Lower Churchill Management Corporation

nalcor energy
LOWER CHURCHILL PROJECT

Mud Lake Groundwater Post Head Pond Diversion Report

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Note: 1. "LCP" coded documents require all Project Managers' approval.

Additional Approvals

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1 PURPOSE

The purpose of this Mud Lake Groundwater Post Head Pond Diversion Report is to determine if there is an effect of reservoir impoundment on salinity levels in Mud Lake drinking water post head pond diversion.

2 SCOPE

This plan addresses the required aspects of the Mud Lake groundwater water quality monitoring for post head pond diversion for the Muskrat Falls Generation Project.

3 DEFINITIONS

Environmental Assessment: An evaluation of a project's potential environmental risks and effects before it is carried out and identification of ways to improve project design and implementation to prevent, minimize, mitigate, or compensate for adverse environmental effects and to enhance positive effects.

Environmental Management: The management of human interactions with the environment (air, water and land and all species that occupy these habitats including humans).

Environmental Protection Plan: Document outlining the specific mitigation measures, contingency plans and emergency response procedures to be implemented during the construction or operations of a facility.

Environmental Effects Monitoring: Monitoring of overall Project effects to confirm the predictions of EA and to fulfill EA commitments.

4 ABBREVIATIONS & ACRONYMS

a.s.l.	Above sea level
CEAA	Canadian Environmental Assessment Act
CLC	Community Liaison Committee
EA	Environmental Assessment
EEMP	Environmental Effects Monitoring Plan
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
EPP	Environmental Protection Plan
HVGB	Happy Valley - Goose Bay
LTA	Labrador Transmission Asset
LCP	Lower Churchill Project
MLGEEMP	Mud Lake Groundwater Environmental Effects Monitoring Plan
NE	Nalcor Energy

NL	Newfoundland and Labrador
PSU	Practical Salinity Units
RTWQ	Real Time Water Quality

5 REFERENCES

LCP-PT-MD-0000-PM-PL-0001-01	LCP Project Execution Plan
LCP-PT-MD-0000-PM-CH-0001-01	LCP Project Charter
LCP-PT-MD-0000-EA-PL-0001-01	LCP Generation Environmental Assessment Commitment Management Plan
LCP-PT-ED-0000-EA-SY-0001-01	Environmental Impact Statement and Supporting Documentation for the Lower Churchill Hydroelectric Generation Project
LCP-PT-MD-0000-EV-PL-0011-01	LCP Muskrat Falls Generation and Labrador Transmission Assets Environmental Protection Plan
LCP-PT-MD-0000-EV-PL-0034-01	LCP Mud Lake Groundwater Environmental Effects Monitoring Plan

6 REGULATORY COMPLIANCE

A commitment was made during the Panel Hearings for the Lower Churchill Hydroelectric Generation Project as a part of Undertaking 84, which stated: *"groundwater monitoring will be carried out in Mud Lake during impoundment to confirm that there is no increase in salinity in the drinking water supply during impoundment".* As a result of this commitment, the Mud Lake Groundwater Environmental Effects Monitoring Plan (MLGEEMP) was prepared and submitted in 2015, further committing that this Mud Lake Groundwater Post Head Pond Diversion Report would be prepared post head pond diversion creation, and that a second report would be prepared post-impoundment, summarizing the results of the Mud Lake drinking water analysis EEM program.

NL Reg. 18/12, also referred to as the *Lower Churchill Hydroelectric Generation Project Undertaking Order* released the Project from environmental assessment and set conditions that LCP must meet. The release of the Project from environmental assessment under section 3 is subject to the following conditions:

(a) LCP shall abide by all commitments made by it in the Environmental Impact Statement dated February 2009, and all the Environmental Impact Statement Additional Information Requests made by the Lower Churchill Hydroelectric Generation Project Environmental Assessment Panel and consequently submitted by LCP, and the submissions made by LCP during the panel hearings and, subsequent to the hearings, to the panel, unless one or more of the commitments, or a part of a commitment is specifically waived by the minister;

(e) LCP shall prepare and abide by the requirements of environmental effects monitoring plans for all phases of the project, and those plans shall be submitted to and approved by the Minister of Environment and Conservation or the appropriate minister of the Crown before the commencement of an activity which is associated with or may affect one or more of the following matters:

(xi) groundwater in Mud Lake

Submission of the Mud Lake Groundwater Environmental Effects Monitoring Plan satisfies the condition/requirement in NL Reg. 18/12, and this report demonstrates LCP's commitment and the results of the EEM post head pond diversion.

7 PROJECT DESCRIPTION

7.1 Muskrat Falls Generation

The Muskrat Falls Generation Project (Figure 6-1) will include the following sub-components which are:

- 22 km of access roads, including upgrading and new construction, and temporary bridges;
- A 1,500 person accommodations complex (for the construction period); and
- A north roller compacted concrete overflow dam;
- A south rock fill dam;
- River diversion during construction via the spillway;
- 5 vertical gate spillway;
- Reservoir preparation and reservoir clearing;
- Replacement of fish and terrestrial habitat;
- North spur stabilization works, and:
- A close coupled intake and powerhouse, including:
    - 4 intakes with gates and trash racks;
    - 4 turbine/generator units at approximately 206 MW each with associated ancillary electrical/mechanical and protection/control equipment;

- 5 power transformers (includes 1 spare), located on the draft tube deck of the powerhouse; and
- 2 overhead cranes each rated at 450 Tonnes

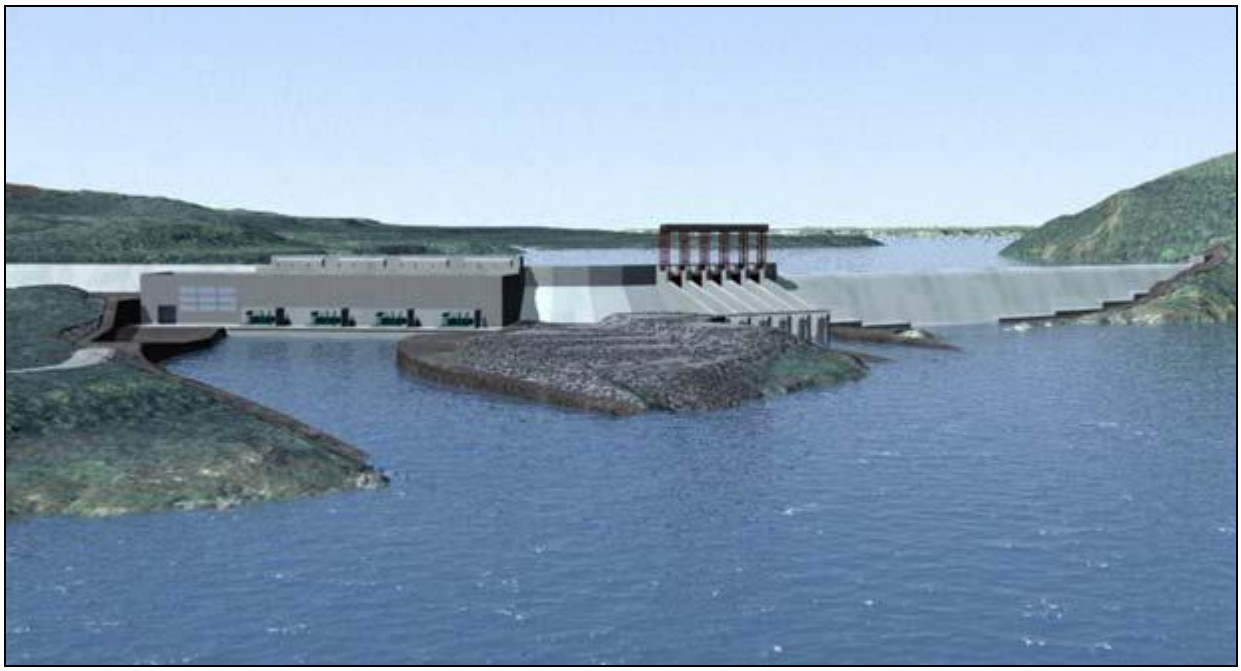

Figure 7-1 Muskrat Falls Generating Facility

8 MUD LAKE GROUNDWATER

8.1 STUDY AREA

The community of Mud Lake is located approximately 8 kilometres (km) east of the Town of Happy Valley - Goose Bay (HVGB), NL, near the mouth of the Churchill River. A channel of the Mud Lake River divides the mainland from an island that is accessible by a foot bridge. Houses are located on the mainland and the island. The community of Mud Lake is accessible by boat in the summer months and by snowmobile in winter from HVGB.

8.2 BACKGROUND

8.2.1 Estuary Environment

An estuary is an area of interaction between salt and fresh water (Hatch 2008). Commonly, it is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage. The environment in estuaries

is generally the result of a dynamic balance between factors such as tides, river runoff and sea salinity, local meteorological conditions, and topography.

The Goose Bay estuary is the receptor for the Churchill River watershed, as well as other, relatively smaller drainage basins (AMEC 2001). The estuary is located at the upstream, western end of Lake Melville, a large brackish water body which discharges into the Labrador Sea through Hamilton Inlet. The Goose Bay estuary is 120 km inland from the sea. The estuary contains a bottom layer of salt water that intrudes from the sea and is covered by a surface layer of fresh water from river inflow.

The fresh water flow from the Churchill River, which is the dominant fresh water input into the Goose Bay estuary, acts to maintain a stable fresh water surface layer (average 5 metres [m]), whereas the exchange flow from Lake Melville (through the Goose Bay Narrows) provides a stable, dominantly saline water bottom layer. This saline layer extends below 10 m depth in most of Goose Bay, except at or near the Narrows where a shallower layer persists (AMEC 2001).

The main driving force in Lake Melville is tidal. Water current circulation in the Goose Bay estuary is controlled by the Goose Bay Narrows which acts as a barrier between Lake Melville and Goose Bay. The tidal currents inside the Goose Bay estuary are much less variable (lower amplitudes) than those found in the western part of Lake Melville (AMEC 2001).

8.2.2 Baseline Salinity Conditions

In stratified situations, the intrusion of salt water in a river connected to the sea occurs by the motion upstream of a definable and limited saline layer underlying fresh water (Hatch 2008). This is called a saline wedge. In its theoretical form, with no tidal action or physical barriers, and with river flow, water depth and sea water salinity remaining constant, the wedge will advance to a point where it achieves equilibrium with the river flow. This is called an arrested saline wedge. According to the theory for the mechanism of an arrested saline wedge, the length of the wedge upstream in a river from the sea is a function of the densities of the fresh and salt water, the river flow velocity, and the depth of the river.

The baseline salinity measurements of the Churchill River were uniform with depth, indicating that the river is well mixed, with no stratification (AMEC 2001). The measured salinity was slightly brackish at 2 to 3 practical salinity units (PSU), for the length of the river between Mud Lake and Muskrat Falls. For comparison purposes, ocean water has a PSU ranging between 31 and 39.

The concern with impoundment is that the flow of water from the Churchill River will be reduced, and will increase the saline wedge upstream, thereby increasing the salinity of the water at Mud Lake.

8.3 IMPOUNDMENT

Head pond diversion occurred over two events. On October 17, 2016, work activities in preparation for raising the water levels in the reservoir above Muskrat Falls began. Nalcor initially planned to raise the

water levels to 25 metres above sea level (a.s.l.), by the fall of 2016, followed by raising the levels to 39 m by 2019. However, after raising the waters to 21.7 between October 21 and November 18, 2016, Nalcor took precautionary measures to lower water levels in the Muskrat Falls reservoir following increased water seepage through the temporary cofferdam. Nalcor opened the spillway gates, thereby increasing the flow of water and reducing the water level in the reservoir.

Following the completion of a full inspection of the cofferdam and remediation work identified through the inspection, the spillway gates were closed, and a second impoundment event occurred between January 23, 2017 and February 20, 2017. Water levels were raised from 15 to 21.5 metres a.s.l. Between February 20, 2017 and January 4, 2018, water levels were maintained between 21.5 and 22.5 metres a.s.l. After January 4, 2018, water levels were slowly raised to 23 – 23.5 metres a.s.l., where it has been maintained to establish a stable ice cover for the winter/spring season.

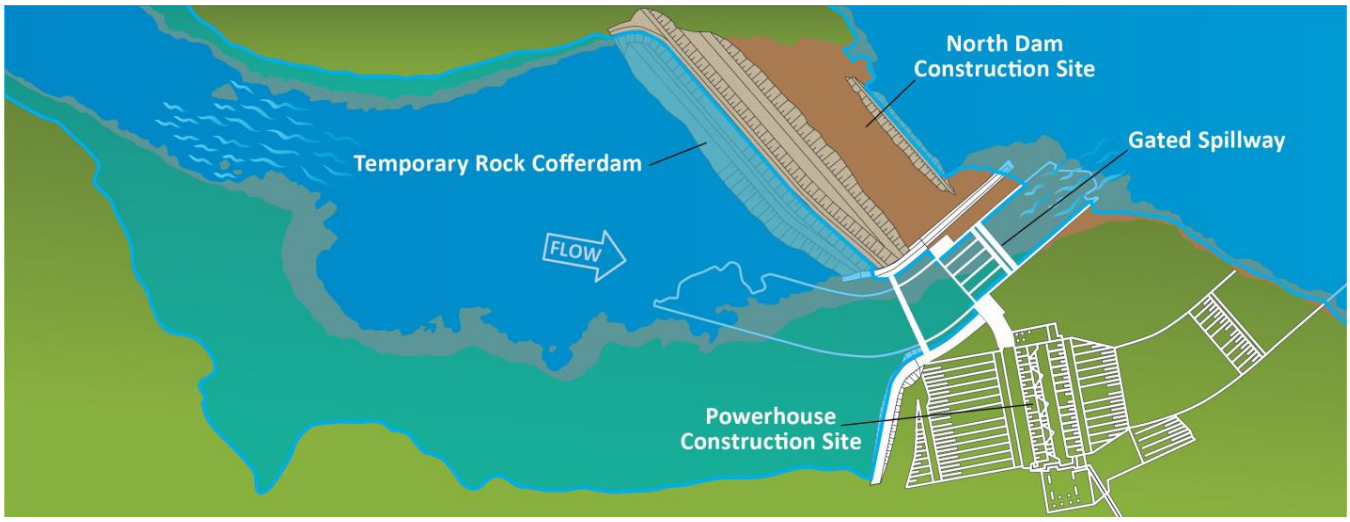

Figure 8-1 Illustration of the Temporary Rock Cofferdam at the Muskrat Falls site.

Figure 8-2 Photo of the Temporary Cofferdam Constructed at Muskrat Falls, November 2016

8.4 WATER QUALITY MONITORING

Table 8-1 presents a summary of the sampling protocol for the Mud Lake groundwater environmental effects monitoring program. Daily during the head pond diversion, the Real Time Water Quality Station located at English Point was monitored for changes in specific conductivity which would indicate saltwater intrusion. A specific conductance value of 14,600 µS/cm (at a conservatively low water temperature of 5^{o}C) was used to indicate a salinity of 14 PSU. At this value, the water is becoming more saline. An exceedance of 14,600 µS/cm would trigger the potential that saltwater was migrating upriver. This monitoring continued during reservoir filling between October 16, 2016 and November 18, 2016, and January 23, 2017 and February 20, 2017.

During the periods Real Time Water Quality data was unavailable due to ice cover, water quality data collected by Amec was used to fill the gaps.

Table 8-1 Summary of the sampling protocol for the Mud Lake groundwater environmental effects monitoring program

Event	Time of sampling	Method	Sampling Parameters
Baseline Data Collection	One time sampling event to collect baseline data on drinking water in Mud Lake	Water samples taken from 15 houses in Mud Lake	General Chemistry; Metals; and Bacteria
Creation of the diversion head pond	Daily during head pond diversion	Real Time Water Quality Network portal accessed daily – Churchill River at English Point, supplemented by Amec water sampling data	Specific conductivity
Full impoundment	Daily during impoundment	Real Time Water Quality Network portal accessed daily for the station – Churchill River at English Point	Specific conductivity

9 RESULTS

Table 9-1 shows water quality monitoring data for the initial impoundment event (October 21, 2016 to November 18, 2016), and Table 9-2 presents the water quality monitoring during the second impoundment event (January 23, 2017 to February 20, 2017). Table 9-3 presents the water quality monitoring data during the time that water levels were maintained between 21.5 to 23.5 metres a.s.l., between February 20, 2017 and January 23, 2018.

Table 9-1 Water Quality Monitoring Data during Initial Impoundment (October 21 to November 18, 2016)

Date	Conductivity (µS/cm)	Salinity	Water Temp Average (C°)	Water Level (m a.s.l.)	Source
21-Oct-16	44.5	0.03	6.3		RTWQ
22-Oct-16	38.0	0.03	6.2		RTWQ
23-Oct-16	21.0	0.02	5.1		RTWQ
24-Oct-16	33.5	0.02	5.3		RTWQ
25-Oct-16	45.8	0.03	5.4		RTWQ
26-Oct-16	43.0	0.03	4.8		RTWQ
27-Oct-16	37.5	0.02	3.9		RTWQ
28-Oct-16	39.1	0.03	3.1		RTWQ
29-Oct-16	38.3	0.03	3.1		RTWQ
30-Oct-16	28.6	0.02	3.4		RTWQ
31-Oct-16	23.6	0.02	3.6		RTWQ
1-Nov-16	31.3	0.02	2.7		RTWQ
2-Nov-16	38.7	0.03	3.4		RTWQ
3-Nov-16	28.7	0.02	3.6		RTWQ
4-Nov-16	26.8	0.02	3.6		RTWQ
5-Nov-16	29.0	0.02	3.1		RTWQ
6-Nov-16	35.4	0.03	2.9		RTWQ
7-Nov-16	47.0	0.04	2.6	17.29	RTWQ
9-Nov-16	20.0	0.01	3.6	18.25	Amec
11-Nov-16	23.0	0.01	3.1	19.70	Amec
13-Nov-16	21.0	0.01	2.9	21.36	Amec
14-Nov-16	22.0	0.01	2.2	21.72	Amec
15-Nov-16	21.0	0.01	1.5	21.71	Amec

Table 9-2 Water Quality Monitoring Data during Secondary Impoundment (January 23 to February 20, 2017)

Date	Conductivity (µS/cm)	Salinity	Water Temp Average (C°)	Water Level (m a.s.l.)	Source
6-Feb-17	33.0	0.01	0.0	17.30	Amec
14-Feb-17	28.0	0.01	0.0	20.17	Amec
22-Feb-17	19.0	0.01	0.0	21.53	Amec

Table 9-3 Water Quality Monitoring Data between February 20, 2017 and January 23, 2018

Date	Conductivity (µS/cm)	Salinity	Water Temp Average (C°)	Water Level (m a.s.l.)	Source
22-Feb-17	19.0	0.01	0.0	21.53	Amec
7-Mar-17	22.0	0.01	0.0	21.47	Amec
17-Mar-17	13.0	0.00	0.0	21.40	Amec
22-Mar-17	20.0	0.01	0.1	21.43	Amec
27-Mar-17	22.0	0.01	0.2	21.54	Amec
6-Apr-17	18.4	0.00	-0.1	22.49	Amec
11-Apr-17	22.0	0.01	-0.1	22.38	Amec
18-Apr-17	23.0	0.00	-0.1	22.33	Amec
25-Apr-17	22.0	0.00	-0.2	22.39	Amec
2-May-17	23.0	0.00	-0.1	22.34	Amec
11-May-17	16.0	0.00	-0.1	21.52	Amec
16-May-17	17.0	0.00	-0.1	21.38	Amec
7-Jun-17	21.0	0.00	6.0	21.65	Amec
14-Jun-17	18.0	0.00	7.1	21.39	Amec
21-Jun-17	18.0	0.00	9.3	21.53	Amec
28-Jun-17	17.0	0.00	11.0	20.86	Amec
5-Jul-17	18.0	0.01	13.2	20.92	Amec
10-Jul-17	21.0	0.00	13.6	20.65	Amec
19-Jul-17	19.0	0.00	17.0	20.19	Amec
27-Jul-17	21.0	0.01	15.3	20.30	Amec
2-Aug-17	22.0	0.00	15.3	20.43	Amec
7-Aug-17	20.0	0.01	17.6	20.44	Amec
18-Aug-17	23.0	0.01	15.2	20.42	Amec
21-Aug-17	22.0	0.00	16.2	20.43	Amec
31-Aug-17	39.0	0.01	15.0	20.42	Amec
14-Sep-17	19.0	0.01	13.5	20.43	Amec
21-Sep-17	23.0	0.00	12.0	20.42	Amec
23-Sep-17	24.8	0.02	12.1	20.46	Amec
24-Sep-17	28.6	0.02	11.5	20.78	RTWQ
25-Sep-17	29.0	0.02	11.4	20.98	RTWQ
26-Sep-17	28.7	0.02		20.97	RTWQ
27-Sep-17	31.5	0.02	10.9	21.06	RTWQ
28-Sep-17	26.6	0.02	10.6	21.49	RTWQ
29-Sep-17	29.9	0.02	9.8	21.70	RTWQ
30-Sep-17	39.8	0.03	10.2	21.63	RTWQ

Date	Conductivity (µS/cm)	Salinity	Water Temp Average (C°)	Water Level (m a.s.l.)	Source
1-Oct-17	40.3	0.03	9.5	21.59	RTWQ
3-Oct-17	43.5	0.03	9.7	21.65	RTWQ
4-Oct-17	28.8	0.02	9.1	21.64	RTWQ
5-Oct-17	27.1	0.02	9.0	21.66	RTWQ
6-Oct-17	30.9	0.02	8.8	21.61	RTWQ
7-Oct-17	33.0	0.02	8.3	21.54	RTWQ
8-Oct-17	29.6	0.02	8.6	21.54	RTWQ
9-Oct-17	28.8	0.02	9.3	21.61	RTWQ
10-Oct-17	28.1	0.02	9.1	21.67	RTWQ
11-Oct-17	28.8	0.02	8.6	21.76	RTWQ
12-Oct-17	29.2	0.03	8.1	21.76	RTWQ
13-Oct-17	37.5	0.03	8.3	21.75	RTWQ
14-Oct-17	38.1	0.03	8.3	21.75	RTWQ
15-Oct-17	29.9	0.02	7.7	21.75	RTWQ
16-Oct-17	27.5	0.02	7.2	21.81	RTWQ
17-Oct-17	33.7	0.02	7.0	21.83	RTWQ
18-Oct-17	31.7	0.02	6.6	21.81	RTWQ
19-Oct-17	32.4	0.02	6.3	21.85	RTWQ
20-Oct-17	30.1	0.02	6.7	21.83	RTWQ
21-Oct-17	25.3	0.02	5.8	21.81	RTWQ
22-Oct-17	30.6	0.02	5.1	21.87	RTWQ
23-Oct-17	35.3	0.03	5.5	21.81	RTWQ
24-Oct-17	31.9	0.02	5.9	21.85	RTWQ
25-Oct-17	28.2	0.02	6.4	21.83	RTWQ
26-Oct-17	35.3	0.03	7.6	21.81	RTWQ
27-Oct-17	31.4	0.02	7.9	21.86	RTWQ
28-Oct-17	32.1	0.02	7.3	21.93	RTWQ
29-Oct-17	32.6	0.02	6.6	21.87	RTWQ
30-Oct-17	30.9	0.02	6.9	21.81	RTWQ
2-Nov-17	20.0	0.00	5.7	21.72	Amec
7-Nov-17	21.0	0.00	2.8	21.95	Amec
14-Nov-17	20.0	0.01	0.5	22.51	Amec
21-Nov-17	20.0	0.00	2.3	22.55	Amec
28-Nov-17	23.0	0.00	-0.1	22.49	Amec
5-Dec-17	29.0	0.00	-0.7	22.40	Amec
19-Dec-17	22.0	0.00	-0.1	22.49	Amec

Date	Conductivity (µS/cm)	Salinity	Water Temp Average (C°)	Water Level (m a.s.l.)	Source
10-Jan-18	21.0	0.00	-0.1	23.48	Amec
17-Jan-18	20.0	0.01	-0.1	23.47	Amec
23-Jan-18	24.0	0.00	0.0	23.41	Amec

10 DISCUSSION

Throughout the entire monitoring period, conductivity was never any higher than 47 µS/cm; maximum salinity had a value of 0.04 PSU. An exceedance of 14,600 µS/cm (salinity of 14 PSU) would have triggered the potential that saltwater was migrating upriver, however our maximum conductivity levels were 0.3%, and maximum salinity levels were 0.2%, of this. Therefore based on the sampling data, it appears that saltwater intrusion did not occur – the saline wedge did not migrate upstream during any impoundment event to date on the Project.

When LCP increases the water level to 39 metres a.s.l., monitoring will commence again, to determine if there is an effect on Mud Lake ground water as a result of full impoundment.

11 EXTERNAL REFERENCES

Amec and BAE-Newplan. 2001. Aquatic environment in the Goose Bay estuary. Report prepared for Newfoundland and Labrador Hydro, St. John's, NL.

Hatch, 2008. Salt Water Intrusion 3D Model Study. Prepared for Newfoundland and Labrador Hydro Lower Churchill Project. October 2008.