Muskrat Falls Generation

Independent Dam Safety Program Audit

Audit #2 April 16-20, 2017

MFA-HE-CD-2000-EN-RP-0003-01
August 2017, Rev. B1

HATCH


Take a
MOMENT
for Safety

Executive Summary

- A dam safety audit of the Dam Safety Management Plan in place at the Muskrat Falls Construction Site was performed between April 16 and April 20, 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, a review of the cofferdam remedial program and a review of the response of the Upstream cofferdam and North Spur to the effects of impounding
- The results of the audit indicate that;
  - the dam safety management program at the site meets and 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;
  - 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;
  - the upstream cofferdam remedial works program was effective. The response of the Upstream Cofferdam and North Spur were in accordance with the design expectations;
  - there are areas of improvement suggested in this report that may further enhance the existing program.

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	Well documented, dam break assessments performed, actual level 2 emergency response performed
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
Upstream Cofferdam Remedial Program	Meets good industry practice	• Cofferdam instrumentation, monitoring and inspections sufficient to minimize risks • Remedial work proved to be effective • Upstream cofferdam now in equilibrium approaching steady seepage conditions
Impoundment preparedness and monitoring – Cofferdams	Exceeds good industry practice	• Number, quality of instruments and surveillance frequency exceeds typical good industry practice
Impoundment preparedness and monitoring – North Spur	Exceeds good industry practice	• Number, quality of instruments and surveillance frequency exceeds 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 with following principals of continuous improvement
Dam Safety Management Program	Meets good industry practice	• Compliant or generally compliant with all CDA dam safety guiding principles

Executive Summary

ES-2 Areas for Improvement

Item	Remarks
Organization	**Fully Compliant** a dedicated dam safety engineer is on site
Inspection and reporting	**Fully Compliant** Implement plan to add photographs to pronto sheets
Training	**Fully Compliant**
Emergency preparedness	**Minor Deficiency** Verify readiness of all third party stakeholders
Operations, Maintenance and Surveillance	**Minor Deficiency** Dam safety personnel roles and responsibilities completed, add to the OMS manual
Upstream Cofferdam Remedial Program	**Fully Compliant** Remediation complete and effective at least to el. 22.5 m
Impoundment monitoring – Cofferdams	**Fully Compliant**

Executive Summary

ES-2 Areas for Improvement

Item	Remarks
Impoundment monitoring – North Spur	**Fully Compliant** - Consider updating the 3D model when impounding commences - Plan to obtain continue seepage monitoring for the north spur to be implemented.
Inspection Frequency	**Fully Compliant** - Monitoring appropriately increased during impounding - Continuous reading data loggers installed
Dam Safety Management Program	**Fully Compliant** - Documentation of training implemented

Gaps

- No material gaps in the program that would constitute a dam safety problem were identified
- Issues that could be improved or clarified include:
  - Provide a mechanism for obtaining continuous seepage flow measurements at the Kettle Lake Outlet Weir year round
  - Consider undertaking a formal PFMA to better defined potential failure modes and remedial solutions

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 April 17 – 20, 2017
  - Provides 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
  - 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.
  - Currently developing 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 Eyes 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

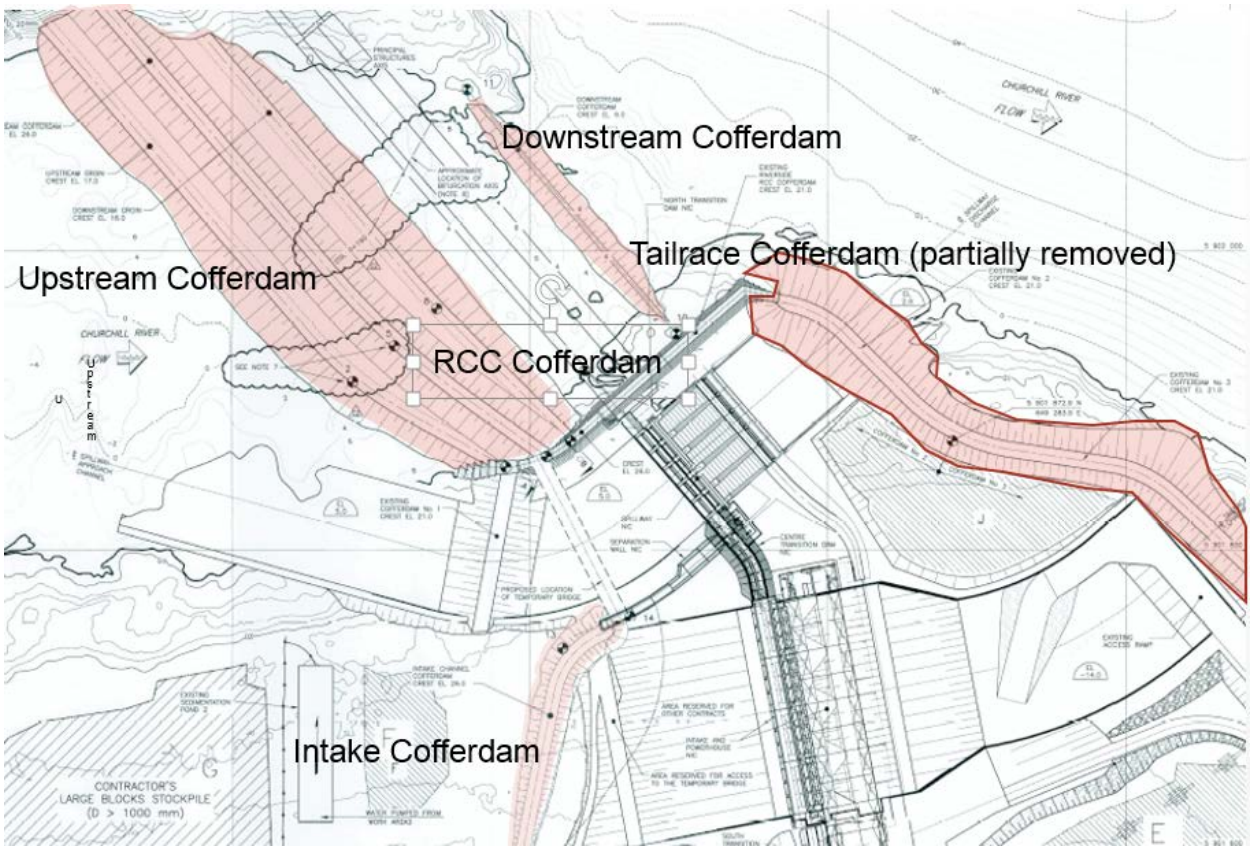
- This independent review involves an audit/assessment of all water retaining structures at the Muskrat Falls site
- Review includes
  - Audit of instrumentation
  - Monitoring
  - Surveillance
  - Operations and Maintenance
  - Emergency Preparedness
  - Public and worker safety
  - Review of cofferdam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

Scope of Work - Permanent Structures

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

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	Description	Current Status (20-Apr-2017)	Follow-up Action
Organization	Continue with plan to provide a dedicated dam safety engineer to the site	Complete – Full time dam safety engineer role filled in the interim by Simon Flurey. Hiring process in progress for permanent dedicated dam safety engineer.	
Inspection and reporting	Implement plan to install additional data loggers	Complete – Data loggers installed in Feb 2017. Fifteen data loggers installed in the Upstream Cofferdam, two piezometers in the Spillway, forty piezometers on the North Spur as well as six inclinometers. Seepage monitoring: - One weir at North Spur - Three seep locations monitored on the Upstream Cofferdam	Accelerometer to be installed on the North Dam on completion. Instrumentation for the North and south dam need to be finalized
Training	Documentation of training can be improved	Complete– Training session held at site (19-Apr-2017) and fully documented.	Quarterly updates or as required
Emergency preparedness	Document contractors procedures meet program requirements	Complete – Dams contractor Emergency Action Plan reviewed and meets requirements.	
	Verify readiness of all third party stakeholders	In progress – Table top exercise planning for HVGB Emergency Response underway. Update with RCMP and FES-NL planned. -	- Document correspondence. - Inundation studies (natural events). - River watch website

Status of suggested improvements (con't)

Item	Description	Current Status (20-Apr-2017)	Follow-up Action
Operations, Maintenance and Surveillance	Add dam safety personnel roles and responsibilities	In progress – Section drafted. OMS Manual content being transferred to LCP report template. Plan to include in OMS Manual by mid May.	To be reviewed by auditor and included in manual
Impoundment preparedness and monitoring – Cofferdams	Update alarm levels based on collected data and in line with EPP alert levels	Complete – Cofferdam monitoring protocol most recently updated in April 2017.	To be included in Weekly Report
Impoundment preparedness and monitoring – North Spur	Update alarm levels based on collected data and in line with EPP alert levels	Complete - Alarm levels updated.	
	Consider updating the 3D model when first stage of impounding complete	Information gathered during impounding should be used to calibrate the model	To be completed
	Documentation of the rational for not undertaking data readings at the Kettle Lake Outlet Weir during the winter is missing	Complete – documented in frequency table	

Summary of Suggested Improvements

Item	Description	Current Status (20-Apr-2017)	Follow-up Action
Inspection Frequency	Continue with plan to increase monitoring frequency during impounding Install continuous reading data loggers as planned	Complete – Inspection frequency increased during impoundment to el. 22.5 m revised with stabilization of cofferdam. Complete – Data loggers installed in Feb 2017.	Review of instrumentation monitoring post impoundment completed
Dam Safety Management Program	Documentation of training could be improved	Complete – Training provided during audit, fully documented using an attendance sheet.	Training session held at site, fully documented

Suggested Reporting Enhancements

Description	Current Status (20-Apr-2017)	Follow-up Action
Ensure that photos are taken from the same point each time.	Complete	Dam Safety Engineer to take responsibility for review weekly
Add plan showing the location of photo points to the inspection form.	Complete	To be included in Pronto Form (take a picture of sketch).
Indicate on form under remarks where other photos have been taken and why	Complete	See follow up action above.
In some cases specific comments on seepage missing.	Complete – all observed seepage documented	
Add in specific comments on form regarding abutment contact condition, (wetness, seepage, not observed etc.)	Complete – all observed seepage documented	
Headpond/tailpond levels at the time of the visit should be noted.	Complete – information noted on engineering inspection reports (2 per day)	Request to Pronto Form developers made to fully comply Waiting on action (24-Apr-2017)

Potential Reporting Enhancements

Description	Current Status (20-Apr-2017)	Follow-up Action
Weekly comprehensive inspection reports	Complete	Draft reviewed by auditor. Inspection frequency and alert levels to be added. To be finalized and submitted via Aconex.
Monthly evaluation reports	To be developed going forward	To be completed prior to next audit. Dam Safety Engineer to compile once format is developed.
Piezometer P291 not responding; consider replacement	Repaired	
Revise inundation mapping to improve contrast between flood and dam break inundation.	Complete	

Potential EPP Enhancements

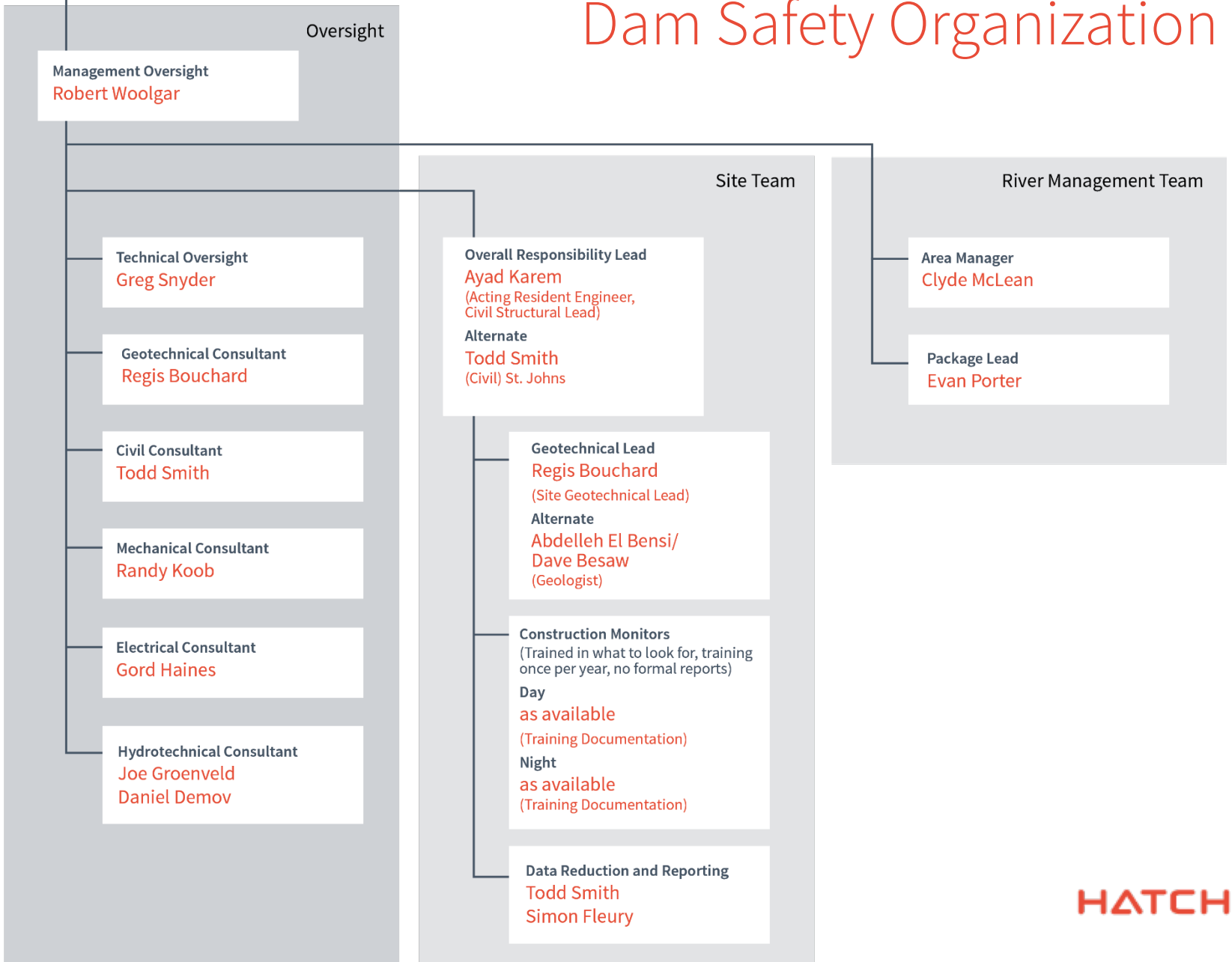
Description	Current Status (20-Apr-2017)	Follow-up Action
Highlight the possibility for immediate action by resident engineer/contractor in the event of an emergency situation	Complete	

Principle 5 – Analysis and Assessment

Principle	Description	Current Status (20-Apr-2017)	Follow-up Action
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, piping, earthquake, seismic, ice loads). Landslide hazard assessment completed.	- A PMFA. Is suggested

Organization

Dam Safety Organization



Comments on Organization

- Oversight team highly experienced. Data provided daily on cofferdam behavior
- Site team is well trained with appropriate experience
  - Experience in James Bay and other similar projects
- Data reduction and reporting appropriate and timely
- Advice provided during the previous audit to engage a Dam Safety Engineer being implemented
- During impounding expert panel assembled and consulted weekly on the results of the monitoring and inspection program

Dam Safety Organization meets good industry practice

Reporting

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

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 previous 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.	In progress
Indicate on form under remarks where other photos have been taken and why	Implemented
In some cases specific comments on seepage missing. The comments might include seepage not observed, wet, flowing/, estimate of flow, number of pumps and size working.	Implemented
Add in specific comments on fill to abutment contact condition, (wetness, seepage, not observed etc..)	Implemented
Headpond/tailpond levels at the time of the visit should be noted	Implemented

Potential Enhancement - Other reports

- Monitoring and reporting practices are considered appropriate to identify any developing issues in a timely manner such that remedial action can be performed.
- In the previous audit two additional reports were suggested
  - Weekly comprehensive inspection
    - Should include summary of daily reports, seepage and piezometric data

    CURRENT STATUS - Implemented
  - Monthly evaluation reports
    - should include an assessment of all collected data what the data means and action

    CURRENT STATUS - Being implemented

Dam Safety Training

Training

- Dam safety training overview provided to site staff during the audit and was noted to be quite complete
  - Training presentation updated Muskrat examples as suggested during the previous audit
- 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.

Emergency Preparedness Planning – Impounding Phase

Assessment of Winter Head Pond Construction Phase Emergency Planning

- Advance preparations were completed 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

Emergency Plan (winter head pond construction phase)

- Reviewed the following 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, 22-July, 2014 .
  - Project-Wide Emergency Response Plan, LCP-PT-MD-0000-HS-PL-0004-01. Nalcor, 24-August 2016
- Emergency Preparedness Plan and Response Plan are current.
  - Should be updated by December 2017 and August 2017 respectively
- Viewed clean version of Inundation mapping as provided to stakeholders in Emergency Response Plan
  - Details are appropriate
- Response coordinated by Emergency Operations Center
  - The set-up is appropriate and in accordance with good industry practice
- Possibility for immediate action by resident engineer/contractor in the event of an emergency situation highlighted in response flowcharts as recommended during the previous audit

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

Operations Maintenance and Surveillance Program

Review of Operations, Maintenance and Surveillance Program and Practices

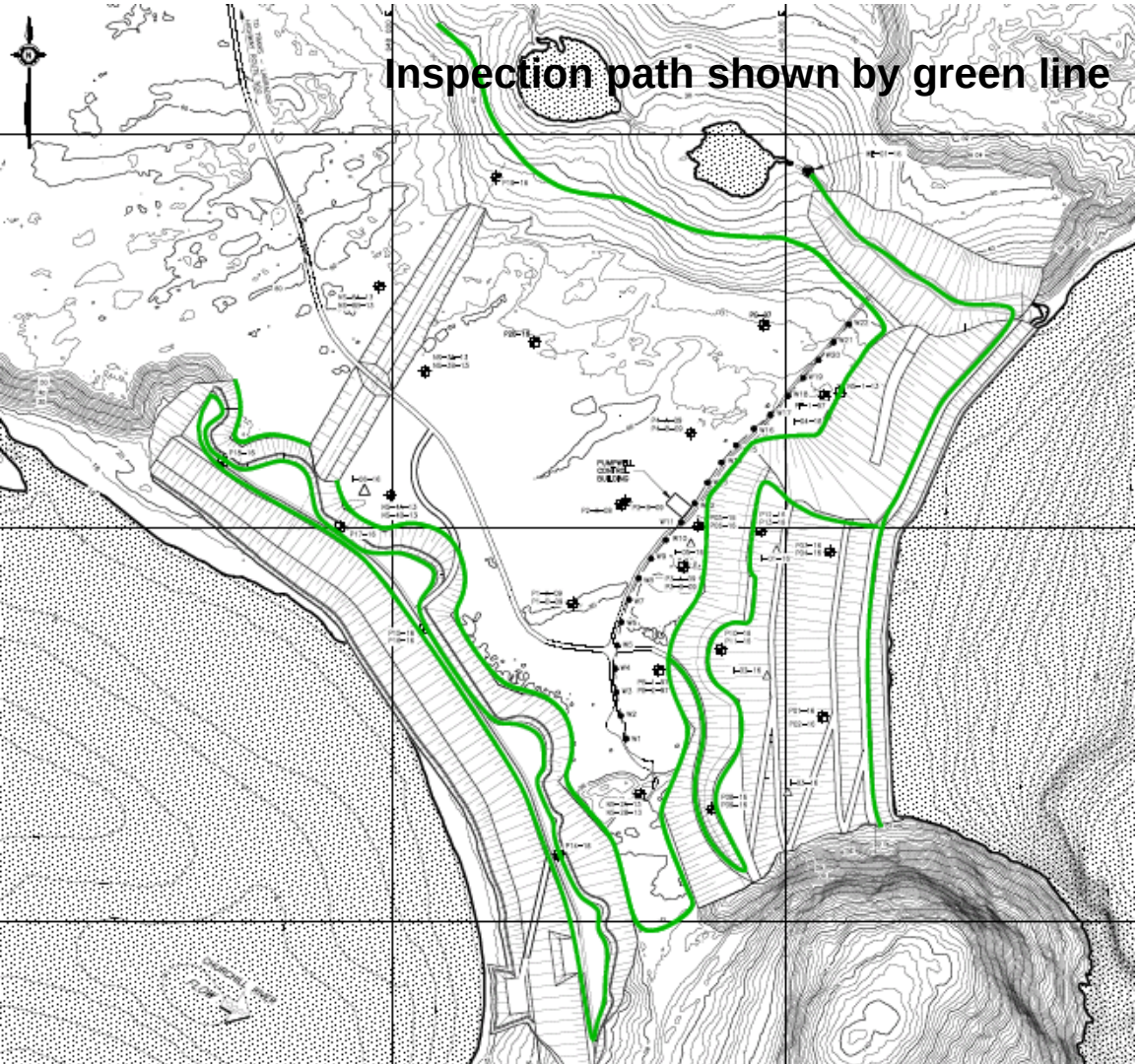
- Document complete and current
- Compliant with CDA guidelines
- Practices observed on site including inspection, reporting and flow control equipment operations to maintain and lower head pond levels met and exceed good industry practice
- Revised roles and responsibilities description prepared to include dam safety group
  - Approved but not yet included in the OMS Manual

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

North Spur Instrumentation and Impounding Planning

North Spur

General Arrangement and location of Instrumentation



- 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

The North Spur April 17, 2017

North Spur

Review of Pre-impoundment Plan

Piezometers	
In place and connected to ADAS (Automatic Data Acquisition System)	complete
LCP access to data available	complete
Remote access to data (from south side) finalized	complete
Inclinometer	
Baseline inclinometer readings established	complete
Kettle Lake Outlet Weir	
Data collection complete	Note 1
Visual Observation	
Inspection "Path“ developed for regular visual observation	complete
Photo points established.	complete
Instrumentation	
Spillway Operators read instruments as part of their routine	complete
Immediate transfer/copy for engineering to review/assess/action being performed	complete
Information issued in Aconex	complete

Note 1 Visual estimates of seepage performed.

Inspection Frequency Audit

Inspection Frequency Audit
(North Spur, Upstream Cofferdam and reservoir)

Site	Information	Action	Frequency	
			Before impoundment	During impoundment
North Spur	Ground water pressure piezometer	Download ADAS	1/week	1/day Note 3
	Inclinometer	Reading	Baseline	1/week
	Weir, seepage	Reading or visual	1/week note 2	1/day note 2
	Visual inspection	Walk Obs. Path	Once for Baseline	1/day
Reservoir	Visual inspection	Helicopter flight	Once for Baseline	1/week
	Middle pool level	Borehole WL (USCD)	Manual: 1/ day	Manual 2/day
	Downstream level	Borehole WL (DSCD)	Manual: 1/ day	Manual 2/day
	Reading	Download Diver	1/day	1/day
U/S Cofferdam	Visual inspection	Walk Obs. Path	1/day	2/day
	Seepage	Reading	1/day	12/day note 1
	Crest deformation	visual	note 3	note 3
	Berm deformation	Survey	1/day	1/day
	Piezometer	Reading	1/day	12/day note 1
	Reading	Download Diver	1/day	1/day

Note 1: Actual is 10 to 12 per day.

Note 2: Visual assessment only on a weekly basis. No change in seepage noted. Means to automate seepage measurements being planned

Note 3: Impounding of the North Spur has not commenced

Inspection Frequency Audit
(Other Structures)

Site	Information	Action	Frequency	
			Before impoundment	During impoundment
D/S Cofferdam	Visual inspection	Walk Obs. Path	1/day	2/day
	Seepage	Reading	1/day	12/day note 1
U/S Intake Cofferdam	Visual inspection	Walk Obs. Path	1/week	1/day
	Seepage	Observation	1/week	1/day
Tailrace Cofferdam	Visual inspection	Walk Obs. Path	1/week	1/day
	Seepage	Observation	1/week	1/day
RCC Cofferdam	Visual inspection	Walk Obs. Path	1/week	1/day
	Seepage	Observation	1/week	1/day
Separation Wall	Visual inspection	Walk Obs. Path	1/week	1/day
	Seepage	Observation	1/week	1/day
Spillway	Ground water pressure piezometer	Download ADAS	1/week	1/day
	Survey monument	Survey	Once for Baseline	1 at WL ele 18m
	Visual inspection	Observation points	1/day	1/day
Power House	Ground water pressure piezometer	Manual reading	Once for Baseline	1/day
Weather information	Temperature, Rain, Snow	From weather station	1/day	1/day

Current planned inspection frequencies

Site	Information	Action	During impoundment	Waterlevel at el 22.5 m After impoundment	Product	Number	Action to come
North Spur	Piezometer	Download ADAS	1/day	2/week	Graph	40	Continue to updated every day
	Inclinometer	Reading	1/ 2 weeks	1/2 weeks	Profile	6	Reduce once a month
	Weir, seepage	Reading or visual	1/day	1/week	Graph	1	Diver will be install and calibrated with Flow meter
	Visual inspection	Walk Obs. Path	1/week	1/week	Report	N/A	Continue once a week
Reservoir	Middle pool level	Reading and Diver download	Manual 10/day	Manual 10/day	Graph	1	Automatic reading will be set up 1st week of May
	Downstream level	Reading and Diver download	Manual 10/day (WL>5m)	N/A	Graph	1	Only applicable if downstream WL > el 5.0 m
	Dowstream level	Survey		1/week	Graph	N/A	Calibrate with downstream station
U/S Cofferdam	Visual inspection	Walk Obs. Path	2/day	1/day	Report		Continue once a day
	Seepage	Reading	10/day	2/day	Graph	1	with 2 Visual inspection between reading, Reduce 1/day
	Crest deformation	Survey	1/week	1/2 weeks	Graph	12	To be reduce once a month
	Berm deformation		N/A	N/A		0	No reading, stop after grouting
	Piezometer	Reading	2/day	2/week	Graph	12	Reduce to once a week for calibration
	Piezometer	Download	2/day	1/day	Graph	12	Reduce to once per week after freshet
D/S Cofferdam	Visual inspection	Walk Obs. Path	2/day	1/week	Report	N/A	Continue once a week
	Seepage	Observation	10/day	1/week	Description	N/A	Continue once a week
Intake Cofferdam	Visual inspection	Walk Obs. Path	1/day	1/week	Report	N/A	Continue once a week
	Seepage	Observation	1/day	1/week	Description	N/A	Continue once a week
Tailrace Cofferdam	Visual inspection	Walk Obs. Path	1/day	1/week	Report	N/A	Reduce to once a month
	Seepage	Observation	1/day	1/week	Description	N/A	Reduce to once a month
RCC Cofferdam	Visual inspection	Walk Obs. Path	1/day	1/week	Report	N/A	Continue once a week
	Seepage	Observation	1/day	1/week	Description	N/A	Continue once a week
Separation Wall and Transition Dam	Visual inspection	Walk Obs. Path	1/day	1/week	Report	N/A	Continue once a week
	Seepage	Observation	1/day	1/week	Description	N/A	Continue once a week
Spillway	Piezometer	Download ADAS	1/day	1/week	Graph	2	Continue once a week up to have automatic reading
	Survey monument	Survey	1 at WL ele 18m, 1 WL ele 22	N/A	Graph	5	At every increase in water level
	Visual inspection	Observation points	1/day	1/day	Report	N/A	Operators will continue once a day for operation purpose
Power House	Piezometer	Manual reading	2/week	1/2 weeks	Graph	2	Continue once every 2 weeks up to have automatic reading
	Visual inspection	Walk Obs. Path	1/day	1/2 weeks	Report	N/A	Reduce once a month after melt season
	Seepage	Reading	1/day	1/2 weeks	Description	0	Flow meter has to be installed and read every week at minimum

N/A: Not Applicable
This revision is for post impoundment to 22.5 m but before impound to 25 m.

Review of inspection frequencies

- The Independent Auditor considers the inspection frequencies during the period of impoundment at el. 22.5 m meet and exceed CDA guidelines for dam safety.

Overall Dam Safety Management Audit

Public Safety Around Dams

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.	**Generally Compliant** Correction of deficiencies performed as they are identified, plans and schedules in place, Training in monitoring and surveillance Minor deficiency – roles and responsibilities for dam safety personnel have been prepared but need to be included in the OMS Manual

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 operating system, unusual conditions covered in OMS manual. Manual reviewed as 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.	**Generally Compliant** Suggestion for improvement include; - Consultation with stakeholders and RCMP to be completed and verified.
3d	The emergency management process shall ensure that adequate staff training, plan testing, and plan updating are carried out.	**Compliant** Nalcor training needs documentation

CDA Guiding Principles
Principle 4 – Dam Safety Review

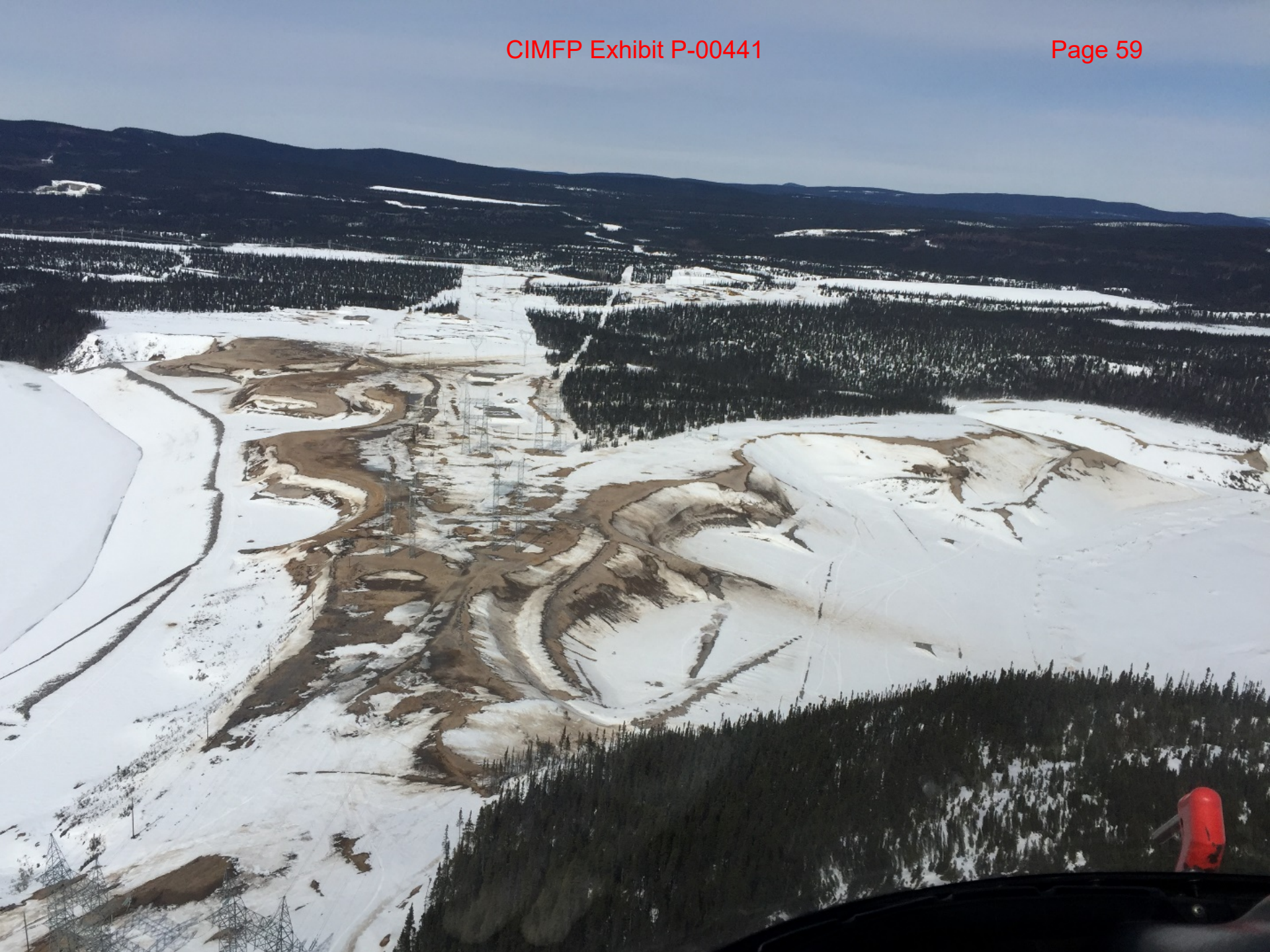
Principle	Description	Compliance
4	Dam Safety Review	Compliant
4a	A safety review of the dam ("Dam Safety Review") shall be carried out periodically.	**Compliant** Daily inspection, assessment and review performed. Weekly comprehensive inspections to be enacted. Comprehensive Dam Safety inspection every two months Dedicated dam safety engineer to be placed at site Third party dam safety audit being performed monthly 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** See above

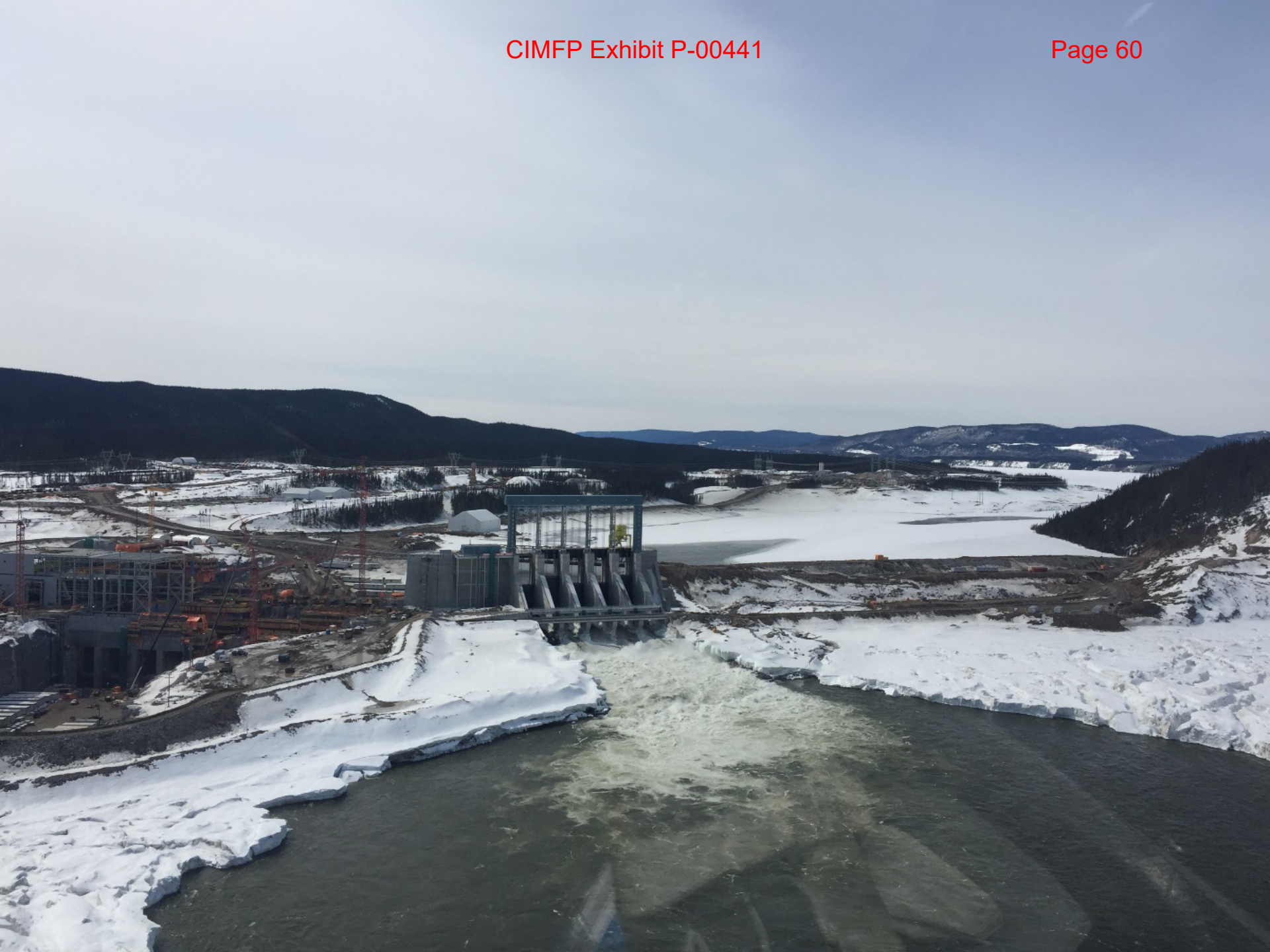
CDA Guiding Principles
Principle 5 – Analysis and Assessment

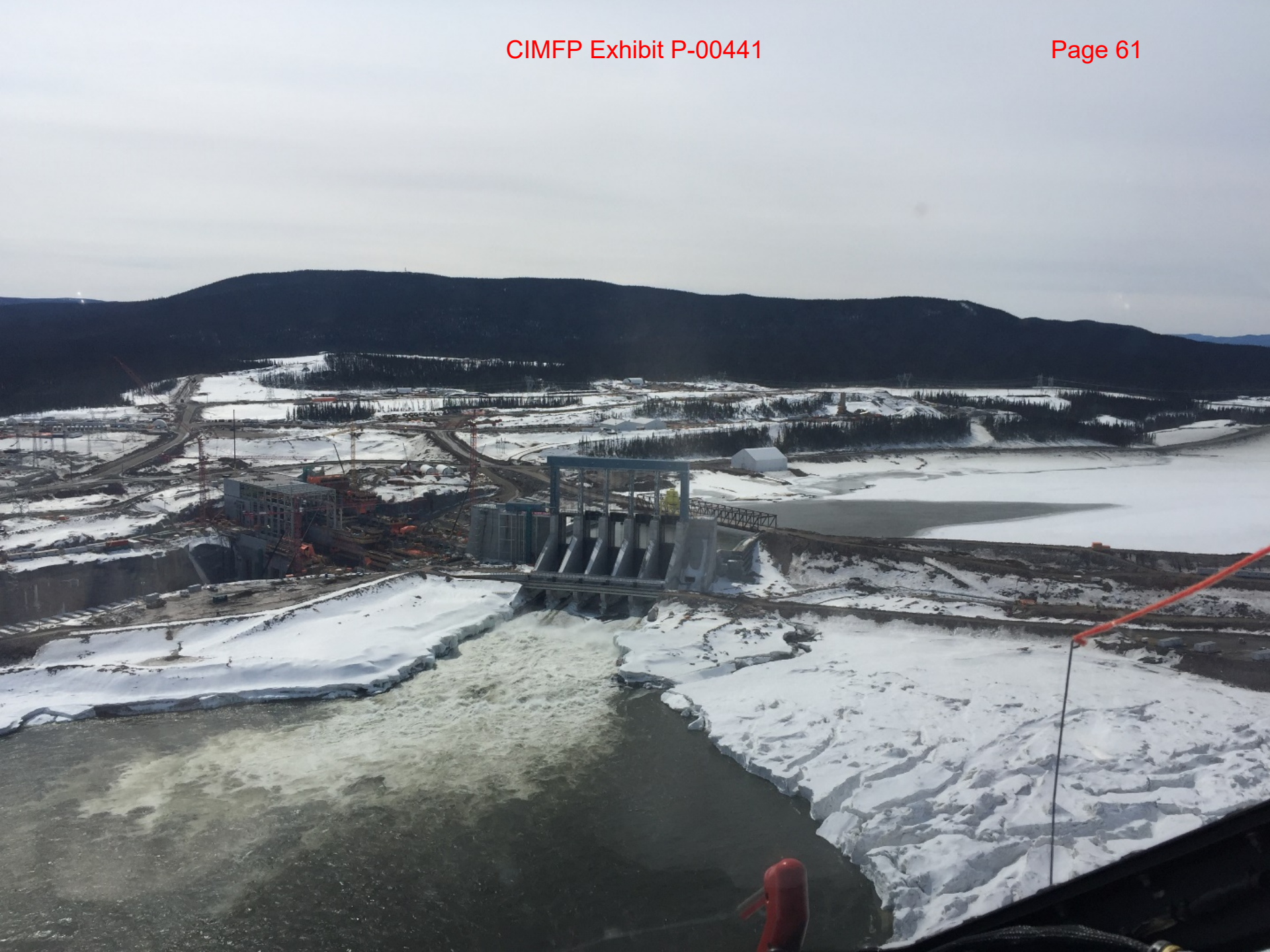
Principle	Description	Compliance
5	Analysis and Assessment	Generally Compliant – check if piping hazard has been assessed
5a	The dam system and components under analysis shall be defined	**Compliant** All components of the system defined with inspection and surveillance procedures identified
5b	Hazards external and internal to the dam shall be defined.	**Compliant** This has been done in the OMS manual and in the Risk Register. Piping failure mode requires additional thought
5c	Failure modes, sequences, and combinations shall be identified for the dam.	**Generally Compliant** All hazards have been assessed as part of the final design (flood, earthquake, seismic, ice loads. Landslide hazard assessment completed.
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

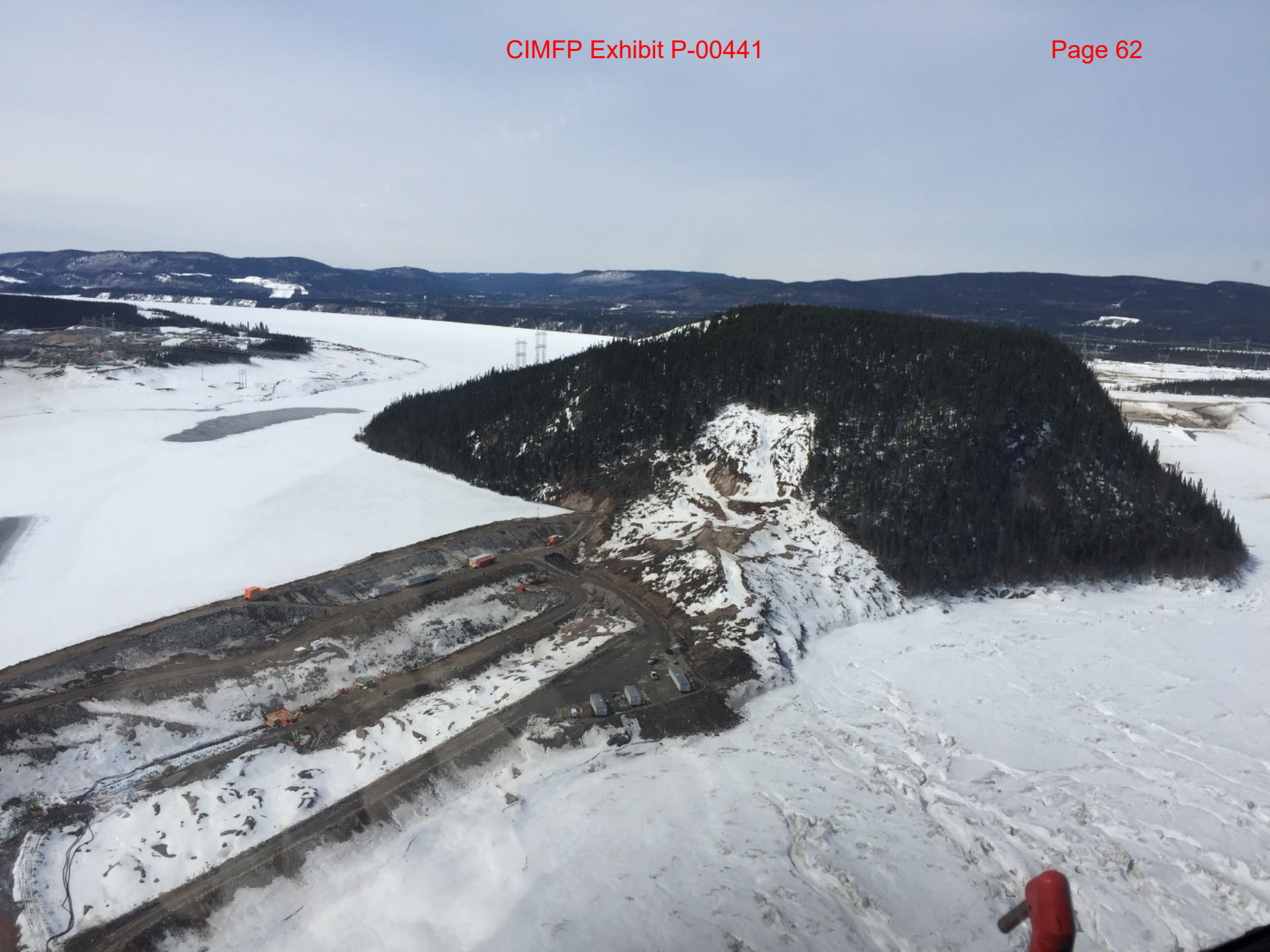
Selected Site Photographs April 19, 2017

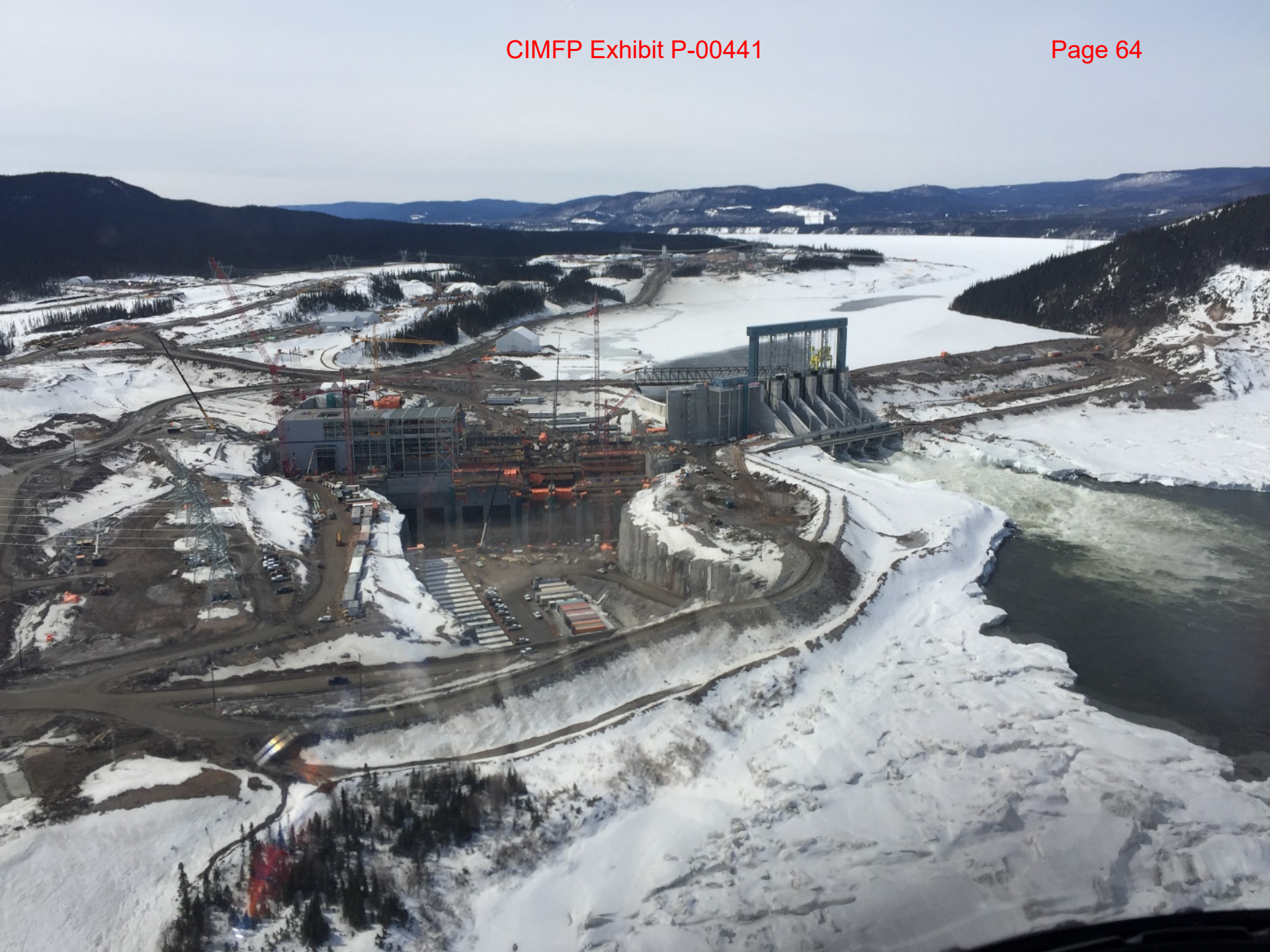
The North Spur











Actions & Items for Discussion

- Comments and discussions
- Additional information to review for next trip
  - Plan to obtain continuous flow measurements at the Kettle Lake outlet weir
- Action Plan
  - Next trip in September 2017
  - Deliverable for next trip update of audit report, general overview
  - Continuous improvement
  - Continue monitoring and reporting
  - Consider PFMA
  - Consider updating the 3D hydrogeological model

Thank you

For more information,
please visit www.hatch.com