers and discusses the key environmental issues and concerns associated with each option, including how to reduce environmental interactions associated with the option; it does not include an formal, detailed environmental assessment that would lead to regulatory approval of a planned development.
- The CER will be based on publicly available desktop data, and is primarily conducted using qualitative means, rather than through quantitative evaluation.
- The CER will not provide a determination or judgment about whether the environmental interactions are acceptable according to legislation, objectives, standards, sustainability targets, legally enforceable limits, or other thresholds.

11.1.2 Summary of Comparative Environmental Review

The options will likely require an environmental assessment of some form. After the preferred option is selected, the PSC will consult with provincial and federal regulators to determine the environmental assessment requirements for the Project.

Valued components (VC) for the Atmospheric, Aquatic, Terrestrial and Socio-Economic environments, as well as Heritage Resources were evaluated as part of the CER. The environmental attributes and potential environmental interactions of each option with the VCs were evaluated and summarized and presented in **Table 12.1** of the CER report, **Appendix F**.

The summary and conclusions show that the three options, while differing in some elements will result in similar environmental effects. Although there are differences in the magnitude, extent, and duration of some potential effects, the pathways of interaction are the same, with a few exceptions (e.g., pile driving would be required for Option C, and changes from farmland to salt march for Option B). Standard mitigation measures will be incorporated into the design and construction of the selected option to effectively avoid or reduce potential environmental interactions.

11.2 Comparative Climate Change Resilience Assessment Risk Review

11.2.1 Purpose

The purpose of this comparative study was to conduct a a Climate Change Resilience Assessment (CCRA) for the options developed under the Chignecto Isthmus Climate Change Adaptation Comprehensive Engineering and Feasibility Study. This section presents a summary this assessment as it relates to the current study; the detailed assessment is included in **Appendix G**.

11.2.2 Methods

This Climate Lens Assessment (CLA) is a requirement applicable to Infrastructure Canada's Investing in Canada Infrastructure Program (ICIP), and Green Infrastructure - Adaptation, Resilience and Disaster Mitigation. The CLA employs a risk management approach to anticipate, prevent, withstand, respond to, and recover from a climate change related disruption or impact to physical infrastructure.

The work scope for this assignment is compliant with Part 2 of the guidance document listed below.

- Climate Lens - General Guidance, Version 1.2 - September 6, 2019, Infrastructure Canada. Available via URL https://www.infrastructure.gc.ca/alt-format/pdf/guidelines-lignes-directrices/climate-lens-general-guidance-2019-10-31.pdf

The CCRA is based on a streamlined application of the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol which is an Infrastructure Canada approved methodology to conduct this type of CCRA. In general, the assessment focuses on the potential interaction between the option infrastructure components and climate change hazards determined by the climate science analysis and engineering judgment. Each climate change hazard is assigned a probability of occurrence score. Similarly, each infrastructure component / climate event interaction is scored based on the expected severity of impact should the climate event occur. The probability of occurrence score in combination with the severity of impact score leads to a quantification of vulnerability. These vulnerability scores can then be used to determine the priority or ranking of each infrastructure component – climate change hazard interaction.

11.2.3 Context

The overall objective of the study is to identify three viable options to protect and sustain the Chignecto Isthmus Trade Corridor in relation to anticipated Climate Change impacts. The assets in the corridor include the TransCanada Highway, CN Rail, 138 kV and 345 kV electricity transmission lines, fibre optical cables, a wind farm, agricultural cropland activities, and various other utilities. This assessment is not concerned with the existing infrastructure in the corridor. There is no change proposed to the linear alignment or physical characteristics to these assets. Rather, the assessment is focused on the three new options which will offer protection to the value-generating assets from projected climate change hazards.

11.2.3.1 Climate Change Hazards

The ten (10) climate change hazard categories considered in this assessment, identified through the Climate Science Analysis for the Chignecto Isthmus region and in consideration of the options' characteristics, are:

1) Sea level rise
2) Freeze thaw cycle
3) Heavy rain / daily total rain
4) Winter rain / freezing rain
5) Storm surge
6) Coastal erosion
7) Hurricane/tropical storm
8) High wind
9) Thunderstorm / hail / lightning
10) Wave uprush

11.2.4 Infrastructure Assessed

The infrastructure components considered for the assessment are presented in **Section 10.0**. The assessment also considers operation and maintenance (O&M) and personnel safety to understand loss-of-service issues related to climate change. The principal features of the options are summarized in **Table 11.1**.

Table 11.1 Option Characteristics

Item	Option A	Option B	Option C
Dyke Length	17. km	13.4 km	27.1 km
Estimated Footprint (ha.)	234	206	373
Dyke Construction Material	Local 90% Imported 10%	Local 75% Imported 25%	Local 90% Imported 10%
Sheet Piling (Steel)	None	None	1.038 km
Small Aboiteaux / Culverts (Concrete Pipe)	9	8	18
Major Aboiteaux / Culverts	Missaguash River: Twin Concrete Box	Missaguash River: Twin Concrete Box	Carter's Brook: 3-Barrel Culvert Aulac River: Twin Concrete Box Missaguash River: Twin Concrete Box
Water Control Structures	4 Sluice Tantramar River	4 Sluice Tantramar River	3 Sluice Tantramar River
Dyke Service / Access Roads	Existing	Existing	Existing
Structure Service / Access Roads	On top of new dyke	On top of new dyke	On top of new dyke

Item	Option A	Option B	Option C
Road Construction Method	Combination of locally sourced and imported material	Combination of locally sourced and imported material	Combination of locally sourced and imported material
Buildings	Electrical Service Shed for Tantramar River Control Structure	Electrical Service Shed for Tantramar River Control Structure	Electrical Service Shed for Tantramar River Control Structure

Source: Wood / Stantec 2021

11.2.4.1 Climate Interactions and Risk Ranking

A total of two hundred and fifty (250) climate change hazard – infrastructure component interactions were assessed to identify those infrastructure components that should be considered for further analysis. A total of one hundred and seventy-eight (178) interactions for Option A and Option B, and a total of one hundred and eighty-eight (188) interactions for Option C were further assessed for risk ranking. The results are summarized in **Table 11.2**.

Table 11.2 Climate- Infrastructure Interaction Summary

Metric	Option A/ Option B	Option C
Total Number of Interactions Assessed	178	188
Number of Interactions Carried Forward for Risk Ranking	178	188
Number of Climate Change Hazards Carried Forward for Risk Ranking	10	10
Infrastructure Components with Highest Number of Interactions	Flap gates Culvert Pipes Armour Stone Filter Stone Drainage Management	Flap gates Culvert Pipes Armour Stone Filter Stone Drainage Management
Climate Change Hazards with Highest Number of Interactions	Freeze / Thaw Cycle Winter Rain / Freezing Rain Storm Surge Hurricane / Tropical Storm SLR	Freeze / Thaw Cycle Winter Rain / Freezing Rain Storm Surge Hurricane / Tropical Storm SLR

The determination of the ranking or priority of the climate change hazard – infrastructure component interaction is accomplished by applying the PIEVC Protocol which defines the priority of a climate effect as risk = probability X severity (R = P X S).

The probability of occurrence of a climate change hazard score factors and the severity of impact score factors are obtained from the PIEVC Protocol which defines three categories of Priority of Climate Effect, as follows:

R > 36: "High" possibility of a severe effect. Interactions in this range should lead to design recommendations.

12 < R ≤ 36: "Medium" possibility of a major effect. These effects are in a "grey area", where it is uncertain whether the severity or duration of the impact could trigger the need for further action. Recommendations can focus on design considerations or mitigative operational actions.

R ≤ 12: "Low" possibility of an effect. These infrastructure-climate interactions are typically excluded from further analysis.

Based on the risk ranking scoring, the results are summarized in **Table 11.3.**

Table 11.3 Risk Ranking Summary

Metric	Options A / B	Option C
Total Number of Interactions	178	188
Interactions in the "High" Category	0	0
Interactions in the "Medium" Category	94	99
Interactions in the "Low" Category	84	89
Climate Change Hazards Exhibiting the Highest Number of Interactions	Freeze / Thaw Cycle Winter Rain / Freezing Rain Storm Surge Hurricane / Tropical Storm Thunderstorm Wave Uprush	Freeze / Thaw Cycle Winter Rain / Freezing Rain Storm Surge Hurricane / Tropical Storm Thunderstorm Wave Uprush

11.2.5 Qualitative Comparative Resilience Assessment

From the perspective of the impact of the climate change hazards on the individual infrastructure components the resilience of all options is relatively similar. However, from a qualitative perspective it is useful to consider the factors presented in **Table 11.4**.

Table 11.4 Comparative Resilience Summary

Factor	Assessment	Option Ranking
Dyke exposure to tidal side climate parameters	Option C is 11 km longer than Option A and 15 km longer than Option B. The degree of exposure of the dykes to climate change hazards is a function of the dyke tidal face length.	**Option B** **Option A** **Option C**
Structure exposure to tidal side climate parameters	Option C has 22 aboiteaux / water control facilities: Option A has 11 and Option B has 10. The combined gate surface area for the Option A/ Option B Tantramar River control structure is approximately 100 m^2 which will catch high wind. This is only slightly more than the 60 m^2 gate area for Option C. The degree of exposure of the structures (length and area) to climate change hazards is a function of the number of structures.	**Option A / Option B** **Option C**
Flexibility and cost of increasing crest elevation in future	This factor is a function of the dyke length and the efficiency / cost of access to suitable material. Based on the local / imported material distribution, Option A and Option B are similar but Option B is of shorter length.	**Option B** **Option A** **Option C**

Factor	Assessment	Option Ranking
Flexibility and cost of operations and maintenance	O&M activity is a function of ease of access for vehicles and personnel and the extent of infrastructure to be maintained / repaired. Access is considered similar for all options. The length and number of structures associated with Option C would imply higher costs than the other Options.	**Option A / Option B** **Option C**
Natural features to mitigate near shore dynamic energy	Option A involves increasing the crest elevation of the existing dykes on the existing alignment. Option B involves retreating to a new, more inland alignment thereby increasing the nearshore buffer effect. Option C provides for some energy reduction up the Tantramar River delta.	**Option C** **Option B** **Option A**

11.2.6 Findings and Recommendations

Based on this Climate Change Risk Assessment it is concluded that the proposed infrastructure components that comprise the three options represent an overall medium risk from the potential impacts of projected climate change hazards. The medium risk reflects intelligence not yet known:

- ✓ The options are only at feasibility/preliminary design stage; future field investigations which will be part of the detailed design effort will bring refined data to the CCRA.

- ✓ The Intergovernmental Panel on Climate Change (IPCC) will release the 6th Report in 2021 and it is anticipated that most climate projections relevant to the CCRA analysis will increase, potentially causing uncertainty in the current design basis. As such, the CCRA should be revisited for any potential dramatic changes that may affect the findings of the CCRA report.

The current effort is primarily a screening effort to inform selection of a preferred option. From the perspective of infrastructure resilience and qualitative factors Option B would appear to be preferable. There may be other factors outside of the scope of the CCRA that may affect this conclusion.

The findings regarding infrastructure resilience are based on the following assumptions:

- The final design of the dykes and water control structures, as well as ancillary features will comply with relevant the Guidelines for Design, Construction, and Rehabilitation of Coastal and Estuarine Dykes, Aboiteaux New Brunswick and Nova Scotia (Amec Foster Wheeler, 2018a), and the Guidelines for Safety of Coastal and Estuarine Dykes and Aboiteaux New Brunswick and Nova Scotia (Amec Foster Wheeler, 2018b), Canadian Dam Association guidelines, and the Geotechnical Design Memo (Stantec, 2021b).
- The construction and implementation of the options will be undertaken by an experienced contractor familiar with dyke and water control structure development in an environment like that of the Chignecto Isthmus.
- The minimal dyke crest elevation, for the purpose of the study, is 10.6 m which is sufficient to prevent seaward flooding (overtopping) from anticipated total water levels for the tri-decadal period 2050-2100 based on the current climate science.
- The final design of the steel sheet pile (Option C) will comply with the USS Steel Sheet Design Manual (1984).
- The operations and maintenance associated with the options will be conducted in accordance with best practices for marine shoreline infrastructure in the Bay of Fundy / Cumberland Basin.

As the options are further refined, design and construction should proceed in a manner that anticipates, adapts to and mitigates projected climate change impacts.

Notwithstanding these findings it must be recognized that climate science is a rapidly changing landscape and extreme weather events that can cause catastrophic damage are difficult to predict in terms of timing, intensity, duration and consequences. The infrastructure damage and socio-economic devastation caused by the recent ice storm in Texas, USA in February 2021 serve to reinforce this threat.

11.2.6.1 Greening Government Strategy

The Greening Government Strategy supports Canada's sustainability goals already established under the Paris Agreement on climate change and in the Pan-Canadian Framework on Clean Growth and Climate Change. The Strategy is consistent with the United Nation's 2030 Agenda for Sustainable Development and the Federal Sustainable Development Strategy.

The Government of Canada's objective with this Strategy is to transition to low-carbon and climate-resilient operations, while also reducing environmental impacts beyond carbon.

The CCRA documented in this report is in alignment with many aspects of the Greening Government Strategy, including:

- ✓ Low-carbon, sustainable, and climate resilient real property;
- ✓ Climate resilient assets, services, and operations;
- ✓ Federal emissions reduction, resiliency and greening government initiatives; and
- ✓ Integrating knowledge from other leading organizations and share best practices broadly.

11.3 Return on Investment / Financial Analysis

11.3.1 Introduction

The return on investment (ROI) is a function of the monetized value generated by the assets in the Trade Corridor that will be protected from future climate change hazards and extreme weather events compared to the total capital cost of the option plus operation and maintenance costs. Anything that has a cost with the potential to derive gains can have an ROI assigned to it.

The Study Terms of Reference require a Cost-Benefit Analysis / financial analysis of the three selected options. The value-generating assets in the trade corridor include the TransCanada Highway, CN Rail, 138 kV and 345 kV electricity transmission lines, Fibre optical cables, a wind farm, agricultural cropland activities, and various other utilities. Of the current options, there is no change proposed to the linear alignment or physical characteristics of these value-generating assets. The estimated value of goods and merchandise transported through the corridor as well as revenues generated by in-corridor economic activity ("benefits") is estimated at approximately $35 billion per annum. This is to be compared with the option total capital costs ("costs") which range from $200 million to $300 million (rounded). Due to the significant imbalance between "benefits" and "costs" a comparative quantitative benefit cost analysis is not considered to be relevant, and an annualized Return on Investment analysis would be more useful.

11.3.2 Factors Informing the Scope

The scope of the analysis has taken the following into consideration:

- There are no proposed modifications to the value-generating assets in the trade corridor; thus, total benefits are the same for all three options.

- There will be no effect on service levels for value-generating assets in the Trade Corridor due to construction (except possible very temporary interruptions on the TransCanada Highway).
- The three options are relatively similar and involve standard and proven construction methods (with the exception of the Tantramar River water control structures).
- The estimated benefits significantly exceed the total costs.

11.3.3 Annual Monetized Benefits

The calculation of the annual benefits is presented in **Table 11.5**.

Table 11.5 Description and Sources of Trade Corridor Benefits

Trade Corridor Asset	Annual Value Unit	Source
TransCanada Highway	Merchandise / goods transported by road.	Analysis of provincial (NB/NS) truck traffic data and application of industry standards / rules of thumb.
CN Rail	Merchandise / goods transported by rail.	Analysis provided directly by CN financial division.
Electrical Transmission Lines	Electricity transmission through NB Power / NS Power interconnections (345 kV and 138 kV).	Analysis of NB / NS imports / exports, generation rates and on-peak pricing.
Wind Farm	Annual value of energy generated.	Based on installed capacity, efficiency rating and retail pricing.
Bell Aliant Fibre Op Cables	Data packages transmitted through two cables.	Not available. Considered as an intangible.
Croplands	Harvested crops.	Analysis by NBDTI and NSDA.
TransCanada Highway	Business travel by private vehicle.	Not available. Considered as an intangible.

Source: Wood, 2021

The annual benefits were calculated based on pre-COVID activity and are assumed to be reasonably constant (2019 levels) into the future. The monetization for individual assets cannot be divulged publicly as the information was obtained subject to non-disclosure agreements and confidentiality agreements. The monetization of local government services, infrastructure and lands is not included.

The annual value of benefits is estimated at approximately $35 billion.

11.3.3.1 Capital Costs

The one-time total capital cost for the options is as follows.

Option A: $200.2 M **Option B: $189.2 M** **Option C: $300.9 M**

11.3.3.2 Operating Costs

The on-going operating costs for the options was calculated as presented in **Table 11.6**. The percentage distribution of contingencies was based on industry experience. These factors may or may not come into play but are considered in order to err on the side of caution. There is no allowance for social costs (noise, visual intrusion, air quality, etc.) during operations given operating characteristics of the dykes and water control facilities and the relative remoteness (from dwellings) of the alignment. Based on these factors, the ongoing annual operating cost is as follows:

Option A: $7.31 M **Option B: $6.90 M** **Option C: $10.98 M**

Table 11.6 Total Operating Cost Factors

Item	Unit	Source
Operation and Maintenance Cost	Operation and maintenance of dykes and water control structures.	**3% x Total Capital Cost**
Communications and engagement	Consultation with landowners, stakeholders, Rights Holders, public and local governments.	**0.1% x Total Capital Cost**
Follow-up program	Environmental monitoring and reporting per EIA Conditions of Approval.	**0.25% x Total Capital Cost**
Landowner compensation contingency	Rental, lease, and access / egress charges to support O&M activities.	**0.2% x Total Capital Cost**
Pandemic contingency	Delays, administrative burden, etc. associated with COVID guidelines compliance.	**0.1% x Total Capital Cost**

11.3.4 Return on Investment

Due to the significant imbalance between "benefits" and "costs" a quantitative comparative benefit cost analysis is not considered to be relevant for the purpose of comparing one option to the another.

From a qualitative perspective it can be argued that implementing an option (with an assumed life span of 30 years) will protect the continuance of current benefits ($35 billion per annum) for the next 30 years. From a "loss avoidance" perspective it is possible to calculate the ROI, which is a function of the value of the trade and revenue in the Corridor that will be protected from future climate change hazards compared to the capital cost of an option. As an example, it could be assumed that, if the status quo persists, over the next 30 years there will be an extreme weather event which results in the closure of the Chignecto Isthmus for two days' duration once every five years. In other words, 6 events or 12 days in total over the period. Based on the annual trade value of $35 billion the 12-day interruption has a total value of $1.2 billion (no discounting), or about $40 million gain from investment on an annualized basis.

Amortizing the total capital costs over 30 years at an interest rate of 3.5% to determine a future annual payment stream and adding the annual operating cost yields a total annual cost. A "Simple ROI" calculation based on the formula below yields the results presented in **Table 11.7**.

$$\text{ROI} = \frac{\text{Gain from Investment - Cost of Investment}}{\text{Cost of Investment}}$$

Table 11.7 Annualized Return on Investment

Metric	Option A	Option B	Option C
Amortized Total Capital Cost ($M, rounded)	10.9	10.3	16.4
Annual total Operating Cost ($M, rounded)	7.31	6.90	10.98
Annual Cost of Investment ($M, rounded)	18.21	17.2	27.38
Simple ROI	120%	133%	46%

11.3.4.1 Conclusion

The findings of the annualized Return on Investment analysis are as follows:

- All options exhibit a significant positive return on investment.
- Option B exhibits the highest ROI due to lower one-time total capital cost and annual total operating cost.
- The analysis is skewed by the significant value generated by the assets in the trade corridor compared to the cost of the options and should be used with caution.

12.0 Further Recommendations

Based on the information provided in this report, this section provides recommendations to refine uncertainties and to improve the cost estimating accuracy associated with one of or the three options selected.

12.1 Rights Holders/Stakeholder/Regulatory Engagement

Once the PSC and their respective provincial government departments have reviewed and accepted this study, early engagement with Stakeholders, Rights Holder and Regulatory Agencies is recommended. A communications/ engagement strategy should be developed to guide these actions.

12.2 Hydrotechnical Analysis

A detailed hydrotechnical/hydrodynamic study is required to provide design inputs including, but not limited to:

1. Dyke classification and inundation mapping. Inundation modelling will determine the impact/extent of flooding during a temporary 10.6 m storm surge/tide.
2. Extent of flooding may be limited such that the dyke classification may be downgraded from very high to high or lower.
3. An examination into potential for significant savings to the Owners in terms of the design, construction, and maintenance if the dyke classification can be downgraded based on more accurate understanding of impact of flooding.
4. Detail freeboard assessment including analyses for fetch, wave runup, design wind speeds based on area exposure.
5. Detailed summary and breakdown for erosion protection based on area exposure.
6. Potential and degree for crest overtopping.
7. Landward hydrotechnical design details, i.e., IDF, freeboard, erosion requirements, etc.

12.3 Geotechnical Analysis

1. Site-Specific Seismic Hazard Assessment:
    a. If the final dyke classification remains very high, then a site-specific seismic hazard assessment is required to complete the detailed design.
    b. The initial screening, based on guidance from NRC, indicates that the current design only marginally satisfies the minimum factors of safety under seismic loading.
2. Detailed Geotechnical Investigation:
    a. There are very significant gaps between boreholes along the length of the alignment.
    b. There are several structures or features which do not have any corresponding geotechnical data.
3. Detailed understanding of the stratigraphy and soil conditions may result in reduced conservatism for soil parameters.
4. State-of-the-art laboratory testing on soil samples to measure strength and consolidation characteristics of the soils may result in reduced conservatism.

5. Requirements for the detailed geotechnical investigation will be dependent on the option selected to be advanced. The proposed locations and type of feature proposed to be constructed (dykes versus structures requiring deep or shallow foundations) will guide the development of the future geotechnical investigations.

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