Q. **Reference: Failure Investigation Report – L3501/2 Tower and Conductor Damage, Icing Event January 2021 in Labrador, Nalcor Energy, May 28, 2021, page 14.**

> Zone 1 of L3501/2, the subject of this investigation, would be classified as an Average Loading Zone with a "50 year Reliability Level Return Period of Loads, with respect to Nalcor Energy operating experience and LCP specific modelling and test programs" as specified in "Basis of Design – LCP-PT-ED-0000-EN-RP-0001-01" and "Overhead Transmission – Meteorological Loading for the Labrador-Island Link ILK-PT-ED-6200-TL-DC-0001-01

Please provide copies of the referenced documents LCP-PT-ED-000-EN-RP-0001-01 and ILK-PT-ED-6200-TL-DC-0001-01.

A. Please refer to NP-NLH-057, Attachment 1 for a copy of Basis of Design, LCP-PT-ED-0000-EN-RP-0001-01, and NP-NLH-057, Attachment 2 for a copy of Overhead Transmission - Meteorological Loading for the Labrador-Island Transmission Link ILK-PT-ED-6200-TL-DC-0001-01.

Nalcor Energy – Lower Churchill Project

nalcor energy
LOWER CHURCHILL PROJECT

Basis of Design

LCP-PT-ED-0000-EN-RP-0001-01

Comments: **Issued for Decision Gate 3**	Total # of Pages (Including Cover): 37

B2	04-Oct-2012	**Issued for Use to Reflect Gate 3 Estimate**	R. Barnes	J. Kean	G. Fleming	R. Power	P. Harrington
B1	**19-Feb-2011**	**Issued for Use**	R. Barnes	J. Kean	G. Fleming	R. Power	P. Harrington
Status/ Revision	Date	Reason For Issue	Prepared By Engineering Manager	Checked By Deputy PM (Generation + Island Link)	Project Manager (Marine Crossings) Approval	Project Manager (Generation + Island Link) Approval	Project Director Approval

Inter-Departmental / Discipline Approval (where required)

Department	Department Manager Approval	Date
Manager System Planning	Paul Humphries	
Manager System Operations	Robert Henderson	
Project Manager Muskrat Falls & Infrastructure	Scott O'Brien	
Project Manager HVdc Specialties & Switchyards	for Darren DeBourke	
Project Manager Overland Transmission	Kyle B. Tucker	

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1.0 Purpose

The purpose of this document is to establish a *Basis of Design* (BOD) for the Lower Churchill Project (LCP). This BOD will form the overarching project definition that will be used to prepare engineering design philosophies, project contract packaging, project estimates, project schedules, design briefs, detailed design specifications and drawings, construction planning, and all other project functions that depend on a clear definition of what is to be specifically financed and constructed.

Typically, this BOD is not changed or altered without major cost and schedule implications to the project as a whole and would only be considered and approved by LCP Executive Management, and then only after a clear recommendation from the Project Director.

2.0 Scope

The objectives of this document are to establish the BOD for the following

- Muskrat Falls Generation
- Labrador Transmission Asset
- Labrador – Island Transmission Link

The Maritime Link is excluded from this BOD and will be prepared under separate cover.

3.0 Definitions

Throughout this document, the following defined words are italicized.

Basis of Design	A compilation of the fundamental criteria, principles and/or assumptions upon which design philosophies and engineering design briefs will be developed.
Bulkhead Gates	Steel gates used to isolate water passages for inspection or maintenance, which are installed and removed under balanced pressures.
Cavitation Resistant Design	A design to prevent the formation of the vapour phase in a liquid flow when the hydrodynamic pressure falls below the vapour pressure of the liquid.
Change Control Board	A panel within the Project Management Team that is responsible for making the ultimate decision to approve reject or elevate a Project Change Notice. See LCP-PT-MD-0000-PM-PL-0002-01, Project Change Management Plan.

Cofferdam	A temporary barrier for excluding water from an area that could otherwise be submerged.
Construction Flood	The seasonal peak river flow that the diversion facilities are designed to pass during construction of the dam. Accepted practice is based on a 5% risk of exceedence for the duration of the operation of the diversion facilities.
Converter Station	A *converter station* consists of equipment that converts power from ac to dc (rectifier) and dc to ac (inverter).
Counterpoise	Steel wire installed along the length of the overhead line and bonded (connected) to each tower. Used to reduce resistivity between the overhead line structures and the ground for lightning protection.
Electrode	A grounded means to provide a return path for unbalanced dc current for HVdc transmission system, enabling it to operate in mono-polar mode.
Electrode Line	A transmission line connecting the *electrode* site to the *converter station*.
Fail Safe Design	A design that in the event of the failure of equipment, processes or systems, the event will produce minimum propagation beyond the immediate environment of the failing entity. In addition, the failure will be economically acceptable, and those devices in the system will perform their intended function and eliminate danger upon the loss of actuating power.
Fish Compensation Flow	Minimum flow required downstream of the dam sites during reservoir impoundment which will be required to maintain fish habitat and reduce the effects of salt water intrusion into the Churchill River.
Fish Habitat Compensation	This involves replacing the loss of fish habitat with newly created habitat or improving the productive capacity of some other natural habitat.

Flip Bucket	A formed geometrical shape at the downstream end of a spillway discharge for the purpose of throwing the water clear of the hydraulic structure and into a *plunge pool* for energy dissipation.
Francis Turbine	A mixed flow reaction turbine with fixed runner vanes that converts hydraulic energy to mechanical energy where the water flow is controlled by the setting of the adjustable *wicket gates*.
Full Supply Level	The maximum normal operating water level, corresponding to the top of the live storage, in a reservoir.
Generator	An assembly of stationary and rotating components coupled to the turbine converting mechanical energy to electrical energy.
Good Utility Practice	The practices, methods and acts engaged in, or approved by, a significant portion of the electrical utility industry in North America, or any of the practices, methods and acts which, in the exercise of reasonable judgment in light of the facts known at the time the decision was made, are expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety and expedition. *Good Utility Practice* is not intended to be limited to optimum practice, method or act to the exclusion of all others, but rather to include all practices, methods or acts generally accepted in North America.
Kaplan Turbine	A reaction type, axial flow, adjustable blade turbine that converts hydraulic energy to mechanical energy.
Life Cycle Cost Analysis	The process of selecting the most cost-effective approach from a series of alternatives so that the least long-term cost of ownership is achieved where life cycle costs are total costs estimated to be incurred in the design, development, production, operation, maintenance, support, and final disposition of an asset over its anticipated useful life from inception to disposal.
Low Supply Level	The minimum normal operating water level, corresponding to the bottom of the live storage, in a reservoir.

Mass Impregnated (MI)	An electrical insulation method used for power cables. The conductor is tightly wrapped with porous paper and saturated with oil, installed under pressure, to provide electrical insulation.
Mitigation	Measures implemented during the design, construction and operations phases of the project which are intended to avoid or reduce known or predicted impacts to the existing environment.
Overhead Ground Wire (OHGW)	Provides lightning protection for the power conductors. When used, direct lightning strikes are minimized, and potential disturbances due to lightning are reduced.
Optical Ground Wire (OPGW)	Performs the same function as *Overhead Ground Wire*; however, it also carries a fibre optic communication system within the wire strands.
Penstock	A conduit that conveys water from the intake to the turbine.
Plunge Pool	A deep depression downstream of a spillway into which spilled water "plunges" to dissipate energy.
Probable Maximum Flood (PMF)	Canadian Dam Association terminology for "an estimate of hypothetical flood (peak flow, volume and hydrograph shape) that is considered to be the most severe 'reasonably possible' at a particular location and time of year, based on relatively comprehensive hydro meteorological analysis of critical runoff-producing precipitation (snowmelt if pertinent) and hydrologic factors favourable for maximum flood runoff".
Proven Technology	This is the state of technology used in the design, construction and operation of any system including each piece of equipment, component or structure that has a proven record of performance. (First technology applications will only be considered after review by the LCP Technical and Design Integrity group and then only after approval by Executive Management).

Rehabilitation	Measures taken to remedy environmental damage to the environment.
Reliability Level Return Period	A statistical measurement denoting the average recurrence interval over an extended period of time. Used to estimate loads to design transmission lines.
Rotor	The multi-poled rotating component of the *generator*.
Split Yard	Switchyard divided physically into two independent sections with an electrical connection so as to limit the loss of generation in order to meet reliability criteria.
Stoplog	Steel sections used to isolate water passages for inspection or maintenance and are installed and removed under balanced pressures.
Tailrace	A watercourse that carries water away from a turbine or powerhouse.
Terrestrial Habitat Compensation	Specific mitigations that would encourage the development of riparian and wetland habitat.
Trash Boom	An anchored, floating barrier spanning the approach channel of the intake. It is used to limit floating objects from reaching the intake and blocking the *Trash Racks*.
Trash Racks	Equally spaced rectangular bars installed at the entrance to the intake to protect the turbine from impinging objects.
Waste Management	The management of waste generation in order to reduce the volume of solid waste deposited in landfills through recycling and the reuse of materials where practical.
Wicket Gates	Adjustable guide vanes used to regulate the flow of water into a turbine.

4.0 Abbreviations and Acronyms

ac	alternating current
ADSS	All Dielectric Self-Supporting
BCC	Backup Control Center
BMS	Building Management Systems
BOD	*Basis of Design*
CCTV	Closed Circuit Television
CF	Churchill Falls Generating Facility
CFRD	Concrete Faced Rockfill Dam
CPU	Central Processing Unit
CTS	Cellular Telephone System
dc	direct current
DFO	Department of Fisheries and Oceans
EPP	Environmental Protection Plan
ECC	Energy Control Centre
FSL	*Full Supply Level* (Reservoir)
GI	Gull Island Generating Facility
HADD	Harmful Alteration Damage or Disruption (Fish Habitat)
HDD	Horizontal Directional Drilling
HVac	High Voltage alternating current
HVAC	Heating, Ventilation and Air Conditioning
HVdc	High Voltage direct current
HVGB	Happy Valley – Goose Bay
kV	kilovolts
kWs	Kilo Watt Seconds
kVA	Kilo Volt Amp
LCC	Line Commutated Converter
LCP	Lower Churchill Project
LEED	Leadership in Energy and Environmental Design
LITL	Labrador – Island Transmission Link Project
LMRS	Land Mobile Radio System
LSL	*Low Supply Level* (Reservoir)

LTA	Labrador Transmission Asset Project
MF	Muskrat Falls Generating Facility
MFL	Maximum Flood Level (Reservoir)
MI	*Mass Impregnated*
MIS	Mobile Internet System
MVA	Mega Volt Ampere
MVAR	Mega Volt Ampere Reactive
MW	MegaWatt
NE	Nalcor Energy
NMS	Network Management Systems
OHGW	*Over-Head Ground Wire*
OLTC	On-load Tap Changer
OPGW	*Optical Ground Wire*
OTN	Optical Transport Network
pf	power factor
PMF	*Probable Maximum Flood*
RCC	Roller Compacted Concrete
ROW	Right of Way
SCADA	Supervisory Control and Data Acquisition
SACS	Security and Access Control System
SLD	Single Line Diagram
SOBI	Strait of Belle Isle
SONET	Synchronous Optical Network
TBD	To Be Determined
TL	Transmission Line
TLH	Trans Labrador Highway
Vac	Voltage Alternating Current
Vdc	Voltage Direct Current
VSC	Voltage Source Converter

5.0 Reference Documents and/or Associated Forms

Engineering Studies comprising the 2007/2008/2009/2010 Engineering Program

Gull Island Generating Facility

GI1010 Gull Island 2007 Site Investigation
GI1013 Gull Island 2008 Site Investigation
GI1015 Inspection and Structural Analysis Goose Bay Dock
GI1017 Update Report - Reassessment of Gull Island Diversion
GI1020 Study of Concrete Face Rockfill Dam (CFRD) Alternative
GI1030 Powerhouse Configuration
GI1050 Tailrace Channel Improvements Phase 1 – Preliminary Assessment
GI1060 Review of Structure Layouts and Interfaces
GI1061 Review of Structure Layouts and Interfaces, 5x450 MW
GI1070 Ice Study (Gull Island and Muskrat Falls) (by Hatch)
GI1071 Ice Studies (Gull Island) (by SNCL)
GI1076 Ice Observation Program (2010-2011)
GI1090 Review of Construction Camp and Other Infrastructure
GI1100 Review of Access Roads and Bridges
GI1110 Hydraulic Modeling of River
GI1130 River Operation during Construction & Impounding
GI1140 PMF and Construction Design Flood Study
GI1141 Upper Churchill PMF and Flood Handling Procedures Update
GI1170 Seismicity Analysis
GI1180 Review of Site Access, Goose Bay and Off-Site Infrastructure
GI1190 Dam Break Study
GI1200 Gull Island Constructability Review
GI1230 Gull Island Site Information for Tenderers
GI1280 Gull Island – Diversion Facilities Numerical Modeling
GI1281 Gull Island – Power Intake and Spillway Facilities – Numerical Modeling
GI1282 Gull Island – Diversion Facilities Physical Modeling Technical Specifications
GI1290 Hydraulic Production Model
GI1300 Gull Island 2008 Report Plates (drawings)
GI1310 Workshop Report on Design and Operational Problems Resulting from Reservoir Preparation
GI1602 Bank Stability and Fish Habitat Deltas

Muskrat Falls Generating Facility

MF1010 Review of Variants
MF1020 Muskrat Falls Site Investigations
MF1050 Spillway Design Review
MF1080 Review of Construction Camp and Other Infrastructure
MF1090 Review of Access Roads and T&W Bridge

MF1091 Desktop Study – Implications/Consequences of Constructing Muskrat Falls Prior to Gull Island
MF1120 Potential Impact of Reservoir Flooding on the TLH
MF1130 River Operation during Construction and Impounding
MF1250 Numerical Modeling of Muskrat Falls Structures
MF1260 Condition Assessment of Existing Pumpwell System (2007)
MF1271 Condition Evaluation of Wells and Pumps in the Muskrat Falls Pumpwell System (2009)
MF1272 Installation of New Piezometers in the Muskrat Falls Pumpwell System
MF1281 Pumpwell System Telecommunication Upgrades
MF1300 2010 Field Investigation Program
MF1310 Site Access Review
MF1320 Power and Energy Study
MF1330 Report #1: Hydraulic Model of the River - 2010 Update
MF1330 Report #2: PMF and Construction Design Study
MF1330 Report #3: Dam Break Study
MF1330 Report #4: Ice Study
MF1330 Report #5: Review of Gull Island 1:60 year Construction Design Flood
MF1330 Report #6: Regulation Study
MF1340 Review and Confirmation of Structure Layout Interfaces
MF1360 Review of Numerical Modeling
MF1380 Site Information for Tenderers
MF1390 Review Impacts of Earlier Construction of MF on GI and Later Construction of GI on MF

HVac Transmission Systems
AC1020 Tower type selection, 735 kV
AC1030 Field Investigations and Construction Requirements - 735 kV TL - GI to CF
AC1050 Tower type selection, 230 kV
AC1060 Field Investigations and Construction Requirements - 230 kV TL - GI to MF
AC1080 Load Control and Failure Containment
AC1090 Assess Cable De-icing
AC1100 Conductor Selection
AC1130 Corridor Selection & Construction Infrastructure - 735 kV Transmission Line - Gull Island to Quebec Border

HVdc Transmission Systems
DC1010 Voltage and Conductor Optimization
DC1020 HVdc System Integration Study
DC1050 Corridor Selection & Construction Infrastructure-Gull Island to Soldiers Pond
DC1051 Field Investigations – HVdc TL – Gull Island to Soldiers Pond
DC1060 Corridor Selection & Construction Infrastructure-Taylor's Brook to Cape Ray
DC1070 Preliminary Meteorological Load Review

DC1080	Tower Type Selection and Preliminary Optimization
DC1090	Site Investigation - Converter Stations Gull Island and Soldiers Pond
DC1110	Electrode Review - Gull Island and Soldiers Pond
DC1130	Submarine Cable - Strait of Belle Isle
DC1131	Submarine Cable Corridor Survey - Strait of Belle Isle
DC1132	Strait of Belle Isle - Existing Data Compilation
DC1133	Regional Multi-Beam Survey - Strait of Belle Isle
DC1140	Submarine Cable - Cabot Strait
DC1141	Submarine Cable Corridor Survey - Cabot Strait
DC1142	Cabot Strait - Existing Data Compilation
DC1180	Fixed Link Tunnel Cost, Strait of Belle Isle
DC1200	HVdc Overland Transmission Re-estimate
DC1210	HVdc System Sensitivity Analysis
DC1240	HVdc and HVac Proximity Analysis
DC1250	Electrode Review – Type and Location
DC1300	Ice Loadings on HVdc Line Crossing Long Range Mountains
DC1301	Section by Section Analysis of Extreme Rime Ice on the Long Range Mountains using WRF Modeling
DC1500	Electrode Review – Confirmation of Type and site Selection
DC1600	VSC Technology Review for LCP
DC1700	Review of Holyrood Units 1 & 2 Conversion to Synchronous Condensers

<u>Other Documents</u>

- LCP-PT-ED-0000-EN-PH-0032-01 Synopsis of Engineering Studies
- LCP-PT-ED-0000-EN-PL-0002-01 Reservoir Preparation Plan
- LCP-PT-ED-0000-EN-PL-0002-02 Reservoir Preparation Plan – Summaries and Map Sheets – Muskrat Falls
- LCP-PT-ED-0000-EN-PL-0002-03 Reservoir Preparation Plan – Summaries and Map Sheets – Gull Island
- LCP-HE-CD-0000-EA-RP-0001-01 Muskrat Falls – Review of Saltwater Intrusion
- LCP-HE-CD-0000-EA-RP-0007-01 Muskrat Falls – Review of Sediment Plume
- LC-EN-011 2010 Transmission Corridor LiDAR and Orthographic Data Collection Program
- LC-EN-006 Coordinate System Evaluation, Survey Engineering Services – Transmission
- MFA-PT-ED-6200-TL-DC-0001-01 Meteorological Loading 315 kV transmission lines Muskrat Falls to Churchill Falls
- ILK-PT-ED-6200-TL-DC-0001-01 Overhead Transmission – Meteorological Loading for the Labrador-Island Transmission Link
- LCP-PT-MD-0000-PM-PL-0002-01 Project Change Management Plan
- MFA-SN-CD-6140-TL-RP-0003-01 HVdc Conductor Optimization
- LCP-SN-CD-8000-EL-SY-0001-01 Reactive Power Studies

- ILK-SN-CD-8000-EL-SY-0002-01 Harmonic Impedance Studies
- ILK-SN-CD-8000-EL-SY-0001-01 Load Flow & Short Circuit Studies
- ILK-SN-CD-8000-EL-SY-0003-01 HVdc System Modes of Operation & Control Strategies Study
- ILK-SN-CD-8000-EL-SY-0004-01 Reliability and Availability Analysis
- ILK-SN-CD-8000-EL-RP-0001-01 Stability Studies
- ILK-SN-CD-6220-EL-SY-0001-01 Electrical Interference (ac – dc Coupling) Study
- ILK-SN-CD-6200-EL-SY-0001-01 HVdc Transmission Line Insulation Coordination Study
- Development of Extra High Voltage Transmission Lines in Labrador – EDM/RSW - 1999
- Gull Island Power Development SNC-Lavalin Power Division - October 1997
- Gull Island Hydro Electric Development – SNC-AGRA Joint Venture - December 2000
- Gull Island to Soldiers Pond Interconnection – Teshmont Consultant Inc. - June 1998
- Muskrat Falls Hydroelectric Development – SNC-AGRA - January 1999
- Lower Churchill Hydroelectric Generation Project Baseline Report, Application of HADD Determination Methodology – AMEC – December 2007
- Evaluate Extreme Ice Loads From Freezing Rain For Nalcor Energy – Kathy Jones – May 2009
- Assessment of Rime Ice Loading on the Long Range Mountains, Landsvirkjun Power, December 2010.
- Newfoundland and Labrador Hydro Environmental and Guiding Principles

6.0 Responsibilities

Project Director – The Project Director is responsible for approval of the BOD.

General Project Manager, Muskrat Falls & Labrador - Island Link – The General Project Manager, Generation and Labrador-Island Link is accountable to ensure that all design reflects the intentions of the BOD.

Project Manager, Marine Crossings – The Project Manager, Marine Crossings is responsible to ensure that all related project estimates and schedules respect the BOD.

Deputy Project Manager, Muskrat Falls & Labrador - Island Link - The Deputy Project Manager for the Generation and Labrador-Island Link is to ensure that all sections of the BOD are prepared as per the applicable LCP Procedures to establish and maintain the Project Change Management process and to ensure that all project estimates and schedules respect the BOD.

Project Managers – The Project Managers must ensure that all design reflects the intentions of the BOD.

Engineering Manager – The Engineering Manager is responsible to prepare the BOD. The Engineering Leads are to support this process and prepare individual sections of the BOD for coordination and final preparation by the Engineering Manager.

Environmental Manager - The Environmental Manager is to ensure that the Environmental Impact Statements and subsequent documentation related to the Environmental Assessments reflect the BOD and that the BOD reflects good environmental practices.

7.0 Descriptions

7.1 General

This BOD includes Muskrat Falls Generation, Labrador Transmission Asset and the Labrador-Island Transmission Link.

The primary reason for developing Muskrat Falls Generation, the Labrador Transmission Asset and the Labrador - Island Transmission Link is to meet increased capacity and energy requirements on the Island of Newfoundland. The electrical system on the Island of Newfoundland will experience a capacity deficit in 2015 and an energy short fall in 2021. Extensive analysis of the alternative supply options for the Island has demonstrated that Muskrat Falls and the associated transmission interconnection is the least cost technically acceptable supply alternative for the Island. Muskrat Falls and the interconnection not only provide for future load growth but also facilitate the retirement of the Holyrood Thermal Generating Station virtually eliminating the Island's dependence on fossil fuel fired generation.

All design assumptions used to establish the BOD respect the following overarching principles:

- Only proven technologies will be considered, unless it can be clearly demonstrated to the satisfaction of the Engineering Manager, Project Managers, Project Director and VP of the LCP that emerging technologies can be as reliable and provide significant cost and/or schedule savings.
- Local climatic/service conditions such as ambient temperature, elevation, humidity, sea temperature, sea currents and wind will be respected throughout the Project.
- All generating plants and transmission systems will be remotely operated and monitored from NE-NLH's Energy Control Centre.
- All designs shall assume a 50 year design life for the purposes of evaluation.
- Environmental *mitigation* and *rehabilitation* will be designed by LCP prior to issuing requests for proposals leading to construction contracts.
- The designs will assume the use of existing transportation infrastructure to the maximum extent possible. In particular, existing roads, bridges, railways and wharfs.
- *Good Utility Practice* will be observed.
- *Fail Safe Design* principles will be employed.
- Principles of *Life Cycle Cost Analysis* will be employed.
- The designs will be consistent with the NE Safety and Health Program.
- The designs will be consistent with NE Environmental Policy and Guiding Principles.
- The designs will be consistent with NE Asset Management Policy and Guiding Principles.
- The designs will be consistent with all applicable governing Standards, Codes, Acts and Regulations.
- All assets and systems will be designed to ensure safety, reliability, efficiency and minimal impact to the environment.

7.2 Muskrat Falls Generation

1100 Access - General

- Site roads to be gravel surfaced unless conditions dictate otherwise e.g. to limit dust and flying stones in areas such as accommodations complex and other site facilities.
- Permanent site access from south, along south side of river via TLH.
- Temporary site access to north side from TLH.

1200 Permanent Accommodations

- No permanent accommodations required.

1320 Construction Power

- Construction power will be supplied from the existing 138 kV transmission line between CF and HVGB by means of a temporary tap station at MF, to be located on the north side of the Churchill River. It will comprise of a 50 MVA, 138 – 25 kV transformer with an on-load tap changer (OLTC), 138 kV circuit breakers for the transformer and the line feeder to HVGB and capacitor banks to provide voltage regulation. The installation will be capable of providing 12 MW peak load and will be remotely controlled and supervised from the Nalcor ECC in St. John's.
- Construction power will be supplied to the south side of the Churchill River with a 25 kV distribution feeder that will take off from this tap station and cross the river to provide power to the construction sites and the campsite located approximately 10.5 km east of Muskrat Falls.
- A new 125 MVA, 230 – 138 kV transformer with OLTC will be installed in CF as a replacement for the two existing 42 MVA transformers without OLTC to accommodate the increase of power transfer to provide 12 MW of power at MF.
- Once the 315 kV HVac network is energized during construction, power will be supplied from the 315 – 138 kV substation transformer tertiary winding until all construction facilities are demobilized.

1420 Construction Telecommunications – Muskrat Falls

- Communications during early works of access road, camp start-up and start of site excavations will be by land mobile radio system and cellular phones.
- Communications during the main construction phase will be linked to a new high-speed fibre-optic network being constructed in Labrador and will include:
  - Data (business and personal)
  - Telephone (business and personal)
  - Video Conferencing
  - Television
  - Land Mobile Radio System (LMRS)
  - Cellular Telephone System (CTS)
  - Mobile Internet System (MIS)
  - Building Management Systems (BMS)
  - Network Management Systems (NMS)
  - Closed Circuit Television (CCTV)

  - Security and Access Control System (SACS)
  - Supervisory Control and Data Acquisition (SCADA) and Protection

1500 Accommodations Complex

- Staged, modular construction to accommodate up to 1,500 persons with appropriate offices, cooking, dining, sleeping, washing, medical, firefighting, entertainment, recreational, power, water, sewage, and administrative and other life support facilities within the project area.
- Main site facilities to be located on south side of river approximately 10.5 km southeast of Muskrat Falls.
- Includes substation and distribution system for construction power supplied from the 25 kV feeder and backup diesel generation at the site.
- Designed for removal following construction.

1800 Offsite Logistics, Infrastructure and Support – General

- Approximately 15 ha of marshalling yards, potentially in multiple locations. Yards to include grading, fencing, storage racks and equipment for loading/offloading.
- Upgrading and/or replacement of the Paradise River and Kenamu River bridges, or some acceptable alternate solution, on the Cartwright access road to accommodate a design load of 250 t.

2100 Reservoir

- FSL = 39 m; LSL = 38.5 m; MFL = 45.1 m without GI and 44.3 m with GI.
- Remove all trees that grow in, or extend into the area between 3 m above FSL and 3 m below LSL, except where determined otherwise by the reservoir preparation strategy.
- Trash management system to include an automated hydraulically operated trash removal system explained in detail under "3200 Intake and Penstocks – General". Trash management also includes a series of trash booms, one located approximately 2.3 km upstream of the intake and a second located approximately 5 km downstream of the plant. Both trash booms will be designed to restrict the movement of floating trash and debris, and guide it to shoreline design and access roads to enable removal and disposal. Both trash booms are to be designed with either mid-channel or shoreline gaps to allow boat travel.
- A series of safety booms, one located approximately 1.4 km upstream of the intake and a second one located downstream of the plant. The design is to include suitable anchorage and shoreline design. The downstream boom is to have a mid-channel gap with several safety buoys.

2200 Diversion

- Through spillway structure.
- Capacity = 5, 990 m^3/s based on a 1:20 year return period.
- *Fish Compensation Flow* will be approximately 550 m^3/s equivalent to 30% of mean annual flow.
- *Fish Compensation Flow* will be through spillway structure.

2300 Dams & Cofferdams - General
- Development flood capacity is based on the PMF, equal to 25,060 m^3/s at 45.1 m without GI and 44.3 m with GI.
- South Dam to be an earth/rockfill dam with a central core crest elevation to be El. 45.5 m.
- North Dam to be a RCC overflow dam, acting as a secondary spillway with a crest elevation of El. 39.3 m over a 430 m long overflow section. The north end of the dam will be rotated slightly downstream in order to improve the north abutment against the rock knoll and eliminate potential erosion during spilling.
- Transition dams to be conventional concrete.
- All concrete dams to be designed with necessary drainage galleries and monitoring equipment.
- All dams are to be founded directly on bedrock.
- *Cofferdams* are to be of the most economical and proven material and technology.

2400 Spillway - General
- Primary spillway structure.
- Concrete structure in rock excavation.
- Capacity = PMF in conjunction with North RCC Dam.
- Five surface vertical lift gates on parabolic rollways, 10.5 m wide with top of gate at El. 40.0 m and sill at El. 18.0 m.
- Gates with heating and hoisting mechanisms designed for severe cold climate operation.
- Structure designed to accommodate an automated, hydraulically operated trash removal system explained in detail under "3200 Intake and Penstocks – General". The system includes a permanent hoist capable of lifting the upstream *stoplogs*.
- One set of upstream steel *stoplogs* with a permanent hoist system.
- One set of downstream steel *stoplogs* operated by a mobile crane.
- *Stoplog* storage on site.
- One emergency diesel *generator* set, complete with fuel storage system, for emergency load requirements sufficient for heating and operation of two surface gates only.

2800 North Spur - General
- The deep well system installed in 1981 is to be placed in standby mode.
- Measures are required to prevent water infiltration and to physically stabilize the upstream and downstream slopes. Pressure relief wells are to be installed in the downstream section of the North Spur to lower the groundwater pressure.
- Measures are required to prevent groundwater infiltration into the North Spur from the Kettle Lakes region.
- Piezometers are to be outfitted with data loggers to monitor the water table levels in the North Spur.

3100 Powerhouse Channels

- Approach channels excavated in bedrock with minimum rock reinforcement required.
- Draft tubes discharge directly into river in rock excavation.
- *Tailrace* channel excavated in bedrock with minimum rock reinforcement required.

3200 Intake & Penstocks - General

- Approach channel in open cut earth/rock excavation and designed to eliminate frazil ice.
- Concrete structure in rock excavation.
- Four intakes (one per unit).
- Four sets of vertical lift operating gates with individual wire rope hoists in heated enclosures.
- One set of steel bulkhead s*toplogs* able to close only one single intake passage opening (1 of 12) at any one time.
- Four sets of removable steel *trash racks*.
- An automated, hydraulically operated trash removal system capable of cleaning both the upstream side of the intake and the gated spillway. System is to include interchangeable heads that will enable cleaning of floating debris, submerged debris, debris lodged in *trash racks*, and debris in rock traps. The system will include a permanent hoist capable for removing the intake bulkhead *stoplogs*.
- No *penstocks*; four individual water passages in concrete (close-coupled intake/powerhouse).

3300 Powerhouse

- Concrete structure in rock excavation.
- Structural steel super-structure with metal cladding.
- Designed, constructed and operated in accordance with applicable requirements of the Provincial Government's Build Better Buildings policy.
- Four-unit powerhouse with two maintenance bays.
  - The south maintenance bay shall be large enough to assemble one complete turbine/*generator* unit, plus assembly and transfer of one extra *rotor*, and include provision of an unloading area. After completion of turbine/*generator* installation, the south maintenance bay will be reduced in size to accommodate permanent offices and warehousing while leaving space for the dismantling of one entire turbine/*generator* unit.
  - The north maintenance bay shall be used to stage civil works construction and shall become a space for mechanical and electrical auxiliary equipment at the completion of the Project.
- Area for offices, maintenance shops and warehouse. Offices, maintenance shops, and warehouse will occupy the south of the maintenance bay.
- All systems are to be designed using *good utility practice*.
- Two sets of steel draft tube *stoplogs* with a permanent hoist system in a heated enclosure.

3410/3420 Turbines and Generators

- Four 206 MW units, approximately, @ 0.90 pf vertical axis *Generators*.
- Inertia constant H not less than 4.1 kWs/kVA.
- Four *Kaplan turbines* with *Cavitation Resistant Design*.
- Unitized approach from intake to *generator* step-up transformer.
- Failure of any equipment/system of one unit not to affect the operation of the remaining units.

3430 Electrical Ancillary Equipment

- Dual 125 Vdc battery systems with dual chargers per battery system for control and protection.
- Independent 125 Vdc battery system with dual chargers for field flashing and other dc power.
- Dual 48 Vdc battery systems with dual chargers per battery system for telecommunication system.
- A minimum of two independent sources of station service.
- Arc flash category two for all electrical panels of 600 Vac or greater.
- Dual digital protection systems.
- One standby emergency diesel *generator* for the powerhouse essential load auxiliaries, complete with fuel storage systems.

3440 Mechanical Ancillary Equipment

- Water systems, for supply of turbine and *generator* cooling water, fire protection water, domestic water and auxiliary water.
- Separate high and low pressure compressed air systems.
- Domestic waste water to septic tank and disposal field.
- HVAC systems using the *generators'* cooling systems as a source of powerhouse heating.
- Two overhead powerhouse cranes, with the capability to operate in tandem having a combined design capacity to lift a fully assembled *rotor*.
- Elevator access to all levels of powerhouse.
- Dewatering and drainage systems complete with oil interception system.
- Permanent waste hydraulic and lubricating oil storage and handling system complete with a permanent centrifuge filtration system.
- Oil water separator for drainage from *generator* transformer basins, powerhouse diesel room and tank room.
- Permanent hoist system in each turbine pit.

3450 Protection, Control & Monitoring

- Redundant protection systems for each element from two different manufacturers.
- Main and backup systems to be installed in two separate panels.
- Protection shall be stable during system transients and operate correctly during system faults.
- A distributed digital control and monitoring system.
- Dual CPU for control system functions.

3460 Generator Transformers

- Four step-up transformers (unit voltage to 315 kV), plus one spare step-up transformer, located on powerhouse draft tube deck.
- Each unit will have a *generator* circuit breaker.
- Each transformer will include drainage to a common oil water separator.
- Transformers will be separated from each other by a concrete firewall.

6160 Collector Lines – Powerhouse to Switchyard

- Four 315 kV HVac overhead transmission lines to connect the high side of the step up transformers to the switchyard.

9112 Fish Habitat Compensation

- *Fish habitat compensation* will include delta enhancements at the Pinus River and Edward's Brook and enhancements of spawning areas located in Gull Lake.

9122 Terrestrial Habitat Compensation

- *Terrestrial habitat compensation* will be based on conditions of EA release and *terrestrial habitat compensation* plans to be agreed to with applicable regulatory bodies.

9220 Operations Telecommunications System – Muskrat Falls

- Telecommunication System shall be comprised of three separate layers: Optical Transport Network (OTN), Convergence, and Access Layers.
- OTN Layer shall be the telecommunications backbone and utilize the single OPGW, All Dielectric Self Supporting (ADSS) or equivalent fibre optic infrastructure. The OTN Layer equipment nodes shall be designed based upon the least total cost of ownership alternative.
- Convergence layer shall be based on the Synchronous Optical Network (SONET) international standard. It shall be used to create logical point-to-point telecommunication links between all MF locations. It will multiplex and de-multiplex the access layer subsystems for transmission on the OTN.

- Access Layer shall be based on the Ethernet (IEEE 802.3) standard. It shall be comprised of a minimum of three separate telecommunication systems: Protection and Control, SCADA, and Administrative systems. The Administrative system may include the following subsystems: telephony, corporate data, security access control system, and video surveillance.

- The Muskrat Falls telecommunication assets specifically include the following:

  - Convergence and access layers telecommunication systems at the MF generating plant, *converter station* and switchyards.
  - NLH ECC and BCC SCADA system upgrades.
  - Network Management System to monitor, notify, and provision the OTN, convergence and access layers telecommunication systems.

7.3 Labrador Transmission Asset

4300 Muskrat Falls Switchyard

- Situated on the south side of the river on a level, fenced site.
- Concrete foundations and galvanized steel structures to support the electrical equipment and switchgear.
- Electrical layout of the switchyard is to be in accordance with the SLD. (See Drawing 3).
- Substation to interconnect the plant to the 315 kV HVac transmission lines to CF and the HVdc *Converter Station*.
- Substation includes two 125 MVA transformers, 315-138 kV with tertiary windings rated at 25 kV to supply station services for switchyard and convertor station.

6130 Muskrat Falls Switchyard to HVdc Converter Station

- Four 315 kV HVac feeders connecting the switchyard to the *converter station* as per the attached single line diagram. Two feeders connecting to the converter transformers and two feeders connecting to the filters.

6140 HVac Overland Transmission - Muskrat Falls to Churchill Falls

- Two 315 kV HVac overhead transmission lines to connect the Muskrat Falls switchyard to the Churchill Falls switchyard extension.
- Provision for Gull Island interconnection to be included through selected placement of dead end towers.
- Transmission lines are to be carried on galvanized lattice steel towers, with self-supported angles and dead ends, and guyed suspension towers.
- Transmission line power capacity is to be 900 MW for each transmission line, allowing for all load to be carried on a single circuit.
- Transmission line corridor as per Key Plan. (See Drawing 1).
- 50 year *Reliability Level Return Period* of loads, with respect to Nalcor Energy operating experience and LCP specific modeling and test programs.
- One transmission line shall have one OHGW and one OPGW and the second line shall have two OHGW.
- *Counterpoise* installed from station-to-station.

4100 Churchill Falls Switchyard Extension

- Extension of the existing 735 kV main bus with bus coupling circuit breakers.
- Two 833 MVA, 735-315 kV auto-transformers, with tertiary windings rated at 13.8 kV to supply the substation service loads.
- Accommodation of two 315 kV HVac transmission lines from MF.
- Provision for space for future 735 kV and 315 kV transmission line feeders in accordance with the SLD. (See Drawing 3).
- CF switchyard extension is to be located approximately 500 m east of the existing CF switchyard on a level, fenced site and includes developed space for future 735 kV and 315 kV line feeders.

- Two 735 kV transmission lines, each approximately 500 m in length, to join the existing CF switchyard to the CF switchyard extension.
- Construction and operation not to adversely impact the existing CF operation.
- Concrete foundations and galvanized steel structures to support the electrical equipment and switchgear.

9250 Operations Telecommunications System – Labrador Transmission

- Telecommunication System shall be comprised of three separate layers: Optical Transport Network (OTN), Convergence, and Access Layers.
- OTN Layer shall be the telecommunications backbone and utilize the OPGW, All Dielectric Self Supporting (ADSS) or equivalent fibre optic infrastructure. The OTN layer equipment nodes shall be designed based upon the least total cost of ownership alternative.
- Convergence layer shall be based on the Synchronous Optical Network (SONET) international standard. It shall be used to create logical point-to-point telecommunication links between all MF locations. It will multiplex and de-multiplex the Access Layer subsystems for transmission on the OTN.
- Access Layer shall be based on the Ethernet (IEEE 802.3) standard. It shall be comprised of a minimum of three separate telecommunication systems: Protection and Control, SCADA, and Administrative systems. The Administrative system may include the following subsystems: telephony, corporate data, security access control system, and video surveillance.
- The Labrador Transmission Link Telecommunication Assets specifically include the following:
    - One OPGW mounted on one 315 kV HVac TL connecting
        - MF 315 kV Switchyard to CF 735-315 kV Switchyard
    - TLH ADSS fibre optics connecting
        - Labrador West to CF to MF to HVGB.
    - OTN Layer optical-electronics associated with the above referenced fibre optic interconnections.
    - Convergence and Access Layer telecommunication systems associated with the above referenced OTN Layer optical-electronics, except these telecommunication layers at MF.
    - NLH ECC and BCC SCADA system upgrades and upgrades to CF SCADA system as required.

7.4 Labrador – Island Transmission Link (LITL)

Overall HVdc system consists of a 900 MW HVdc Island Link between Labrador and Newfoundland.

<u>1330 Construction Power</u>

The following power supply sources will be used for construction power:

- Muskrat Falls: A 25 kV tap from the construction power system for the Muskrat Falls Generating Facility (see 1320 Construction Power)
- Forteau Point: A 25 kV tap from an existing distribution system located approximately 2.5 km away.
- Shoal Cove: A 25 kV tap from an existing distribution system located approximately 700 m away.
- L'Anse Au Diable: A 14.4 kV tap from an existing distribution system located approximately 400 m away.
- Dowden's Point: A 14.4 kV tap from an existing distribution system located approximately 1.5 km away.
- Soldiers Pond: A 25 kV tap from an existing distribution system located approximately 4 km away.

<u>1430 Construction Telecommunication Systems – Labrador-Island Link</u>

- Provision of telecommunications services and infrastructure during the construction phase to the end of the Project along the 315 kV HVac and the ±350 kV HVdc transmission lines and associated construction camps, including the CF Extension Switchyard construction camp.
  - Services along the transmission line rights-of-way
    - Land Mobile Radio System (LMRS)
    - Services available at the various remote campsites
    - Data (corporate and personal)
    - Telephony (corporate and personal)
    - Network Management System (NMS)
    - Closed Circuit Television (CCTV) and
    - Security and Access Control System (SACS)

<u>8210 Labrador Converter Station</u>

- 900 MW, ±350 kV bi-pole, LCC *converter station* capable of operating in mono-polar mode.
- Each pole rated at 450 MW with 100% overload capacity for ten minutes and 50% overload capacity for continuous operation.
- Situated on the south side of the Churchill River on a level fenced site.
- Concrete foundations and galvanized steel structures to support the electrical equipment and switchgear.
- Mono-polar operation shall be supported by an *electrode*.

6310 Electrode Line - Labrador

- An *electrode line* carrying two conductors with the first 370 km to be supported on the HVdc lattice steel towers from Muskrat Falls to Forteau Point and the remaining section from Forteau Point to L'Anse au Diable to be supported on a wood pole line.
- 50-year *Reliability Level Return Period* of loads.
- *Electrode line* will have provision for arcing horns.

8610 Electrode Labrador

- A shoreline pond *electrode* to be located at L'Anse au Diable on the Labrador side of the SOBI.
- Nominal rating of 450 MW with 100% overload capacity for ten minutes and 50% overload capacity for continuous operation.

6220 Labrador – Island Overland HVdc Transmission

- An HVdc overhead transmission line, ±350 kV bi-pole, to connect the Muskrat Falls *Converter Station* to the Labrador Transition Compound at the Strait of Belle Isle and then to connect the Northern Peninsula Transition Compound at the Strait of Belle Isle to the Soldiers Pond *Converter Station*.
- Transmission line to carry both poles (single conductor per pole) and one OPGW. The Labrador section is to carry two *electrode* conductors from the Muskrat Falls *Converter Station* to Forteau Point (see 6310 Electrode Line – Labrador).
- Transmission line corridor as per Key Plan. (See Drawings).
- The HVdc transmission line is to have a designed nominal power capacity of 900 MW; however, given the mono-polar operation criteria, each pole is to have a nominal rating of 450 MW with 100% overload capacity for ten minutes and 50% overload capacity for continuous operation.
- *Counterpoise* installed from station-to-station.
- Towers are to be galvanized lattice steel, with self-supported angles and dead ends, and guyed suspension towers.
- 50 year *Reliability Level Return Period* of loads, with respect to Nalcor Energy operating experience and LCP specific modeling and test programs.

8510 Transition Compound - Labrador

- Situated on a level fenced site at Forteau Point.
- Enclosed building and provision for submarine cable termination system and associated switching requirements.
- Concrete pads and steel structures to support the electrical equipment and switchgear.
- Overhead line to cable transition equipment.
- High-speed switching, control, protection, monitoring and communication equipment.

8110 Marine Crossing – SOBI - General

- 350 kV, 900 MW submarine cable system to transmit power across the SOBI in bi-polar mode for 50-year design life, with capabilities to allow configuration in mono-polar mode.
- Each cable to have a nominal rating of 1286 A (one pu per pole) and a transient rating of 2572 A (two pu per pole) for five minutes in mono-pole mode.
- Consists of three *mass impregnated* submarine cables and associated components, inclusive of one spare submarine cable.
- Land cables shall connect submarine cables to cable termination system within the transition compound.
- The route for the submarine cable(s) crossing shall be designed to meet the transmission, protection, reliability, and design life requirements, and give consideration to technical and economic optimization.
- Cable corridor as per Key Plan. (See Drawing 1).
- Cables shall be adequately protected along the entire length of the crossing as required. Cable protection methodology will employ proven technologies only, and may include rock placement, trenching, horizontal directional drilling (HDD) and concrete mattresses.
- Where discrete protection application is required, protection measures shall be designed to meet the transmission and reliability requirements.

8520 Transition Compound – Northern Peninsula

- Situated on a level fenced site at Shoal Cove.
- Enclosed building and provision for submarine cable termination system and associated switching requirements.
- Concrete pads and steel structures to support the electrical equipment and switchgear.
- Cable to overhead line transition equipment.
- High-speed switching, control, protection, monitoring and communication equipment.

8220 Soldiers Pond Converter Station

- 900 MW, ±350 kV bi-pole, LCC *converter station* capable of operating in mono-polar mode.
- Each pole rated at 450 MW with 100% overload protection for ten minutes and 50% overload protection for continuous operation.
- Situated next to the Soldiers Pond switchyard on the Avalon Peninsula on a level fenced site.
- Concrete foundations and galvanized steel structures to support the electrical equipment and switchgear.
- Mono-polar operation shall be supported by an *electrode*.

6320 Electrode Line – Newfoundland East

- An *electrode line* carrying two conductors generally follows the existing transmission ROW from Soldiers Pond to Conception Bay.
- Wood pole construction.
- 50-year *Reliability Level Return Period* of loads.
- *Electrode line* will have provision for arcing horns.

8620 Electrode Newfoundland East

- A shoreline pond *electrode* to be located at Dowden's Point on the east side of Conception Bay.
- Nominal rating of 450 MW with 100% overload protection for ten minutes and 50% overload protection for continuous operation.

4500 Soldiers Pond Switchyard

- Situated on the north-east side of Soldiers Pond on a level, fenced site.
- Concrete foundations and galvanized steel structures to support the electrical equipment and switchgear.
- Electrical layout of the switchyard is to be in accordance with the proposed SLD. (See Drawing 2).
- Switchyard to interconnect eight 230 kV HVac transmission lines (four existing transmission lines looped in), the synchronous condensers and the Soldiers Pond *Converter Station*.

7100 Island System Upgrades East

- Three 175 MVAR high-inertia synchronous condensers at Soldiers Pond.
- 230 kV and 138 kV circuit breaker replacements.
- Replacement of conductors, 230 kV transmission line – Bay d'Espoir to Sunnyside.
- Looping in-out of the four existing 230 kV transmission lines into the new Soldier's Pond Switchyard. This requires reconstruction of the resulting eight transmission lines entering and leaving the switchyard to account for lightening protection.
- Upgrade of the protection and control systems at Hardwoods, Oxen Pond, Holyrood and Western Avalon Switchyards.

9230 Operations Telecommunications System – Island Link

- Telecommunication System shall be comprised of three separate layers: Optical Transport Network (OTN), Convergence, and Access Layers.

- OTN Layer shall be the telecommunications backbone and utilize the OPGW, All Dielectric Self Supporting (ADSS) or equivalent fibre optic infrastructure. The OTN Layer equipment nodes shall be designed based upon the least total cost of ownership alternative.

- Convergence Layer shall be based on the Synchronous Optical Network (SONET) international standard. It shall be used to create logical point-to-point telecommunication links between all MF locations. It will multiplex and de-multiplex the Access Layer subsystems for transmission on the OTN.

- Access Layer shall be based on the Ethernet (IEEE 802.3) standard. It shall be comprised of a minimum of three separate telecommunication systems: Protection and Control, SCADA, and Administrative systems. The Administrative system may include the following subsystems: telephony, corporate data, security access control system, and video surveillance.

- The Island Transmission Link Telecommunication Assets specifically includes the following.

  - HVdc OPGW fibre optics connecting
    - Muskrat Falls *Converter Station* to Forteau Point Transition Compound
    - Shoal Cove Transition Compound to Soldiers Pond *Converter Station*
  - ADSS fibre optics connecting
    - Forteau Point Transition Compound to the L'Anse au Diable *Electrode*
    - Soldiers Pond *Converter Station* to Dowden's Point *Electrode*
  - Fibre optic infrastructure shall also be used to connect
    - Forteau Point Transition Compound to Shoal Cove Transition Compound by optic fibres embedded in each power cable being installed across the SOBI
    - Soldiers Pond *Converter Station* to the NLH Energy Control Centre (ECC) in St. John's
    - Soldiers Pond *Converter Station* to the NLH Backup Control Centre (BCC) in Holyrood
  - OTN Layer optical-electronics associated with the above referenced HVdc OPGW fibre optic interconnections.
  - Convergence and Access Layers telecommunication systems associated with all of the above referenced fibre optic interconnections, except these telecommunication layers at MF.
  - NLH ECC and BCC SCADA system upgrades.

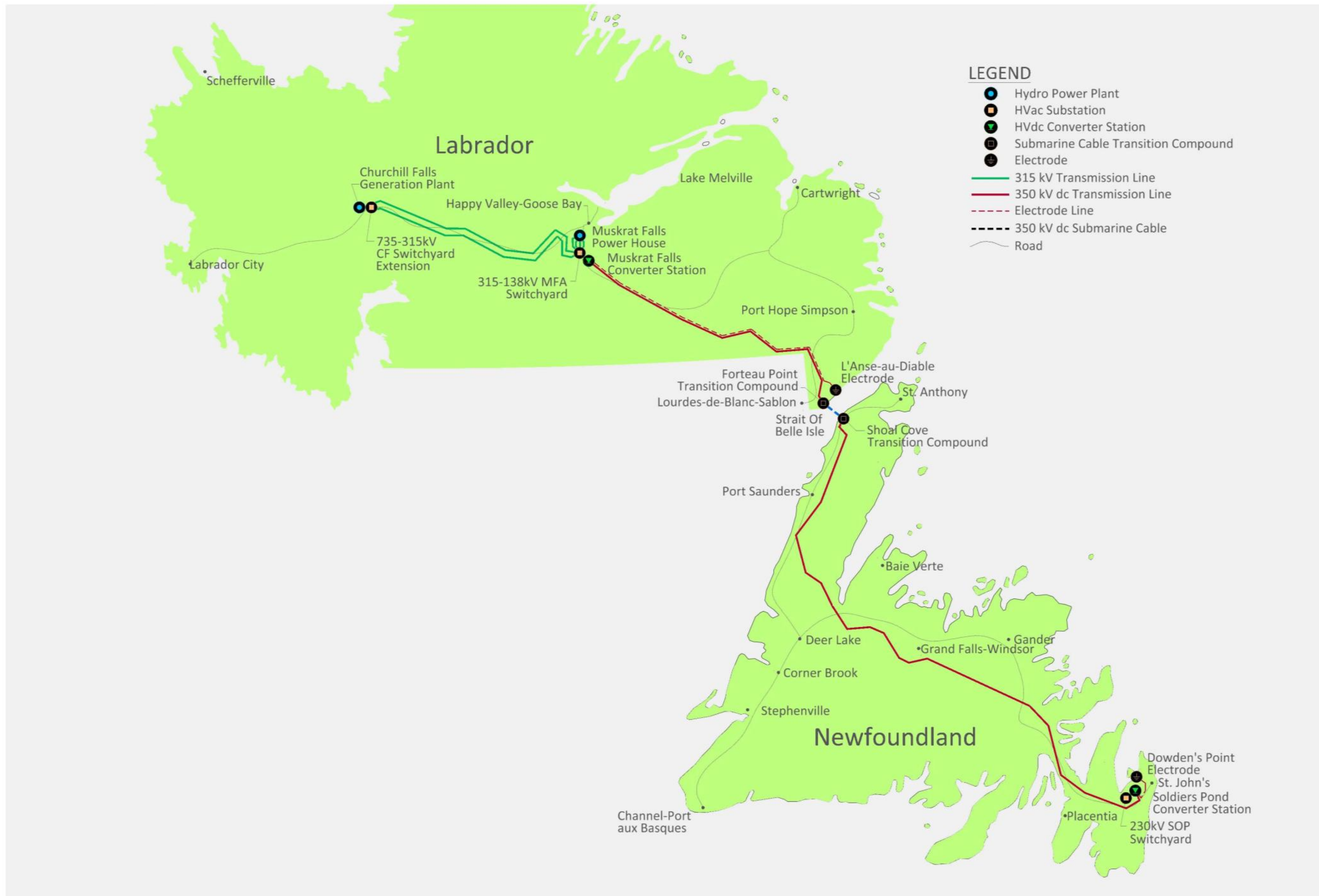
A.0 Activity Flow Chart

N/A

B.0 Attachments/Appendices

B.1 DRAWINGS

1. Key Plan
2. Schematic
3. Single Line Diagram
4. Muskrat Falls – General Arrangement
5. Muskrat Falls - Elevation
6. Muskrat Falls



nalcor energy	NALCOR ENERGY - LOWER CHURCHILL PROJECTS
LOWER CHURCHILL PROJECT KEYPLAN	
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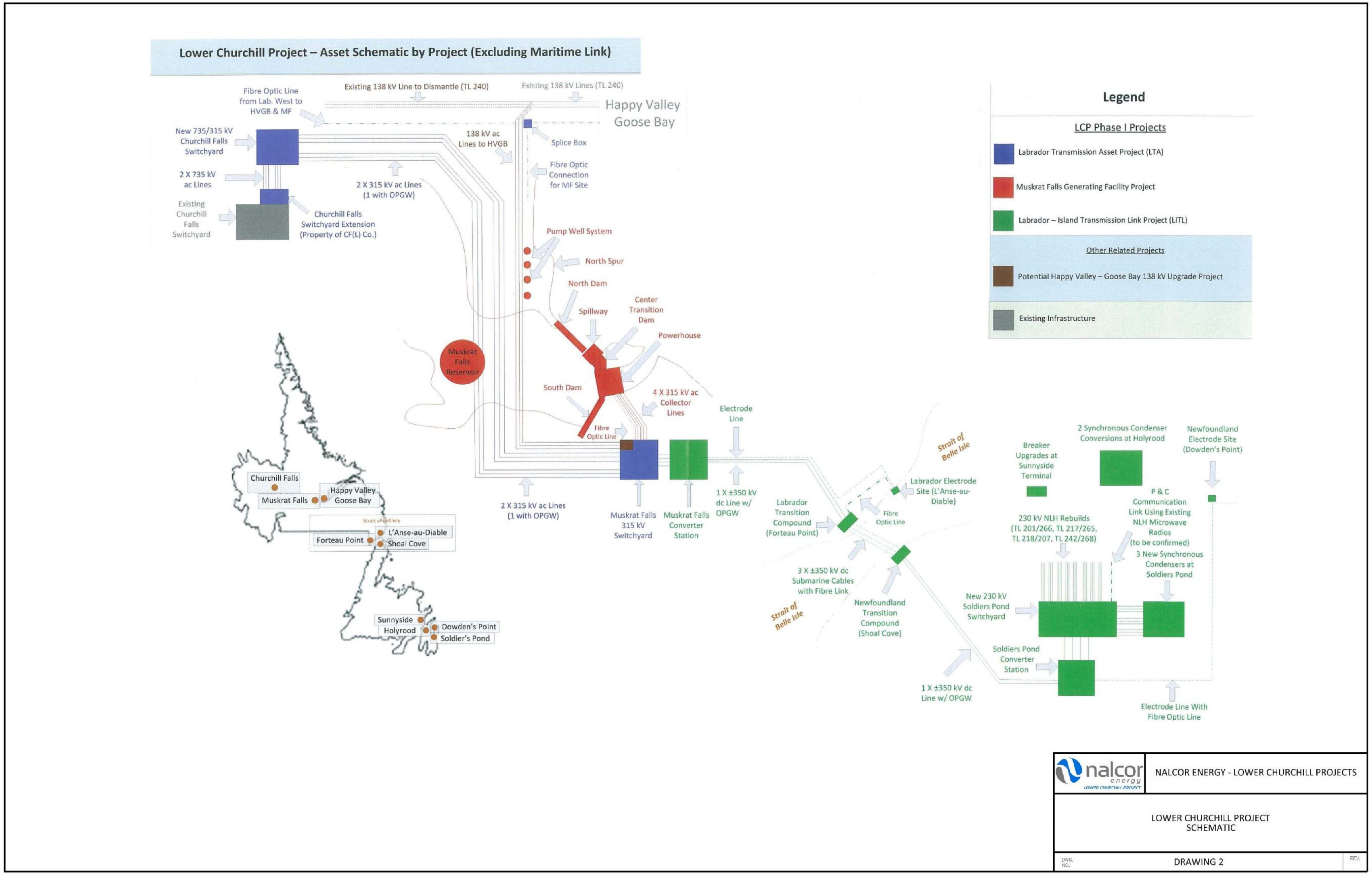
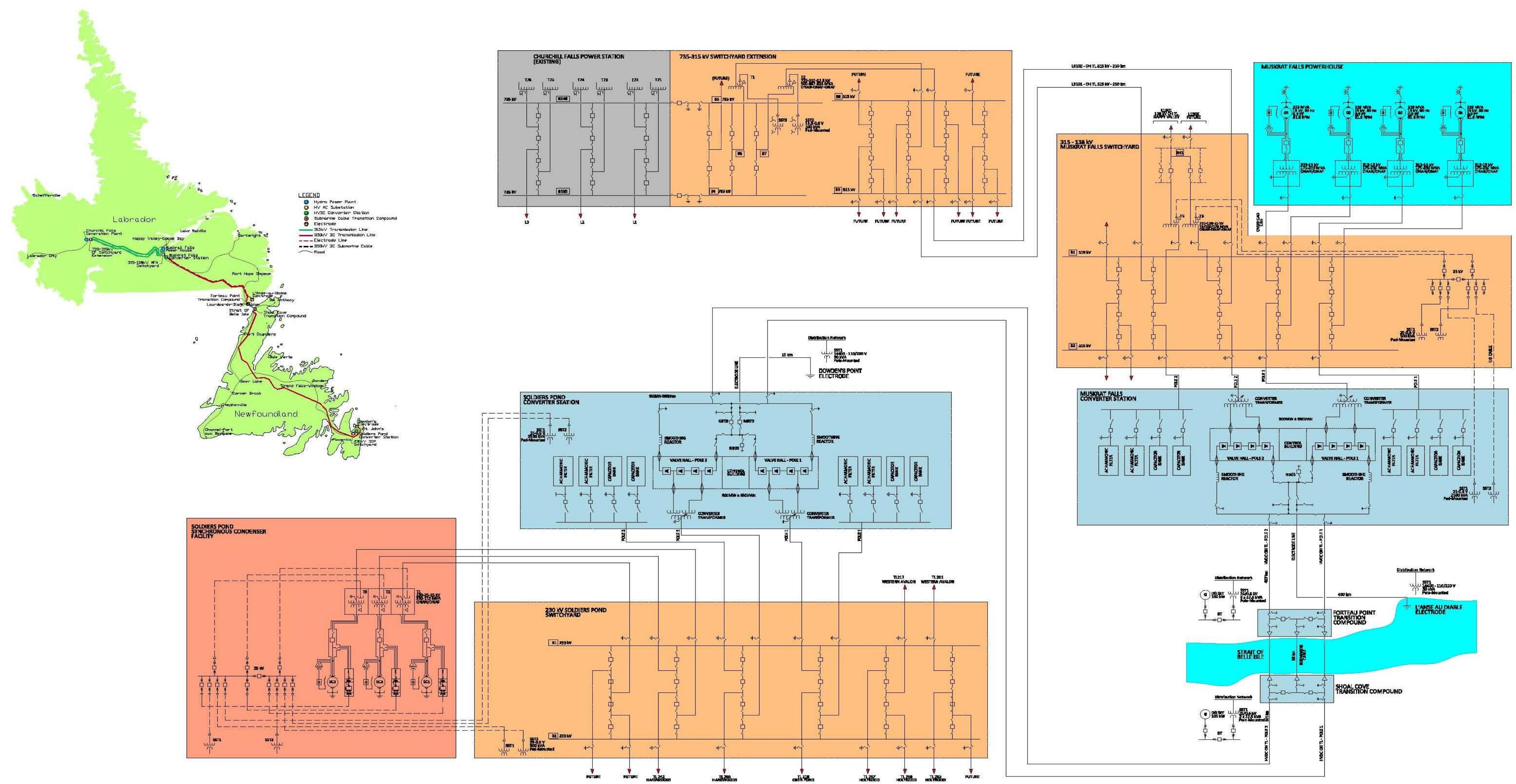

Lower Churchill Project – Asset Schematic by Project (Excluding Maritime Link)
Fibre Optic Line from Lab. West to HVGB & MF
Existing 138 kV Line to Dismantle (TL 240)
Existing 138 kV Lines (TL 240)
Happy Valley Goose Bay
New 735/315 kV Churchill Falls Switchyard
138 kV ac Lines to HVGB
Splice Box
Fibre Optic Connection for MF Site
2 X 735 kV ac Lines
2 X 315 kV ac Lines (1 with OPGW)
Existing Churchill Falls Switchyard
Churchill Falls Switchyard Extension (Property of CF(L) Co.)
Pump Well System
North Spur
North Dam
Spillway
Center Transition Dam
Powerhouse
Muskrat Falls Reservoir
South Dam
4 X 315 kV ac Collector Lines
Fibre Optic Line
Electrode Line
2 X 315 kV ac Lines (1 with OPGW)
Muskrat Falls 315 kV Switchyard
Muskrat Falls Converter Station
1 X ±350 kV dc Line w/ OPGW
Labrador Transition Compound (Forteau Point)
Strait of Belle Isle
Labrador Electrode Site (L'Anse-au-Diable)
Fibre Optic Line
3 X ±350 kV dc Submarine Cables with Fibre Link
Newfoundland Transition Compound (Shoal Cove)
Churchill Falls
Muskrat Falls
Happy Valley Goose Bay
L'Anse-au-Diable
Forteau Point
Shoal Cove
Sunnyside
Holyrood
Dowden's Point
Soldier's Pond
Legend
LCP Phase I Projects
Labrador Transmission Asset Project (LTA)
Muskrat Falls Generating Facility Project
Labrador – Island Transmission Link Project (LITL)
Other Related Projects
Potential Happy Valley – Goose Bay 138 kV Upgrade Project
Existing Infrastructure
Breaker Upgrades at Sunnyside Terminal
2 Synchronous Condenser Conversions at Holyrood
Newfoundland Electrode Site (Dowden's Point)
P & C Communication Link Using Existing NLH Microwave Radios (to be confirmed)
230 kV NLH Rebuilds (TL 201/266, TL 217/265, TL 218/207, TL 242/268)
3 New Synchronous Condensers at Soldiers Pond
New 230 kV Soldiers Pond Switchyard
Soldiers Pond Converter Station
1 X ±350 kV dc Line w/ OPGW
Electrode Line With Fibre Optic Line
NALCOR ENERGY - LOWER CHURCHILL PROJECTS
LOWER CHURCHILL PROJECT SCHEMATIC
DWG. NO.
DRAWING 2
REV.



NALCOR ENERGY - LOWER CHURCHILL PROJECTS

LOWER CHURCHILL PROJECT
SINGLE LINE DIAGRAM

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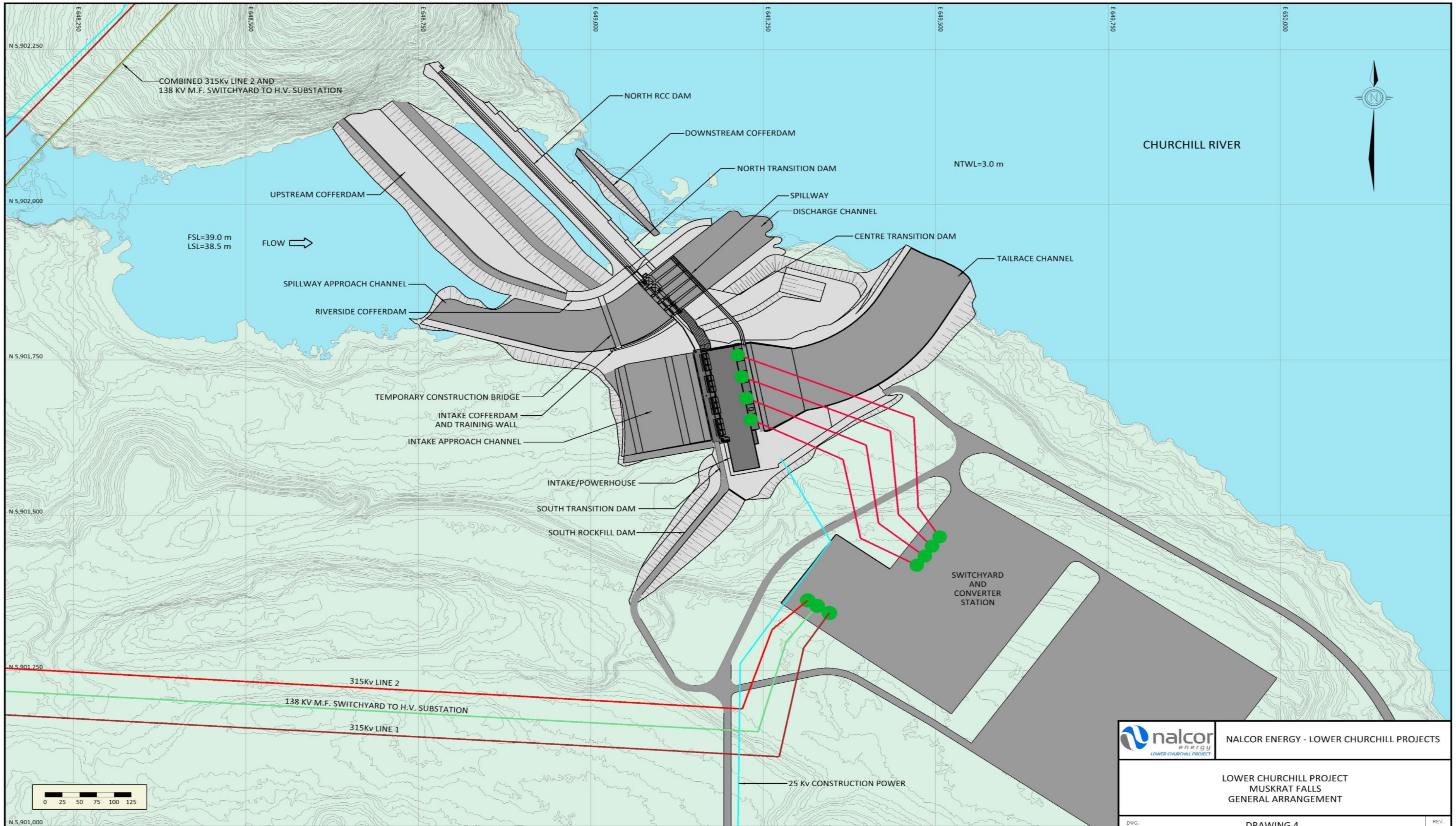
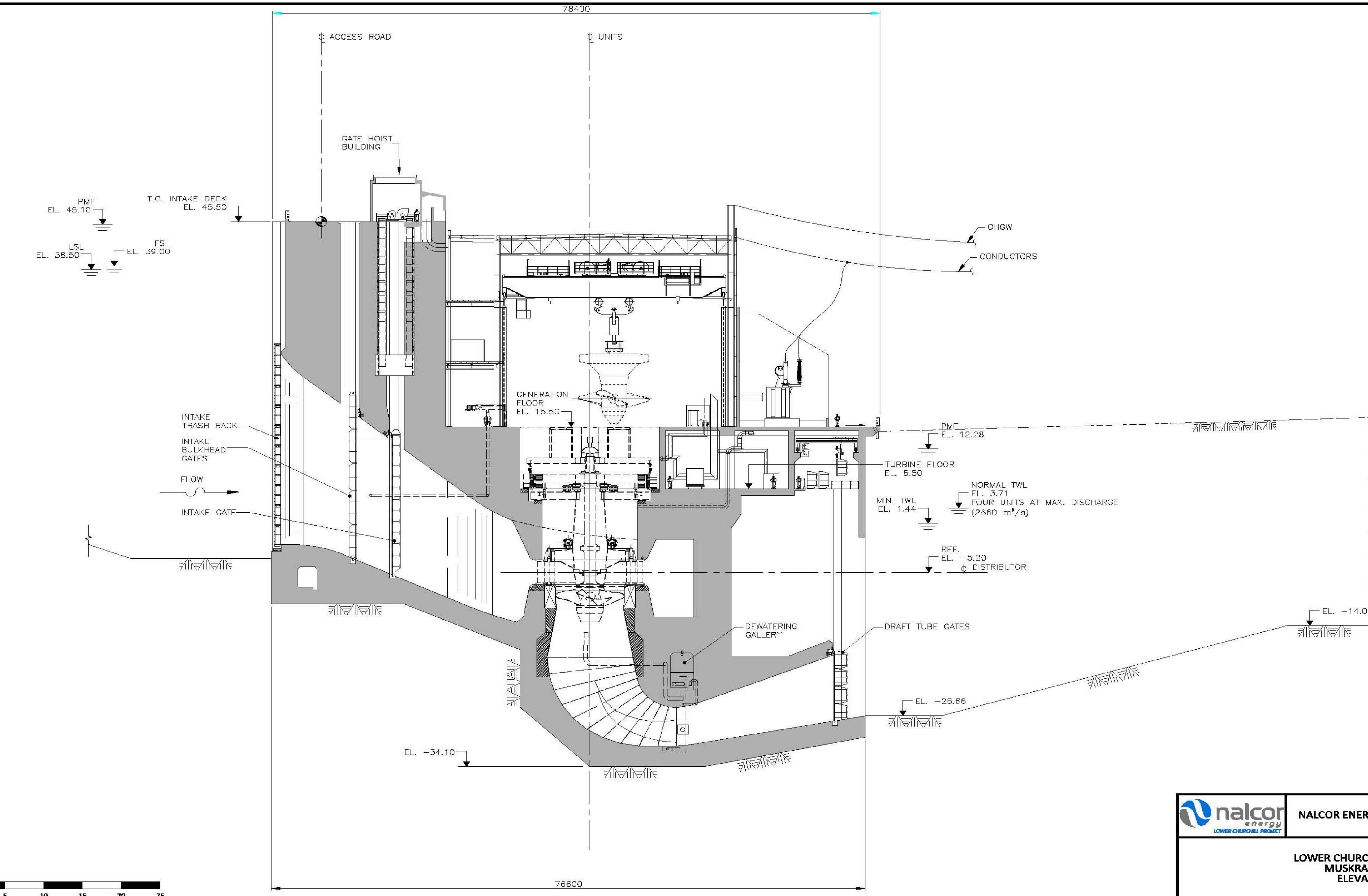

COMBINED 315Kv LINE 2 AND
138 KV M.F. SWITCHYARD TO H.V. SUBSTATION
NORTH RCC DAM
DOWNSTREAM COFFERDAM
NORTH TRANSITION DAM
SPILLWAY
DISCHARGE CHANNEL
CENTRE TRANSITION DAM
TAILRACE CHANNEL
CHURCHILL RIVER
NTWL=3.0 m
UPSTREAM COFFERDAM
FSL=39.0 m
LSL=38.5 m
FLOW
SPILLWAY APPROACH CHANNEL
RIVERSIDE COFFERDAM
TEMPORARY CONSTRUCTION BRIDGE
INTAKE COFFERDAM
AND TRAINING WALL
INTAKE APPROACH CHANNEL
INTAKE/POWERHOUSE
SOUTH TRANSITION DAM
SOUTH ROCKFILL DAM
SWITCHYARD
AND
CONVERTER
STATION
315Kv LINE 2
138 KV M.F. SWITCHYARD TO H.V. SUBSTATION
315Kv LINE 1
25 Kv CONSTRUCTION POWER
N 5,902,250
N 5,902,000
N 5,901,750
N 5,901,500
N 5,901,250
N 5,901,000
0 25 50 75 100 125
NALCOR ENERGY - LOWER CHURCHILL PROJECTS
LOWER CHURCHILL PROJECT
MUSKRAT FALLS
GENERAL ARRANGEMENT
DRAWING 4



nalcor energy	NALCOR ENERGY - LOWER CHURCHILL PROJECTS
LOWER CHURCHILL PROJECT MUSKRAT FALLS ELEVATION	
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nalcor energy
LOWER CHURCHILL PROJECT
NALCOR ENERGY - LOWER CHURCHILL PROJECTS
LOWER CHURCHILL PROJECT
MUSKRAT FALLS
DWG. NO.
DRAWING 6
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Nalcor Energy – Lower Churchill Project

Overhead Transmission - Meteorological Loading for the Labrador- Island Transmission Link

ILK-PT-ED-6200-TL-DC-0001-01

Comments: Supersedes MFA-PT-ED-6200-TL-DC-0002-01	Total # of Pages (Including Cover): 30

B1	20-Dec-2011	**For Use/ Implementation**	J. Walsh	B. Barnes	K. Tucker	R. Power
Status/ Revision	Date	Reason For Issue	Prepared By	Engineering Manager Approval	Area Manager Overland Transmission Approval	Project Manager (Generation + Island Link) Approval

Inter-Departmental / Discipline Approval (where required)

Department	Department Manager Approval	Date
	Name	
	Name	
	Name	
	Name	

TABLE of CONTENTS

1.0 Purpose

The purpose of this technical note is to provide SLI with the 1:50 Return Period Meteorological Loads required to design the ±350 kV HVdc overhead transmission line as part of the Labrador – Island Transmission Link.

2.0 Scope

The scope of this technical note is to specify the 1:50 Return Period Meteorological Loads that are required to design the ± 350 kV HVdc overhead transmission lines as part of the Labrador – Island transmission link. SLI are to incorporate this information into the design of the dc transmission system only. Provision of these primary load cases does not remove the design responsibility and accountability from SLI for the engineering design for the structural and transmission line design aspects.

3.0 Definitions

Meteorological Loads	For the purposes of this document, Meteorological Loads are the primary load cases used in the design of the ± 350 kV HVdc transmission line.
Return Period	Statistical reoccurrence time for a specific event. The assigned Return Period for the HVdc transmission system is 1:50 years.

4.0 Abbreviations and Acronyms

SLI	SNC-Lavalin Incorporated
kV	kilovolt
NE-LCP	Nalcor Energy – Lower Churchill Project
SOBI	Strait of Belle Isle

5.0 Reference Documents

a) CSA C22.3 No. 60826-10, Canadian Standard Associations Design Criteria for Overhead Transmission Lines
b) DC 1300 - Review of in-cloud icing on the Long Range Mountain Ridge Nalcor Energy Lower Churchill. EFLA & Landsvirkjun Power.
c) DC 1301 - Report #1 and Evaluation of in-cloud icing in the Long Range Mountain Ridge. Landsvirkjun Power. December 2010.
d) DC 1070 - Preliminary Meteorological Load Review. Hatch Ltd., August 2008.
e) Evaluate Extreme Ice Loads From Freezing Rain. Cold Regions Research and Engineering Laboratory (Jones, K). January 2010.
f) LCP-PT-ED-0000-EN-PH-0022-01 Design Philosophy for HVdc Transmission Lines, Rev B1

g) LCP-PT-ED-0000-EN-RP-0001-01 – Lower Churchill Project - Basis of Design
h) Meteorological Study of the Gull Island- Stephenville-Holyrood Transmission Line Routes. M.C. Richmond, M.J. Fegley (Meteorology Research Inc.) 30 November 1973.
i) RSW, "Development of EHV Transmission Lines in Labrador", February 1999
j) Teshmont Consultants Limited, "Design Transmittal, 138 kV Transmission Line, Churchill Falls – Happy Valley/Goose Bay – TL 240", March, 1976

6.0 Responsibilities

NE-LCP have provided this information as the Project Owner, having performed significant analysis in the development of these loads. It is the responsibility of SLI to use this information to form the basis of design loads, incorporate these loads into its design processes, and take responsibility of the engineering design that utilizes information included herein.

7.0 Meteorological Load Cases

The ±350 kV HVdc transmission line has been sectioned into three separate loading regions based on varying meteorological conditions over the proposed corridor. The attached mapping (Attachment B.1) delineates NE-LCP's general section locations throughout the line corridor.

The following primary load cases are the meteorological loads to be applied to all transmission structures on the ± 350 kV HVdc transmission line within their respective loading sections. Loads have a return period of 1:50 years. SLI shall submit these and all other additional load cases required for design of the ± 350 kV HVdc transmission line in the Transmission Line Design Criteria.

The HVdc transmission line corridor has been subdivided into three major meteorological loading zones with varying loading conditions throughout. SLI shall provide a design solution that optimizes the quantity of tower families needed throughout the entire transmission line.

7.1 Average Meteorological Loading Zone

Zone 1, 8b and 10 (see Attachment B.1)

The following load case is to be applied in the location shown in attachment B.1. Please note that this loading is valid for the northern corridor alternative only.

Maximum Ice	50 mm radial glaze, 0.9 g/cm^3 density
Maximum Wind	105 km/h (10 minute average wind speed at 10 m height above ground)
Combined Ice and Wind	25 mm radial glaze, 0.9 g/cm^3 density 60 km/h (10 minute average wind speed at 10 m height above ground)

Maximum wind and combined wind values assume Terrain Type C as per CSA C22.3 NO 60826-10. Any deviation for this terrain type for select locations along the corridor must be included in the HVdc tower design criteria.

Zone 3, 4, 6 and 8a (see Attachment B.1)

The following load case is to be applied in the location shown in attachment B.1. Please note that this loading is valid for the northern corridor alternative only.

Maximum Ice	50 mm radial glaze, 0.9 g/cm^3 density
Maximum Wind	120 km/h (10 minute average wind speed at 10 m height above ground)
Combined Ice and Wind	25 mm radial glaze, 0.9 g/cm^3 density 60 km/h (10 minute average wind speed at 10 m height above ground)

Maximum wind and combined wind values assume Terrain Type C as per CSA C22.3 NO 60826-10. Any deviation for this terrain type for select locations along the corridor must be included in the HVdc tower design criteria.

7.2 Alpine Meteorological Loading Zone

Zone 2 – The Labrador Alpine Region (see Attachment B.1)

The following load cases are to be applied in the locations shown in attachment B.1. Please note that these loading are valid for the western corridor alternative only.

Labrador High Alpine Loading Zone (Zone 2a and 2c)

Maximum Ice	115 mm radial rime, 0.5 g/cm^3 density
Maximum Wind	135 km/h (10 minute average wind speed at 10 m height above ground)
Combined Ice and Wind	60 mm radial rime, 0.5 g/cm^3 density 95 km/h (10 minute average wind speed at 10 m height above ground)

Labrador Extreme Alpine Loading Zone (Zone 2b)

Maximum Ice	135 mm radial rime, 0.5 g/cm^3 density
Maximum Wind	135 km/h (10 minute average wind speed at 10 m height above ground)
Combined Ice and Wind	70 mm radial rime, 0.5 g/cm^3 density

	95 km/h (10 minute average wind speed at 10 m height above ground)

Maximum wind and combined wind values assume Terrain Type B as per CSA C22.3 NO 60826-10. Design shall consider soft rime accretion and use appropriate conditions from CSA C22.3 NO 60826-10. Any deviation for this terrain type or rime type for select locations along the corridor must be included in the HVdc tower design criteria.

Zone 5 – The Highlands of St. John Region (see Attachment B.1)

The following load cases are to be applied in the locations shown in attachment B.1. Please note that these loadings are valid for the western corridor alternative only.

Maximum Ice	115 mm radial rime, 0.5 g/cm^3 density
Maximum Wind	150 km/h (10 minute average wind speed at 10 m height above ground)
Combined Ice and Wind	60 mm radial rime, 0.5 g/cm^3 density 105 km/h (10 minute average wind speed at 10 m height above ground)

Maximum wind and combined wind values assume Terrain Type B as per CSA C22.3 NO 60826-10. Design shall consider soft rime accretion and use appropriate conditions from CSA C22.3 NO 60826-10. Any deviation for this terrain type or rime type for select locations along the corridor must be included in the HVdc tower design criteria.

Zone 7 – The Long Range Mountains Region (see Attachment B.1)

The following load cases are to be applied in the locations shown in attachment B.1. Please note that these loadings are valid for the eastern corridor alternative only.

The Long Range Mountains High Alpine Loading Region (Zone 7a and 7c)

Maximum Ice	115 mm radial rime, 0.5 g/cm^3 density
Maximum Wind	180 km/h (10 minute average wind speed at 10 m height above ground)
Combined Ice and Wind	60 mm radial rime, 0.5 g/cm^3 density 125 km/h (10 minute average wind speed at 10 m height above ground)

The Long Range Mountains Extreme Alpine Loading Region (Zone 7b)

Maximum Ice	135 mm radial rime, 0.5 g/cm^3 density
Maximum Wind	180 km/h (10 minute average wind speed at 10 m height above ground)

Combined Ice and Wind	70 mm radial rime, 0.5 g/cm^3 density 125 km/h (10 minute average wind speed at 10 m height above ground)

Maximum wind and combined wind values assume Terrain Type B as per CSA C22.3 NO 60826-10. Design shall consider soft rime accretion and use appropriate conditions from CSA C22.3 NO 60826-10. Any deviation for this terrain type or rime type for select locations along the corridor must be included in the HVdc tower design criteria.

Zone 9 – The Birchy Narrows Alpine Loading Region (see Attachment B.1)

The following load case is to be applied in the location shown in attachment B.1. Please note that this loading is valid for the northern corridor alternative only.

Maximum Ice	75 mm radial glaze, 0.9 g/cm^3 density
Maximum Wind	130 km/h 10 minute average wind speed (10 minute average wind speed at 10 m height above ground)
Combined Ice and Wind	45 mm radial glaze, 0.9 g/cm^3 density 60 km/h (10 minute average wind speed at 10 m height above ground)

Maximum wind and combined wind values assume Terrain Type C as per CSA C22.3 NO 60826-10. Any deviation for this terrain type for select locations along the corridor must be included in the HVdc tower design criteria.

7.3 Eastern Meteorological Loading Zone

Zone 11 (see Attachment B.1)

The following load case is to be applied in the location shown in attachment B.1. Please note that this loading is valid for the northern corridor alternative only.

Maximum Ice	75 mm radial glaze, 0.9 g/cm^3 density
Maximum Wind	130 km/h 10 minute average wind speed (10 minute average wind speed at 10 m height above ground)
Combined Ice and Wind	45 mm radial glaze, 0.9 g/cm^3 density 60 km/h (10 minute average wind speed at 10 m height above ground)

Maximum wind and combined wind values assume Terrain Type C as per CSA C22.3 NO 60826-10. Any deviation for this terrain type for select locations along the corridor must be included in the HVdc tower design criteria.

8 Activity Flowchart (Excel Format)

A.1. N/A

9 Attachments/Appendices

B.1 HVdc Meteorological Loading Region Mapping

B.2 HVdc Loading Combination Summary Table

HVdc Meteorological Loading Region Mapping

Attachment B.1

Boundless Energy

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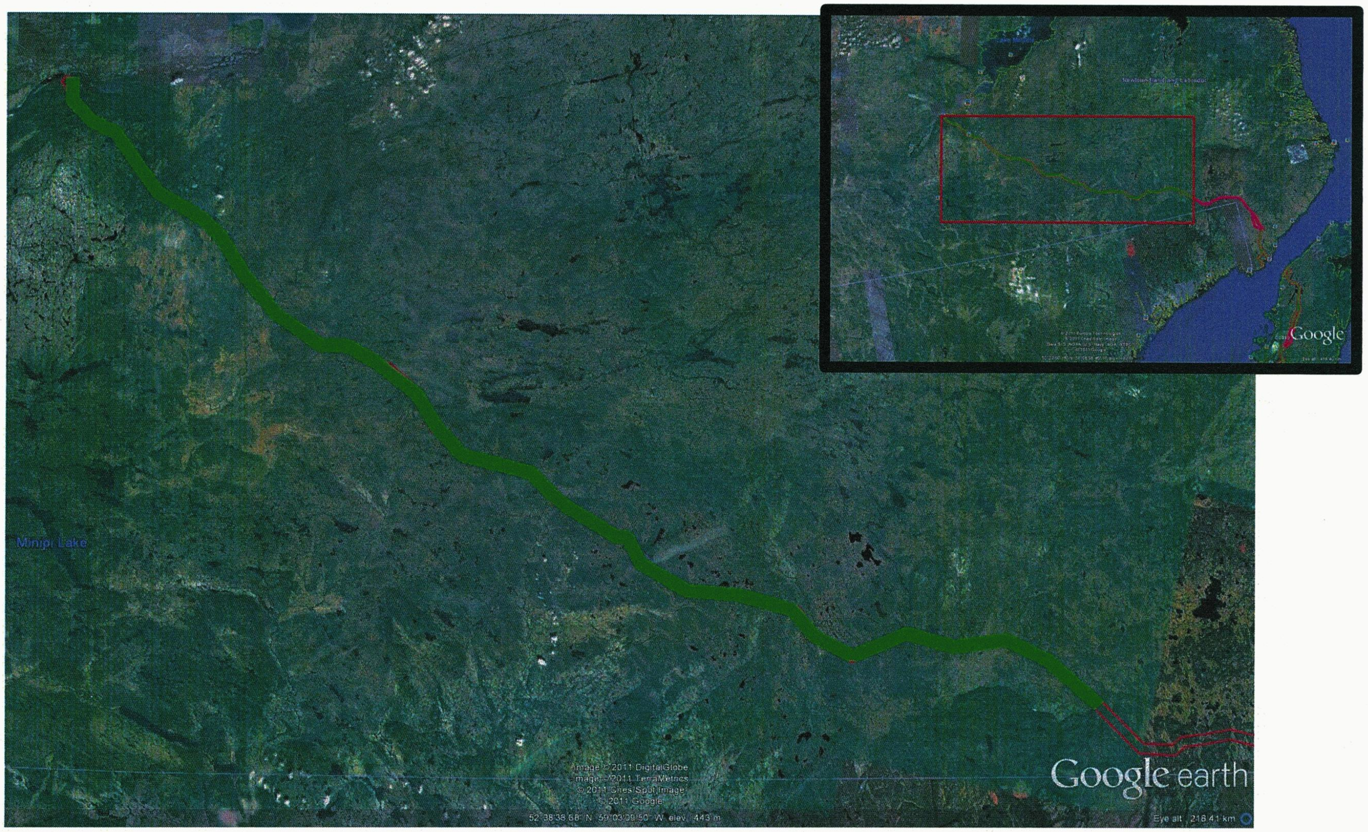
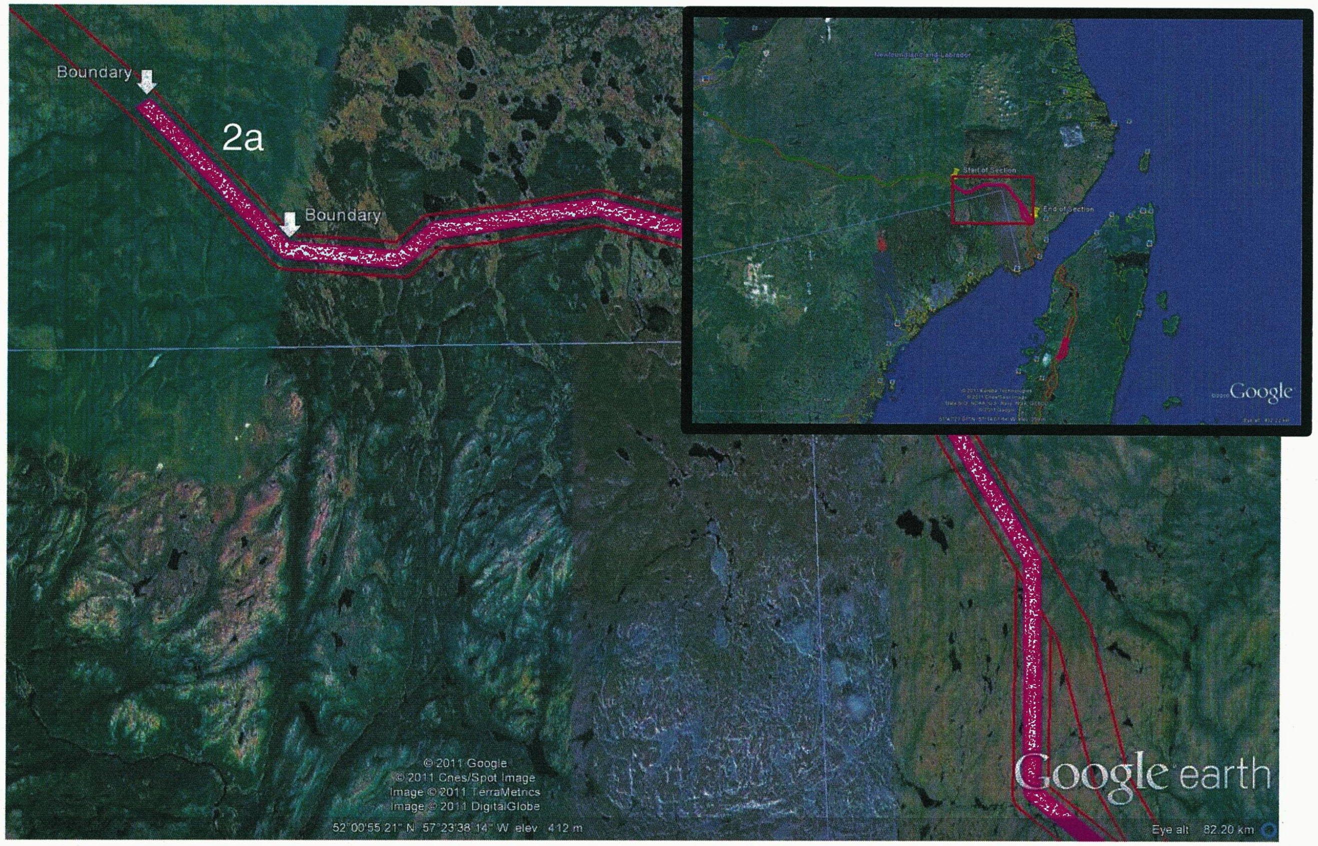


Zone 1 – Inner Labrador

Average Meteorological Loading Zone

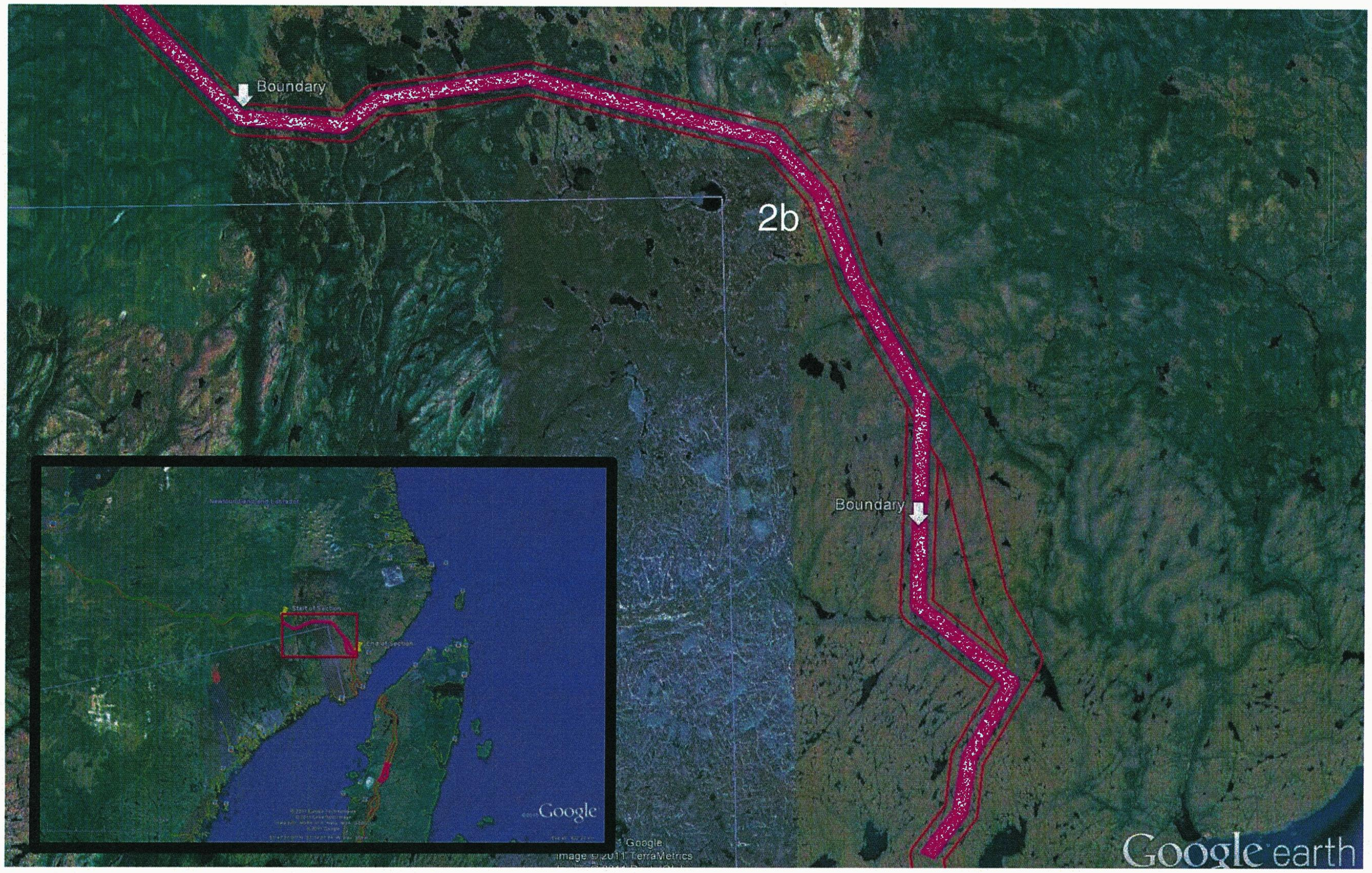
Maximum Ice: 50 mm glaze, Maximum Wind: 105 km/h, Combined Ice and Wind: 25 mm glaze and 60 km/h



Zone 2a – Alpine Labrador

High Alpine Meteorological Loading Zone

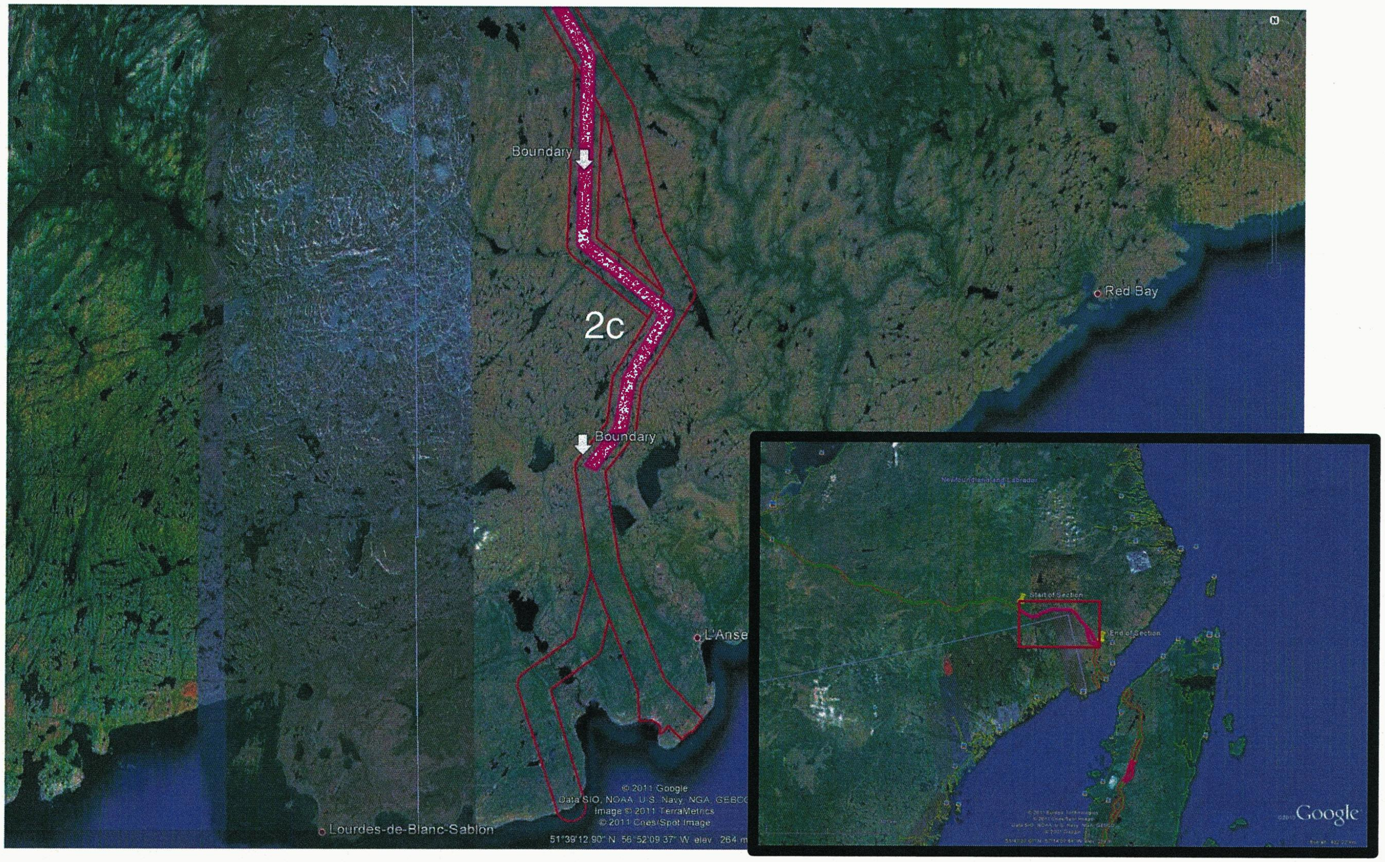
Maximum Ice: 115 mm (Rime), Maximum Wind: 135 km/h, Combined Ice and Wind: 60 mm (Rime) and 95 km/h



Zone 2b – Alpine Labrador

Extreme Alpine Meteorological Loading Zone

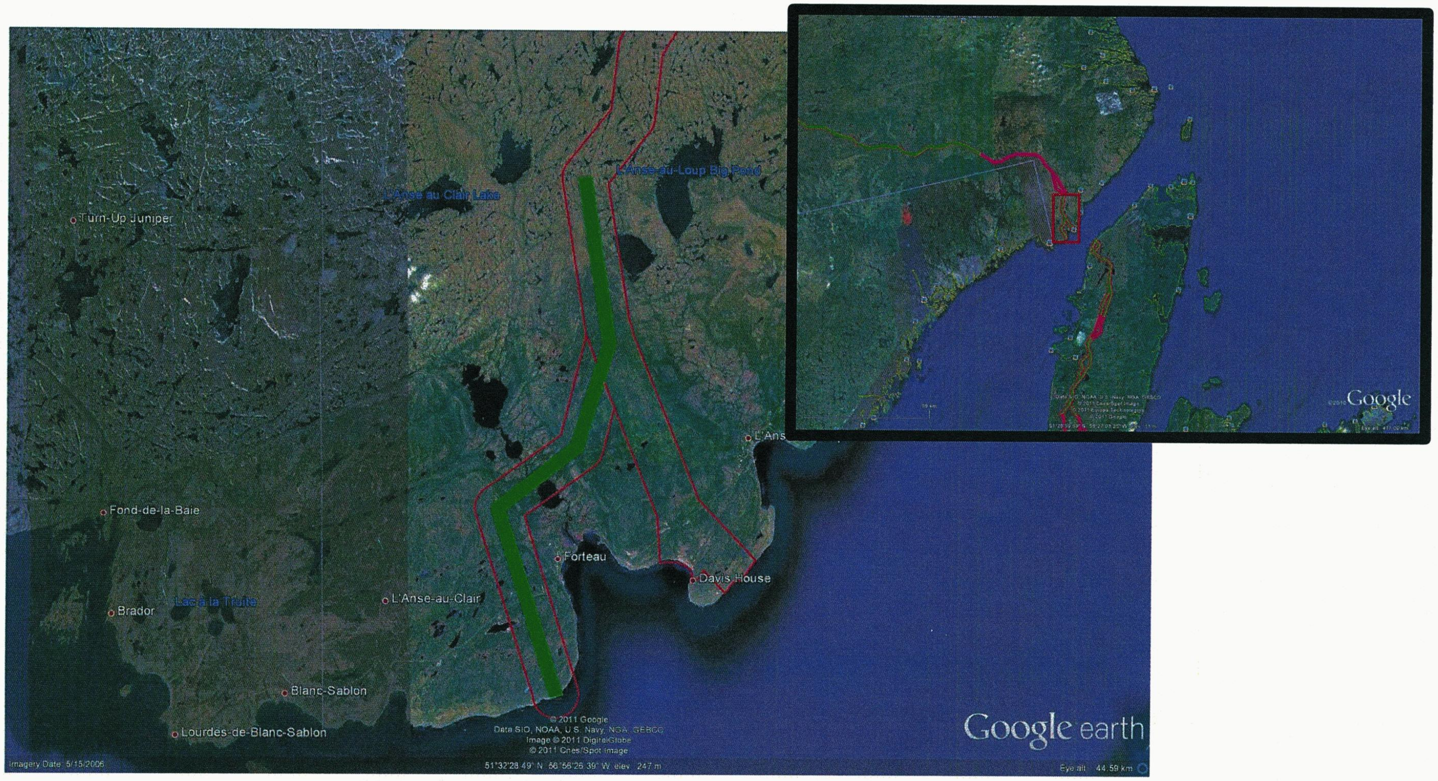
Maximum Ice: 135 mm (Rime), Maximum Wind: 135 km/h, Combined Ice and Wind: 70 mm (Rime) and 95 km/h



Zone 2c – Alpine Labrador

High Alpine Meteorological Loading Zone (Western Corridor Alternative Only)

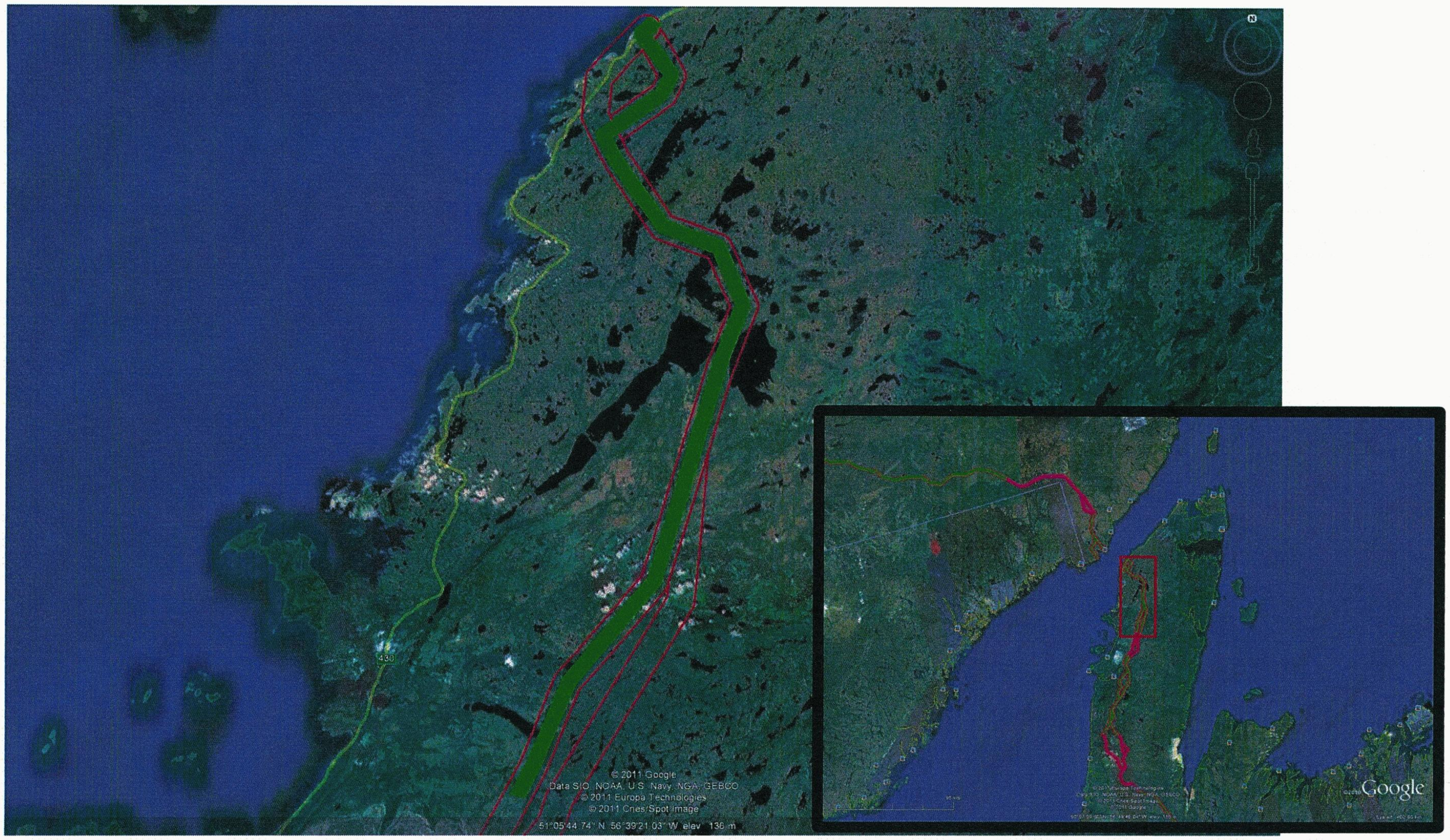
Maximum Ice: 115 mm (Rime), Maximum Wind: 135 km/h, Combined Ice and Wind: 60 mm (Rime) and 95 km/h



Zone 3 – Labrador Coast

Average Meteorological Loading Zone

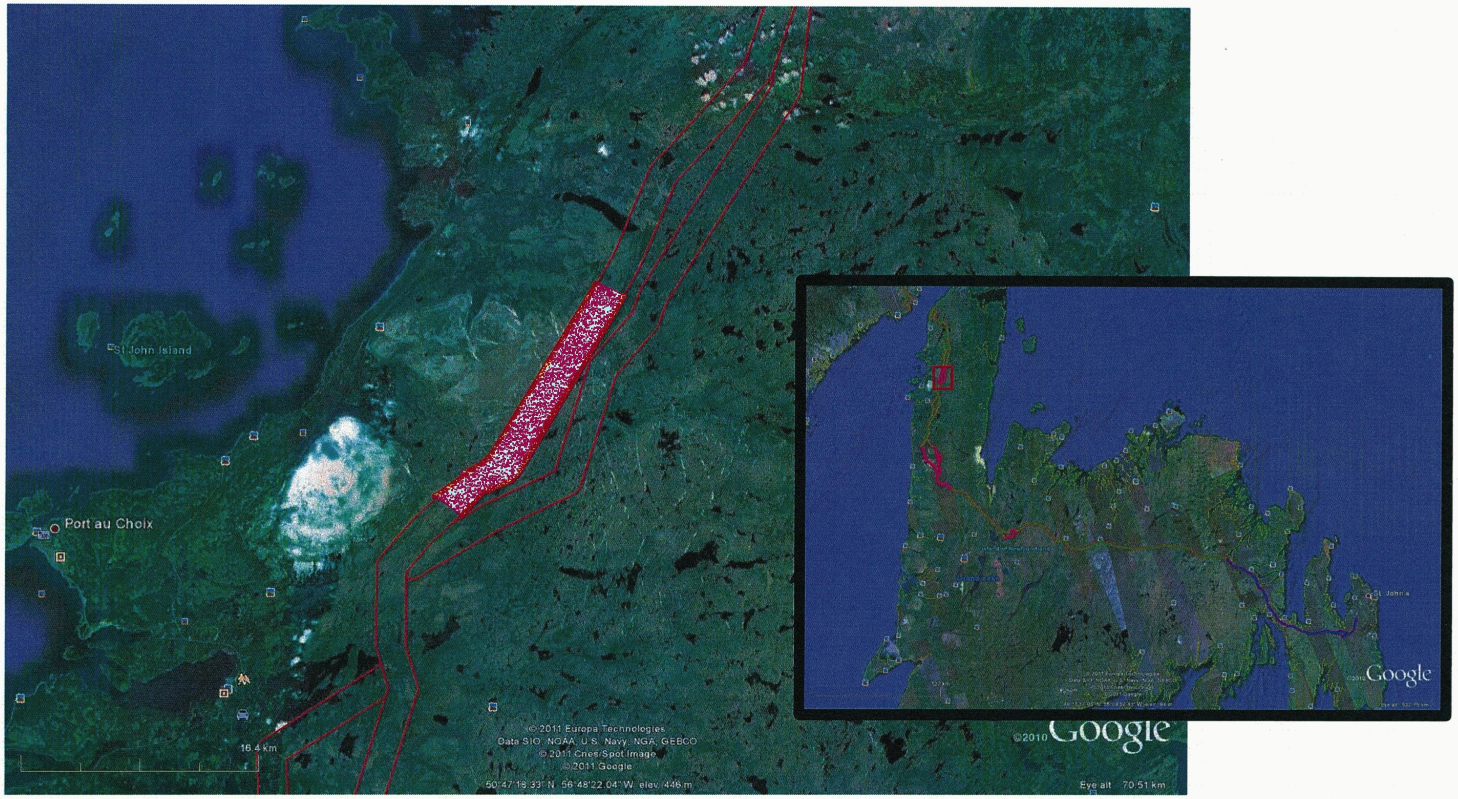
Maximum Ice: 50 mm (Glaze), Maximum Wind: 120 km/h, Combined Ice and Wind: 25 mm (Glaze) and 60 km/h



Zone 4 – Northern Peninsula Coast

Average Meteorological Loading Zone

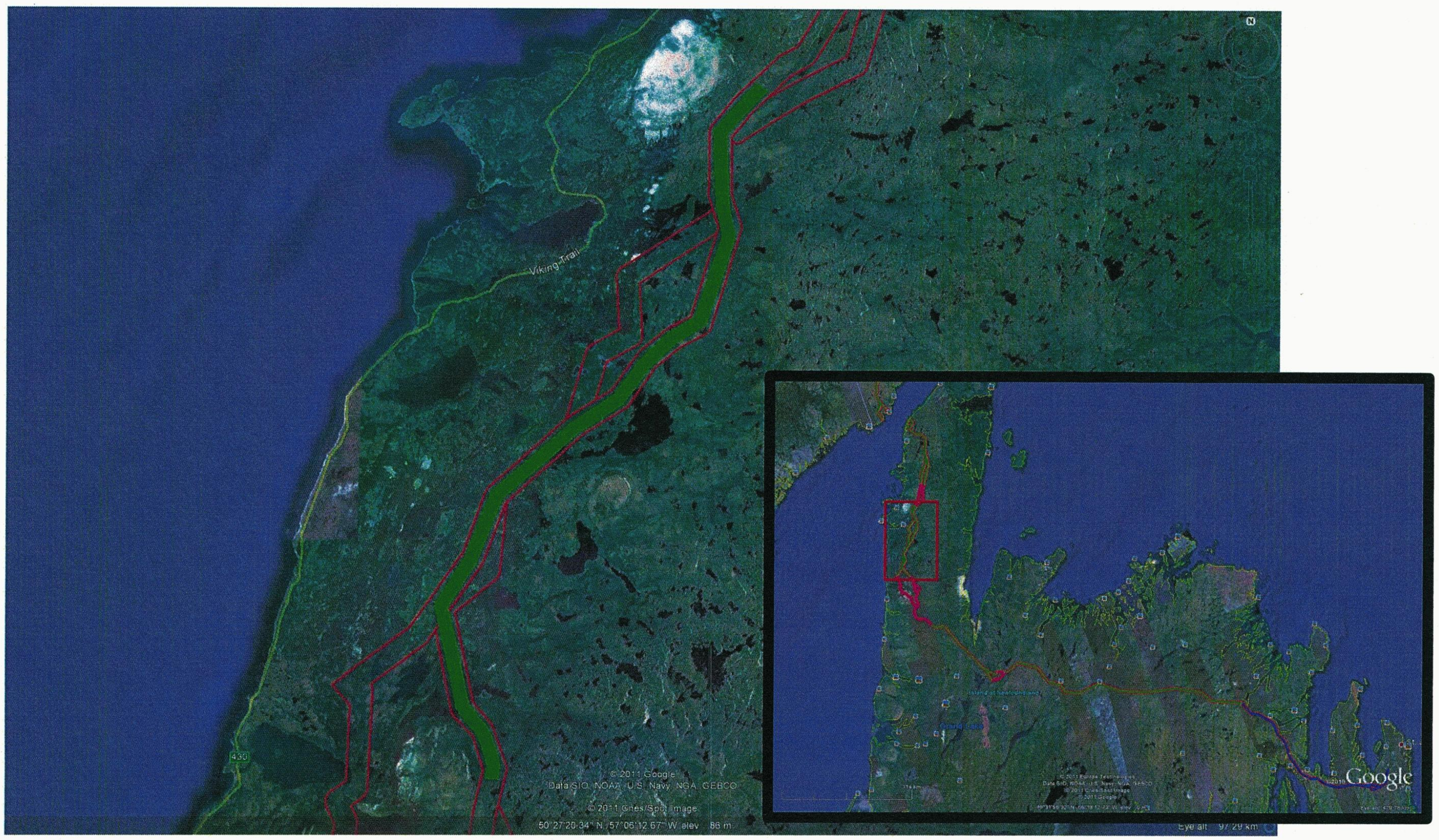
Maximum Ice: 50 mm (Glaze), Maximum Wind: 120 km/h, Combined Ice and Wind: 25 mm (Glaze) and 60 km/h



Zone 5 – Highlands of St. John

High Alpine Meteorological Loading Zone (Western Corridor Alternative Only)

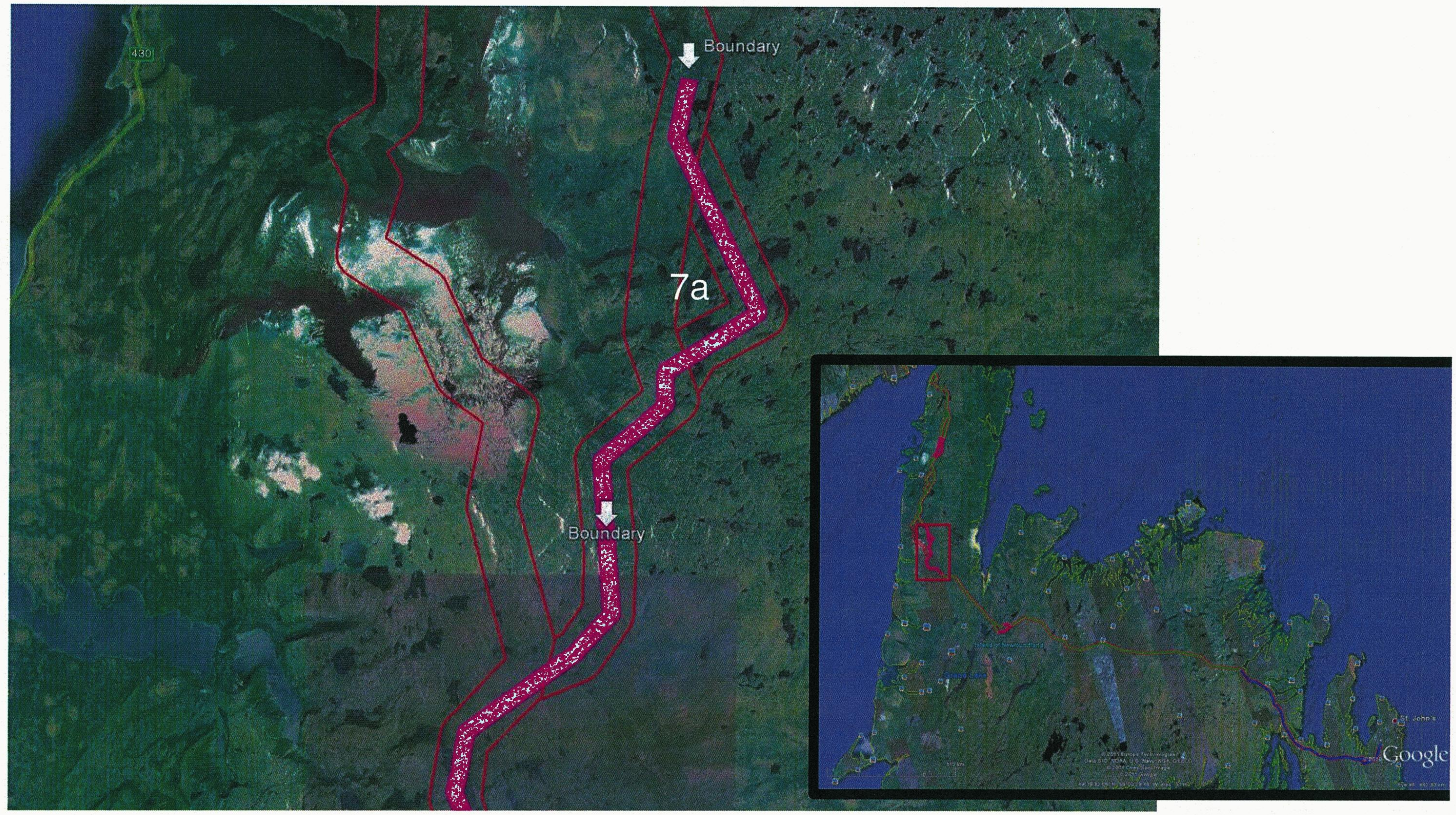
Maximum Ice: 115 mm (Rime), Maximum Wind: 150 km/h, Combined Ice and Wind: 60 mm (Rime) and 105 km/h



Zone 6 –Northern Peninsula

Average Meteorological Loading Zone

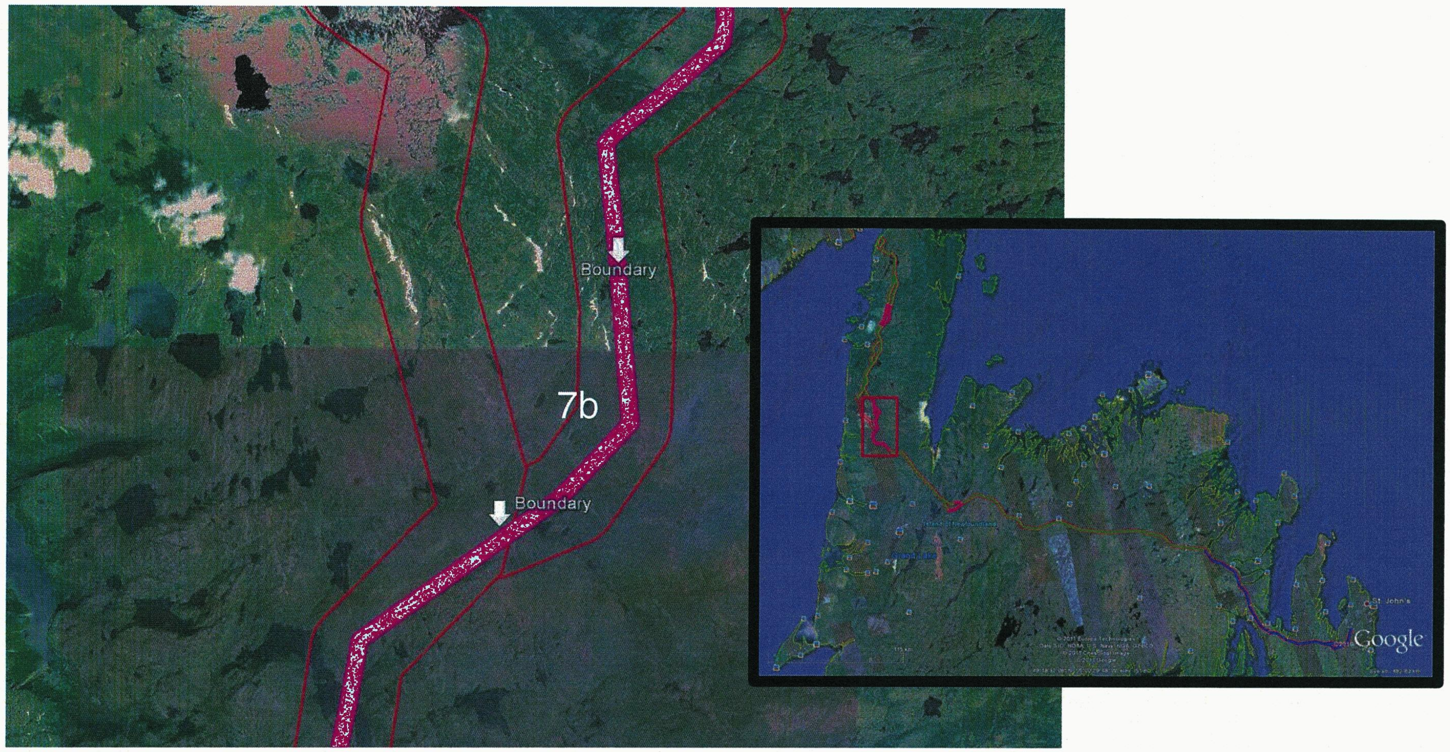
Maximum Ice: 50 mm (Glaze), Maximum Wind: 120 km/h, Combined Ice and Wind: 25 mm (Glaze) and 60 km/h



Zone 7a – Long Range Mountains Crossing

High Alpine Meteorological Loading Zone (Eastern Corridor Alternative Only)

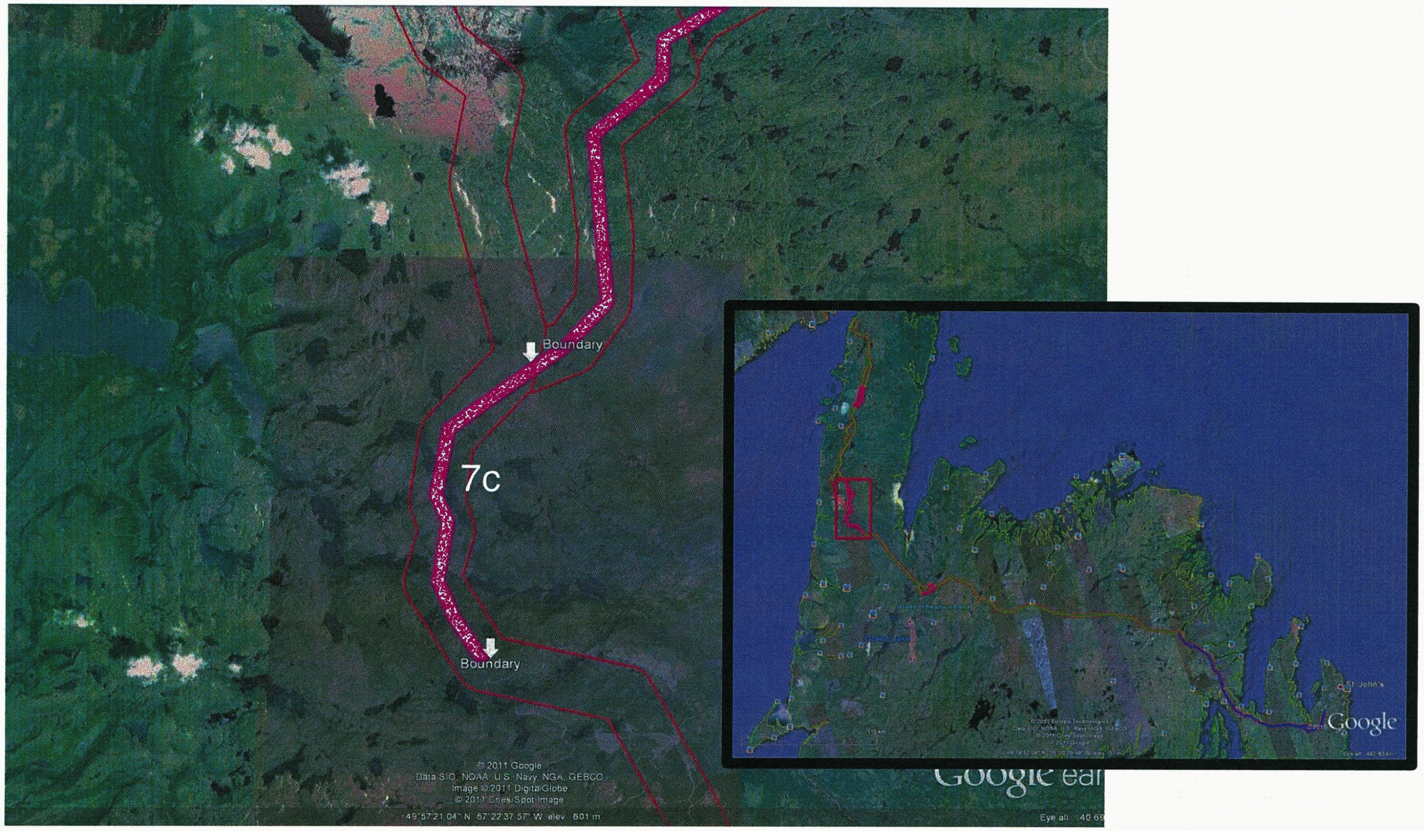
Maximum Ice: 115 mm (Rime), Maximum Wind: 180 km/h, Combined Ice and Wind: 60 mm (Rime) and 125 km/h



Zone 7b – Long Range Mountains Crossing

Extreme Alpine Meteorological Loading Zone (Eastern Corridor Alternative Only)

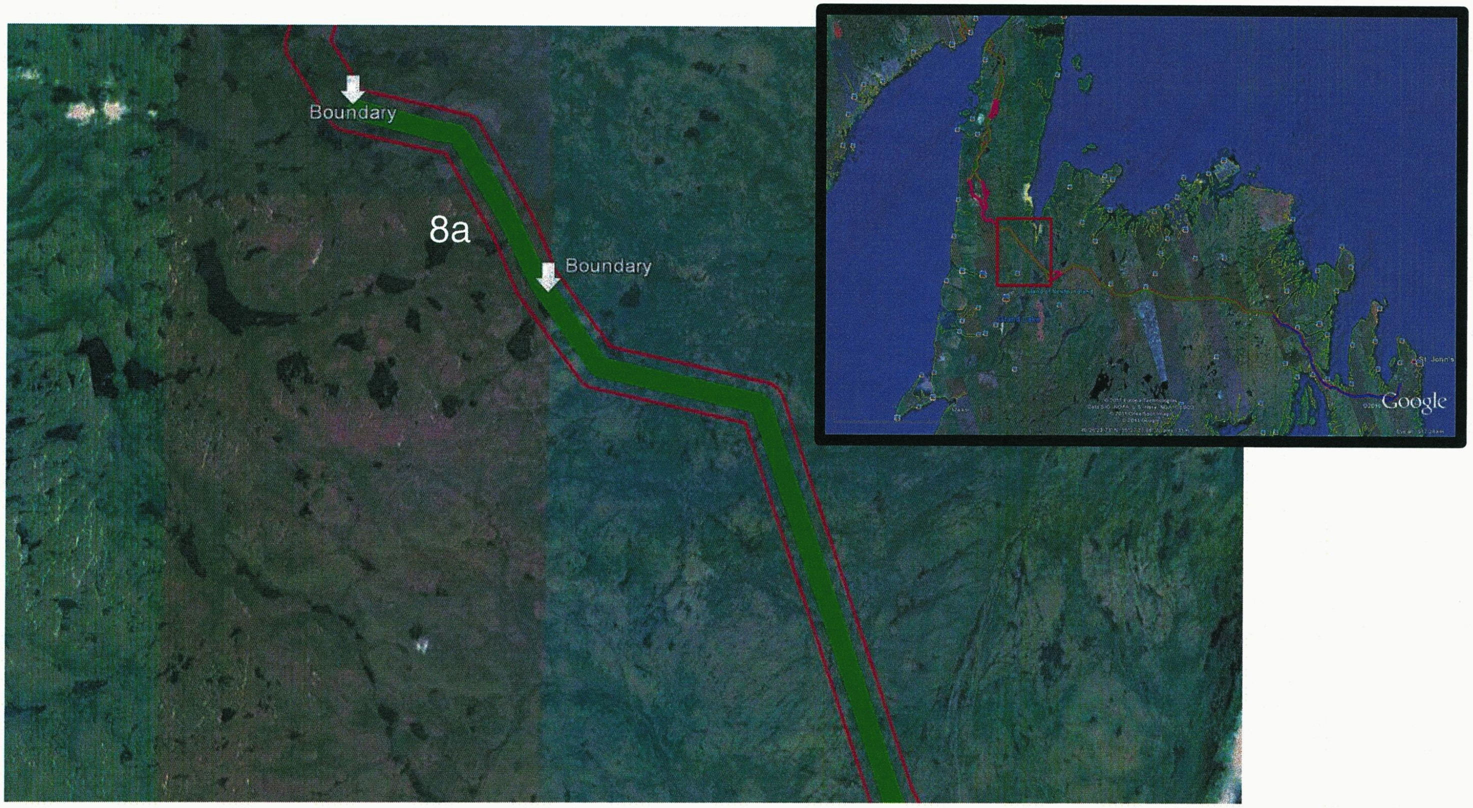
Maximum Ice: 135 mm (Rime), Maximum Wind: 180 km/h, Combined Ice and Wind: 70 mm (Rime) and 125 km/h



Zone 7c – Long Range Mountains Crossing

High Alpine Meteorological Loading Zone

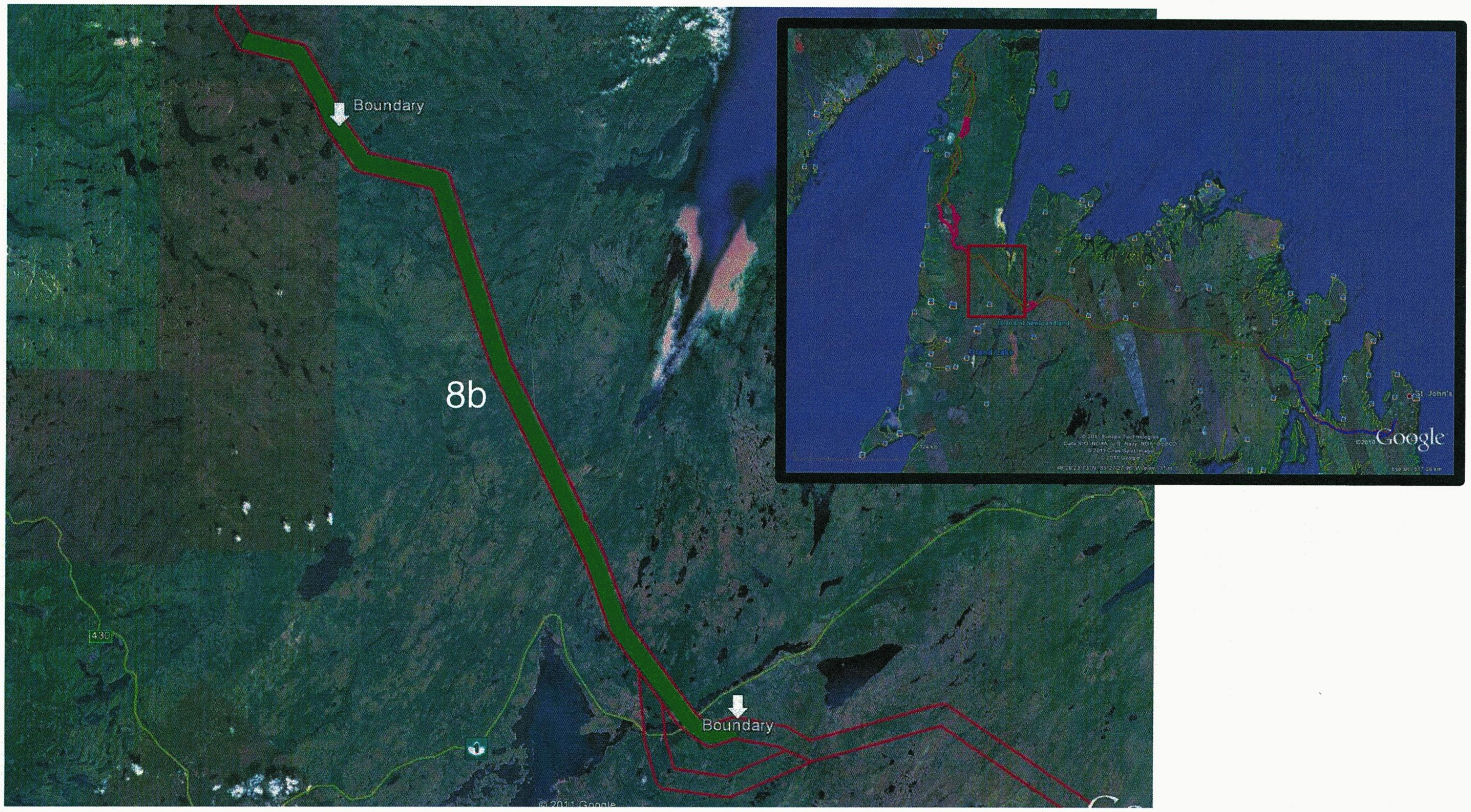
Maximum Ice: 115 mm (Rime), Maximum Wind: 180 km/h, Combined Ice and Wind: 60 mm (Rime) and 125 km/h



Zone 8a – Central-West Newfoundland

Average Meteorological Loading Zone

Maximum Ice: 50 mm (Glaze), Maximum Wind: 120 km/h, Combined Ice and Wind: 25 mm (Glaze) and 60 km/h



Zone 8b – Central-West Newfoundland

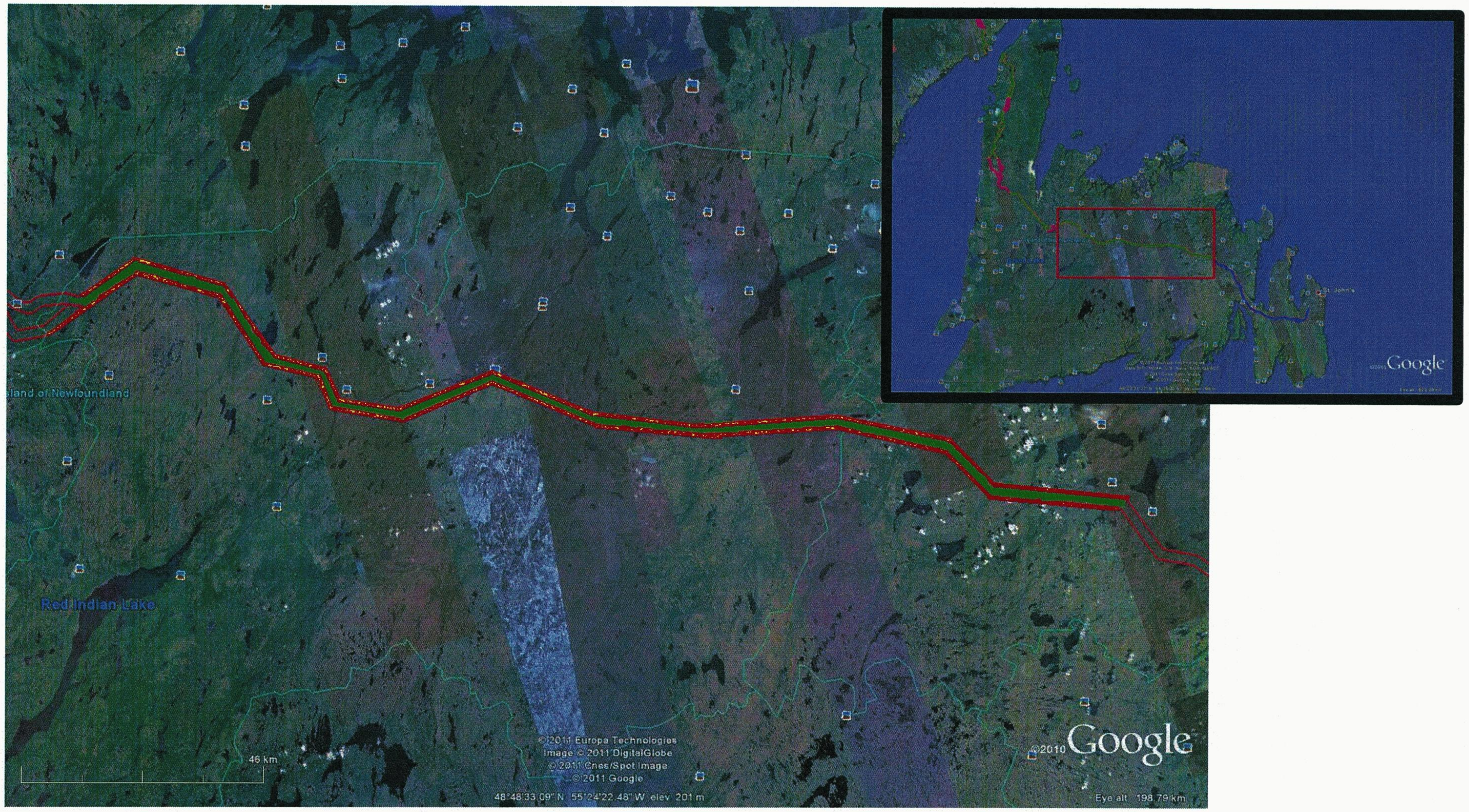
Average Meteorological Loading Zone

Maximum Ice: 50 mm (Glaze), Maximum Wind: 105 km/h, Combined Ice and Wind: 25 mm (Glaze) and 60 km/h

Zone 9 – The Birchy Narrows

Alpine Meteorological Loading Zone (Northern Corridor Alternative Only)

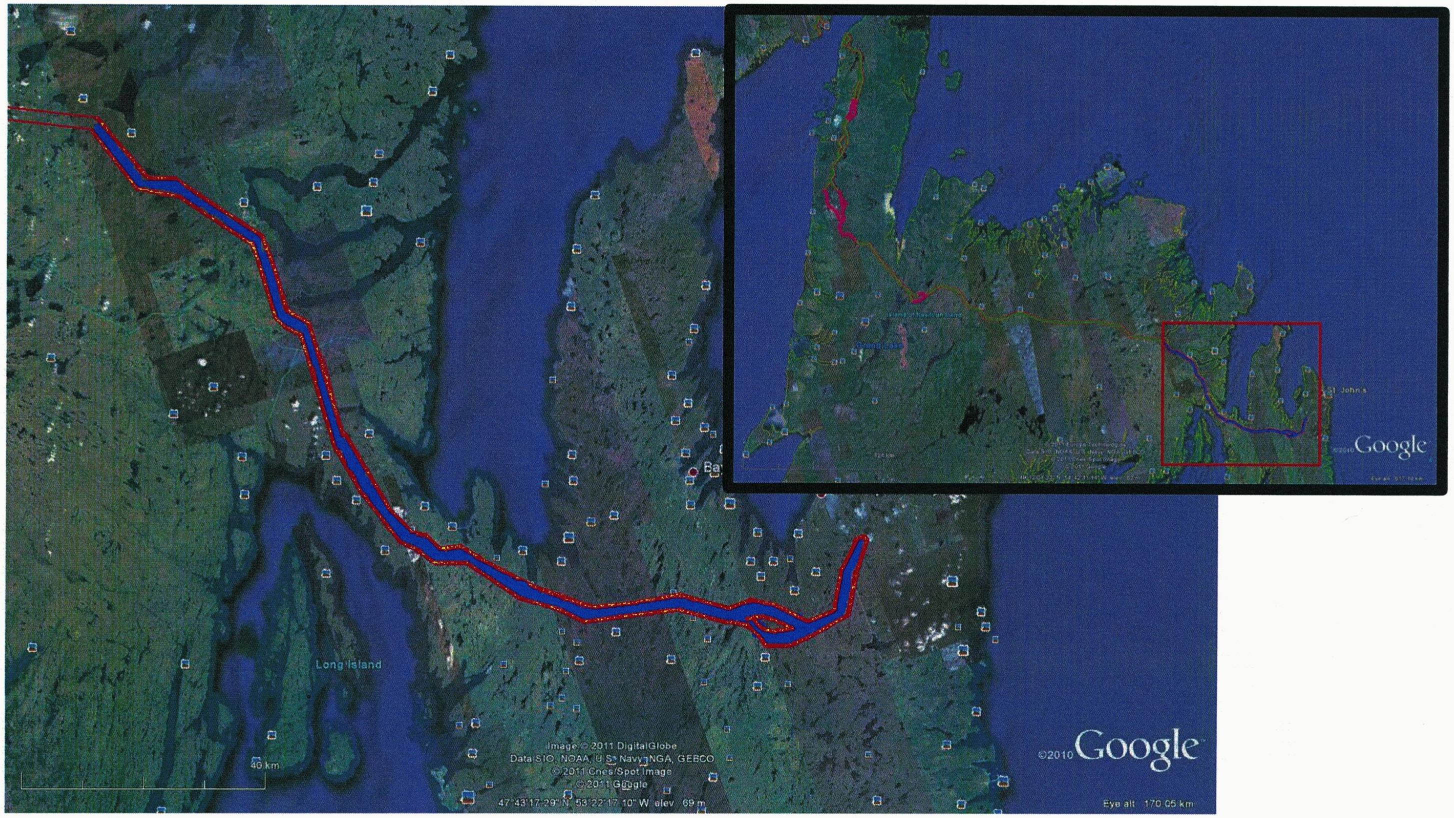
Maximum Ice: 75 mm (Glaze), Maximum Wind: 130 km/h, Combined Ice and Wind: 45 mm (Glaze) and 60 km/h



Zone 10 – Central-East Newfoundland

Average Meteorological Loading Zone

Maximum Ice: 50 mm (Glaze), Maximum Wind: 105 km/h, Combined Ice and Wind: 25 mm (Glaze) and 60 km/h



Zone 11 – Eastern Newfoundland

Eastern Meteorological Loading Zone

Maximum Ice: 75 mm (Glaze), Maximum Wind: 130 km/h, Combined Ice and Wind: 45 mm (Glaze) and 60 km/h

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HVdc Loading Combination Summary Table

Attachment B.2

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		Section Start Point		Section End Point				Combined	
Zone	Classification	Northing	Easting	Northing	Easting	Max Ice (mm)	Max Wind (km/h)	Ice (mm)	Wind (km/h)
1	Average Zone 1	5901122	649870	5775248	454182	50	105	25	60
2a	Lab High Alpine	5775248	454182	5766353	462609	115 R	135	60 R	95
2b	Lab Extreme Alpine	5766353	462609	5738927	504509	135 R	135	70 R	95
2c	Lab High Alpine	5738927	504509	5720016	504462	115 R	135	60 R	95
3	Average Zone 2	5720016	504462	5699140	502774	50	120	25	60
4	Average Zone 2	5689888	525602	5633705	514385	50	120	25	60
5	HOSJ High Alpine	5633705	514385	5618753	503365	115 R	150	60 R	105
6	Average Zone 2	5618753	503365	5558714	479391	50	120	25	60
7a	LRM High Alpine	5558714	479391	5541271	475942	115 R	180	60 R	125
7b	LRM Extreme Alpine	5541271	475942	5535907	473711	135 R	180	70 R	125
7c	LRM High Alpine	5535907	473711	5525110	471924	115 R	180	60 R	125
8a	Average Zone 2	5525110	471924	5517033	480645	50	120	25	60
8b	Average Zone 1	5517033	480645	5458903	518909	50	105	25	60
9	Alpine	5458903	518909	5457755	524473	75	130	45	60
10	Average Zone 1	5457755	524473	5360645	705553	50	105	25	60
11	Eastern Zone	5360645	705553	5253533	350617	75	130	45	60

Note:

- LRM – Long Range Mountains
- HOSJ – Highlands of St. John
- Lab – Labrador
- "R" refers to Rime Ice Conditions
- UTM Zones 20, 21 and 22

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