Muskrat Falls Generation

Independent Dam Safety Program Audit

Audit #3 November 27 to 30, 2017

HATCH

Take a MOMENT for Safety

Agenda

Executive Summary

Executive summary

- An audit of the Dam Safety Management Plan in place at the Muskrat Falls Construction Site was performed between November 28 to 30, 2017
  - Based on observations made during the site visit and information obtained from Nalcor
- The audit included interviews with dam safety personnel, a review of dam safety related documents and plans, visual reconnaissance level inspection of the temporary and permanent water retaining structures and a fly over of the site
- The results of the audit indicate that:
  - the dam safety management program at the site meets or exceeds good industry practice;
  - the dam safety organization is appropriate and staff are experienced;
  - emergency preparedness planning and Operations and Maintenance procedures are in accordance with good industry practice, previous suggestions have been implemented;
  - the dam safety management program is in compliance with the CDA guiding principles;
  - the practices as witnessed are appropriate to reduce dam safety risks such that the probability of a significant dam safety incident are very low;
  - all of the temporary and permanent structures are performing in accordance with design expectations

Executive summary

ES-1 Results of audit

Item	Assessment	Remarks
Organization	Meets good industry practice	Staff well experienced, all positions filled
Inspection and reporting	Exceeds good industry practice	Extensive instrumentation, real time data collection and assessment
Training	Meets good industry practice	All staff trained, annual updates, excellent training materials
Emergency preparedness	Meets good industry practice	Previous suggestions re third party engagement implemented The plan was tested during the November 2016 drawdown of the reservoir Documents were updated in November 2017
Operations, Maintenance and Surveillance	Exceeds good industry practice	Number, quality of instruments and surveillance frequency exceeds good industry practice

Executive Summary

ES-1 Results of audit (cont'd)

Item	Assessment	Remarks
Monitoring – Cofferdams and North Spur	Exceeds good industry practice	Number, quality of instruments and surveillance frequency exceeds typical good industry practice
Inspection Frequency	Exceeds good industry practice	Frequency of monitoring to el. 22.5 m exceeds good industry practice Will be further enhanced following the principle of continuous improvement
Dam Safety Management Program	Meets good industry practice	Compliant with all CDA dam safety guiding principles

Executive summary

ES-2 Areas for improvement

- All key areas for improvement identified in Audit #2 have been acted upon
- Outstanding minor suggestions include:
  - A mechanism for obtaining continuous seepage flow measurements at the Kettle Lake Outlet Weir year round should be considered when impounding above el. 25 m commences
  - Lessons learned and workshop sessions to share experiences recommended to be performed on a quarterly basis
- No new areas for improvement were identified during Audit #3

Gaps

– No material gaps in the program that would constitute a dam safety problem were identified

General

General

- The objective of this presentation is to cover the results of a dam safety audit and overall review performed for the Muskrat Falls GS between November 28–30, 2017
  - Provide details of the audit
  - Observations
  - Potential areas for improvement
  - Update of previous audit
  - Review of the performance of structures under the effects of impoundment to el. 22.5 m
- Audit covers a review of the dam safety management plan and implementation
  - This audit is **not** a design review. Designs were previously reviewed as part of the design process by the Engineer of Record, the independent Lenders Engineer and by a number of independent hydropower consultants in accordance with good industry practice.

Audit Definitions

- Fully Compliant
- Materially compliant
  - Minor issues such as documentation or demonstration of documentation needed for full compliance
- Materially Non-compliant
  - Minor issues not performed such as appropriate documentation or rational for decisions
- Non-compliant
  - Issue that might affect safety not demonstrated or in the plan

"Good industry practice" – Dam safety practices as recommended by the Canadian Dam Association and/or as observed by the Auditor at other major utilities and construction sites

Auditor – C. Richard Donnelly

- Principal Consultant for Dams and Waterpower
- Advanced Degree in Geotechnical Engineering
- Over 39 years experience in the design and construction of dams
  - Received two national engineering awards for dam design and construction
- Worked in 14 countries around the globe
- Recognized leader in the field of dam safety
  - Over 300 dam safety and condition assessments for individual dams and entire hydroelectric facilities
  - Assisted in updated of the Canadian Dam Association 2007 Dam Safety Guidelines
  - Led the preparation of National Dam Safety Guidelines for Parks Canada
  - Serves on the Ontario Government's Lakes and River Improvement Act advisory panel
  - Assisted in the development of 2011 Ontario dam safety guidelines
  - Led development of dam safety standards and regulations for the National Utilities of El Salvador and Costa Rica
  - Led the development of national dam safety standards for Nepal as part of the nations reconstruction efforts
  - Received two national engineering awards for dam safety
  - Led development of a new Dam Safety Risk Screening tool which received the inaugural Innovation Award from the Ontario Waterpower Association
- Currently serving as the principal geotechnical consultant for the Keeyask GS
- Awarded the Professional Engineer's of Ontario's medal for excellence in engineering in 2013
- Published over 100 technical papers and received several awards for these articles

Statement of independence

- Neither Hatch nor the Independent Auditor have had any direct involvement in the design of the Muskrat Falls project
  - The Engineer of Record is SNC Lavalin
  - Hatch have provided expert advice to the Engineer of Record as part of several Cold Eye Review sessions
  - Hatch prepared a three dimensional hydrogeological model of the North Spur to the Engineer of Record for use in design
- Neither Hatch nor the Auditor were responsible for the development of the dam safety management program at the Muskrat Falls site
  - Hatch provided technical input in the form of dam break analysis and inundation mapping in the development of the project Emergency Response Plan
- The Independent Auditor is solely responsible for the review of the dam safety management program that has been implemented by the Engineer of Record
  - Expert advice on dam safety issues is provided to the Engineer of Record as part of this review

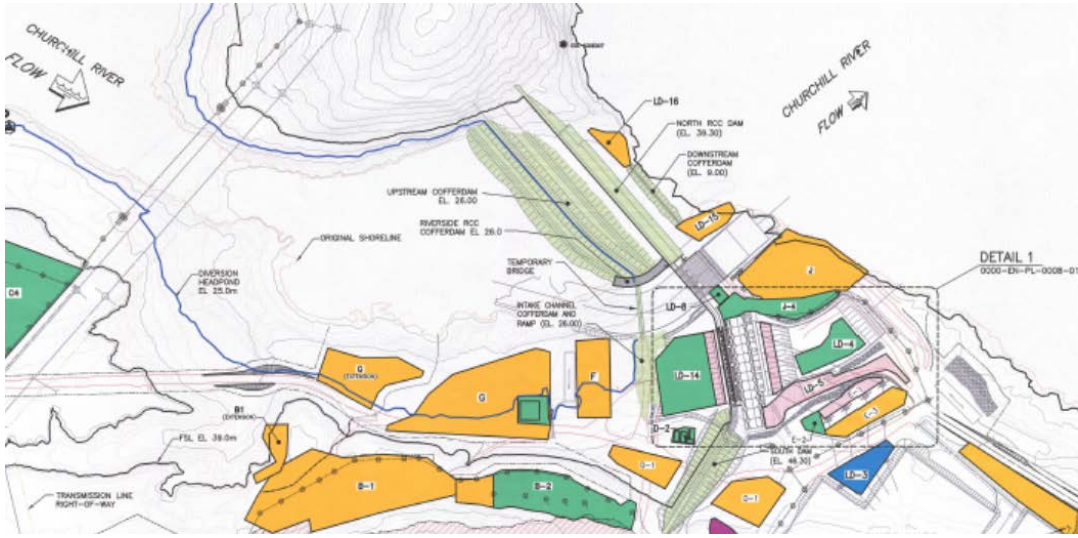
Scope of Work

Scope of work
The dam safety program

- This independent review involves an audit/assessment of all water retaining structures at the Muskrat Falls site
- Review includes:
  - Audit of instrumentation
  - Monitoring
  - Surveillance
  - Operations and Maintenance
  - Emergency Preparedness
  - Public and worker safety
  - Review of cofferdam remediation program
  - Review of response of Cofferdams and North Spur to impounding to el. 22.5 m
- Performed in accordance with Canadian Dam Association Guidelines (2013 revision)

Dam safety program

- Dam Safety monitoring is performed for the following structures:
  - Upstream Cofferdam
  - Intake Channel Cofferdam
  - RCC Cofferdam & North Transition Dam
  - Separation Wall and Centre Transition Dam
  - Spillway
  - Powerhouse
  - South Transition Dam
  - North Spur



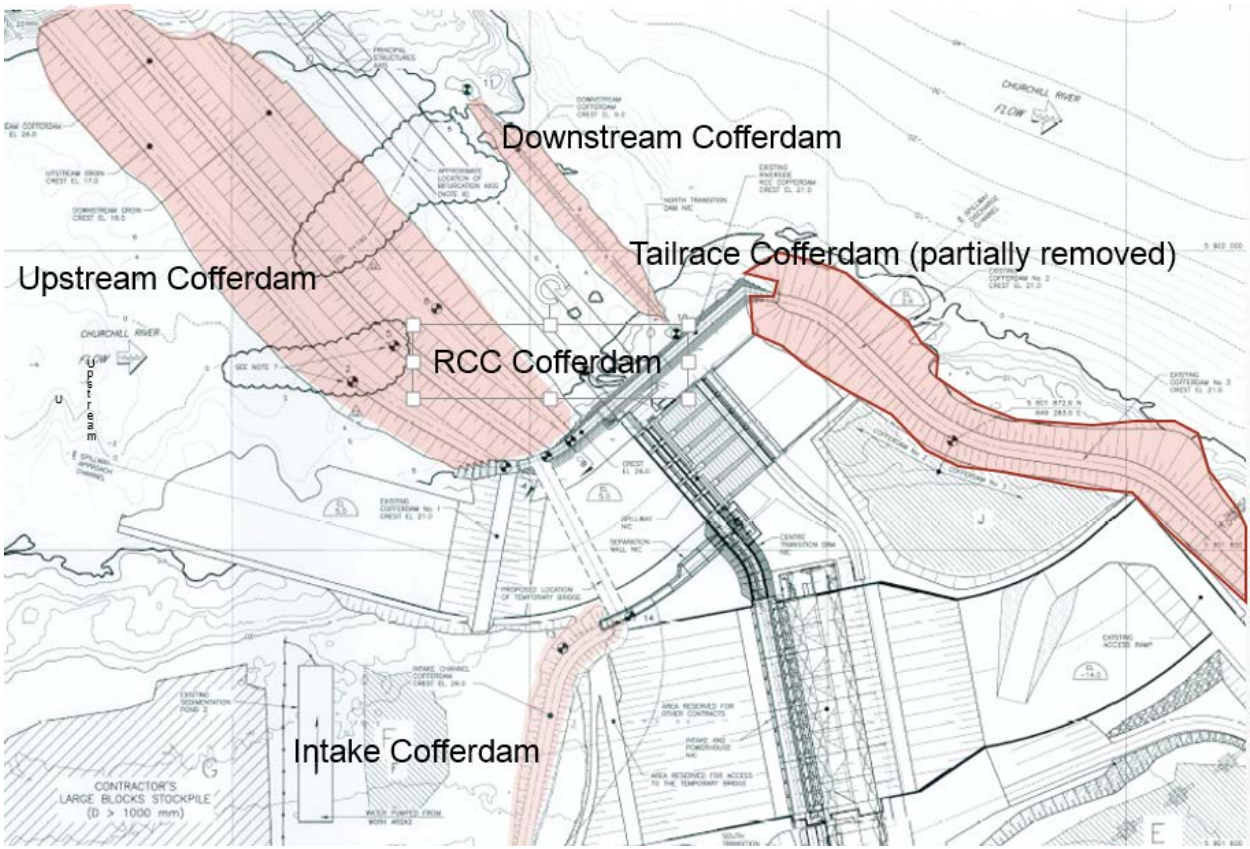
Scope of work
Permanent structures

- South Dam
- Intake/Powerhouse
- Spillway
- North Dam
- North Spur
- Transition Dams
  - North
  - South
  - Centre
- Separation Wall

Highlighted structures have water impounded against them to el. 22.5 m

Scope of work
Temporary structures

- Upstream Cofferdam
- Downstream Cofferdam
- Tailrace Cofferdam
- Intake Cofferdam
- RCC Cofferdam



Design review

- The review of the design of structures did not form part of this audit
  - Audit intended to review dam safety management processes at site
  - Designs performed by SNC-Lavalin (SLI) a well respected waterpower engineering company
  - Internal QA performed internally by SLI in accordance with good industry practice
  - Independent reviews of the designs performed by highly respected waterpower professionals

Update since the last audit

Status of improvements suggested in previous audit

Item	Audit #2 Recommendation	Current Status (30-Nov-2017)	Follow-up Action
Inspection and reporting	Accelerometer to be installed on the North Dam on completion Instrumentation for the South Dam and North dam to be finalized	Accelerometer to be installed upon completion South dam instrumentation installed North dam instrumentation will be finalized on dam completion	Accelerometer to be installed on the North Dam on completion Instrumentation for the North dam to be finalized
Training	Documentation of training Quarterly updates or as required to be performed	Complete	Quarterly updates or as required
Emergency preparedness	Undertake stakeholder tabletop exercises as planned	Complete Stakeholder notification and engagement completed Table top exercises performed internally Table top exercises involving key stakeholder and RCMP planned prior to impounding above el. 25 m	Complete stakeholder tabletop exercises as planned

Status of suggested improvements (con't)

Item	Description	Current Status (30-Nov-2017)	Follow-up Action
Operations, Maintenance and Surveillance	Dam safety personnel roles and responsibilities to be reviewed by auditor and included in manual	Complete	Update as required
Impoundment preparedness and monitoring – North Spur	Consider updating the 3D model when first stage of impounding complete	Complete	Not required at this point. May be considered following final impoundment

Suggested reporting enhancements

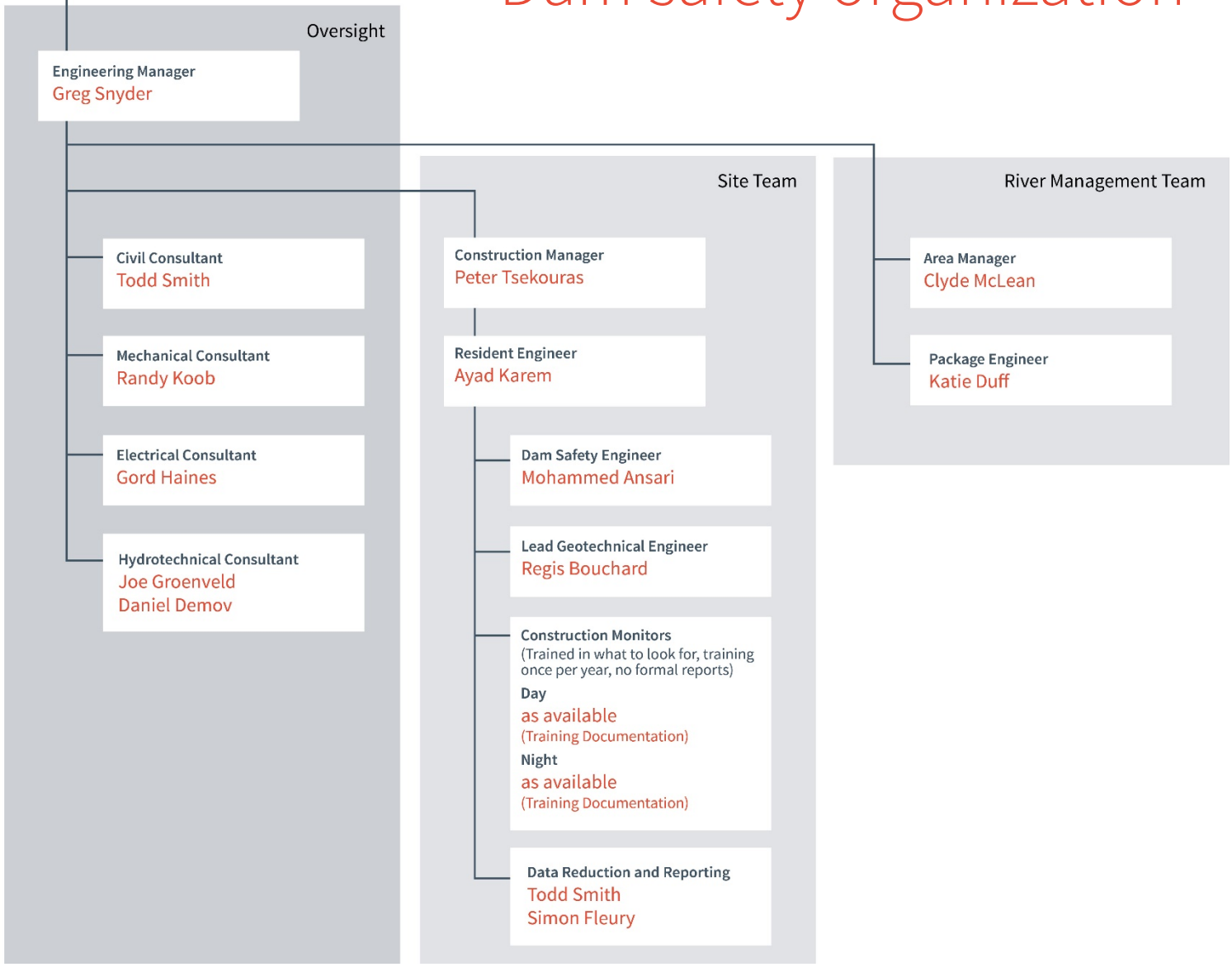
Description	Current Status (30-Nov-2017)	Follow-up Action
Pronto Form developers to add head pond/tailpond levels on standard form	Complete	None
Weekly comprehensive inspection reports To be finalized and submitted via Aconex	Complete	None
Prepare monthly evaluation reports	Complete Weekly evaluation reports are now being prepared	None

Principle 5 – Analysis and Assessment

Principle	Description	Current Status (20-Apr-2017)	Follow-up Action
5c	A PFMA is suggested	Complete All hazards have been assessed in accordance with the requirements of the CDA	None Potential to be performed after project hand over

Organization

Dam safety organization



Key dam safety team members

The Dam Safety Team is responsible for the development, implementation & maintenance of the Dam Safety Program at Muskrat Falls. The team includes the following LCP members:

Engineering Manager – *Greg Snyder*

- Responsible for direct oversight of program, coordination of technical resources & providing dam safety training to project staff

Construction Manager – *Peter Tsekouras*

- Responsible for management of construction activities related to the dams

Lead Geotechnical Engineer – *Regis Bouchard*

- Technical lead for the dam structures, first point of contact regarding unusual conditions. Responsible for developing mitigation plans.

Dam safety team

Resident Engineer – *Ayad Karem*

- Responsible for direct oversight of the dam safety program, performing occasional dam safety inspections and ensure conditions are being properly recorded

Dam Safety Engineer – *Mohammed Ansari*

- Responsible for performing dam safety inspections of all water retaining structures

Construction Monitors

- Responsible for collecting seepage measurements, visual assessments of seepage turbidity and color, and piezometer readings, as well as performing visual inspections of the cofferdam crest and U/S & D/S slopes for any deformations

Comments on organization

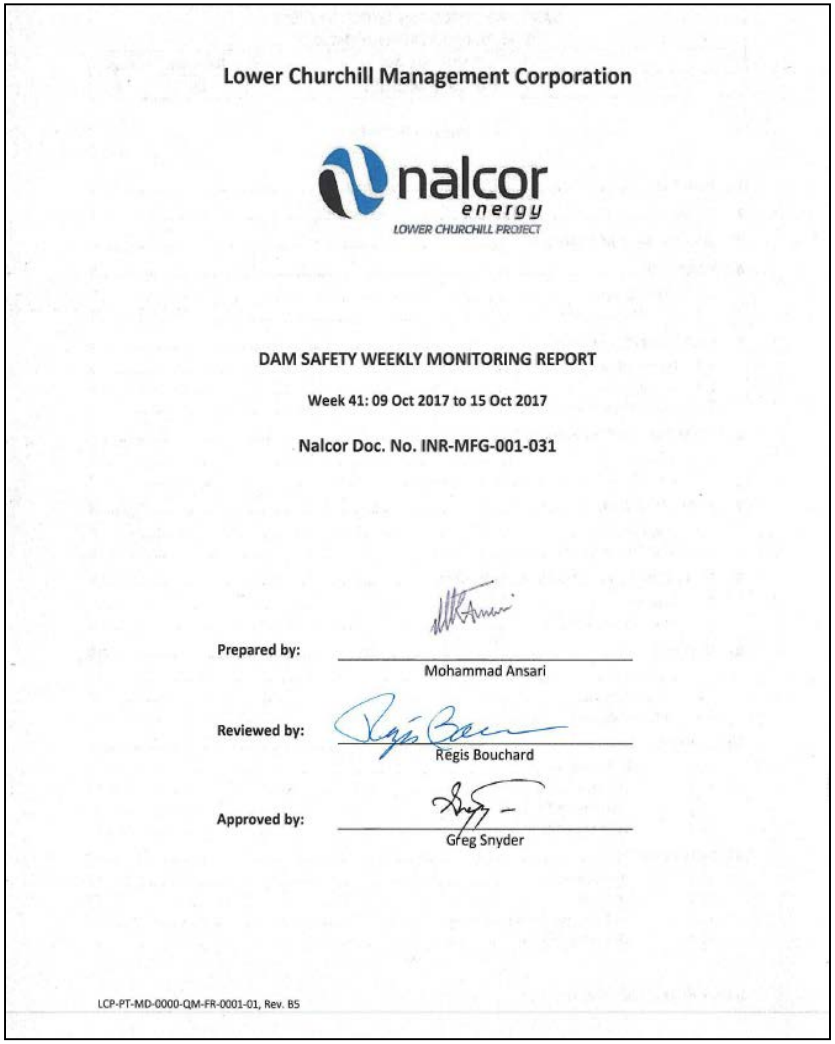
- Some changes and consolidation since Audit #2 but team, remains highly experienced
- Information continues to be collected on all structures in a timely manner
- Site team is well trained with appropriate experience
- Data reduction and reporting remains appropriate and timely

Dam Safety Organization meets good industry practice

Reporting

Dam safety reporting

- Dam Safety Weekly Monitoring Reports are completed each week to provide an update on inspections of the water retaining structures
- The report summarizes each structure and includes information on any observed deformations, seepage and an overview of the visual inspections performed by the LCP Dam Safety Team



Lower Churchill Management Corporation

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LOWER CHURCHILL PROJECT

DAM SAFETY WEEKLY MONITORING REPORT

Week 41: 09 Oct 2017 to 15 Oct 2017

Nalcor Doc. No. INR-MFG-001-031

Prepared by: Mohammad Ansari

Reviewed by: Regis Bouchard

Approved by: Greg Snyder

LCP-PT-MD-0000-QM-FR-0001-01, Rev. B5

Review of current status of reporting

- Instrumentation, frequency of readings, compilation and assessment of data continue to meet and exceed good industry practice
- Meteorological station at the site provides accurate information needed for assessments exceeds good industry practice
- Status of Audit #2 recommendations for enhancements to the program as follows:

Previous Audit	Current Status
Ensure photos are taken from the same point each time. Add plan showing the location of photo points to the inspection form.	Implemented

Dam safety reporting meets good industry practice

Dam Safety Training

Dam safety training

- The Engineering Manager provides dam safety training to all new project staff, as well as refresher training for all dam safety personnel
- The last dam safety training session was 19-Apr-2017
- Refresher training for current dam safety site personnel was completed on the 12th and 13th of December 2017

Training

- All dam safety staff are trained
  - New staff are trained as they come on board
  - Regular training refreshers performed
    - Lessons learned and workshop sessions to share experiences recommended
    - Quarterly refresher courses recommended

Training in dam safety procedures and monitoring meets and exceeds good industry practice

Monitoring and Inspection

Dam safety monitoring and inspection

- Inspection and reporting program of all dams and water retaining structures at the Muskrat Falls site
- A daily or weekly inspection report is available for each structure resulting from an inspection completed by a member of the Dam Safety Team
- Data is collected through visual inspections and monitoring of flow meters, piezometers, thermistors, inclinometers and survey monuments

The dam safety monitoring program

- Instrumentation used to collect monitoring data includes:
  - Seepage pump flow meters
  - Piezometers
  - Thermistors
  - Inclinometers
  - Survey Monuments

Muskrat Falls Dam Safety - Inspection Checklist

Date: _____ Time: _____ Cofferdam Name: _____

Inspector: _____ Water Level.: _____

Weather: _____ Temperature: _____

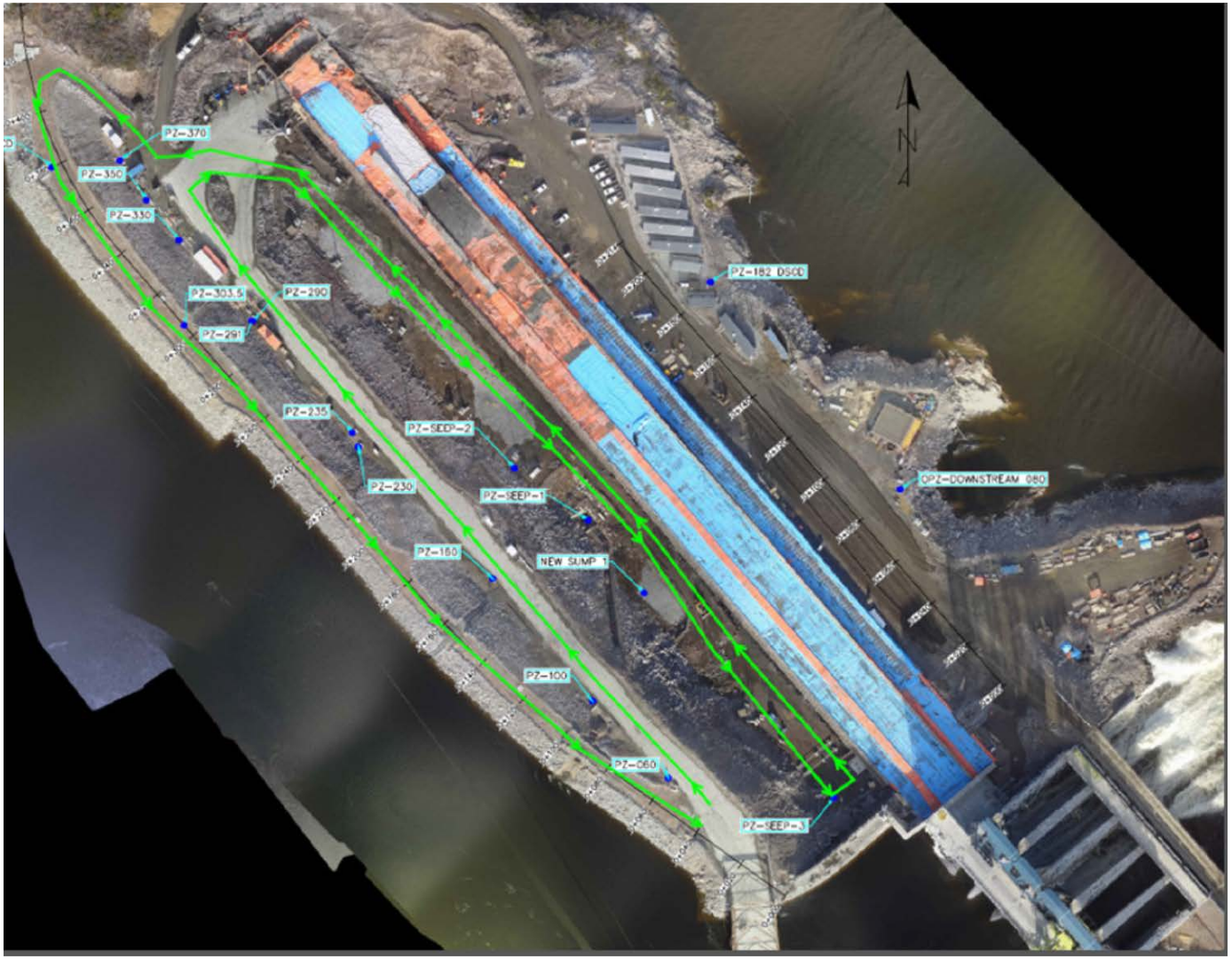
Item Inspected	Condition	Remarks
A. Waterside Slope (Wet side)		
Signs of Movement, Cracks, Sinkholes, Settlement, Slope Protection, Erosion ,Beaching Debris, Ice		
Unusual Conditions		
B. Landside Slope (Dry side)		
Signs of Movement, Cracks, Sinkholes, Settlement Seepage or Wet Areas		
Unusual Conditions		
C. Left Abutment (looking at landside slope)		
Signs of Movement, Cracks/joints, Bedding Planes, Seepage		
Unusual Conditions		
D. Right Abutment (looking at landside slope)		
Signs of Movement, Cracks/joints, Bedding Planes, Seepage		
Unusual Conditions		
E. Crest		
Cracking, Settlement, Sinkholes Lateral Movement, Camber		
Unusual Conditions		
F. Landside Toe - Seepage		
Location(s)		
Estimated Flow		
Colour- clear or cloudy		
Additional Remarks:		
Action Required: Y/N Describe Action: Notification Given: _____ To Whom: _____ Date:/Time: _____		

Condition: NI = Not Inspected. NC = No Change since last inspection. C = Changed, enter remarks.

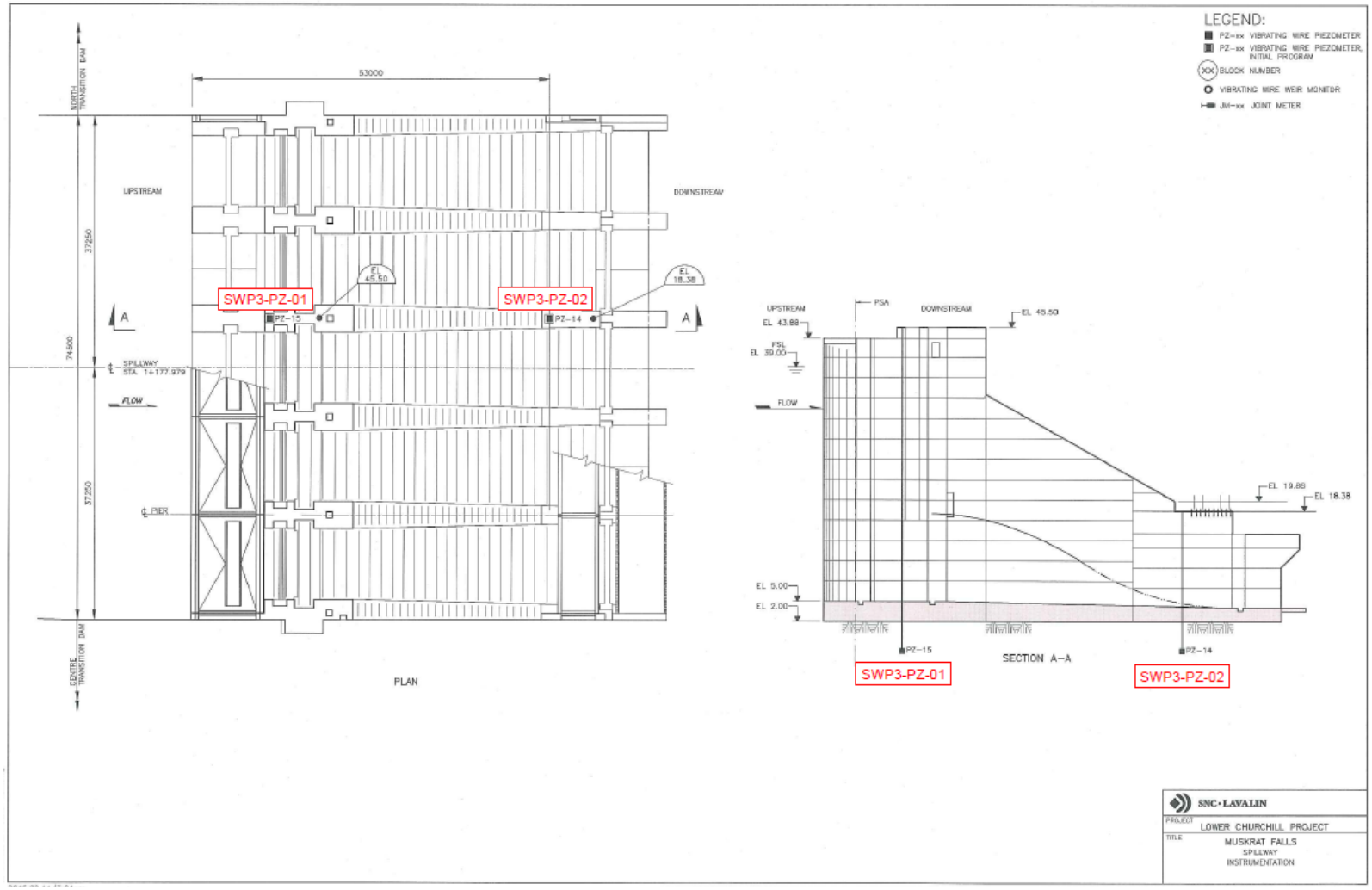
Dam safety daily inspection form

- Simple, effective, collects the needed data in an efficient manner
- Information is provided twice daily and processed in real time
- Meets and exceeds good industry practice for data collection, processing and interpretation

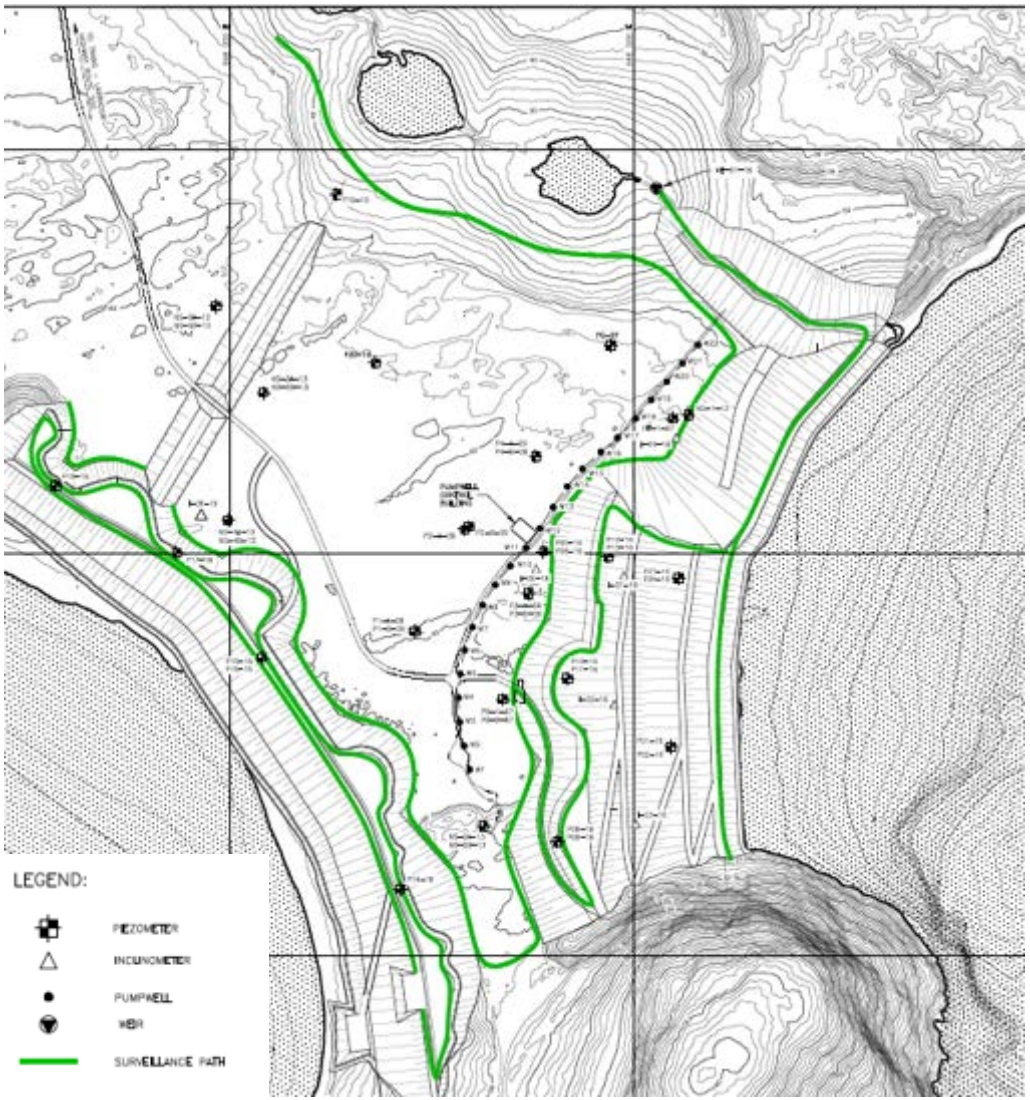
Location of instruments- upstream cofferdam



Location of instruments- spillway



Location of instruments- north spur



- 40 piezometers
  - 3 in lower aquifer
  - 7 upstream
  - 6 NW cow
  - 24 downstream
- 6 inclinometers
  - 5 downstream
  - 1 upstream
- 1 flow meter
  - Kettle Lake outlet

Monitoring and inspection frequency

- Each structure monitored and inspected at an appropriate frequency
- Actual frequency varies depending on structure and state of impounding

Dam safety inspection and monitoring exceeds good industry practice

Site	Information	Action	Holding Water Level	During Impoundment	Product
North Spur	Piezometer	Download ADAS	2/week	1/day	Graph
	Inclinometer	Reading	1/4 weeks	1/2 weeks	Profile
	Weir, seepage (download)[1]	Reading or visual	1/2 weeks	1/week	Graph
	Visual inspection	Walk Obs. Path	1/2 weeks	1/week	Report
	Pump Well divers	Download diver	1/2 weeks	1/week	Graph
Reservoir	Middle pool level	Reading download	Automatic reading (15 min)	Automatic reading (15 min)	Graph
	Downstream level	Download diver	1/day	2/day	Graph
	Downstream level	Survey	1/day - WSC Gauge	1/day - WSC Gauge	Graph
U/S Cofferdam	Visual inspection	Walk Obs. Path	1/day	2/day	Report
	Seepage	Reading	1/day	2/day	Graph
	Crest deformation	Survey	1/week	1/week	Graph
	Piezometer	Manual reading	1/2 weeks	1/week	Graph
	Piezometer	Download diver	1/day (reading 30 min)	1/day (reading 30 min)	Graph
Reservoir Rim Survey	Helicopter Survey on North and South bank	Upstream Survey for slope stability	1/week	2/week	Report
Intake Cofferdam	Visual inspection	Walk Obs. Path	1/week	1/day	Report
	Seepage	Observation	1/week	1/day	Description
RCC Cofferdam	Visual inspection	Walk Obs. Path	1/week	1/day	Report
	Seepage	Observation	1/week	1/day	Description
Separation Wall & Transition Dam	Visual inspection	Walk Obs. Path	1/week	1/day	Report
	Seepage	Observation	1/week	1/day	Description
Center transition Dam	Piezometer	Download ADAS	1/week	1/week	Graph
	Weir	Reading	1/week	1/week	Graph
Spillway	Piezometer	Download ADAS	1/week	1/week	Graph
	Survey monument	Survey	N/A	N/A	Graph
	Visual inspection	Observation points	1/day	1/day	Report
Power House	Piezometer	Download ADAS	1/2weeks	1/2 weeks	Graph
	Visual inspection	Walk Obs. Path	1/week	1/week	Report
	Seepage	Reading	1/week	1/week	Description
South Transition Dam	Piezometer	Download ADAS	1/week	1/week	Graph
	Weir	Reading	1/week	1/week	Graph
	Inclinometer	Download ADAS	1/week	1/week	Graph
Weather information	Temperature, Rain, Snow	From weather station	1/day	1/day	Report

River Management

River management

– An essential part of the dam safety program is maintaining water levels

The system installed exceeds industry good practice and has proven to be effective

nalcor energy
LOWER CHURCHILL PROJECT

Muskrat Falls Reservoir Forecast Report

Date: 10-Nov-2017	Rev: 0	Document Number:

CURRENT CONDITIONS

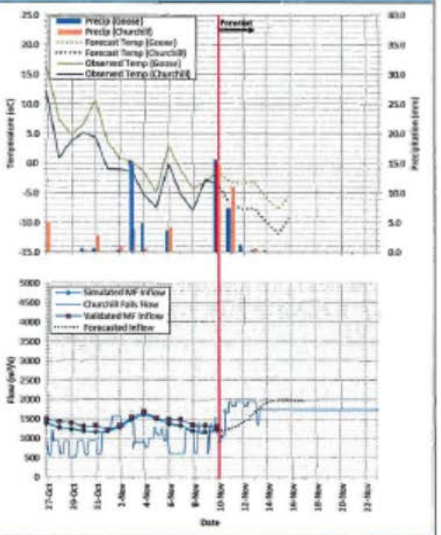
RESERVOIR WATER LEVEL	
Current WL (m)	22.47 (15:00)
Upper WL Limit (m)	22.65
Lower WL Limit (m)	22.35
FLOWS	
Current Spillway Discharge (m^3/s)	1020
Final Spillway Discharge (m^3/s)	1390
Current Reservoir Inflow (m^3/s)	1320
Forecasted Inflow (m^3/s)	1400
Inflow Offset (m^3/s)	+100
7-DAY WEATHER FORECAST	
Mean Daily Temperature (°C)	-7.8 to -1.4
Total Precipitation (mm/cm)	24.6

SPILLWAY OPERATIONS SUMMARY

Date & Time	Gate 1	Gate 2	Gate 3	Gate 4	Gate 5
Start of Day Shift	CLSD	4.6	4.6	CLSD	CLSD
10-Nov-2017 17:00	CLSD	6.3	6.3	CLSD	CLSD
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

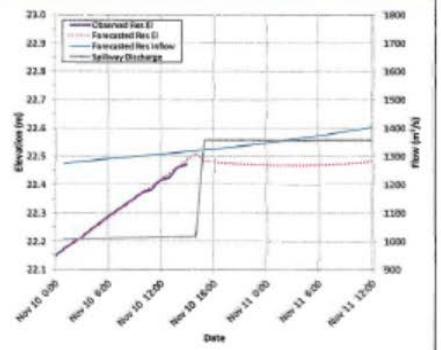
Notes:
- Gates 2 and 3 may only be operated from 3.0 m to 10.0 m
- Gates 1 & 4 remain closed; Gate 5 dogged open & U/S Stoplogs in place

FLOW FORECAST



RESERVOIR LEVEL FORECAST

Inflow modified based on observed level changes



Prepared By:	Evan Porter, Package Leader – River Management	Signature:	
Approved By:	Clyde McLean, Area Manager – River Operations	Signature:	

Emergency Preparedness Planning and Action– Update

The emergency preparedness plan

- LCP document for use as a guide to assist communities and external agencies in developing EPP's in the unlikely event of a cofferdam failure while passing a major flood at the MF site during the Winter Head pond Construction Phase (at el. 25 m)
- The document has been revised as of November 2017 with updated contact information
- A separate EPP has been prepared for Full Supply Level (at el. 39 m) which will be updated prior to impoundment to full supply level in 2019
- Full contact details are included in the plan

LCP Emergency Preparedness Planning Meets Industry Good Practice

Emergency planning documents

- CH009-001 RCC Dams – North and South Emergency Action Plan-Cofferdams. Barnard-Pennecon Limited Partnership, 05-April, 2017
- Muskrat Falls Dam Related Emergency (Winter Headpond Construction Phase – Emergency Preparedness Plan, MFA-PT-MD-0000-EN-PL-0001-01. Nalcor, 22-December, 2017
- Town of Happy Valley-Goose Bay Emergency Management Plan. Town of Happy Valley-Goose Bay, 2-Nov-2017
- Project-Wide Emergency Response Plan, LCP-PT-MD-0000-HS-PL-0004-01. Nalcor, November 2017

The Emergency Preparedness and Response documents and practices as observed meet and exceed good industry practice

Stakeholder updates

- LCP Communications Team publishes Stakeholder Updates on an as-needed basis to keep public informed on project information and public safety advisories
- At time of this audit, a recent Stakeholder Update, issued November 9th , updated current water levels at site and the preparations for forming an ice cover (ice cover formed upstream of the ice boom on November 28th 2017)
- Updates are also shared via Twitter, Facebook and the LCP website

Stakeholder meetings

- In addition to the Stakeholder Updates, several Emergency Preparedness meetings have taken place over the past year in various Labrador communities to keep the public informed
- At the time of this audit, the latest available information indicated that the most recent meeting occurred in July 2017 in Happy Valley-Goose Bay with the HVGB Fire Chief to discuss emergency response systems

Summary of stakeholder meetings and updates

Date	Group(s)	Location	Number of External Participants	Purpose and Focus
16-Jan-17	General Public	Sheshatshiu	115	Community Information session about North Spur construction, dam stability and dam safety
17-Jan-17	Town of Happy-Valley Goose Bay, NG, NCC, LNCC, Mud Lake, Labrador Institute, Grand River Keepers. Happy Valley-Goose Bay Seniors Committee, Gov NL	Happy Valley-Goose Bay	13	Key stakeholder meeting to discuss North Spur construction, dam stability, dam safety and emergency preparedness
17-Jan-17	General Public	Happy Valley-Goose Bay	100	Community Information session about North Spur construction, dam stability and dam safety
18-Jan-17	General public	Mud Lake	30	Community Information session about North Spur construction, dam stability and dam safety
18-Jan-17	General public	North West River	50	Community Information session about North Spur construction, dam stability and dam safety
12-Apr-17	Dave Raeburn, Mud lake	Happy Valley-Goose Bay	1	Meeting to discuss emergency response plan and community contacts
12-Apr	Dave Raeburn- Mud Lake, Mario Berthiaume - Fire & Emergency Services (FES)	Happy Valley-Goose Bay	2	Meeting with Mud Lake representative of the regional FES committee, and the regional FES coordinator to discuss the development of an emergency response plan for the community of Mud Lake
15-Jun-17	Brad Butler, Fire Chief-Happy Valley-Goose Bay	Happy Valley-Goose Bay	1	Meeting with Fire Chief Butler to discuss emergency response systems
20-Jul-17	Brad Butler, Fire Chief-Happy Valley-Goose Bay	Happy Valley-Goose Bay	1	Follow up meeting with Fire Chief Butler to discuss emergency response systems

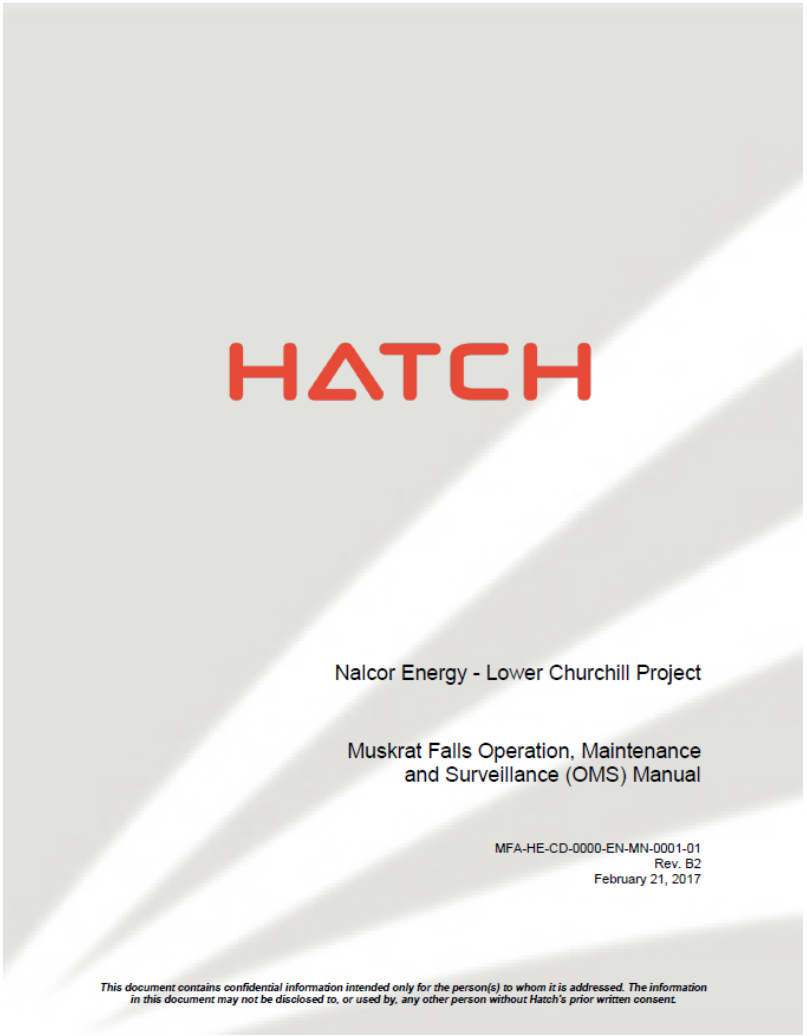
Assessment of emergency preparedness planning and communications

- Advance preparations were compiled in accordance with site plan and are in accordance with good industry practice
- Instrumentation to monitor the cofferdams and North Spur behavior exceeds good industry practice
- Monitoring frequency and reporting meet and exceed good industry practice

Operations Maintenance and Surveillance Program

OMS manual update

- In February 2017, a detailed manual of all operation, maintenance and surveillance requirements for Muskrat Falls during the construction phase was prepared
- In November 2017, LCP's River Management Team updated the manual provided by Hatch to provide more current project information



OMS manual update

Updates to the OMS Manual were made to the following sections:

- ***Roles & Responsibilities*** **–** updated contact information as well as a new section outlining the Dam Safety Team
- ***Spillway Operating Parameters*** **–** updated with more accurate information pertaining to gate exercising, gate heating requirements and target water levels at each period
- ***Spillway Maintenance*** **–** updated to reflect the approved Preventative Maintenance Plans submitted by Andritz and routine inspections which will be completed by Spillway Operations Team

Review of operations, maintenance and surveillance program and practices

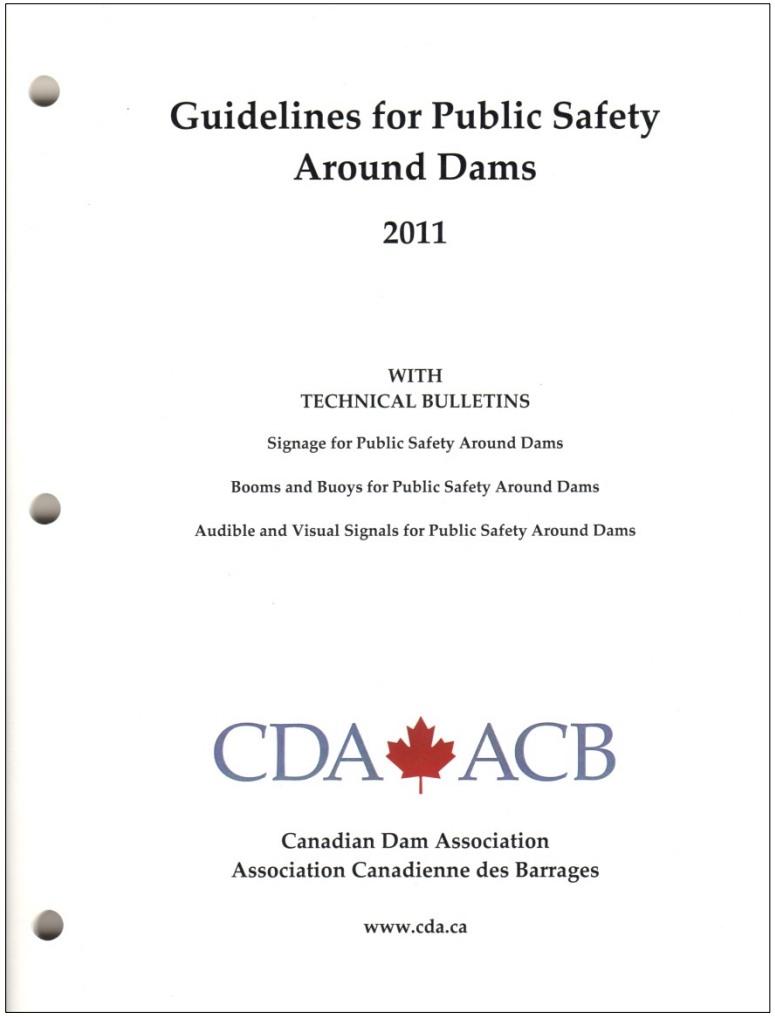
- Document complete and current
- Compliant with CDA guidelines
- Practices observed on site including inspection, reporting and flow control equipment operations to maintain and lower headpond levels met and exceed good industry practice
- Revised roles and responsibilities descriptions updated in accordance with Audit #2 recommendations

The OMS Manual and practices as observed meet and exceed good industry practice

Public Safety Around Dams

Public safety around dams audit

- Public Safety around dams was introduced by the CDA in 2011
  - Recognized by the dam safety community as an essential component of any dam safety management program
- In 2014, a Public Safety Around Dams (PSAD) Review was performed for the LCP that provided an assessment of Public Safety at the Muskrat Falls site



The public safety plan

- LCP used this importation to develop a plan for managing Public Safety at the MF construction site
  - Updated as necessary to reflect changing site conditions
  - Revision completed November 2017
- Plan details the following:
  - Roles & Responsibilities
  - Detailed site description
  - Common public/recreational uses around site
  - The PSAD risk assessment results
  - Planned Public Safety infrastructures
  - Spillway operations procedures
  - Impoundment procedures
  - External & Internal education programs

Lower Churchill Management Corporation

nalcor energy
LOWER CHURCHILL PROJECT

Muskrat Falls Public Safety Plan – Construction Phase

Nalcor Doc. No. MFA-PT-MD-0000-EN-PL-0002-01

Comments:	Total # of Pages: (Including Cover):

B1	12-Apr-2016	For Use	E. Porter	J. Hiscock	C. McLean	S. O'Brien
Status / Revision	Date	Reason for Issue	Prepared by	Package Lead Approval	Functional Manager Approval	Project Manager Approval

LCP-PT-MD-0000-QM-FR-0001-01, Rev B4

Public safety infrastructure

Public safety requirements developed for two situations

1. The Winter Headpond Phase
2. Full Supply Phase

For each phase of the project, specific signage and other safety measures developed

Public safety infrastructure
Winter headpond stage

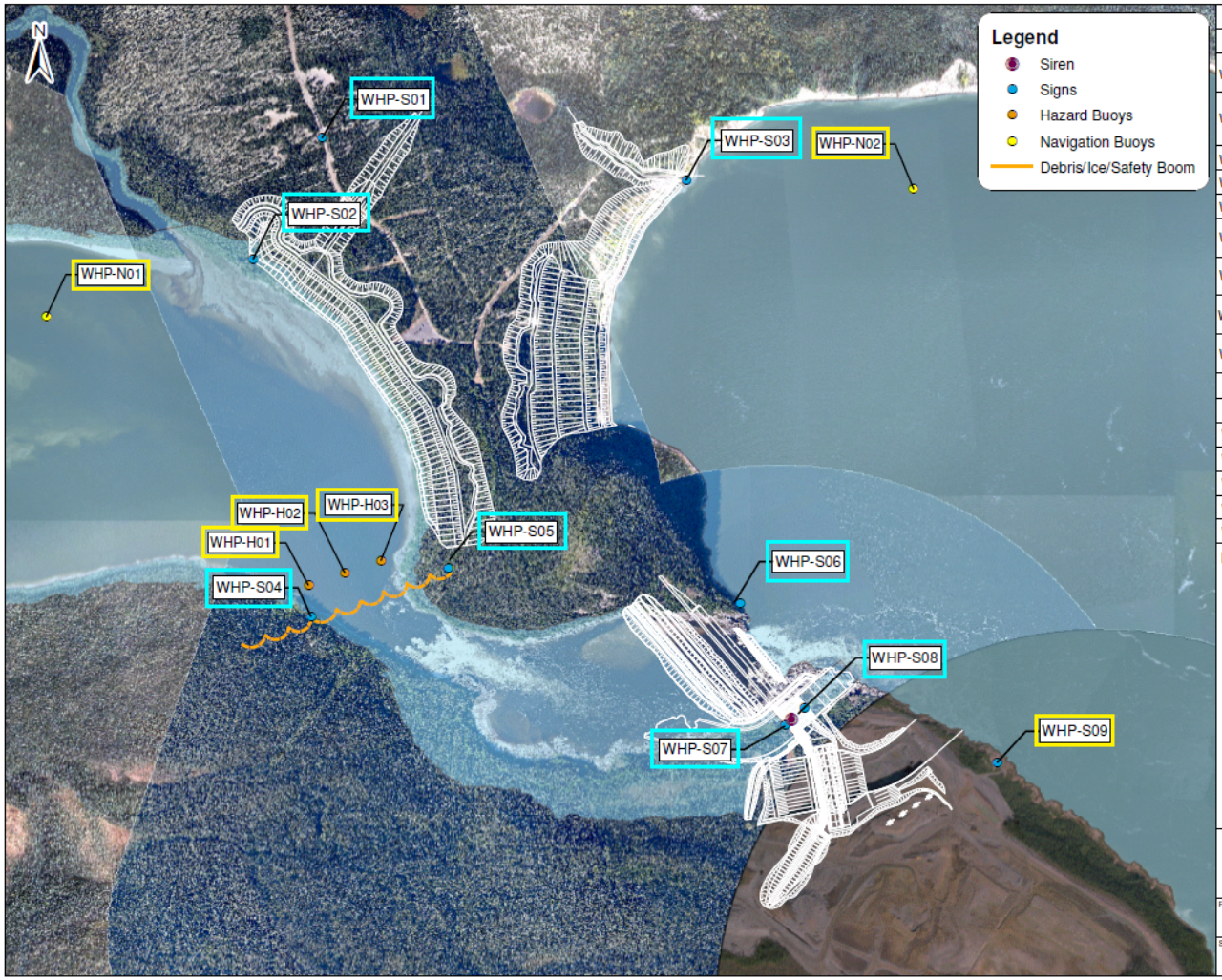
- Period leading up to the impoundment of the reservoir to winter headpond level and while headpond held at el. 25 m
- All recommended winter headpond stage infrastructure installed

Table 2-1: Summary of Infrastructure – Winter Headpond Construction Phase

Component	Type	Qty	Size	Installation
Upstream Waterway & Shorelines	Signage	2	8 ft x 16 ft	Complete
	Debris/Ice/Safety Boom	1	Approx. 660 m length	Complete
	Hazard Buoys	3	n/a	Seasonal
	Navigation Buoys	2	n/a	Seasonal
Portage Trail	Signage	2	4 ft x 8 ft	Spring 2018
North Spur Access Road	Signage	1	2 ft x 4 ft	Complete
Spillway Structure	Signage	2	7 panels – 4 ft x 8 ft	Complete
Downstream Waterway & Shorelines	Signage	2	4 ft x 8 ft	Complete

Details of public safety infrastructure

Winter headpond stage



PUBLIC SAFETY SIGNAGE

ID	Message	Size (ft)
WHP-S01	DANGER - No Trespassing, Authorized Personnel Only	2 x 4
WHP-S02	NOTIFY WORKER OF ARRIVAL STAY IN DESIGNATED AREA NALCOR NORTH SPUR SITE OFFICE #: 709-733-6547	4 x 8
WHP-S03	See sign WHP-S02	4 x 8
WHP-S04	DANGER - Dam Ahead, Keep Away	8 x 16
WHP-S05	DANGER - Dam Ahead, Keep Away	8 x 16
WHP-S06	DANGER - Slippery Rocks, Keep Away, Rapid Changes in Water Level and Flow	4 x 8
WHP-S07	DANGER - Keep Away	4 x 8 (7 Panels)
WHP-S08	DANGER - Keep Away	4 x 8 (7 Panels)
WHP-S09	DANGER - Slippery Rocks, Keep Away, Rapid Changes in Water Level and Flow	4 x 8

HAZARD / NAVIGATION BUOYS

ID	Message	Features
WHP-H01	BOOM	Yellow Flashing Light
WHP-H02	BOOM	Yellow Flashing Light
WHP-H03	BOOM	Yellow Flashing Light
WHP-N01	PORTAGE	n/a
WHP-N02	PORTAGE	n/a

NOTES

1. COORDINATE SYSTEM UTM ZONE 20 NORTH AMERICAN DATUM 1983.
2. LCP ORTHOPHOTO IMAGERY AS BASEMAP.
3. SIGNS WHP-S03, S04, & S05 WILL BE RELOCATED ABOVE WATER LINE WHEN REQUIRED.

0 200 400 600
Meters

MUSKRAT FALLS PUBLIC SAFETY PLAN
WINTER HEADPOND STAGE
PUBLIC SAFETY INFRASTRUCTURE

FIGURE NO. A-1
SCALE 1:10,000

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LOWER CHURCHILL PROJECT

The ice/safety/debris boom

Winter headpond stage

- Installed October 2017
- Permanent structure located 1.2 km U/S of the Spillway
- 12 spans of highly visible yellow steel pontoons
- Extension for full supply phase completed
- Promote formation of stable ice cover
- Visual safety warning to public users on the river
- Self-rescue mechanism

Public safety infrastructure
Full supply stage

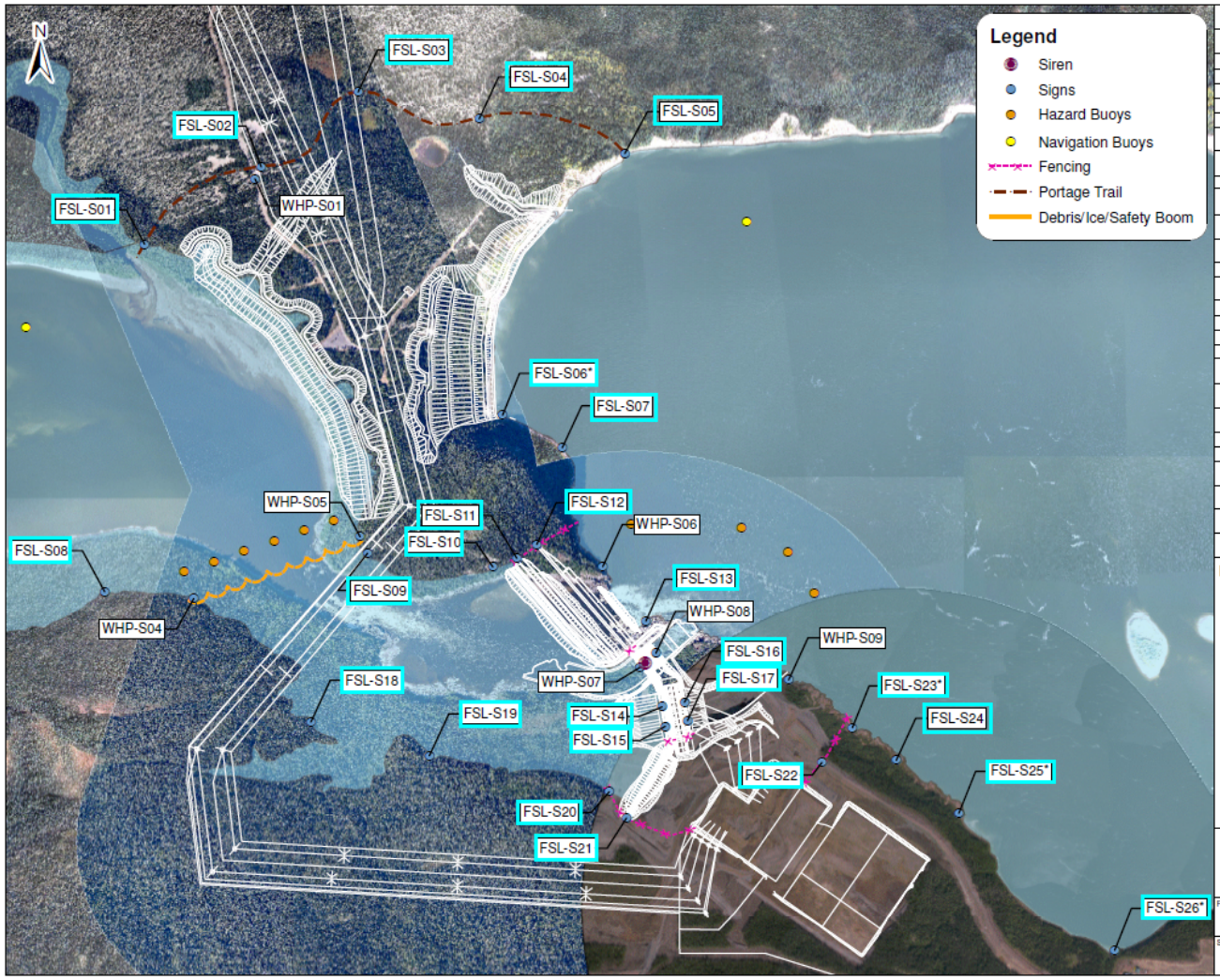
- Period from el. 25 m to the impoundment of the reservoir to Full Supply Level at el 39 m and subsequent
- Installation dates for this infrastructure is planned for Spring 2019

Table 2-2: Summary of Infrastructure – Fully Supply Construction Phase

Component	Type	Qty	Size	Installation
Upstream Waterway & Shorelines	Signage	6	4 ft x 8 ft	To be determined
	Signage	3	8 ft x 16 ft	To be determined
	Fencing	450 m	8 ft high	To be determined
	Vehicle Gate	1	8 ft high	To be determined
	Hazard Buoys	6	n/a	To be determined
	Navigation Buoys	2	n/a	To be determined
Portage Trail	Signage	2	4 ft x 6 ft	To be determined
	Signage	3	2 ft x 3 ft	To be determined
Spillway, Powerhouse, & Dam Structures	Signage	4	4 ft x 8 ft	To be determined
	Signage	3	2 ft x 4 ft	To be determined
	Gate & Fencing	3	8 ft high	To be determined
Downstream Waterway & Shorelines	Signage	2	8 ft x 16 ft	To be determined
	Signage	2	4 ft x 8 ft	To be determined
	Fencing	250 m	8 ft high	To be determined
	Vehicle Gate	1	8 ft high	To be determined

Details of public safety infrastructure

Full supply stage



PUBLIC SAFETY SIGNAGE

ID	Message	Size (ft)
FSL-S01	PORTAGE	4 x 6
FSL-S02	PORTAGE	2 x 3
FSL-S03	PORTAGE	2 x 3
FSL-S04	PORTAGE	2 x 3
FSL-S05	PORTAGE	4 x 6
FSL-S06*	DANGER - Slippery Rocks, Keep Away, Rapid Changes in Water Level and Flow	4 x 8
FSL-S07	WARNING - Dam Ahead, Water Levels and Flow May Change Rapidly	8 x 16
FSL-S08	PORTAGE - Keep to North Shore (Left Shore)	8 x 16
FSL-S09	DANGER - Keep Away, Dangerous Footing, Steep Slopes	4 x 8
FSL-S10	DANGER - Keep Away, Dangerous Footing, Steep Slopes	4 x 8
FSL-S11	DANGER - Dam Ahead - Keep Out, Strong Currents and Undertow	4 x 8
FSL-S12	DANGER - No Trespassing	2 x 4
FSL-S13	DANGER - Slippery Rocks, Keep Away, Rapid Changes in Water Level and Flow	4 x 8
FSL-S14	DANGER - Keep Away	4 x 8
FSL-S15	DANGER - Keep Away	4 x 8
FSL-S16	DANGER - Keep Away	4 x 8
FSL-S17	DANGER - Keep Away	4 x 8
FSL-S18	DANGER - Keep Away, Dangerous Footing, Steep Slopes	4 x 8
FSL-S19	DANGER - Keep Away, Dangerous Footing, Steep Slopes	4 x 8
FSL-S20	DANGER - Dam Ahead - Keep Out, Strong Currents and Undertow	4 x 8
FSL-S21	DANGER - No Trespassing	2 x 4
FSL-S22	DANGER - No Trespassing	2 x 4
FSL-S23*	DANGER - Slippery Rocks, Keep Away, Rapid Changes in Water Level and Flow	4 x 8
FSL-S24	WARNING - Dam Ahead, Water Levels and Flow May Change Rapidly	8 x 16
FSL-S25*	DANGER - Slippery Rocks, Keep Away, Rapid Changes in Water Level and Flow	4 x 8
FSL-S26*	DANGER - Slippery Rocks, Keep Away, Rapid Changes in Water Level and Flow	4 x 8

NOTES

1. COORDINATE SYSTEM UTM ZONE 20 NORTH AMERICAN DATUM 1983.
2. LCP ORTHOPHOTO IMAGERY AS BASEMAP.
3. SIGNS DENOTED WITH AN ASTERIX (*) ARE POTENTIAL FUTURE IMPLEMENTS BASED ON OBSERVED PUBLIC INTERACTION.

0 200 400 600
Meters

MUSKRAT FALLS PUBLIC SAFETY PLAN
FULL SUPPLY STAGE
PUBLIC SAFETY SIGNAGE

FIGURE NO. A-2
SCALE 1:12,000

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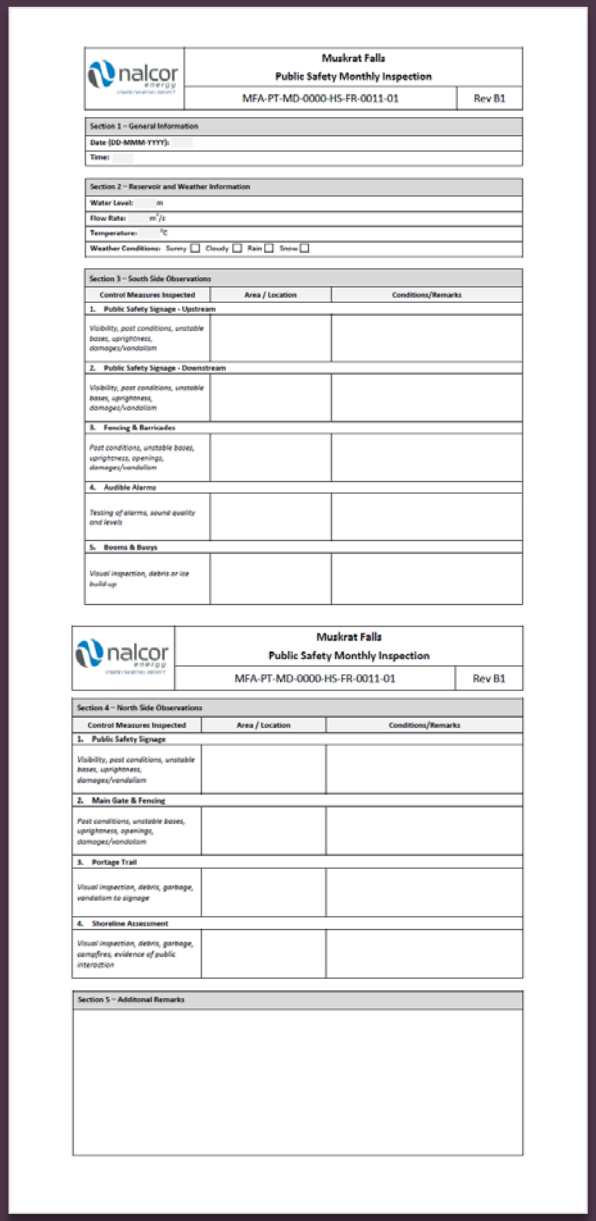
LOWER CHURCHILL PROJECT

HATCH

Typical signage
Winter headpond and full supply stages



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Muskrat Falls
Public Safety Monthly Inspection

MFA-PT-MD-0000-HS-FR-0011-01 | Rev B1

Section 1 – General Information

Date (DD-MMM-YYYY):
Time:

Section 2 – Reservoir and Weather Information

Water Level: m
Flow Rate: m^3/s
Temperature: °C
Weather Conditions: Sunny ☐ Cloudy ☐ Rain ☐ Snow ☐

Section 3 – South Side Observations

Control Measures Inspected	Area / Location	Conditions/Remarks
1. Public Safety Signage - Upstream		
Visibility, post conditions, unstable bases, uprightness, damages/vandalism		
2. Public Safety Signage - Downstream		
Visibility, post conditions, unstable bases, uprightness, damages/vandalism		
3. Fencing & Barricades		
Post conditions, unstable bases, uprightness, openings, damages/vandalism		
4. Audible Alarms		
Testing of alarms, sound quality and levels		
5. Booms & Buoys		
Visual inspection, debris or ice build-up		

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Muskrat Falls
Public Safety Monthly Inspection

MFA-PT-MD-0000-HS-FR-0011-01 | Rev B1

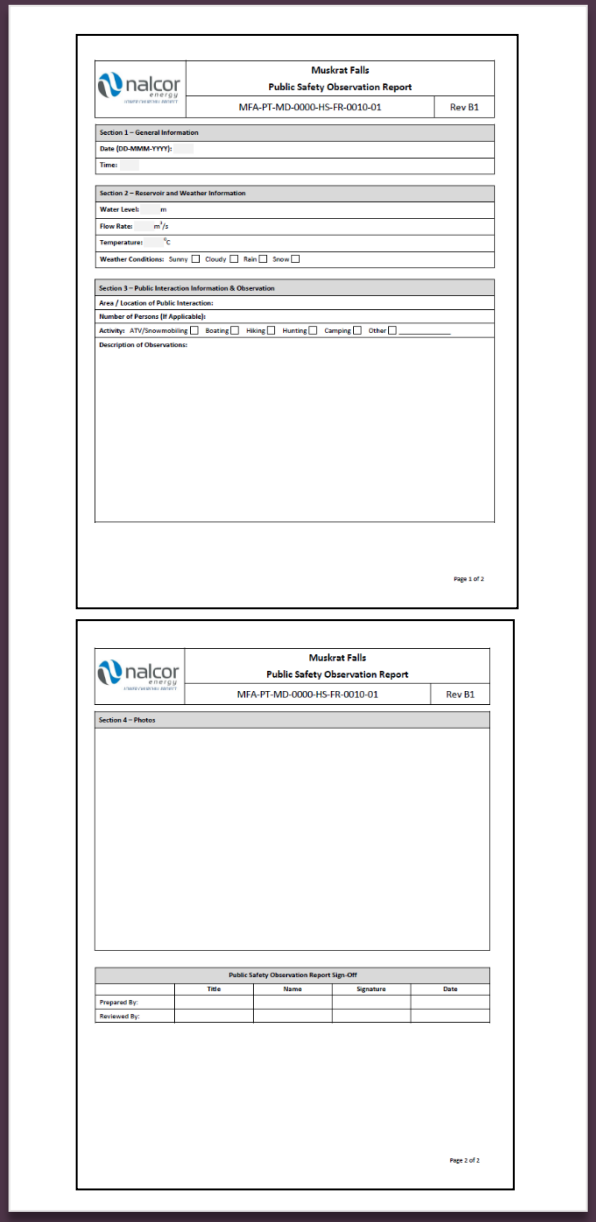
Section 4 – North Side Observations

Control Measures Inspected	Area / Location	Conditions/Remarks
1. Public Safety Signage		
Visibility, post conditions, unstable bases, uprightness, damages/vandalism		
2. Main Gate & Fencing		
Post conditions, unstable bases, uprightness, openings, damages/vandalism		
3. Portage Trail		
Visual inspection, debris, garbage, vandalism to signage		
4. Shoreline Assessment		
Visual inspection, debris, garbage, campfires, evidence of public interaction		

Section 5 – Additonal Remarks

Public safety around dams monthly inspection program

- As of October 2017, a Muskrat Falls Monthly Public Safety Inspection Report is to be filled out each month
- Includes a checklist verifying the conditions of all Public Safety Infrastructure on site
- The North Spur infrastructure is inspected by the Dam Safety Engineer
- Remainder of site (south of the river) is inspected by the Spillway Technicians



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Muskrat Falls
Public Safety Observation Report
MFA-PT-MD-0000-HS-FR-0010-01 Rev B1

Section 1 – General Information
Date (DD-MMM-YYYY):
Time:

Section 2 – Reservoir and Weather Information
Water Level: m
Flow Rate: m^3/s
Temperature: °C
Weather Conditions: Sunny ☐ Cloudy ☐ Rain ☐ Snow ☐

Section 3 – Public Interaction Information & Observation
Area / Location of Public Interaction:
Number of Persons (If Applicable):
Activity: ATV/Snowmobiling ☐ Boating ☐ Hiking ☐ Hunting ☐ Camping ☐ Other ☐ _____
Description of Observations:

Page 1 of 2

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Muskrat Falls
Public Safety Observation Report
MFA-PT-MD-0000-HS-FR-0010-01 Rev B1

Section 4 – Photos

Public Safety Observation Report Sign-Off

	Title	Name	Signature	Date
Prepared By:				
Reviewed By:				

Page 2 of 2

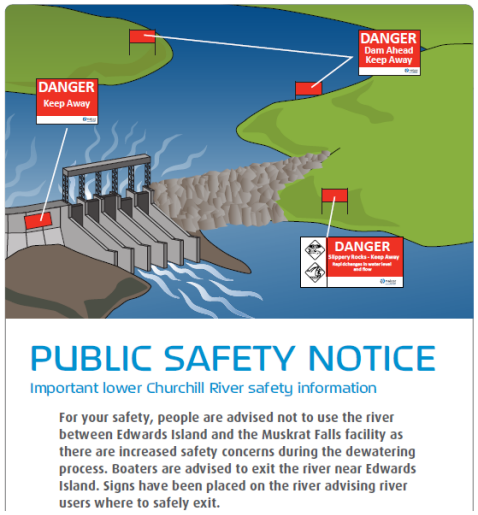
Public safety around dams observation report

- The Muskrat Falls Public Safety Observation Report is used to report observations or evidence of public interaction on/near the Muskrat Falls site
- Developed in October 2017
- Such interactions could include activities such as snowmobiling, boating, hiking, hunting, camping, etc.
- These reports are filled out on an as-needed basis

Public education

- Public informed of the potential dangers surrounding the Muskrat Falls Facility by means of a *River Safety Campaign that includes:*
  - Newspaper Postings
  - Community Posters
  - Social Media
  - Stakeholder Update Memos
  - Winter Public Notices

Public education



- Community Posters
  - Distributed in the Upper Lake Melville Area to advise the Public against boating and recreational activities on the Churchill River upstream of Muskrat Falls
- Project Stakeholder Updates
  - Safety messages have been included in stakeholder updates issued on June 12, June 22 and July 7, 2017
  - Updates issued as required
- Social Media
  - Public notices posted through platforms such as Facebook and Twitter

Public education

Winter safety notices

PUBLIC SAFETY NOTICE

Be safe around hydroelectric facilities this winter

At Nalcor Energy, the safety of the public, our employees and contractors is our number one priority.

We remind the public to use caution when taking part in outdoor winter recreational activities around the Muskrat Falls hydroelectric facilities.

Nalcor advises people to avoid the ice and river upstream and immediately downstream of these facilities as the ice cover may be unsafe for recreational use due to fluctuating water flows and changing ice conditions.

It's important to always be aware of your surroundings and exercise caution at all times.

For more information, please contact us:

1.888.576.5454
lowerchurchillproject@nalcorenergy.com

Twitter: @nalcorenergy
Facebook: facebook.com/nalcorenergy

nalcor energy
LOWER CHURCHILL PROJECT

PUBLIC SAFETY NOTICE

Be safe when taking part in outdoor winter activities

At Nalcor Energy, the safety of the public, our employees and contractors is our number one priority.

We remind the public to use caution when taking part in outdoor winter recreational activities. For your safety, please avoid the river and reservoir near the Muskrat Falls generating facility where fluctuating water levels and currents may result in unstable ice conditions.

As part of the Muskrat Falls Project, construction activities are also ongoing on the transmission lines being constructed throughout the province. It's important to be aware of your surroundings and to exercise caution at all times.

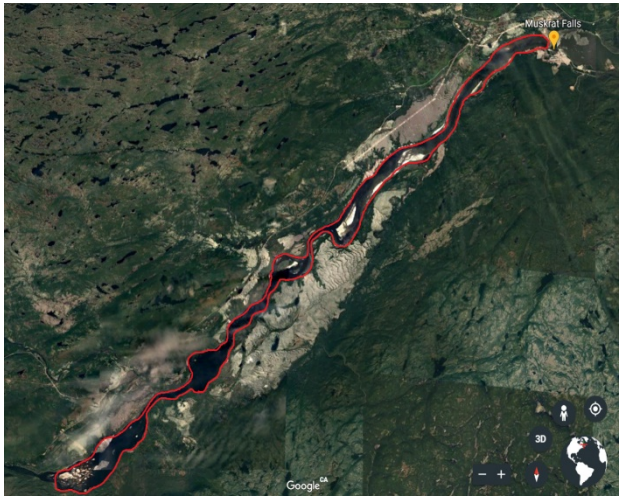
For more information, please contact us:

1.888.576.5454
lowerchurchillproject@nalcorenergy.com

Twitter: @nalcorenergy
Facebook: facebook.com/nalcorenergy

nalcor energy
LOWER CHURCHILL PROJECT

2016-2017 Augmented public safety efforts



- Additional Signage
  - In addition to infrastructure outlined in the Public Safety Plan, LCP installed Public Safety signage upstream at Edward's Island, Gull Island and Churchill Falls
- River Security Watch
  - Prior to the boom installation, a security person was present at the Astaldi Water Intake (approx. 2 km U/S of Spillway) to monitor for boaters
- Reservoir Rim Surveys
  - Visual surveys of the reservoir completed from helicopter from the Muskrat Falls site to Gull Island
  - Began in July 2017 performed regularly
  - Includes assessment of erosion or landslides that could be hazardous to river users or impact the MF site
  - Notes and photos are compiled and recorded into a Reservoir Rim Survey Report

Public safety around dams

- Safety procedures and practices observed in accordance with good industry practice

Outstanding discussions from Audit #2

Requirement for additional 3-D modelling of the North Spur

A 3D Hydrogeological model developed for the project in October 2015 that was designed to;

- Estimate the behaviour of the Intermediate and the Lower Aquifer in response impounding to el 25 and 39 m
- Assess the need to install relief wells

Due to the fact that;

- Pump wells will remain in operation at least until handover;
- an observational approach including daily monitoring has been implemented to assess the behaviour of the North Spur and
- the response of the North Spur has been in accordance with expectations

Additional Modelling is not considered to be required at least until after the headpond reaches full supply

Requirement to undertake Probable Failure Modes Assessment

- CDA Principle 5c:
  - Failure modes, sequences and combinations shall be identified for the dam
- Failure modes and risk assessments have been performed during the course of design and preparation for construction that effectively satisfies this principle. This has included:
  - Internal review of design concepts, materials properties and calculation methods
  - Independent expert panel
  - Maintenance of a risk register
  - Specific studies on critical subjects including:
    - Potential for rock erodibility
    - Assessment of seismic impacts including site specific seismic risk analysis
    - Stability analyses
    - Dam break analysis

Review of Behavior of Structures to Impounding to el. 22.5 m

Response of water retaining structures to impounding to el. 22.5 m

Structure	# of seeps	Total estimated seepage (L/min)
RCC Cofferdam	none visible	NA
separation wall	2	6 to 8
Downstream cofferdam	1	Minor (included in US cofferdam seepage)
Intake Cofferdam	none visible	NA
Powerhouse	none visible	NA
Spillway	none visible	NA
Tailrace cofferdam	none visible	NA

- Upstream/downstream *cofferdams*
  - Leakage remains steady at 100 to 150 L/sec
    - in line with what would be expected for a cofferdam of this type
    - for a similar cofferdam at the Keeyask GS seepage in the order of 1000 L/sec recorded
  - Seepage now reduced to 2 locations
- Other structures show very little seepage
  - Not all structures impounding water
- Leakage at North Spur has remained steady, no material response to impounding to el. 22.5 m

Overall Dam Safety Management Audit

CDA Guiding Principles

Principle 1 – Dam Safety Management

Principle	Description	Compliance
1	Dam Safety Management	Generally Compliant – Document defining responsibilities
1a	The public and the environment shall be protected from the effects of dam failure, as well as release of any or all of the retained fluids behind a dam, such that the risks are kept as low as reasonably practicable	**Compliant** Inundation mapping, monitoring , trained personnel, adequate instrumentation
1b	The standard of care to be exercised in the management of dam safety shall be commensurate with the consequences of dam failure	**Compliant** Cofferdam designed in accordance with requirements for a temporary structure, consequences known. EPP in place. Gates have sirens in the event of gate opening. Emergency preparedness plan (Level 2) has been exercised
1c	Due diligence shall be exercised at all stages of a dam's life cycle	**Compliant** Current plans meet and exceed good industry practice
1d	A dam safety management system, incorporating policies, responsibilities, plans and procedures, documentation, training, and review and correction of deficiencies and non-conformances, shall be in place	**Compliant** Previously identified issues corrected

CDA Guiding Principles

Principle 2 – Operation, Maintenance, and Surveillance

Principle	Description	Compliance
2	Operation, Maintenance, and Surveillance	Compliant
2a	Requirements for the safe operation, maintenance, and surveillance of the dam shall be developed and documented with sufficient information in accordance with the impacts of operation and the consequences of dam failure	**Compliant** Plans, instrumentation, and monitoring exceed good industry practice
2b	Documented operating procedures for the dam and flow control equipment under normal, unusual, and emergency conditions shall be followed	**Compliant** Vista used as inflow modeling system, unusual conditions covered in OMS manual. Manual as reviewed is compliant
2c	Documented maintenance procedures shall be followed to ensure that the dam remains in a safe and operational condition	**Compliant** Plan in place and training that meets or exceeds good industry practice
2d	Documented surveillance procedures shall be followed to provide early identification and to allow for timely mitigation of conditions that might affect dam safety	**Compliant** Surveillance procedures well documented and extensive monitoring in place. Monitoring plan reviewed and updated during audit

CDA Guiding Principles

Principle 3 – Emergency Preparedness

Principle	Description	Compliance
3	Emergency Preparedness	Generally Compliant - training and engagement of stakeholders to be completed and documented
3a	An effective emergency management process shall be in place for the dam	**Compliant** Documentation and procedures in line with good industry practice
3b	The emergency management process shall include emergency response procedures to guide the dam operator and site staff through the process of responding to an emergency at a dam	**Compliant** Communications protocol in place, Emergency Preparedness and response Plans in place in accordance with good industry practice
3c	The emergency management process shall ensure that effective emergency preparedness procedures are in place for use by external response agencies with responsibilities for public safety within the floodplain	**Compliant** Previously identified issues with consultation with stakeholders and RCMP completed and documented Internal table top exercises completed Planning for external table top exercise underway
3d	The emergency management process shall ensure that adequate staff training, plan testing, and plan updating are carried out	**Compliant** Nalcor training documentation completed

CDA Guiding Principles
Principle 4 – Dam Safety Review

Principle	Description	Compliance
4	Dam Safety Review	Compliant
4a	A safety review of the dam ("Dam Safety Review") shall be carried out periodically	**Compliant** Daily inspection, assessment and review performed. Weekly comprehensive inspections to be enacted. Comprehensive Dam Safety inspection every two months. Dedicated dam safety engineer is at site. Third party dam safety audit being performed. Consequence classifications based on CDA. Classification appropriate and selected dam safety parameters compliant.
4b	A qualified registered professional engineer shall be responsible for the technical content, findings, and recommendations of the Dam Safety Review and report	**Compliant** Well trained, experienced dam safety personnel

CDA Guiding Principles
Principle 5 – Analysis and Assessment

Principle	Description	Compliance
5	Analysis and Assessment	Generally Compliant – check if piping hazard has been assessed
5a	The dam system and components under analysis shall be defined	**Compliant** All components of the system defined with inspection and surveillance procedures identified
5b	Hazards external and internal to the dam shall be defined	**Compliant** This has been done in the OMS manual and in the Risk Register
5c	Failure modes, sequences, and combinations shall be identified for the dam	**Compliant** All hazards have been assessed as part of the final design (flood, earthquake, seismic, ice loads. piping). Landslide hazard assessment completed. PFMA recommendation effectively satisfied
5d	The dam shall safely retain the reservoir and any stored solids, and it shall pass flows as required for all applicable loading conditions	**Compliant** Adequate discharge capacity, redundant capacity for almost all phases except for period in which two rollways are under construction where capacity exists but redundancy does not Gates are exercised several times daily to maintain specified impounding levels

Actions & items for discussion

- Additional information to review for next trip
  - Plan to obtain continuous flow measurements at the Kettle Lake outlet weir
  - Documentation of external table top exercise
- Action Plan
  - Continuous improvement
  - Continue monitoring, analysis and reporting

Selected Site Photographs November 29, 2017

The Powerhouse and Spillway

November 2017

MFA-HE-CD-2000-EN-RP-0002-02

May 2017, Rev. A1

Thank you

For more information,
please visit www.hatch.com