MEETINGS IN ST. JOHN'S AND VISITS TO LOWER CHURCHILL PROJECT SITES, JUNE 26 TO 29, 2018

Prepared for: Natural Resources Canada and Nalcor Energy

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Quality Assurance Statement

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1. GENERAL

The Independent Engineer (IE) team visited the Muskrat Falls Generating Station and Convertor Station and Soldiers Pond construction sites on June 26 to 28 and attended project briefings and meetings at the Lower Churchill Project Delivery Office in St. John's on June 27 to 29. NALCOR senior management representatives and technical specialists, representatives from the Government of Newfoundland & Labrador and Government of Canada also attended the various briefings and site visits of the HVDC Converter Stations and Muskrat Falls generating plant.

IE team: Nik Argirov (IE Team Lead)
Paul Hewitt (IE Infrastructure and Cost Subject Matter Expert (SME))
Vlad Kahle (IE Electrical SME)
Tim Little (IE Geotechnical SME)

The trip itinerary:

June 25:
- Arrive and overnight in St John's

June 26:
- Travel to Goose Bay
- Muskrat Falls generating plant (C1), Converter Station and Switchyard (C3) visit
- Return to and overnight in St John's

June 27:
- Travel to Soldiers Pond (SOP)
- Attend SOP Special Event
- Technical meetings on Muskrat Falls (BPLP, RCC Dam, T&G, Gates, Power House, BOP) in LCP office

June 28:
- LCP office C3 / C4 Technical meeting
- SOP Converter Station control room visit (VK only)
- Govt NL oversight committee meeting (NA only)

June 29:
- Technical meetings on Muskrat Falls dams and dam safety in LCP office
- Depart for home bases

2. MUSKRAT FALLS PROJECT SITE – JUNE 26, 2018

2.1 Muskrat Falls Reservoir

Photographs taken during the visit are presented in Appendix 1, Section A.

The reservoir was at about El. 23 m at the time of the IE site visit.

Since the debris/ice/safety boom was installed in 2017, the positions of some of the boom buoys have shifted due to slippage of holding clamps. Nalcor plans to replace the clamps with an improved device this year. Nalcor reported that it will maintain a

24-hour safety watch of the upstream area until the buoys are repositioned and the clamps replaced in order to avoid potential public access.

2.2 Muskrat Falls Intakes and Powerhouse

Photographs taken during the visit are presented in Appendix 1, Section B.

Overall construction of the powerhouse was reported to be about 79% complete at the time of the site visit. Most of the remaining work is related to installation of turbines, generators and balance of plant works. The turbine pit steel liners are in place for all four generating units, with second stage concrete at various stages of completion.

Installation of cable trays and cabling, piping systems and heating ventilation and air conditioning (HVAC) systems were in progress in various areas of the powerhouse. Construction of concrete walls between generator transformer bays on the tailrace deck was in progress.

Most temporary construction facilities have been removed from the tailrace channel. Removal of the overburden portion of the tailrace plug has started, the bedrock portion will remain in place until the construction access road across the top of the plug can be decommissioned.

2.3 Muskrat Falls Spillway

Photographs taken during the visit are presented in Appendix 1, Section C.

Spillway bays 1 and 5 are closed for construction of concrete rollways and the reservoir is being controlled by the three central gates.

2.4 Muskrat Falls North RCC Overflow Dam

Photographs taken during the visit are presented in Appendix 1, Section D.

At the time of the site visit, the north RCC overflow dam was approximately 60% complete and the top of the RCC dam was at El. 24.69 m, approximately 1.7 m above current reservoir level. Recent placement rates were reported to be about 1200 m^3 per day, with forecasted completion in September 2018.

RCC placement continues to be with the slope layer method, with layers currently sloping at 40H:1V. It was reported that placement rates this season had been sufficient to achieve mostly hot joints between RCC lifts.

The downstream face is being constructed with steps formed with conventional concrete on the outer surfaces. The flip bucket at the toe of the dam is also being constructed with conventional reinforced concrete.

The RCC level is now above the gallery in the dam, and grouting of the dam foundation from the gallery is in progress. At the time of the site visit, it was reported that about 25% of the grout hole drilling and about 13% of the grouting were complete, and that initial grout takes were within expected ranges.

2.5 Muskrat Falls South Embankment Dam

Photographs taken during the visit are presented in Appendix 1, Section E.

Construction of the south embankment dam was completed in Fall 2017. The dam was snow-covered at the time of the last IE site visit in late November 2017.

During the site visit, the IE team noted that the outer slopes of the dam were finished with neatly-placed riprap, and a compacted granular road surface with no-post concrete side barriers constructed along the top of the dam.

2.6 Muskrat Falls North Spur

Photographs taken during the visit are presented in Appendix 1, Section F.

The North Spur was not inspected during this site visit as construction was completed in 2017 and there had been no construction activity since last visit.

The location of a local surficial slide that occurred downstream of the North Spur in early February was pointed out to the IE team. The slide occurred within the limits of a pre-existing erosional slope above the riverbank. Several kilometers of the north riverbank are visible from the dam site, and much of that slope shows similar natural erosion, including recent erosion along the toe of the slope.

The IE team notes that in February 2018, an external four-member Geotechnical Peer Review Panel issued their report on the analyses of the North Spur. The panel concluded that "*the overall approach, concepts and methods used for checking the stability and integrity of the North Spur follow the current standards and state of the art practice*". The IE team considers that the members of the panel are well qualified, and that their review was very comprehensive and has no further comments.

2.7 Muskrat Falls Dam Safety (Technical meeting - June 29, 2018)

Nalcor's dam safety management program includes dam safety monitoring of reservoir and tailwater levels, all cofferdams, the North Spur, powerhouse, spillway, and separation wall. Monitoring includes visual inspections and measurements of piezometric levels, seepage flows and movements using instruments and surveys.

Instrumentation data are collected automatically or manually, depending on factors such as the types of instruments and their locations. Data are regularly entered into a computer database and plots can be viewed on-line. The results of the dam safety inspections and instrumentation data continue to be presented in Dam Safety Weekly Monitoring Reports. The IE receives copies of these reports.

Independent Dam Safety Program Audits are also periodically performed by Hatch, with the most recent audit completed in late November 2017. That audit concluded that "*all of the temporary and permanent structures are performing in accordance with design expectations*".

The reservoir has operated within a narrow elevation range of about 3 m since the first stage of filling in early 2017 and has been held very close to El. 23 m since January 2018. Tailwater has varied within a maximum range of about 4 m since early 2017, with less than 2 m of variation since January 2018. With these relatively stable upstream and downstream water levels, and with water not yet ponded against most of the permanent structures, dam safety instruments have shown little or no movement and only small variations in piezometric levels. The IE team reviewed the instrumentation data with Nalcor and confirmed that no unusual conditions or dam safety concerns have been identified.

Several piezometers in the central area of the North Spur showed temporary piezometric level variations of about 2 to 10 m over a period of about one year. These effects appear to correlate with a time when some of the pump wells were out of service, which indicates that the wells are effective at controlling piezometric levels if required.

2.8 HVDC System

Photographs taken during the visit are presented in Appendix 1, Section G.

Converter station, gas insulated switchgear (GIS), AC substation control building and AC switchyard are virtually complete. The LIL has been energized and the line voltage and load was transmitted from Labrador to Newfoundland. Power transfer is presently limited to 45MW pending the completion and implementation of the Protection and Control software.

3. SOLDIERS POND (SOP) PROJECT SITE – JUNE 27, 2017

Photographs taken during the visit are presented in Appendix 1, Section H.

Following the safety briefing the participants conducted walk through visit of the HVDC Pole 2 valve hall, Control Room, DC switchyard and the Synchronous Condenser Building. LIL has been energized at the line voltage and load was transmitted from Labrador to Newfoundland. Power transfer is presently limited to 45MW pending the completion and implementation of the Protection and Control software. Partial software reportedly permits safe operation of the HVDC link, albeit with only limited control capabilities. One of the two redundant control and HVDC protection systems is in service at the time and the operating configurations are limited to the Pole 1 only. HVDC valves, high voltage equipment and auxiliary systems such as the AC Protections, cooling, HVAC have been fully commissioned.

With the load limited to 45MW, SOP synchronous condensers (SC's) are not required and have not yet been commissioned into service. During this interim period the required reactive power is supplied from the grid and by one A-Type filter at MFA and one B-Type filter at SOP.

4. SOP CONVERTOR CONTROL ROOM VISIT - JUNE 28, 2018

Purpose of the visit was to view the HMI screens, their features, level of completion and obtain feedback from the operating staff. Commissioning specialist Grant Herzog conducted briefing on the HMI screens. Due to time constraints not all screens were viewed, and only cursory overview of the HMI capabilities was possible.

- Station Yard View: A live mimic representation of the station operating one diagram with displays of electrical parameters, equipment operational status, command input and the control modes. Equipment status indication is monochromatic rather than using the more common colors-red for Closed and green for Open status. In addition, the disconnect switch symbols closely align with the capacitor and surge arrester symbols used by most of the North American utilities. The technical specialist suggested that after training and familiarization operators will have little problem using this screen. Voltage levels are color coded to replicate the screens at the ECC. Ultimately, each HVDC terminal will also have a display of the other station equipment.
- Help Electrical View: A pop- up screen that assists the Operators in interpreting the various symbols.
- Help System View: A pop- up screen that displays the status of the intelligent electronic devices, GPS, HMI, data acquisition system and communication links.
- Converter Transformer Monitoring: This is a comprehensive transformer condition monitoring screen with data and alarm display capability. It will allow trending, however the data is not automatically stored. Alarms are stored in the plant historian.
- Sequencing: Display of the overall 'yard format' (operating configuration) linked with pop-up screen showing the individual equipment operational status. At present it has manual capability only and just one operating configuration has been activated. The sequencing will be automated in the future.
- SOPCS Comms Network: Status display of Soldiers Pond Converter Station communication network and Lane 1/ Lane 2 operational status for both Pole 1 and Pole 2.
- System View: Lay-out and status of the station's computer networks and servers.

- Overview: Global view of the converter station and AC yard equipment operational status.
- Auxiliary Services: Station Service operating one-line diagram (by voltage class) and electrical parameters display.
- Valve Cooling: Single line display of the valve cooling system, coolant flow and its temperatures.
- Reactive Power Control Screen: The Reactive Power Control screen provides the Operator with a means to monitor the total Q exchange and manually switch in the necessary filters required for Harmonic Performance and Reactive Power Compensation during LIL Power Transfer. Eventually this will be an automatic sequence, with filters switching in and out depending on the loading of the LIL.
- HMI Control Features: Equipment operation commands are by a three-step sequence, select the device- select open/ close command- execute.

IE Comments on P&C Software:

1. *P&C S/W version 1.0.15 is now in service, next version 1.0.16 is coming by mid-July and the revision 1.0.20 may be the final issue. Partial regression testing is normally carried out in cases where the previous versions of the software work flawlessly. Such is apparently not the case with the version 1.0.15 of the S/W package. Number of outstanding items/deficiencies remain in the punch lists, HMI's are sparsely populated, and the controls reportedly suffer from unreliability. Combined with the practice of releasing numerous sequential revisions of partial S/W package into the trial service conditions may result in unpredictable S/W performance. IE suggests that only a complete regression testing referenced to documented performance criteria will provide reasonable assurance of the software completeness and reliability.*
2. *IE now has copies of comprehensive control strategy documents such as the Apparatus Control Point Architecture, Block Deblock Sequence, Common HVDC Protection Strategy, AC Yard Interlocking Principles, Control Cubicle Architecture and decision tree for Corrective and Preventive Action Procedures. These documents are very useful references that will provide the IE with a checklist for monitoring the commissioning work. Requested software logic diagrams are not yet provided (re: IE Factory Visit report and request made on Feb. 27, 2018 at the PES Stafford office).*
3. *HMI displays are very comprehensive, and offer ready access to the equipment status indication, metered values, alarms and equipment conditions. Equipment status monochromatic displays and some device symbols may not be the most commonly used in North American electric utilities, however, the solution has been accepted by the Owner and commissioning staff. Equipment controls are performed by a conventional three step sequence. At this time only a very limited HMI features have been commissioned. Completing the HMI programming likely represents a significant amount of S/W programming work. Finally, the functionality of the entire HMI system should be tested and re-verified requiring future commitment of the ECC and NALCOR resources.*
4. *Performance metrics presented to date were the item counts on Punch List A and Punch List B. Sorting the outstanding items into two weighted Punch Lists is a good start, however, lists do not provide complete indication of the outstanding programming work. It is recommended that detailed work breakdown with firm time/resource estimates would be the only realistic indicator of the effort and time required to complete the S/W package. In order to firm up the planned Nov. 2018 commencement date for dynamic testing at 225MW, supportable estimate for the outstanding work is required.*

5. TECHNICAL MEETING IN LCP OFFICE - JUNE 28, 2018

5.1 C3/ C4 update (presented by Steve Follet)

- Incidents of unreliability attributed to the software have been reported. Further details are expected to be provided for the IE to determine if the unreliability can be attributed to the component 'infant mortality' during the initial burn-in period or to the problems with unproven programming codes.
- NALCOR and NLSO accept the grid reliability risks associated with operating the LIL with only partial software (S/W) package. To limit the potential impact of HVDC outages on the grid, the Operators will not exceed the 45MW load. It is noted that 45MW is not considered sufficient to start the trial operations.
- When operating with partial S/W package the liability for equipment damage rests with GE.
- After the final version of the S/W has been fully acceptance tested (FAT) in the Stafford factory, dynamic commissioning of the link can commence.
- Providing NLSO will agree, the plan is to go to 225MW and start the trial operations in Nov. 2018.

5.2 Protection and Control Software Development (presented by Ricardo Quijada and Tim Ralph)

- Software release version 1.0.15 has been approved for power transfer testing at 45MW. Version 1.0.16 is expected to be released in 2 weeks i.e. mid - July 2018.
- FAT of the Protection System Software for Pole 1 has been executed, Pole 2 FAT is pending.
- Full time staffing coverage for the FAT is expected in late summer. Interim S/W development and de-bugging at site is being performed by PES (Power Electronics Stafford).
- Current issues relate to reliability improvements associated with system failures, interlocking, lane changeover ('lane' is the GE terminology for one of the redundant control and protection systems; two independent fully redundant systems with automatic lane changeover between them will ultimately be installed), HMI's, loss of DCCT (Direct Current Current Transformer) signal.
- Contractor issues relate to retention of resources and the PES not providing back up for the staff on leave.
- IE was advised that the programmers perform only partial regression testing ensuring that only the previous S/W version was unaffected by the succeeding revision.

5.3 IE Questions and Responses

- What are the risks of uncommand operations or failure of HVDC Protection while operating with the partial S/W? With no present ability to transfer between the lane 1 and lane 2 systems, what is the expected 'failure mode'?

  Response: Any control glitch or failure will result in the HVDC block and AC breaker trip.

- How is the S/W roll-out process managed between the PES and the two sites?

  Response: Ricardo tracks the S/W versions. NALCOR approves the S/W versions to be deployed to site.

- Who has the responsibility for the HMI accuracy and integrity of the displays at all three sites (SOP, MFA, and ECC)?

Response: *GE has the responsibility for accurate representation of the electric installations (operating single line diagrams), NALCOR implements the information.*

- What are the operating contingencies in case of the communication link(s) failure?

  Response: *Local control mode has been proven at both SOP and MFA.*

- What HVDC system operating skills are available on sites?

  Response: Contractor specialists and NALCOR technical staff currently provide technical support at both the SOP and MFA. As for the ECC, there are 15 operators and 90% of the training has been completed. System simulator is available for operator training at the ECC.

Appendix 1

Site Photographs

Photo A.1: Upstream view of spillway approach channel and lower reservoir.

Photo A.2: Upstream view of debris boom, showing irregular spacing of buoys due to slippage of clamps.

Photo B.1: Power intakes and intake channel, with south embankment dam in background.

Photo B.2: Power intakes deck.

Photo B.3: Interior view of powerhouse from North Service Bay (generator floor level), with Unit 4 in foreground.

Photo B.4: Second stage concrete around pit liner nearing completion in Unit 1.

Photo B.5: Installation of reinforcing steel and embedded piping in preparation for second stage concrete around pit liner in Unit 2.

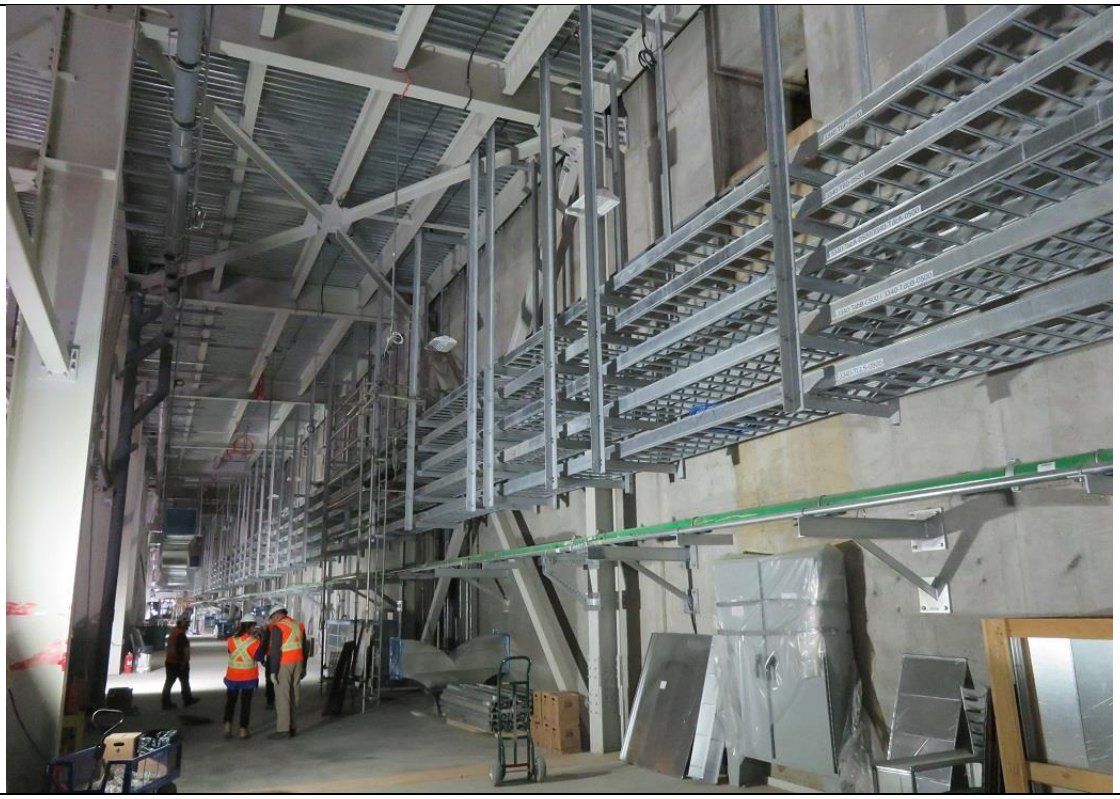

Photo B.6: Mezzanine floor.

Photo B.7: Powerhouse HVAC works in progress.

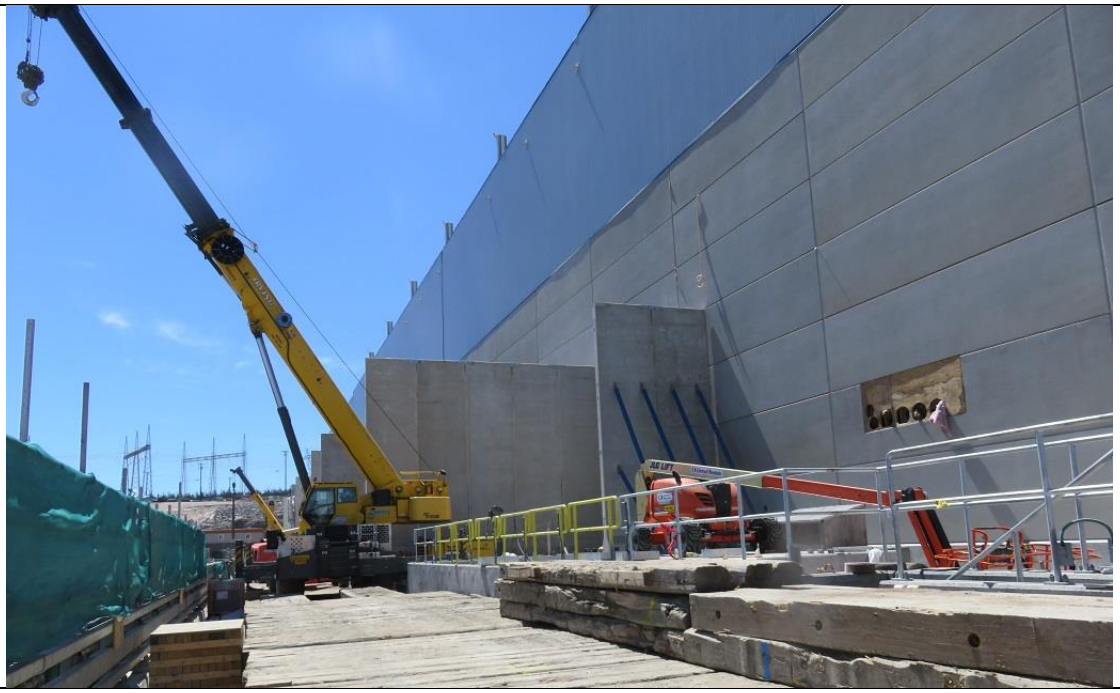

Photo B.9: Transformer bays on tailrace deck.

Photo B.10: Tailrace channel.

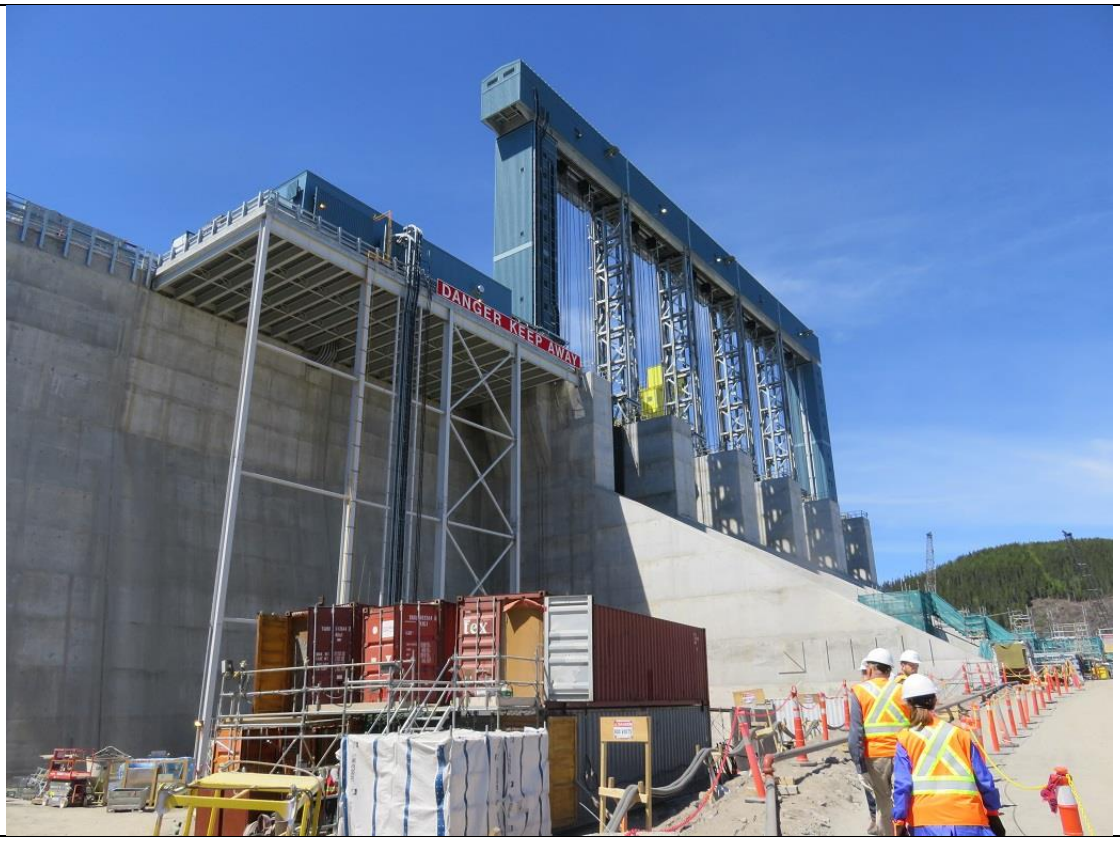

Photo C.1: Spillway with centre transition dam at left.

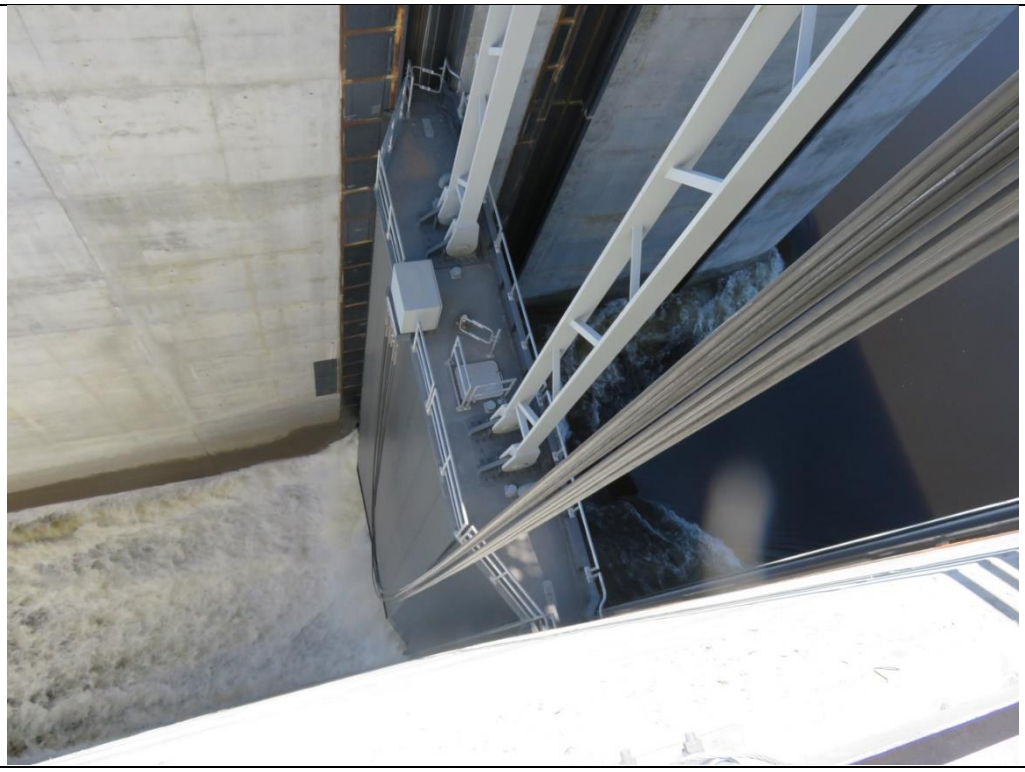

Photo C.2: Looking down at partially-open spillway service gate. Flow is right to left.

Photo C.3: Spillway outlet channel with central three gates partially open. Bays 1 and 5 are closed for rollway construction.

Photo C.4: Looking upstream in spillway bay 1 where rollway construction works are starting. Service gate is in raised position at top of photo with stoplogs (visible below) closing the bay.

Photo D.1: View from north transition dam looking northerly along top of RCC dam. Spillway flip bucket, being constructed with conventional cast-in-place concrete, is along right (downstream) side; upstream cofferdam is to left.

Photo D.2: RCC placement in progress at north end of RCC dam. Smooth concrete at right is conventional concrete that forms one of the steps on the downstream side of the dam.

Photo D.3: Downstream side of RCC dam, with north transition dam at left.

Photo D.4: Stepped downstream side of RCC dam, constructed with RCC and facial conventional concrete.

Photo E.1: Upstream side of south embankment dam, with spillway and intakes in background at left.

Photo E.2: Southerly view along downstream side of south embankment showing neatly-finished riprap cover.

Photo F.1: North river bank downstream of North Spur. Arrow indicates approximate location of local surficial slide reported in early February 2018, within a pre-existing erosional slope. Dark area just above river level to downstream indicates extent of ongoing recent erosion along toe of other similar slopes.

Photo G.1: Muskrat Falls -.GIS equipment energized.

Photo G 2: AC Switchyard with GIC and Control buildings on the background.

Photo G.3: Converter Station Transformers – fully dressed with Pole 1 (on the opposite side) energized.

Photo G.4: Converter Station AC filters yard.

Photo G.5: Muskrat Falls – Converter Valve 1 energized.

Photo G.6: Muskrat Falls Converter Station - protection panels

Photo H.1: Converter Station - Valve hall 2.

Photo H.2: Convertor Station - Valve cooling system.

Photo H.3: Synchronous Condensers.

Photo H.4: Synchronous Condenser lube oil system details.