MUSKRAT FALLS PROJECT OVERVIEW

Stan Marshall, Nalcor CEO

Presentation to MF Public Inquiry

September 19, 2018

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AGENDA

- **Electrical System Basics**
- Churchill River System
- Muskrat Falls Project Overview
- Generation Project
- Transmission Projects
- Optimizing NL Energy Resources

ELECTRICITY TERMS

		Common Units		
Prefix	Number 1	Voltage (Volts)	Power (Watts)	Energy (Wh) (Watts x hours)
Kilo	1,000	kV	kW	kWh
Mega	1,000,000		MW	MWh
Giga	1,000,000,000		GW	GWh
Tera	1,000,000,000,000			TWh

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NL ELECTRICAL SYSTEM

- NL has a winter peaking electrical system
  - Highest or peak load is in the winter
  - The system is sized to meet the winter peak
  - In summer, less energy and capacity are required

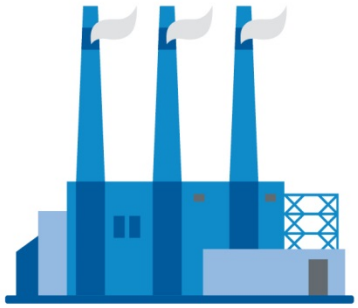
NL HYDRO'S SYSTEM

newfoundland labrador hydro
a nalcor energy company

9 HYDROELECTRIC GENERATING STATIONS

956 MW Capacity

(Bay d'Espoir **604 MW**)

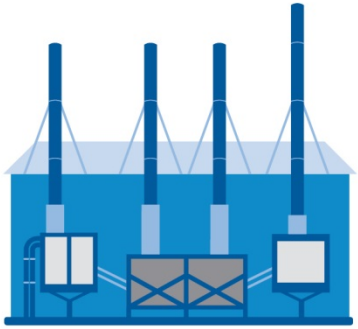


1 OIL-FIRED PLANT

490 MW Capacity

4 GAS TURBINES

251 MW Capacity



25 DIESEL GENERATING STATIONS

67 MW Capacity

54 HIGH-VOLTAGE TERMINAL STATIONS

25 LOWER-VOLTAGE INTERCONNECTED DISTRIBUTION SUBSTATIONS

MORE THAN **7,100km** OF TRANSMISSION & DISTRIBUTION LINES

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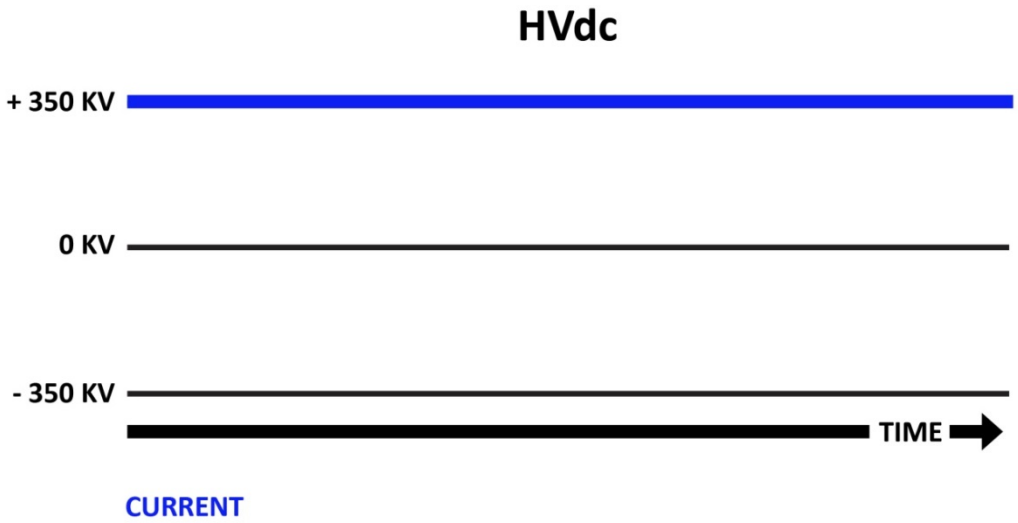
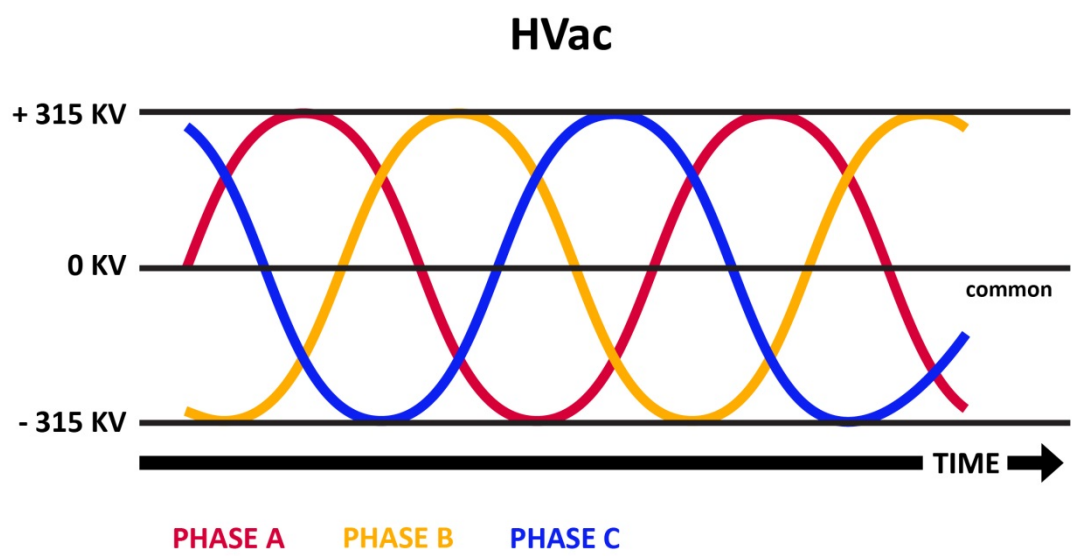
TRANSMISSION

- There are two types of transmission lines built for the Muskrat Falls Project - High Voltage alternating current (HVac) and High Voltage direct current (HVdc)
  - ***HVac*** – ac power is an electric current that periodically reverses direction. ac power is typically the form of power delivered to households and businesses
  - ***HVdc*** – dc power is an electric current that flows only in one direction. dc is used to transport power over long distances. dc power has to be converted to ac power before it can be used by homes and businesses

TRANSMISSION LINE PHASES





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- Electrical System Basics
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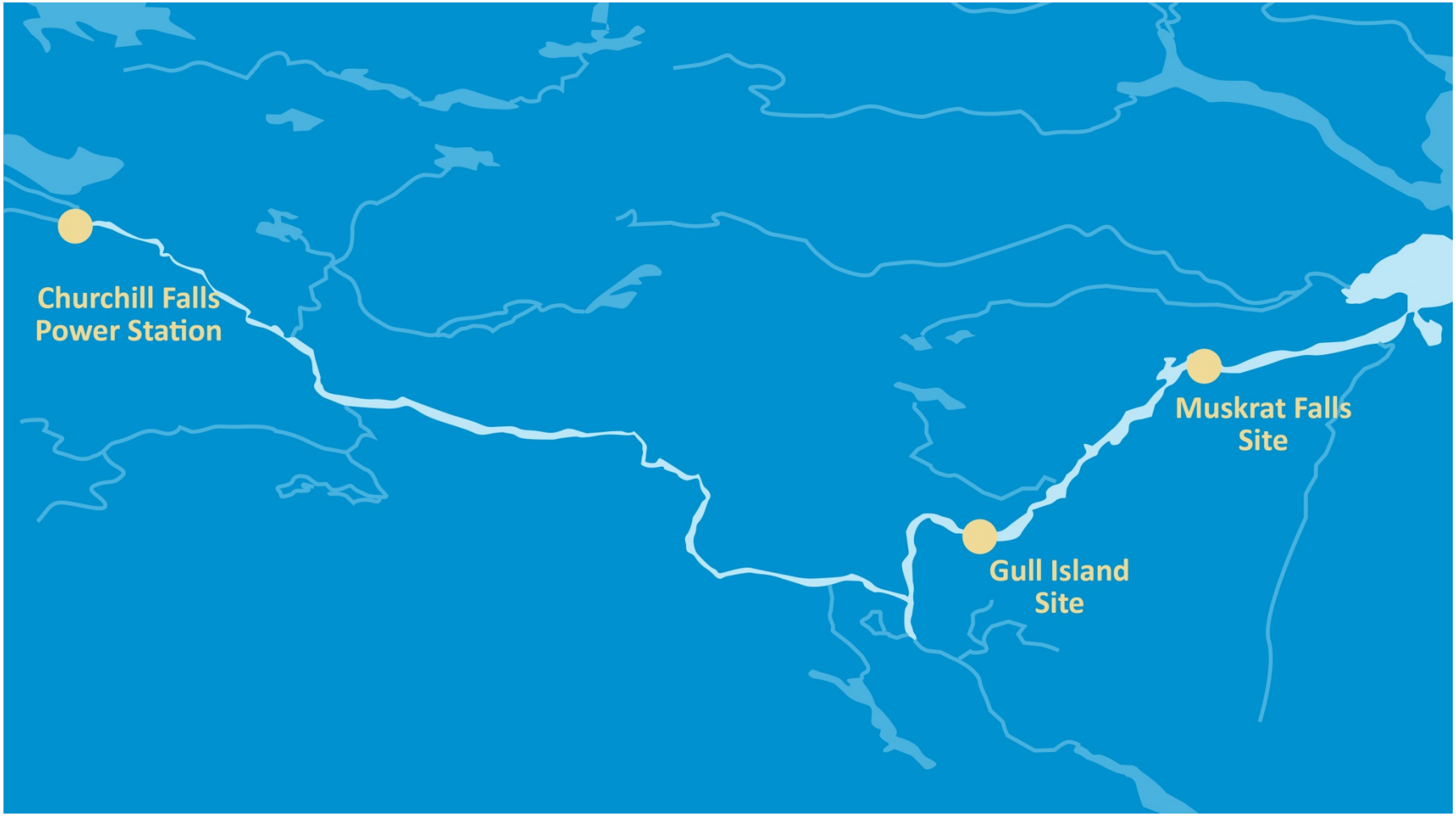
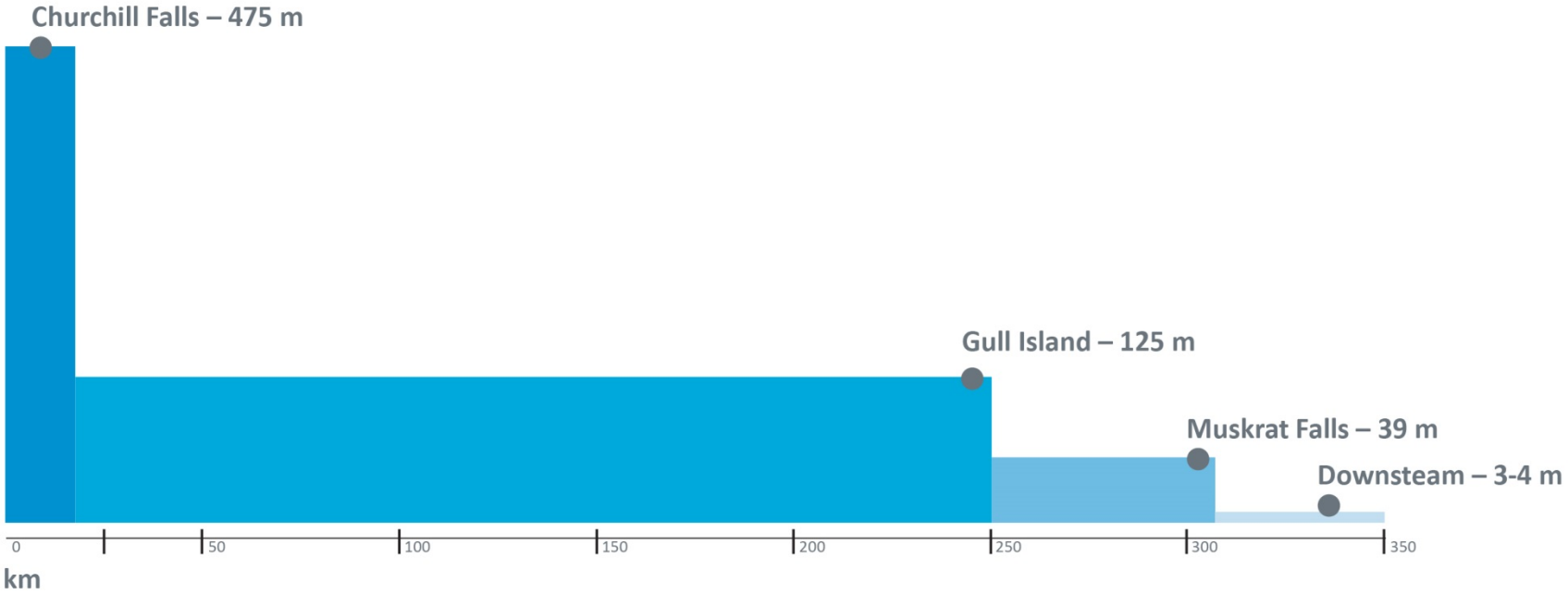
MAP OF CHURCHILL RIVER



ELEVATION LEVELS OF HYDRO FACILITIES



	CHURCHILL FALLS	GULL ISLAND	MUSKRAT FALLS
Capacity	5,428 MW	2,250 MW	824 MW
Average Annual Energy	34 TWh	11.9 TWh	4.8 TWh
Gross Head	321 M	86 M	36 M
Mean Annual Flow	1390 m^3/s	1780 m^3/s	1840 m^3/s

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- **Muskrat Falls Project Overview**
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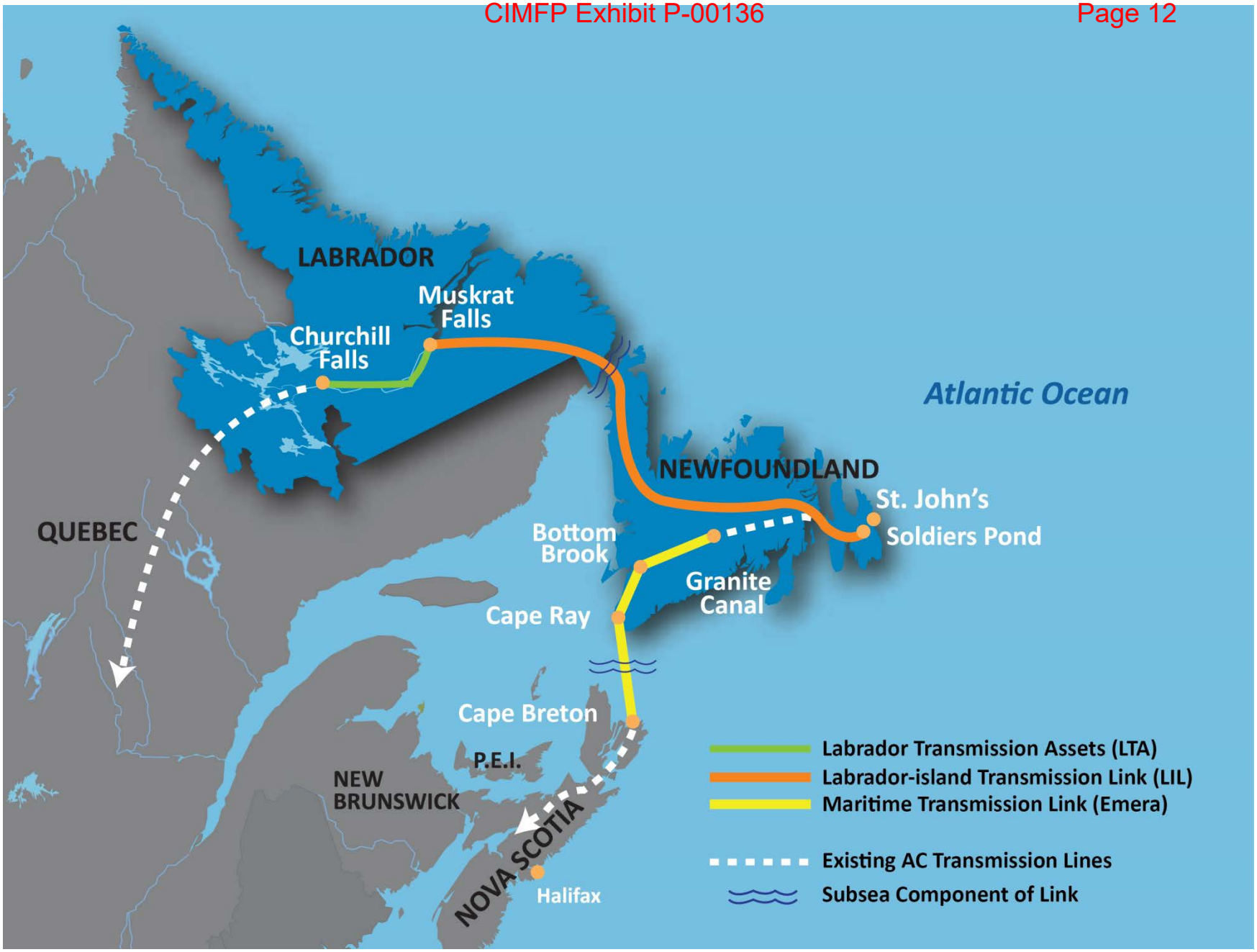
LABRADOR
Muskrat Falls
Churchill Falls
Atlantic Ocean
NEWFOUNDLAND
St. John's
Soldiers Pond
QUEBEC
Bottom Brook
Granite Canal
Cape Ray
Cape Breton
P.E.I.
NEW BRUNSWICK
NOVA SCOTIA
Halifax
Labrador Transmission Assets (LTA)
Labrador-island Transmission Link (LIL)
Maritime Transmission Link (Emera)
Existing AC Transmission Lines
Subsea Component of Link

MAIN PROJECT COMPONENTS

- 824 MW hydro development at Muskrat Falls, Labrador *(Muskrat Falls Generation)*
- Two parallel 315 kilovolt (kV) HVac transmission lines run 250 km between Muskrat Falls and Churchill Falls (*Labrador Transmission Assets)*
- 1,100 km, 350 kV 900 MW HVdc transmission line between Muskrat Falls and Soldiers Pond *(Labrador-Island Transmission Link)*

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MUSKRAT FALLS GENERATION

- 824 MW (capacity)
- 4.9 terawatt hours per year (energy)
- Major components:
  - 3 main dams
    - North Spur Dam
    - North Dam
    - South Dam
  - Powerhouse
  - Spillway

LABRADOR TRANSMISSION ASSETS (LTA)

- Two 250 km 315 kilovolt lines from Churchill Falls to Muskrat Falls
- Major components:
  - HVac transmission line
  - HVac sites at Churchill Falls and Muskrat Falls

LABRADOR-ISLAND TRANSMISSION LINK (LIL)

- 1,100 km line from Muskrat Falls to Soldiers Pond
- 30 km across the Strait of Belle Isle
- Major components:
  - HVdc transmission line
  - Converter Stations at Muskrat Falls and Soldiers Pond
  - Grounding Stations and Transition Compounds

MARITIME LINK (EMERA)

- Constructed, owned and operated by Emera for 35 years
- 500 MW capacity
- HVdc 170 km undersea link from Cape Ray, NL to Cape Breton, NS

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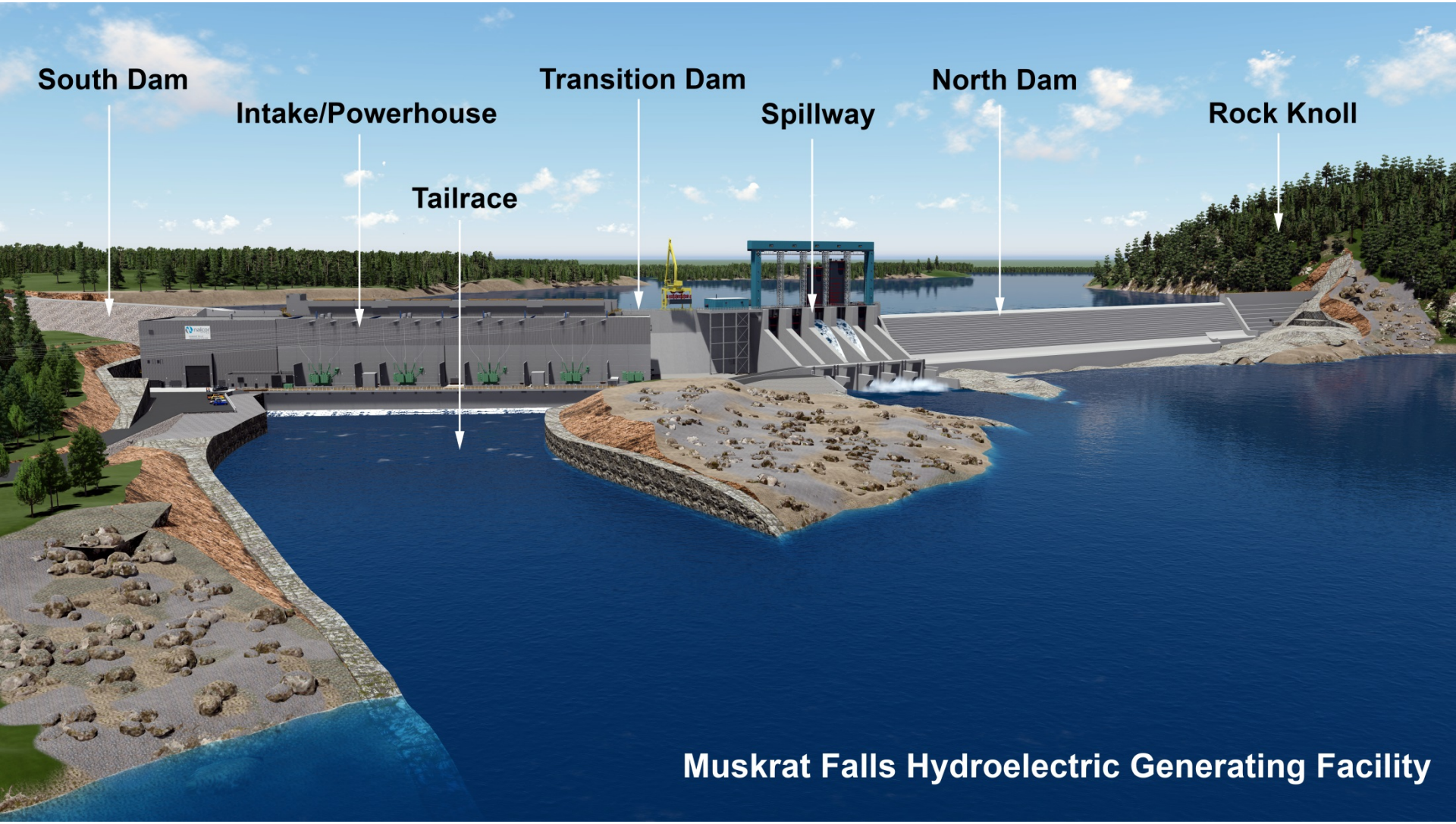
GENERATION FACILITY LAYOUT



MUSKRAT FALLS SITE – AUGUST 2013

VIDEO #1 MUSKRAT FALLS SITE 2013 SITE VIDEO

MUSKRAT FALLS SITE – AUGUST 2018

VIDEO #2 MUSKRAT FALLS FULL SITE VIDEO

BULK EXCAVATION

– IKC-ONE Earthwork Constructors

SPILLWAY

- Primary function is to pass water that isn't used to generate electricity
- 5 bays with gates that open and close as needed to control the release of water from the reservoir
- 40 m tall and 75 m wide
- Fully operational August 2016
- Main Contractors:
  - Astaldi (civil works)
  - Andritz Hydro (supply & install hydro-mechanical equipment)

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2014


2015


2016

SPILLWAY CONSTRUCTION

- 2018 – began installation of concrete rollways for the 5 Spillway openings
- Required for Spillway operation once reservoir is impounded to elevation 39 m
- Main Contractor:
  - Astaldi (civil works)

2016

August 2018 Rollway Installation

- Rock dam used to divert the river through the Spillway so the North Dam could be built
- Completed fall 2016
- Main Contractor:
  - Barnard Pennecon JV

TRANSITION DAMS

– Astaldi

SOUTH DAM

- Conventional rock-fill till-core dam that closes the south part of the reservoir between the south bank and Powerhouse
- 250 m long with 46.3 m elevation
- Road at the top of the dam provides access to Intake and Spillway facilities
- Completed fall 2017
- Main Contractor:
  - Barnard Pennecon JV

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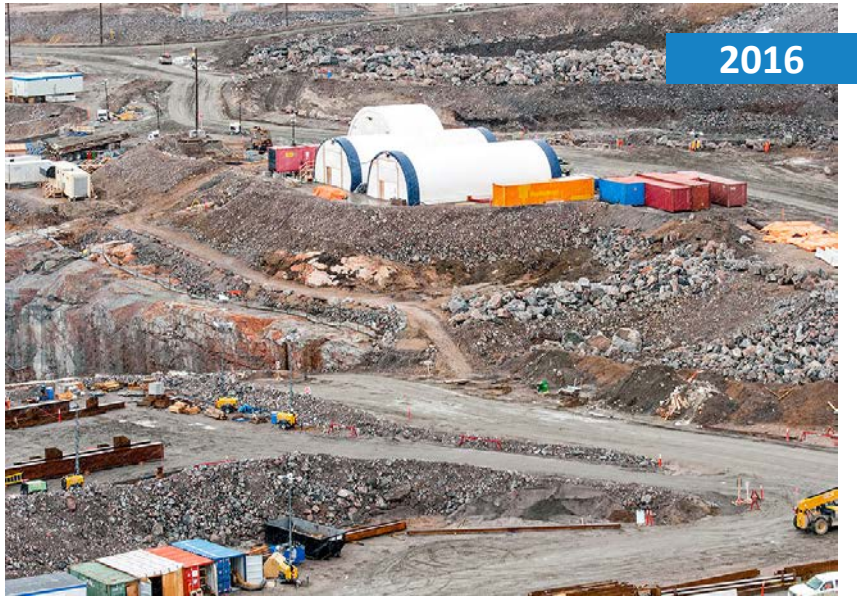
2016


2017


2017

NORTH DAM

- Final major civil component required for the creation of the Muskrat Falls reservoir
- Spans the river from the Spillway to the North Spur
- ~400 m long; elevation ~39 m
- 250,000 m^3 of concrete will be used in the dam's construction
- Work started 2017 - substantial completion expected at end of 2018
- Main Contractor:
  - Barnard Pennecon JV

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2017


2017


2018

VIDEO #3 NORTH DAM TIME LAPSE VIDEO

NORTH SPUR DAM

- Construction started in 2015 and was completed in August 2017
- Main Contractor: Gilbert NL Contracting Ltd.

NORTH SPUR DAM CONSTRUCTION

UPSTREAM

- Regraded slopes
- Installed cement-bentonite cut-off walls
- Built protective rock berms along the shoreline

DOWNSTREAM

- Regraded slopes
- Built protective rock berms along the shoreline
- Installed drainage and relief wells
- Installed monitoring equipment

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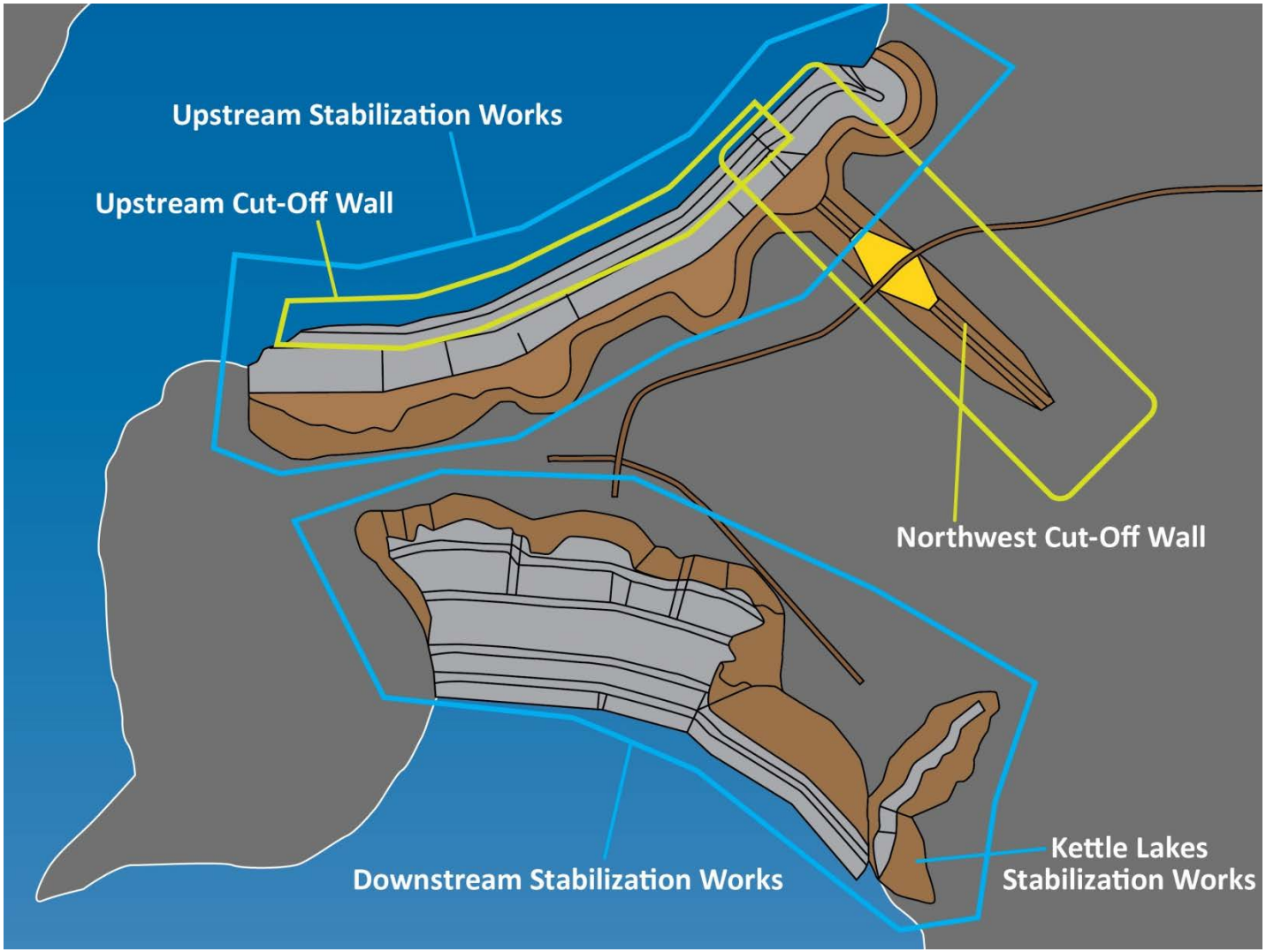
Upstream Stabilization Works
Upstream Cut-Off Wall
Northwest Cut-Off Wall
Downstream Stabilization Works
Kettle Lakes
Stabilization Works

2014

2015

Upstream Completed

Downstream Completed

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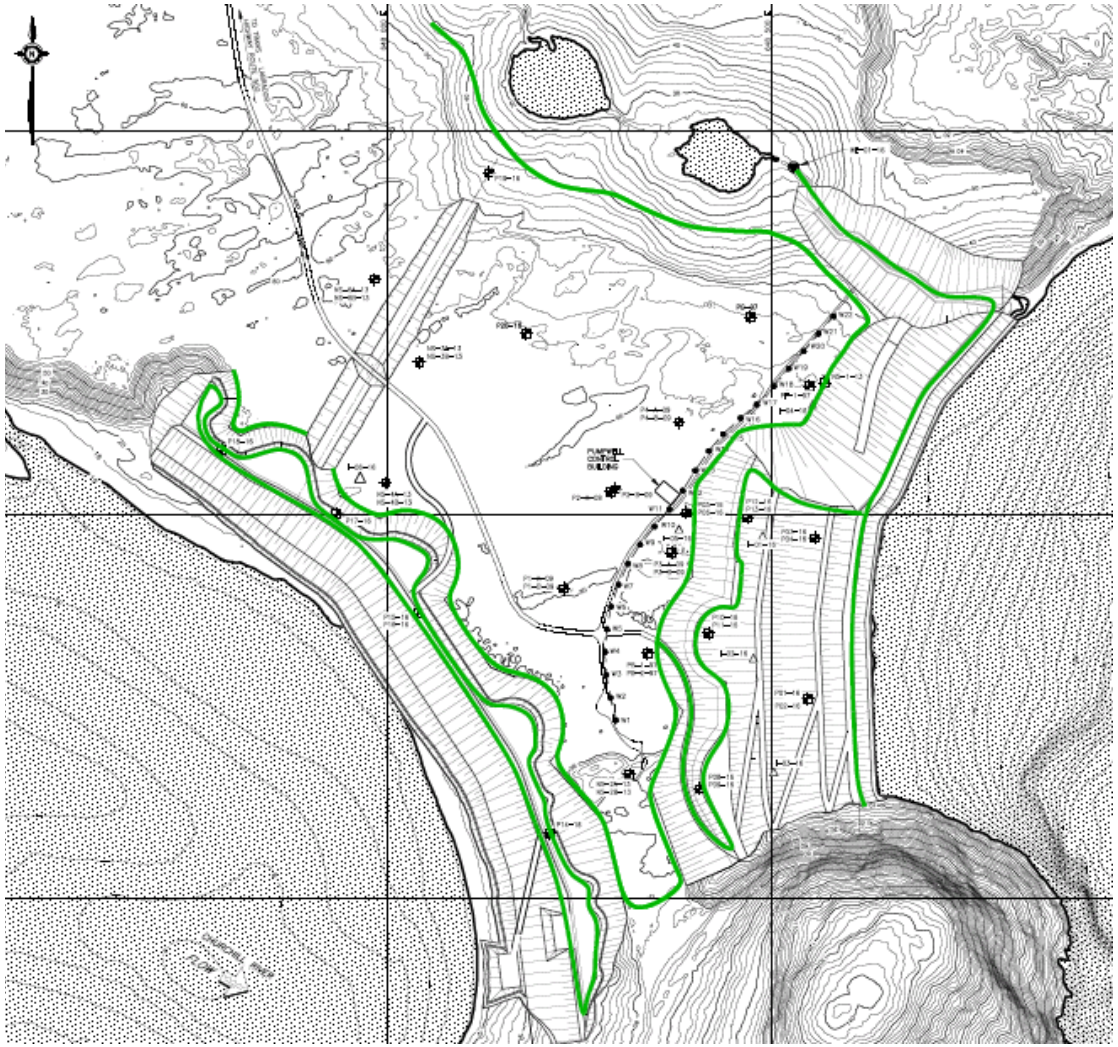
VIDEO #4 NORTH SPUR VIDEO



- Ongoing monitoring of the North Spur dam
- 40 Piezometers
  - 7 upstream
  - 6 northwest cut-off wall
  - 24 downstream
- 6 inclinometers
  - 5 downstream
  - 1 upstream
- 1 flow meter
  - Kettle lake outlet

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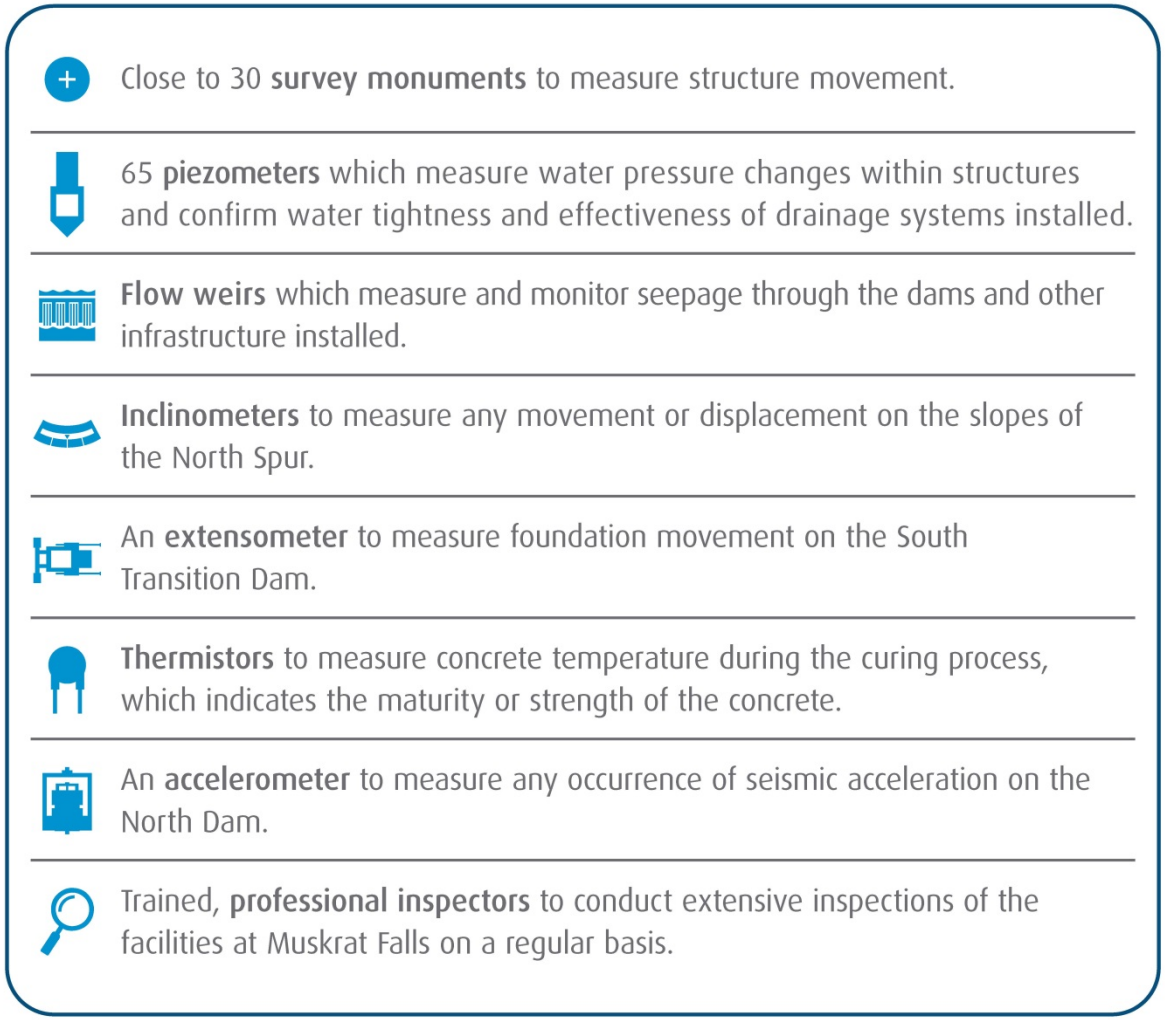
DAM SAFETY FOR MUSKRAT FALLS



- Monitoring for:
  - Structure movement
  - Water pressure
  - Water flow & seepage
  - Slope, foundation & joint movement
  - Temperature
  - Seismic acceleration

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DEBRIS/ICE/SAFETY BOOM

- Serves 3 purposes:
  - prevents an ice dam from forming downstream
  - catches debris (logs) upstream of the facility
  - provides visual warning and promotes self rescue to river users on approach to the facilities
- Installed fall 2017
- Main Contractor:
  - Johnson's Construction (installation)

ACCOMMODATIONS COMPLEX

- Liannu Ltd Partnership (supply/install)
- Labrador Catering (operations)

- Houses the four generating units
- Includes North and South service bays for equipment assembly and maintenance
- Includes overhead cranes for construction and maintenance of generating units
- 84 m tall and 78 m wide
- Structure substantially completed November 2017
- Main Contractor:
  - Astaldi

INTAKE (Upstream)

- Draws water from the river into the Powerhouse
- 4 intakes, each with 3 bays
- 56 m tall and 143 m wide
- Structure substantially completed November 2017
- Main Contractors:
  - Astaldi
  - Andritz Hydro

TAILRACE (Downstream)

- Water exits from the Powerhouse
- 4 outlets, each with 2 bays
- Structure substantially completed November 2017
- Main Contractors:
  - Astaldi
  - Andritz Hydro

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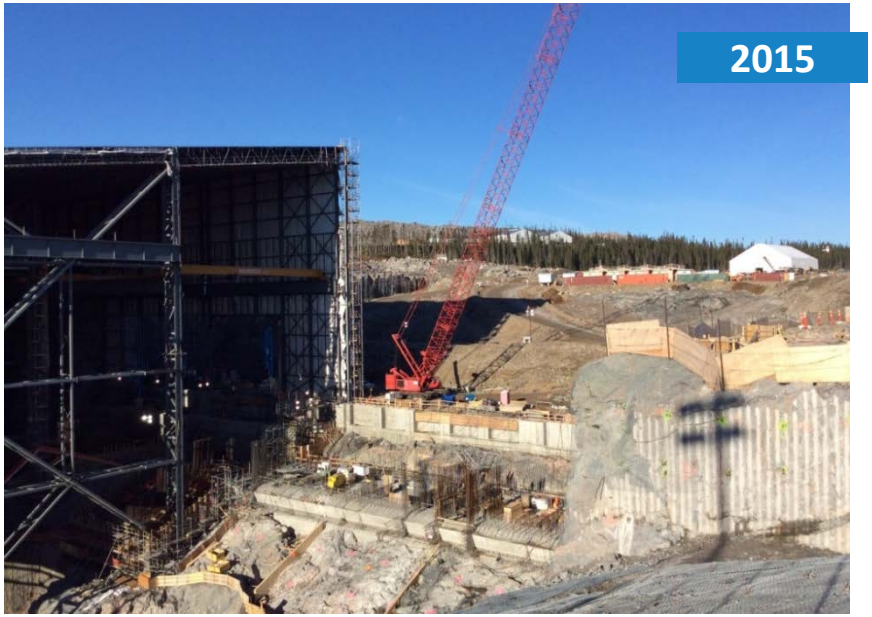
2013


2014


2015

2016

2017

2018


2013
2013/11/02


2014


2015

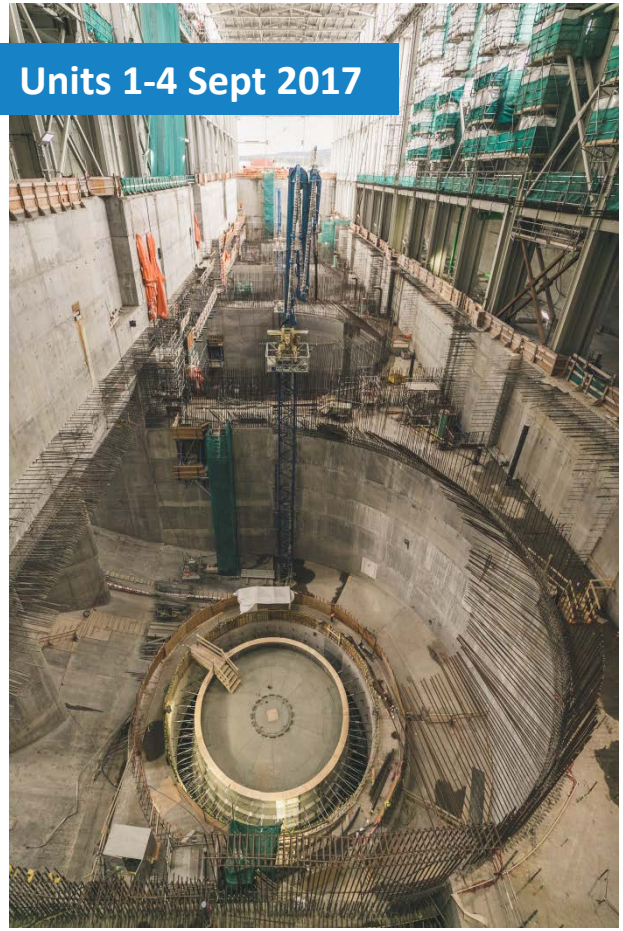

2016

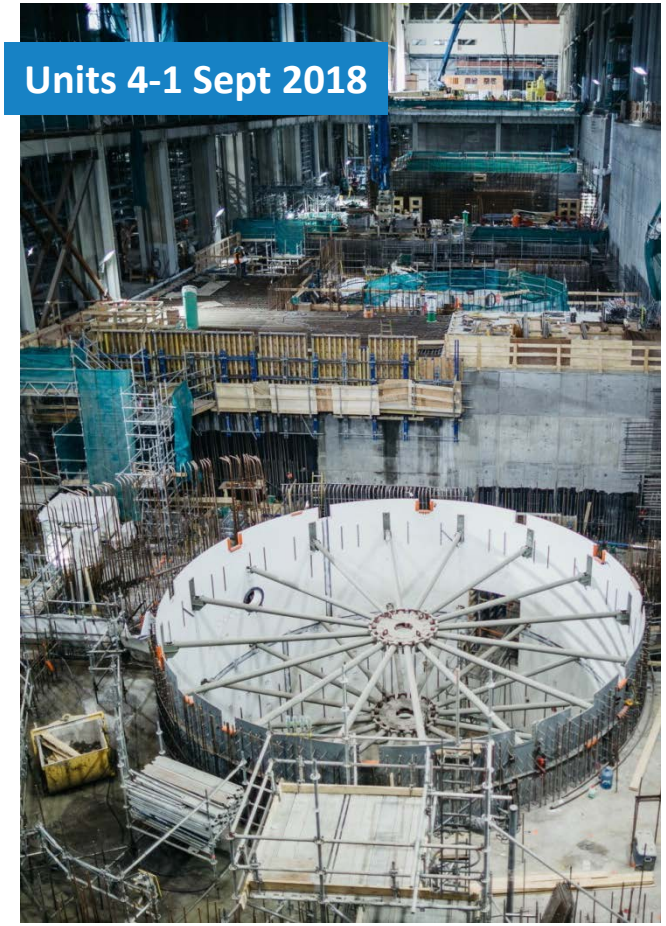

2017


2018

VIDEO #5 MUSKRAT FALLS GENERATION FACILITY VIDEO

INSIDE THE POWERHOUSE





- Main Contractors:
  - Astaldi (civil works)
  - Andritz Hydro (turbine and generators/hydro mechanical)
  - Cahill-Ganotec JV (mechanical & electrical auxiliaries)
  - Groupe LAR Inc. (powerhouse cranes)

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VIDEO #6 POWERHOUSE TIME LAPSE VIDEO

UPCOMING WORK – 2018 TO 2020

- Completion of North Dam – 2018
- Continuation of installation of turbine and generators – 2018-2020
- Continuation of Balance of Plant work – 2018-2020
- Completion of Intake and Tailrace gates – 2019
- Impoundment to ~39 m – 2019
- Completion of rollways in Spillway – 2019
- First power – Q4 2019; Full power Q3 2020

OVERVIEW OF COMMISSIONING SCHEDULE

- End of 2019:
  - Unit #1 first power followed by (power flowing to grid)
- 2020:
  - Unit #2 commissioned and ready for operation
  - Unit #3* commissioned and ready for operation
  - Unit #4 commissioned and ready for operation
  - Full power from MF – planned for August 2020
  - Commissioning completed – September 2020

**Muskrat Falls power due to Emera under commercial agreements*

VIDEO #7 POWER GENERATION ANIMATION VIDEO

AGENDA

- Electrical System Basics
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- **Transmission Projects**
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TRANSMISSION PROJECT COMPONENTS

- Labrador Transmission Assets (HVac)
  - two 250 km, 315 kV transmission lines between Muskrat Falls and Churchill Falls
  - AC switchyards and AC equipment at Churchill and Muskrat Falls
- Labrador-Island Transmission Link (HVdc)
  - 1,100 km, 900 MW line between Muskrat Falls and Soldiers Pond
  - Converter station at Muskrat Falls and Soldiers Pond; switchyard and synchronous condenser at Soldiers Pond
  - Strait of Belle Isle Marine Crossing
  - Transition compounds at Forteau Point and Shoal Cove
  - Grounding stations at L'Anse au Diable and Dowden's Point

LABRADOR TRANSMISSION ASSET

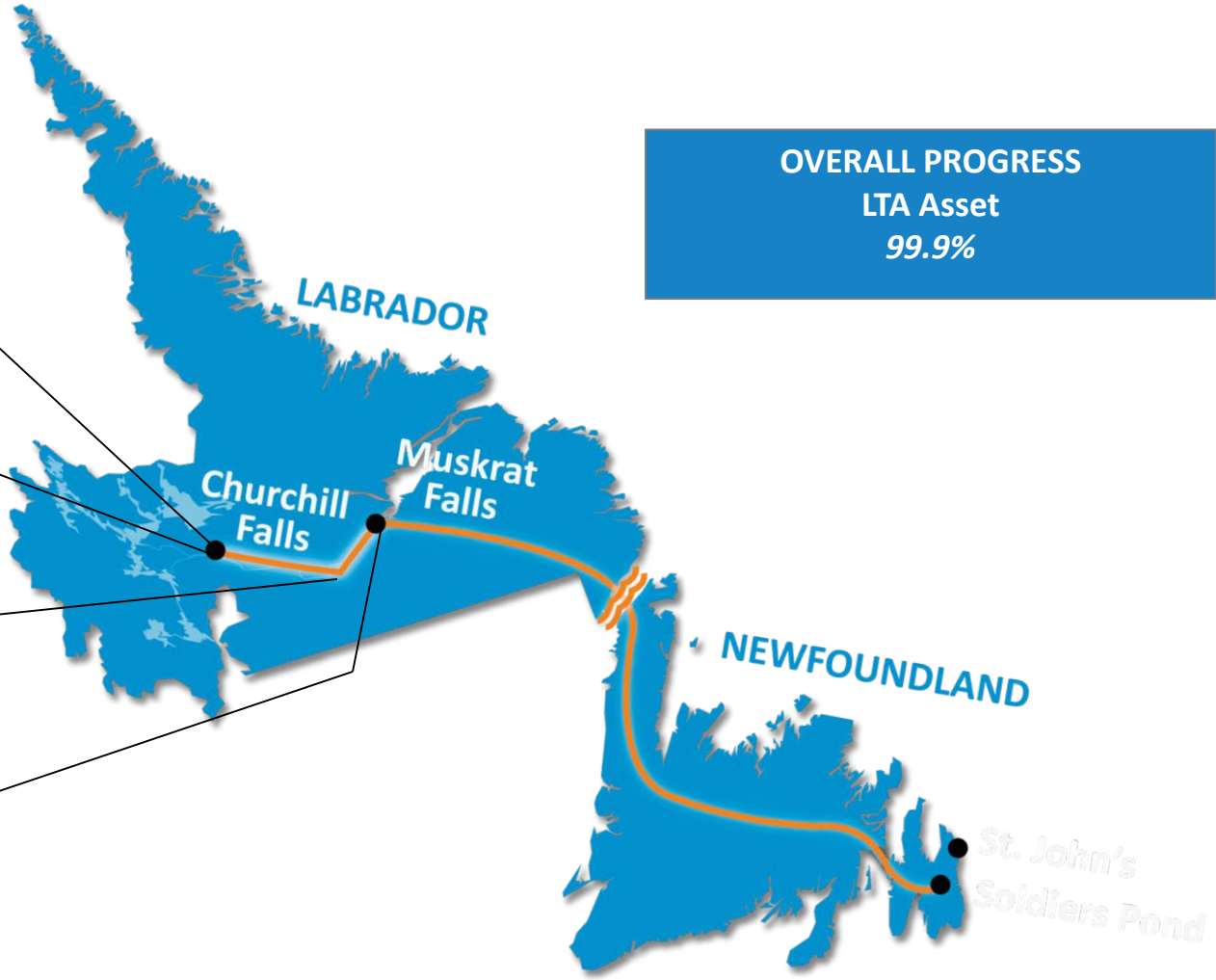
Progress Map – LTA (August 2018)

735-315 kV HVac Substation
Churchill Falls
Complete

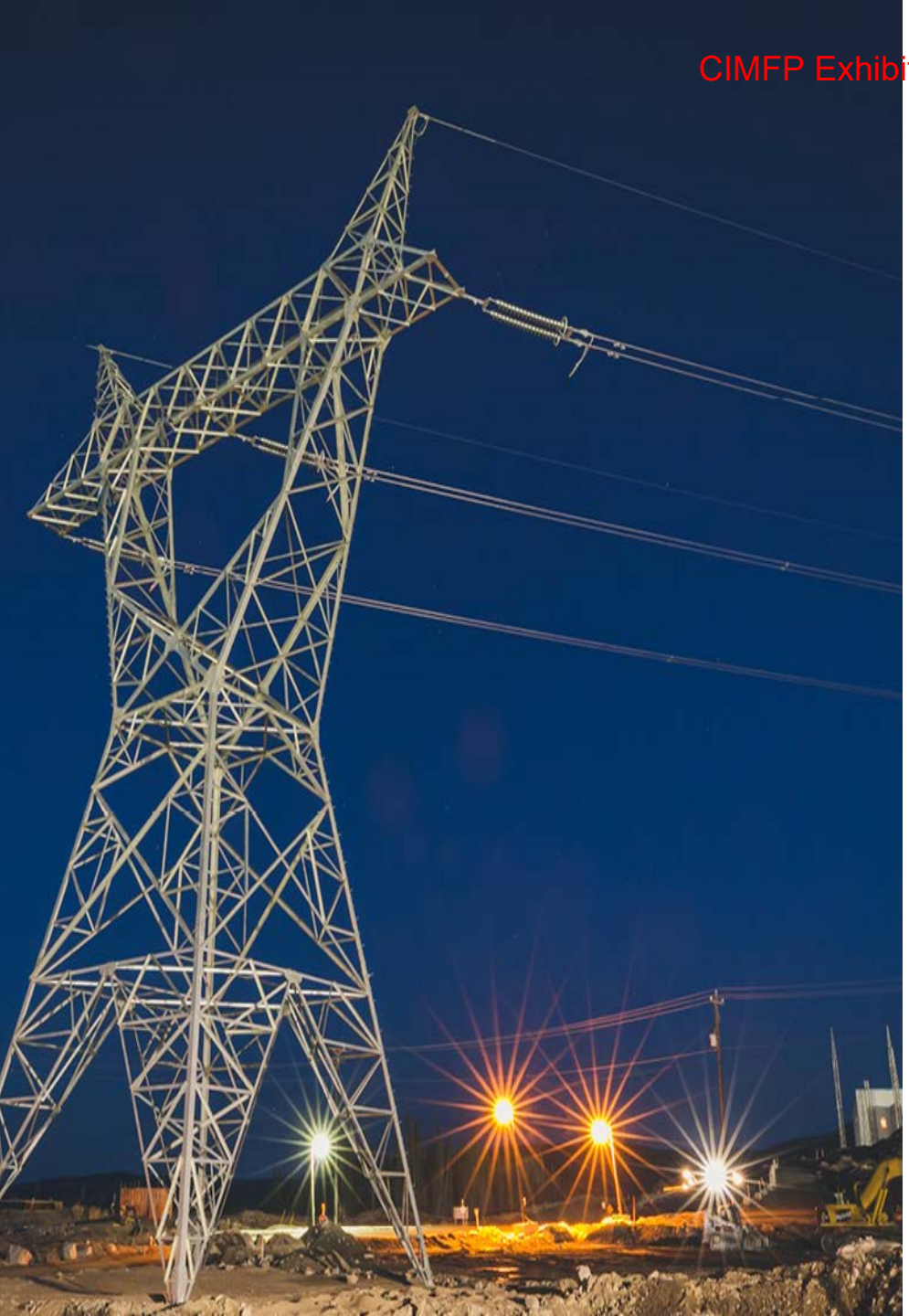
735 kV HVac Lines
Churchill Falls Extension
Complete

315 kV HVac Lines
Muskrat Falls to Churchill Falls
Complete

315 kV HVac Substation
Muskrat Falls
99.9%



OVERALL PROGRESS
LTA Asset
99.9%



LTA TRANSMISSION PROJECT

- Transmits power between Churchill Falls and Muskrat Falls
- Construction started 2013; completed 2017
- Energized April 2018
- Main Contractors:
  - Johnson's Construction (clearing)
  - Valard (line construction)
  - SA-RA Energy (tower steel)
  - Fabrimet (foundations)
  - Midal Cables (conductor)
  - Seves Canada (insulators)

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ROW CLEARING/ACCESS CONSTRUCTION

TRANSMISSION TOWER CONSTRUCTION

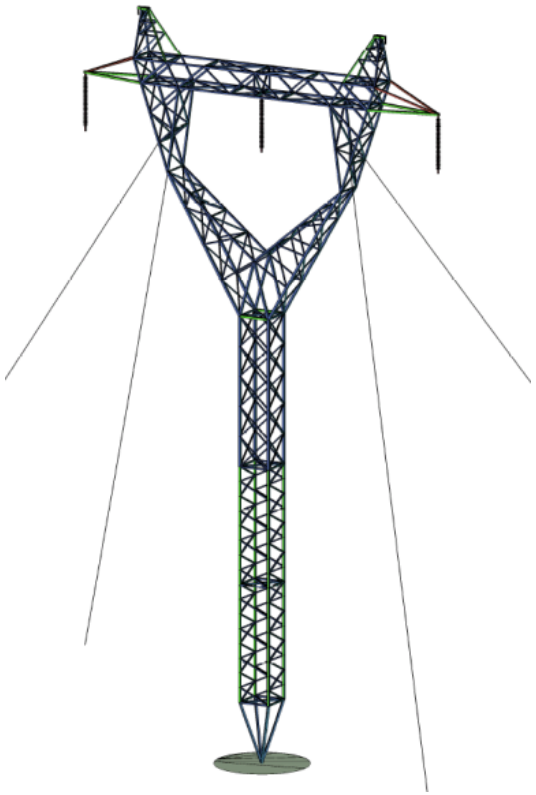
FOUNDATION INSTALLATION

- Grillage foundations consist of steel members buried in the ground and connected to the tower legs to support the tower structure

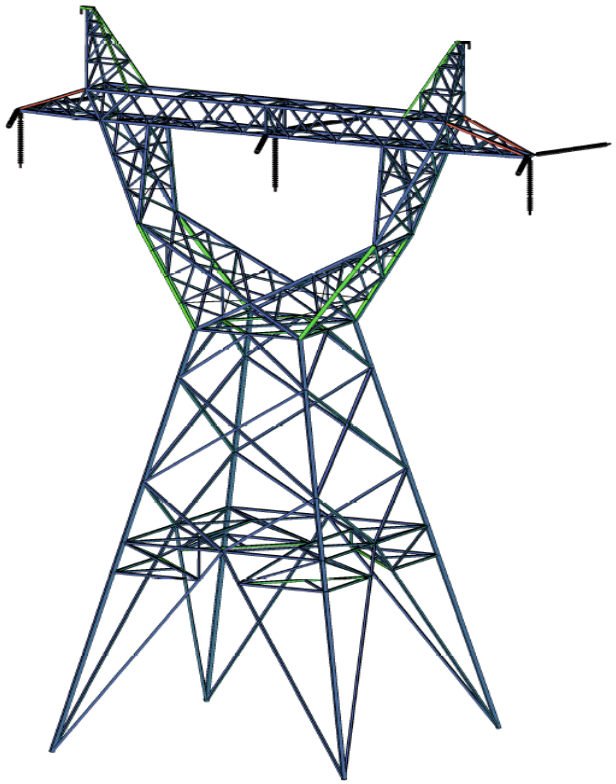
TOWER ASSEMBLY & INSTALLATION

- 1,262 towers assembled and installed

TYPES OF TRANSMISSION TOWERS



Tangent (Suspension) Towers - used for straight away or in-line section of the line where there is no turn in the line. Typically guyed with a single mast for support.



Self-supported (Dead-end) towers - used on line angle turns. Typically four legs with no guys.

TRANSMISSION TOWER ERECTION/STRINGING

VIDEO #8 TRANSMISSION LINE VIDEO

CHURCHILL FALLS SWITCHYARDS

CHURCHILL FALLS (NEW SWITCHYARD)

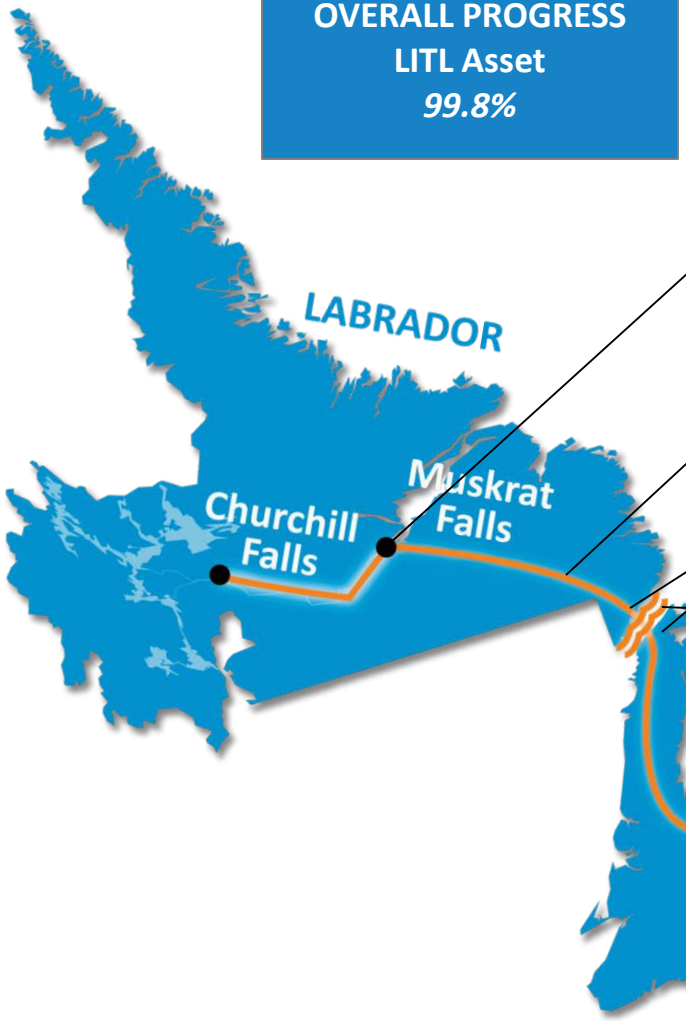
- HVac transmission lines connect to the ac switchyard at MF which interconnects with the MF generating facility and LIL
- Main Contractors: GE Grid

Note: Photo taken Oct 2017

TRANSMISSION LINK

LIL & HVdc Specialties (August 2018)

OVERALL PROGRESS
LITL Asset
99.8%



350kV HVdc Converter Station
Muskrat Falls
98.4%

350kV HVdc Transmission Line
Muskrat Falls to Soldiers Pond
Complete

350kV Transition Compounds

Forteau Point	Shoal Cove
Complete	***Complete***

Shoreline Grounding Sites

L'Anse Au Diable	Dowden's Pt.
Complete	***Complete***

Soldiers Pond Facility

230 kV HVac Switchyard	350kV HVdc Converter Station
Complete	***99%***

- First dc line built in NL
- Construction started 2013; completed November 2017
- Energized spring 2018
- 3,215 towers installed –1,933 (island) & 1,282 (Labrador)
- ~ 4,000 km of wire installed (2,250 km of transmission wire; 1,750 km of optical ground and electrode wire)
- Main Contractors:
  - Valard (line construction)
  - Jyoti Americas (tower steel)
  - Locweld (foundations)
  - General Cable & Midal Cables (conductor)
  - Seves Canada (insulators)

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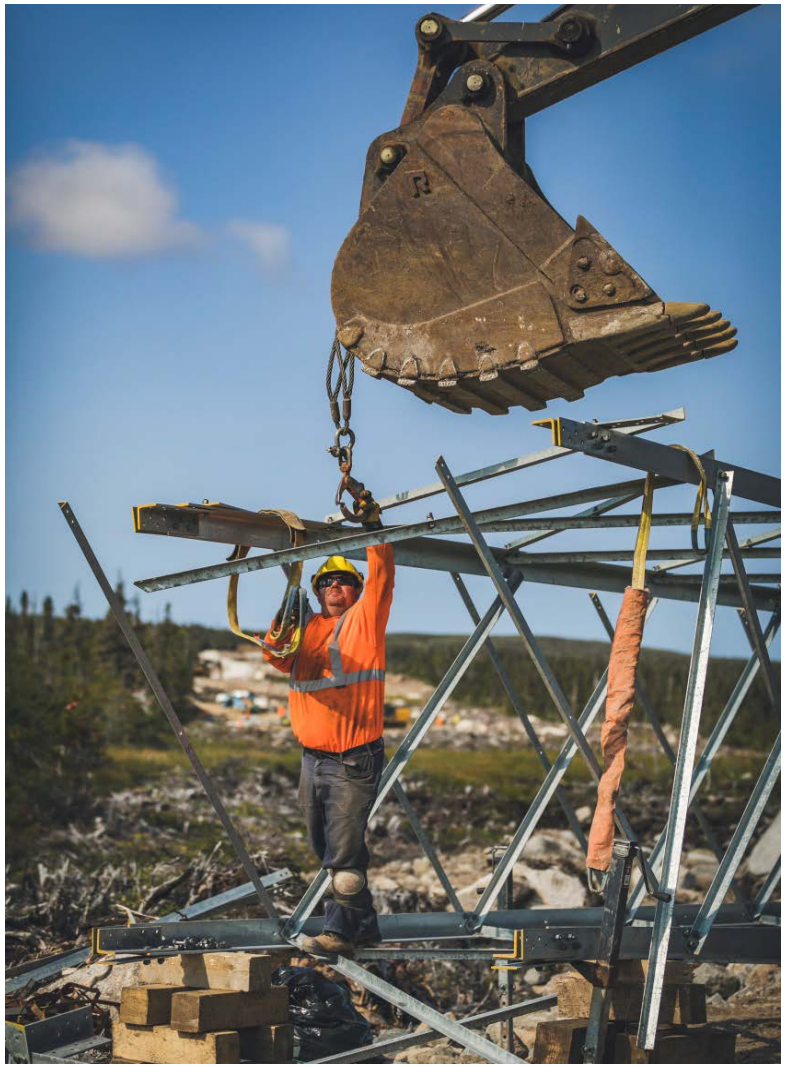
ROW CLEARING/ACCESS CONSTRUCTION

- Johnson's Construction
- C&T Enterprises
- Springdale Forest Resources
- Mike Kelly & Sons

TRANSMISSION TOWER CONSTRUCTION



VIDEO #9 TRANSMISSION TOWER INSTALLATION

TRANSMISSION LINE STRINGING

VIDEO #10 TRANSMISSION LINE VIDEO

LIL - HVdc SPECIALITIES

- Muskrat Falls:
  - Converter building
  - HVdc switchyard
- Soldiers Pond:
  - Converter building
  - HVdc switchyard
  - Synchronous condenser
- Transition compounds at Forteau Point & Shoal Cove
- Grounding Stations at L'Anse au Diable & Dowden's Point

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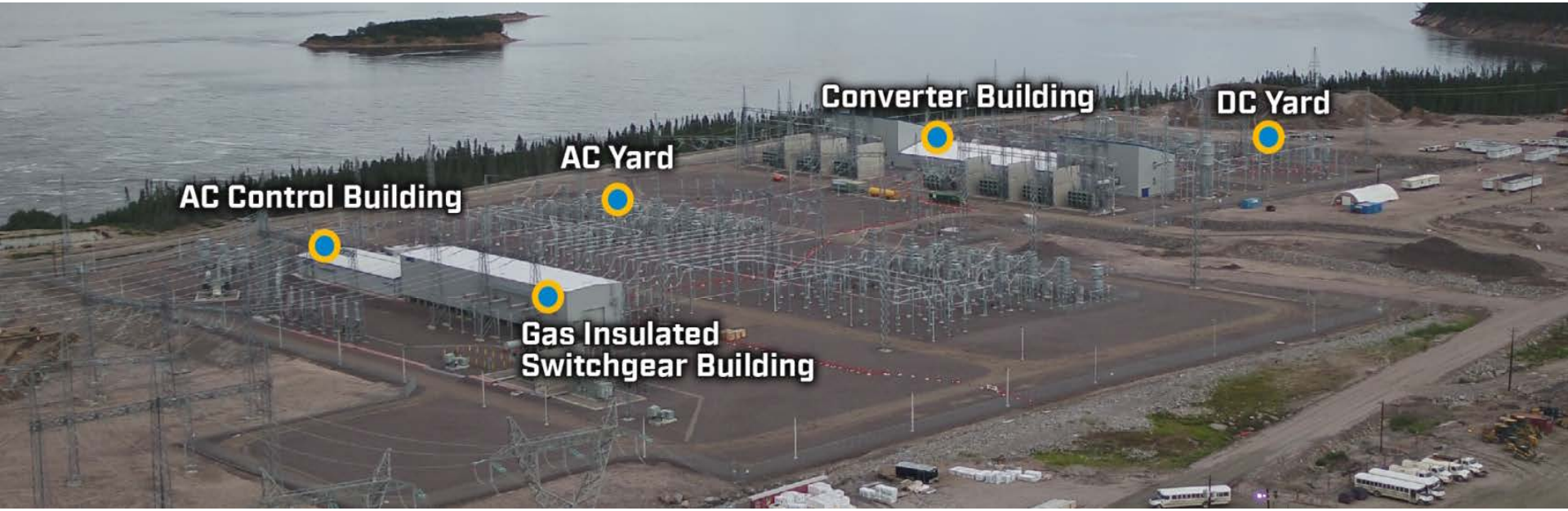
HVdc - MUSKRAT FALLS



- ac power from CF and MF facilities is converted to dc power at the MF Converter Station
- MF and SP sites are essentially mirror sites, except:
  - MF ac switchyard is housed in a Gas Insulated Switchgear building, and
  - SP has Synchronous Condensers to provide inertia and voltage support for the island system
- Main Contractors:
  - GE Grid

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HVdc – MUSKRAT FALLS

Transformers

- Transformers provide the electrical connections necessary between the ac and dc systems, and ensure voltage is at the level needed for transmission
- 7 transformers at MF site

Converter Building/Valve Hall

- ac power passes through the valves and is converted to dc power for delivery across LIL

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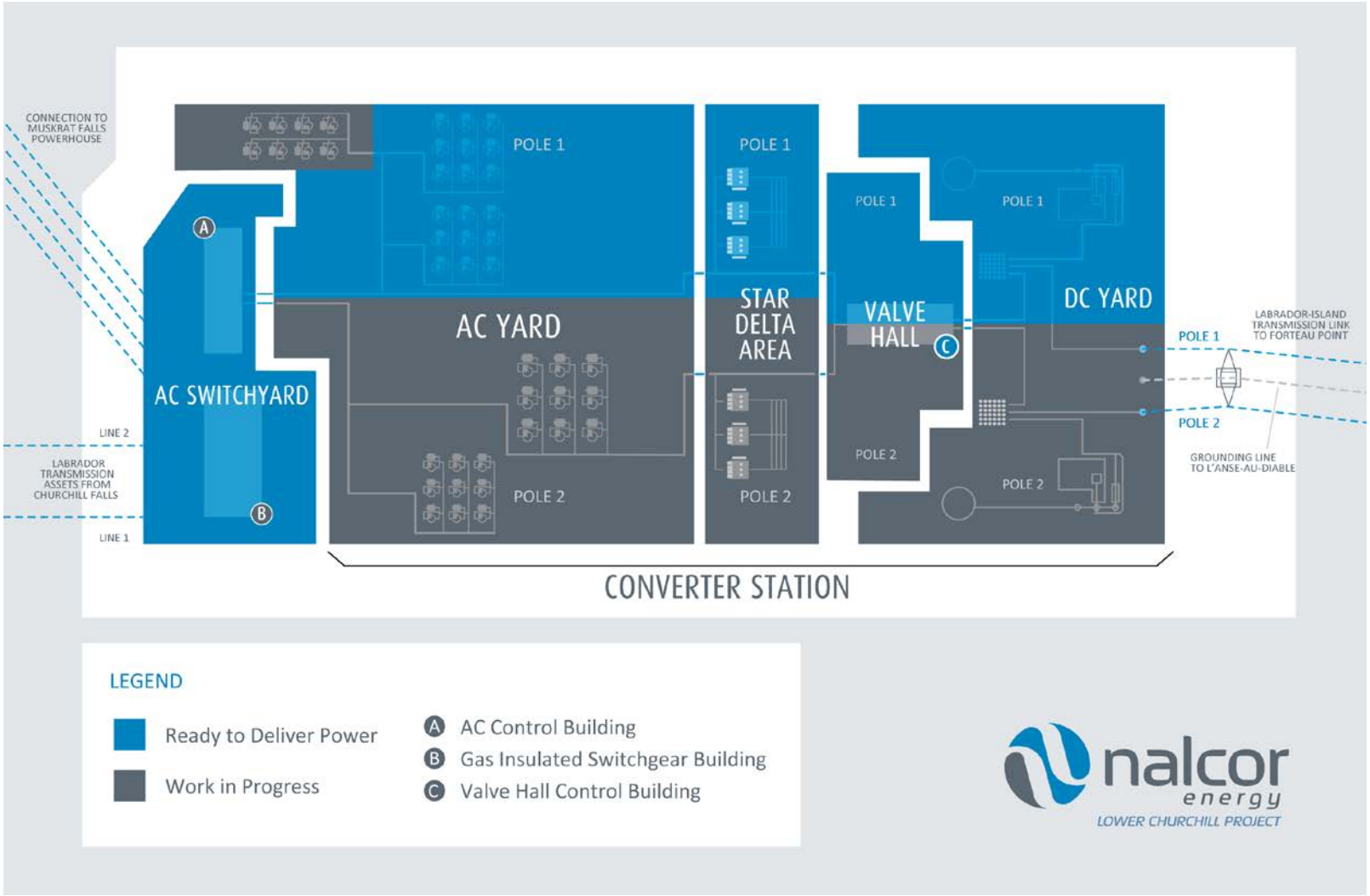
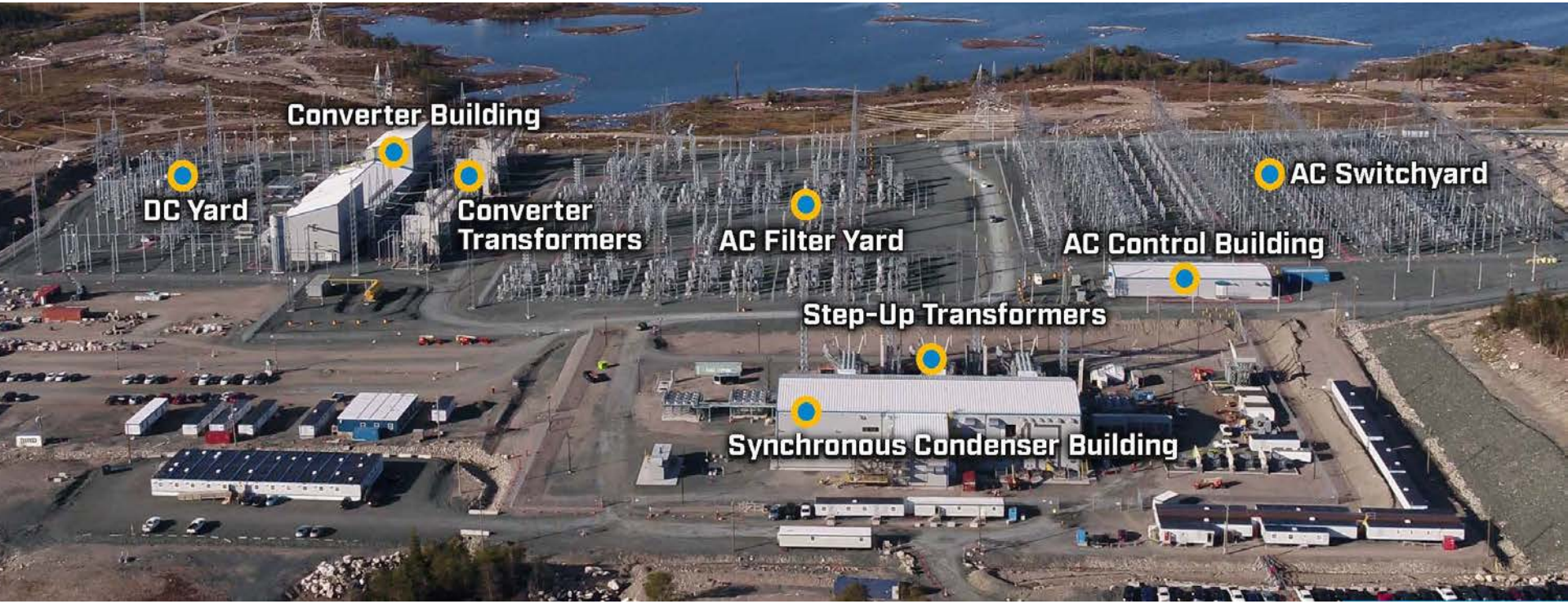
MUSKRAT FALLS TRANSMISSION ENERGIZATION



HVdc – SOLDIERS POND



- dc power is received here and converted back to ac power to deliver to customers
- Site preparation began April 2014
- Site is 50 acres in size
- Main Contractors: GE Power, Bird Heavy Civil (earthworks)

HVdc – SOLDIERS POND

CONVERTER BUILDING/VALVE HALL – SOLDIERS POND

- Valve Hall is considered the heart of the Converter Building at SP
- Where dc power passes through and is converted to ac power

CONVERTER TRANSFORMERS – SOLDIERS POND

- Transformers provide the electrical connections between the dc and ac systems, and ensure voltage is at the level needed for power distribution
- 7 transformers were transported from Bay Bulls to Soldiers Pond in spring 2017

SYNCHRONOUS CONDENSER – SOLDIERS POND

- 3 synchronous condensers help maintain stability and reliability on the electricity grid and maintain voltage on the ac system
- The installation and operation is similar to a large electric motor or generator

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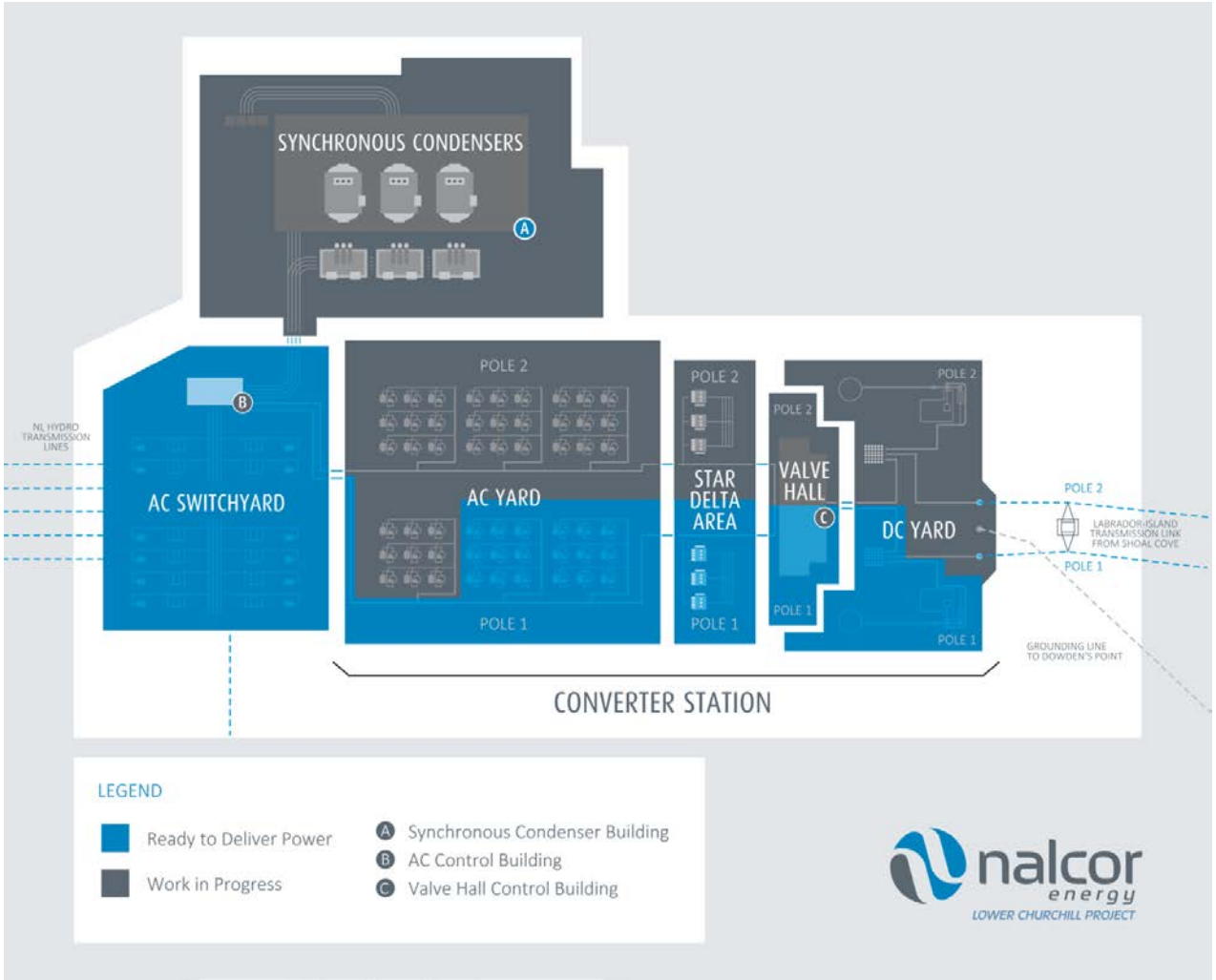
AC COMPONENTS – SOLDIERS POND

- SP also includes: ac Filter Yard, ac Switchyard, ac Control Building
- **ac filter banks** ensure the quality of the power being transmitted into the existing ac network meets industry standards
- Existing NL Hydro transmission lines connect into the **ac Switchyard**; once power passes through the yard it is ready for distribution to customers
- **ac Control Building** houses the protection and control equipment required for the safe operation of the ac Switchyard

SOLDIERS POND



VIDEO #11 SOLDIERS POND SITE VIDEO

HVdc – TRANSITION COMPOUNDS

- Transition compounds located on each side of the Strait of Belle Isle act as the transition point between the subsea cables and overhead dc transmission lines.
- Main Contractors:
  - GE Grid
  - Pennecon Heavy Civil
  - C&T Enterprises

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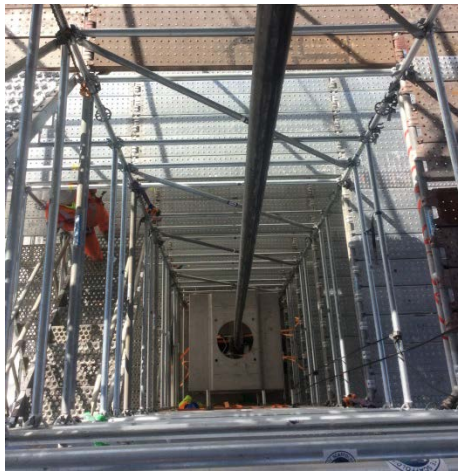
TRANSITION COMPOUNDS – LAND CABLE INSTALLATION



HVdc – GROUNDING STATIONS

Dowden's Point

L'Anse au Diable

- Two grounding stations - Dowden's Point and L'anse au Diable
- Grounding stations add reliability to the HVdc transmission system
- They allow the system to continue to supply electricity to customers in the event the transmission system needs repair or maintenance
- Main Contractors:
  - Bird Heavy Civil
  - Locke's Electrical

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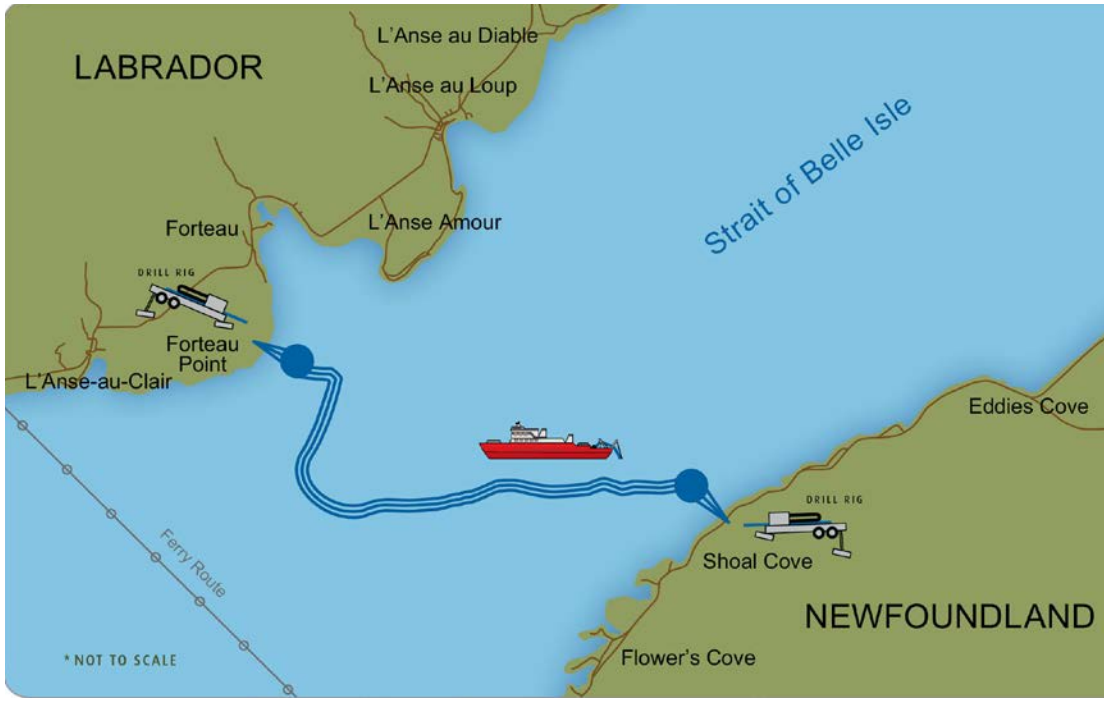
STRAIT OF BELLE ISLE CABLE CROSSING (SOBI)

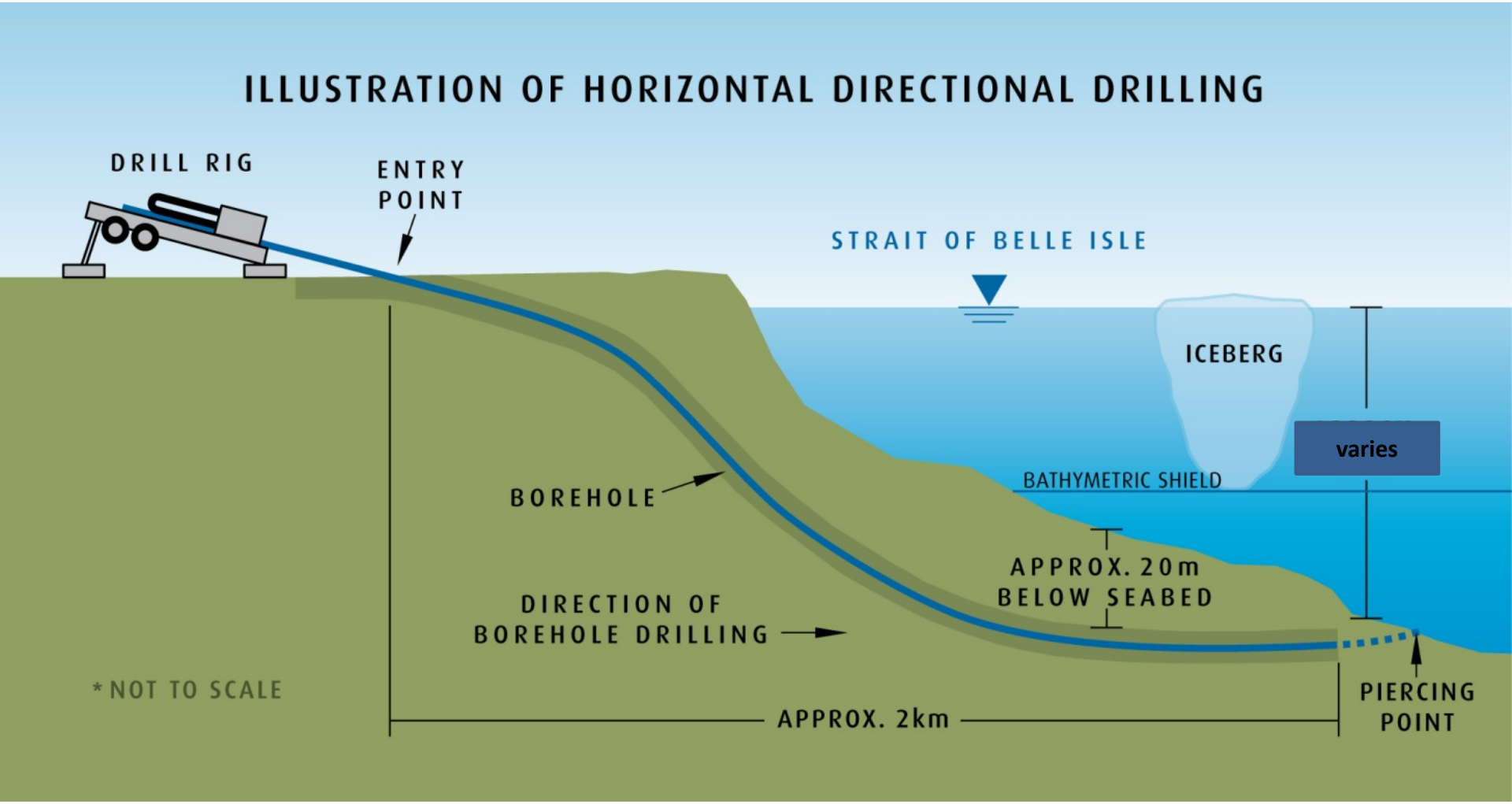
- 30 km marine cable crossing from Forteau, Labrador to Shoal Cove, Newfoundland
- 3 marine power cables along the seabed (30 km each)
- Using horizontal directional drilling (HDD) technology, drill rigs bored 3 holes from the shoreline and out under the seabed on both sides of the Strait
- Cables placed along the sea floor and covered by rock berms to protect against marine traffic and fishing activity
- Cables follow natural bathymetric lines, below depth of icebergs in the area

SOBI



- Nexans (cable design/install)
- Tideway (rock quarry/placement)
- C&T Enterprises (civil work)
- Direct Horizontal Drilling (HDD)

SOBI – HDD ILLUSTRATION



- To complete the 6 boreholes, 10 km was drilled through hard rock
- Each borehole is 375 mm in diameter and ranged from 1.25 to 2 km from the shoreline into water depths of about 75 m

SOBI – MARINE CABLE

SOBI – CABLE JOIN

Laying of the first cable

- August 2016 - first cable join for SOBI connecting Labrador to the island for the first time in history
- Fall 2016 - final cable laid
- 2018 - cables energized

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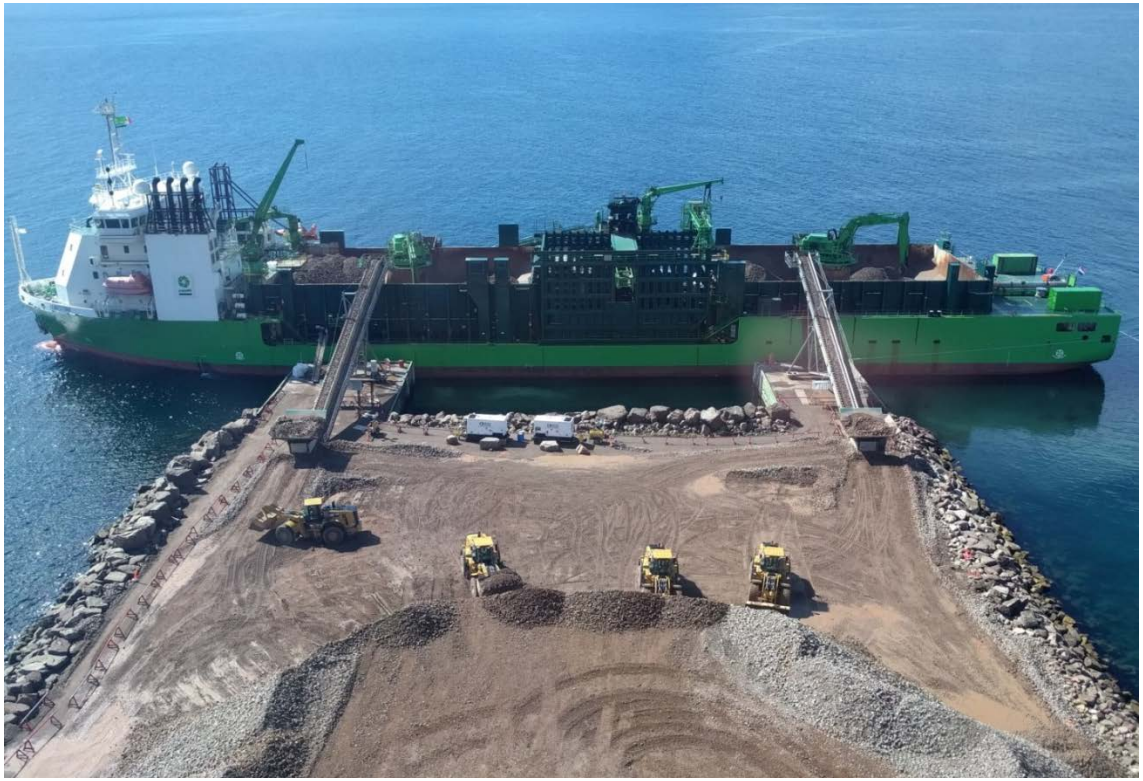
SOBI – ROCK QUARRY

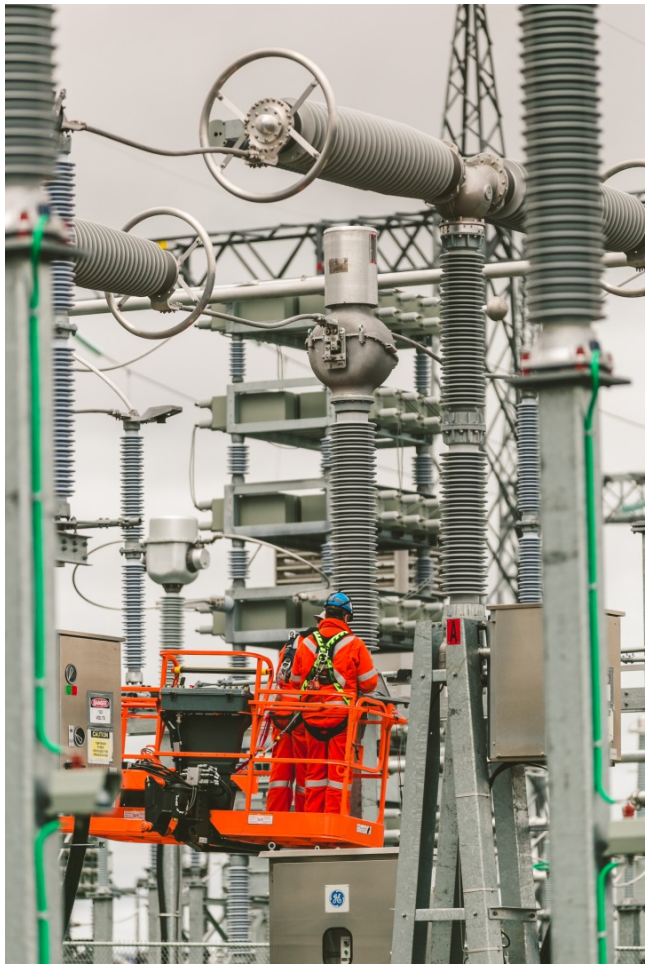


- 550,000 tonnes of locally quarried rock was installed over 80 km to create the protective berm over the three subsea cables.

ENERGIZATION OF TRANSMISSION ASSETS

- November 2017 - Soldiers Pond AC switchyard concluded a staged energization procedure that fully integrated the switchyard into the NL Hydro island system
- April 2018 - LTA was energized
- May 2018 - testing began on the Labrador portion of LIL as well as the converter station at MF and the Forteau Point transition compound
- May 2018 - testing began on the island portion of LIL as well as the converter station at SP and the Shoal Cove transition compound
- May 31, 2018 - delivery of power across the transmission line from Churchill Falls to Soldiers Pond at 45 MW

UPCOMING WORK – 2018-2020



- Dynamic commissioning ongoing
- Focus on Protection and Control software development to ensure safe and reliable operation of system

AGENDA

- Electrical System Basics
- Churchill River System
- Muskrat Falls Project Overview
- Generation Project
- Transmission Projects
- **Optimizing NL Energy Resources**

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TRANSMISSION ACCESS

- With access through Quebec, and into and through the Maritime Provinces, energy from NL can be sold to external markets in Canada and the United States
- A portion of the capacity of the Maritime Link will be dedicated to existing commitments to Emera and Nova Scotia Power
- The remainder of the Maritime Link will be used to export to/import from external markets

Thank You

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