Nalcor Energy – Lower Churchill Project

LCP Mud Lake Groundwater Environmental Effects Monitoring Plan

LCP-PT-MD-0000-EV-PL-0034-01

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B4		Issued for Use	J. Wells	D. Haley	D. Green	R. Power
B3		Issued for Use	P. Madden	D. Haley	D. Green	R. Power

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1 PURPOSE

The purpose of this Mud Lake Groundwater Environmental Effects Monitoring Plan (MLGEEMP) is to confirm the potential effects of reservoir impoundment on Mud Lake drinking water. This program will determine if model predictions were correct from the environmental assessment that there will be no adverse environmental effects on Mud Lake drinking water as a result of the Lower Churchill River Hydroelectric Generation Project (the Project) and to set out a program for monitoring.

To comply with regulatory requirements and commitments made in the Environmental Impact Statement (EIS), the Lower Churchill Project's (LCP) MLGEEMP approach includes consideration of:

- Mitigation objectives – performance objectives in respect of each adverse environmental effect;
- Mitigation – measures planned to achieve the mitigation objectives;
- Metrics and targets – specific, quantifiable, relevant and time constrained;
- Follow-up or Monitoring Programs – how the Project will include follow-up or monitoring surveys to confirm that mitigation strategies are meeting the mitigation objectives; and
- Contingency – plan to be implemented should monitoring reveal that mitigation measures have not been successful.

The LCP's MLGEEMP builds on existing information and commitments made in the EIS (LCP 2009), and conditions of permits and licenses for the Project.

NL Reg. 18/12, also referred to as the *Lower Churchill Hydroelectric Generation Project Undertaking Order* releases the Project from environmental assessment and sets conditions for this release 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 this EEMP satisfies the condition/requirement in NL Reg. 18/12 that LCP prepare and submit to the Minister of Environment and Conservation or the appropriate minister of the Crown, an environmental effects monitoring plan for all phases of the project, before the commencement of an activity which is associated with or may affect the following matters:

(xi) groundwater in Mud Lake

Note some of the information presented in this plan is also included under the Aquatic Environmental Effects Monitoring Plan (LCP-PT-MD-9112-EV-PL-0001-01).

2 SCOPE

This plan addresses the required aspects of the Mud Lake Groundwater environmental effects monitoring for the operation phases of the LCP 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

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
LTA	Labrador Transmission Asset
LCP	Lower Churchill Project
NE	LCP Energy
NL	Newfoundland and Labrador
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-9112-EV-PL-0001-01	LCP Aquatic Environmental Effects Monitoring Plan

6 PROJECT DESCRIPTION

6.1 MUSKRAT FALLS GENERATION

The Muskrat Falls Generation Project (Figure 6-1) will include the following sub-components which are broken down under the five principal areas of the development:

- 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 6-1 Muskrat Falls Generating Facility

6.2 LABRADOR TRANSMISSION ASSET (LTA)

LTA consists of the AC transmission line system from Churchill Falls to Muskrat Falls, specifically (Figure 6-2):

- Churchill Falls switchyard extension;
- Muskrat Falls switchyard;
- Transmission lines from Muskrat Falls to Churchill Falls: double-circuit 315 kV ac, 3 phase lines, double bundle conductor, Single circuit galvanized lattice steel guyed suspension and rigid angle towers; 247 km long; and
- 735 kV Transmission Line at Churchill Falls interconnecting the existing and the new Churchill Falls switchyards.

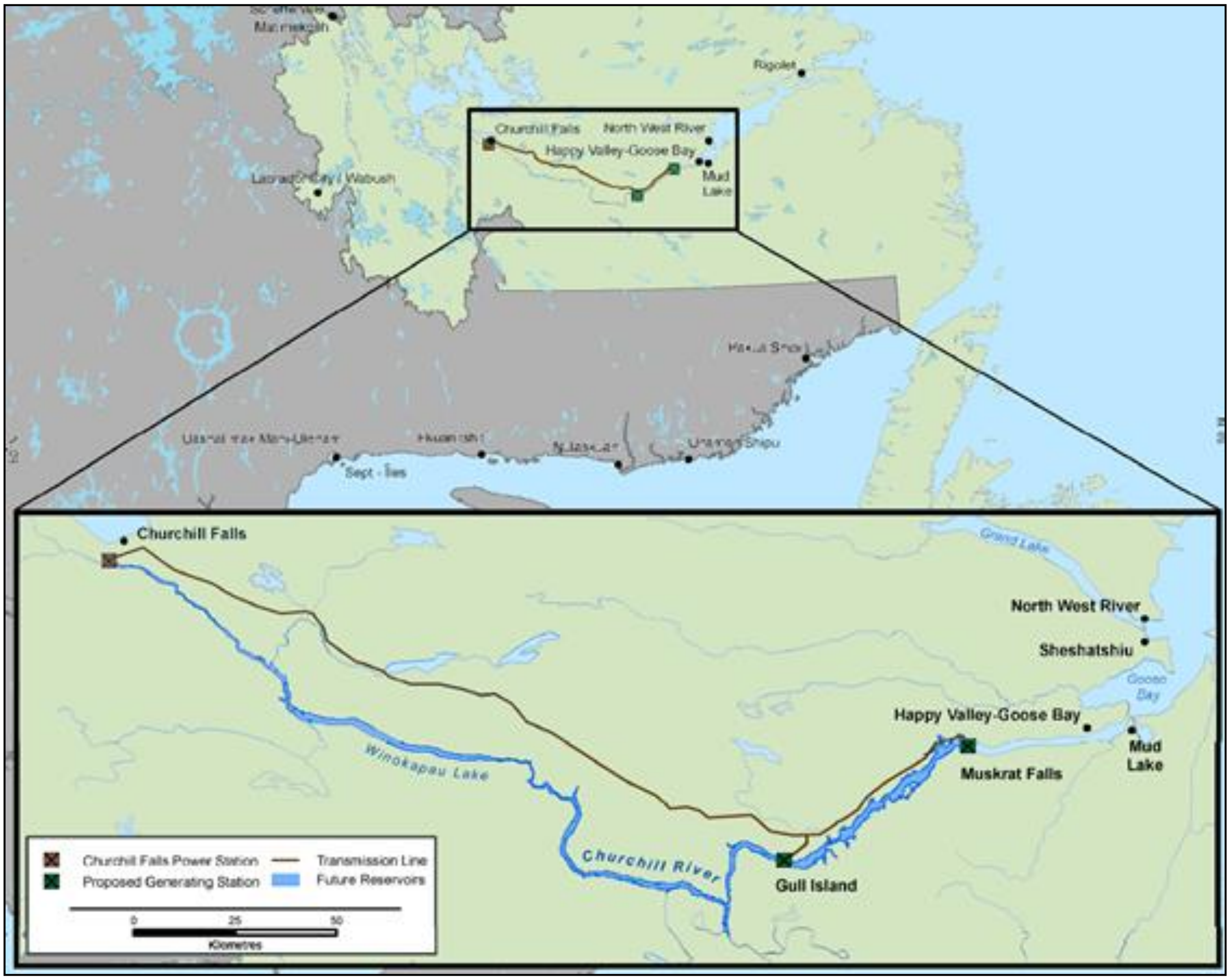

Figure 6-2 Labrador Transmission Asset

7 STUDY AREA AND BACKGROUND

The purpose of this EEM is to confirm the model predictions made during the environmental assessment (EA) that the Project will have no impact on Mud Lake drinking water quality.

Provided in section 7.1 is a summary of the study area and section 7.2 provides a summary of previous studies completed on groundwater in Mud Lake.

7.1 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.

7.2 BACKGROUND AND PREVIOUS STUDIES

7.2.1 Estuary Environment

An estuary is an area of interaction between salt and fresh water (Hatch 2008a). 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).

7.2.2 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 2008a). 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.

7.2.3 Hatch Salt Water Intrusion Study

The 1980 Environmental Impact Statement for the Lower Churchill Project (LCDC 1980) identified the Churchill River below Muskrat Falls as potentially susceptible to salt water intrusion from Goose Bay during the temporary reduction in river flows that would occur during the process of reservoir impoundment. To estimate the extent of any salt water intrusion (defined as the section where salinity increases by approximately 2 parts per thousand) that could occur, a three-dimensional numerical model of the Churchill River and Goose Bay estuary was set up and run by Hatch in 2008 to predict the space and time behaviour of the salinity in the lower Churchill River during impoundment of the Gull Island Reservoir (Hatch 2008a and 2008b).

The model was set up using DHI MIKE3, a three-dimensional, hydraulic, modelling package applicable to simulations of flow in rivers, lakes, estuaries, bays and seas. Bathymetric surveys of the Churchill River and Canadian Hydrographic Service nautical chart data, and temperature and salinity measurements obtained from a previous report completed by AMEC in 2001 were used.

The DHI MIKE 3 model was used to simulate the effect of impounding the Gull Island Reservoir under average flow conditions and assuming that all flow from the upstream of Gull Island was cut off. Examining the effects of compensation flow release over the spillway at Gull Island were not considered necessary (Hatch 2008b).

For the purposes of the Hatch 2008 study, it was initially assumed that river closure would occur on September 1, with no compensation flow release, the inflow at the model boundary was reduced from 1,457 m^3/s to 59 m^3/s during the impoundment of the reservoir. Once reservoir filling is complete, normal river flow would be restored on October 8. The model results indicated a potential for salt water intrusion within approximately 2 km upriver of Mud Lake at its maximum extent during impoundment of the Gull Island Reservoir. The salinity in the area of Mud Lake was temporarily expected to reach a maximum of 4 to 6 PSU. The intrusion was not stratified, instead taking the form of a diffuse well-mixed salinity gradient, oscillating with the tide within the last few kilometres of the river.

A reduction of flow during the Muskrat Falls reservoir impoundment period has raised concerns in the Upper Lake Melville area, particularly Mud Lake, regarding the potential effects salt water intrusion may have on the quality of groundwater used for drinking. To mitigate this potential effect, LCP has committed to begin compensation release at the initiation of impoundment, which is expected to further limit the extent of the modeled salt water intrusion into the Churchill River during reservoir impoundment (see below).

As a mitigation, LCP committed to a compensation flow of 552m^3/s (30% MAF). The modelling predicted no salt water intrusion when the compensation flow was 552m^3/s (30% MAF) (Figure 7-1).

7.3 AMEC 2010 BASELINE WATER QUALITY AND SALT WATER INTRUSION STUDY

A possible implication of this temporary salt water intrusion is an impact (i.e., reduced water quality) to groundwater used by the residents of Mud Lake. AMEC was retained by Nalcor in May 2009 to conduct a Baseline Water Quality and Salt Water Intrusion Study in the community of Mud Lake.

The AMEC 2010 Baseline Water Quality and Salt Water Intrusion Study included the following scope of work:

- Conducting a water well inventory of all of the accessible houses in the community of Mud Lake using standardized questionnaires. Information about the well owner, the property, the construction of the well, water treatment and the history of the well was requested from the home owner at the time of sampling.

- Collecting potable water samples from the most common tap source in accessible houses within the community.
- Submitting water samples to the Government Service Centre (GSC) in HVGB, NL for analyses of bacteriological parameters and to Maxxam Analytics (Maxxam) in St. John's, NL for analyses of general chemistry and metals parameters.
- Comparing the laboratory results for the water samples to the GCDWQ.
- Installing six (6) monitoring wells (MW1 to MW6) at various locations within Mud Lake (refer to Figure 7-2). Boreholes were drilled using a hand auger and gas auger drill to approximately 3 - 5 m below ground surface (bgs). Monitoring wells were installed in the boreholes to gauge the water table level.
- Surveying the tops of each newly installed monitoring well to a relative elevation in order to determine the groundwater flow direction. In addition, several surface water features surrounding the community of Mud Lake, including the Churchill River, were surveyed to determine relative elevations.
- Installing transducers in the monitoring wells for a period of 30 hours in order to determine any change of groundwater levels resulting from tidal impacts.
- Based on survey results, creating a groundwater flow map. The map illustrated groundwater elevations, surface water elevations and groundwater flow direction (see Figure 7-2)
- Preparing a report stating AMEC's opinion on the potential for salt water to intrude the shallow wells located in Mud Lake, along with a record of baseline water quality for the drinking water resource of Mud Lake.

Based on the findings of the Baseline Water Quality and Salt Water Intrusion Study conducted by AMEC in 2010, the following conclusions were made:

- Ten (10) of the 15 home owners interviewed obtained water from a private well. The remaining five (5) home owners obtained water from surface water (the "Channel"). SA-4, SA-5, SA-8, SA-9, SA-10, SA-11, SA-12, SA-13, SA-14, and SA-15 obtain their water from a private well (See Figure 7-3.)
- Private wells are completed in the overburden sand aquifer at shallow depths and draw water from the top of the water table.

- The low sodium and chloride concentrations in all tap water samples indicated that neither the Channel nor the shallow aquifer used by local water wells are affected by a pre-existing salt water condition.
- Baseline drinking water salinity measurements obtained from the tap water samples were 2 orders of magnitude less than baseline salinity measurements of the Churchill River, indicating that there is no existing interaction between the Churchill River and the shallow groundwater aquifer used by local water wells.
- The elevation of the top of groundwater ranged from 0.19 m above sea level (asl) in monitoring well MW2 to a maximum of 1.81 m asl in monitoring well MW6 during the monitoring period with the temporal fluctuations varying between 0.0 m and 0.03 m in monitoring wells MW4 and MW1, respectively. The greatest fluctuation in groundwater levels occurred at the monitoring wells near the Channel. For comparison, the fluctuations in Channel levels were 0.25 m.
- The groundwater and surface water level data indicated that groundwater flow was consistently towards the Channel and the Churchill River under both low and high tide conditions, indicating that neither the Channel nor the Churchill River was a source of water for those residents that use wells.

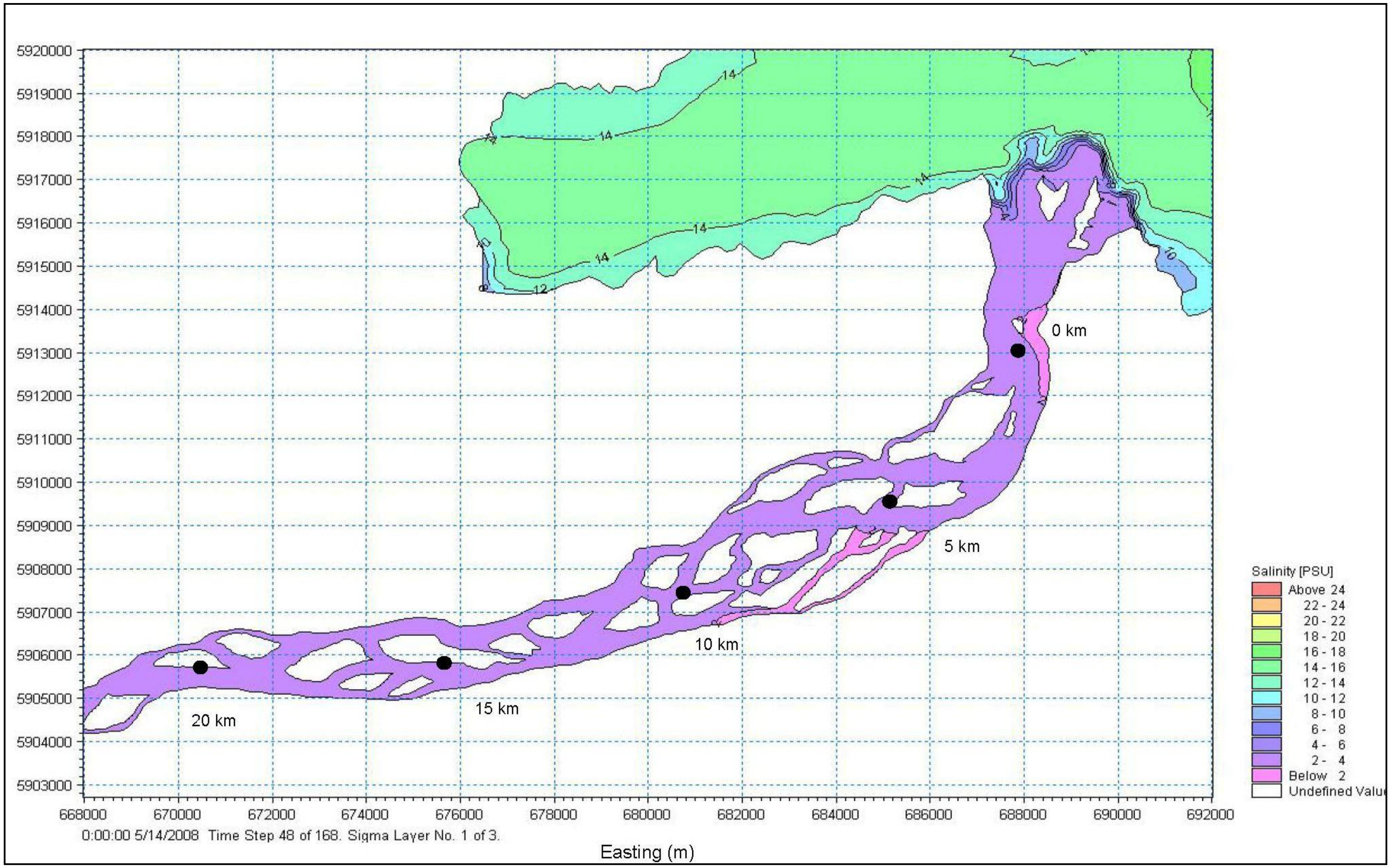

Figure 7-1 Modeled salinities with 30% MAF compensation flow during reservoir filling

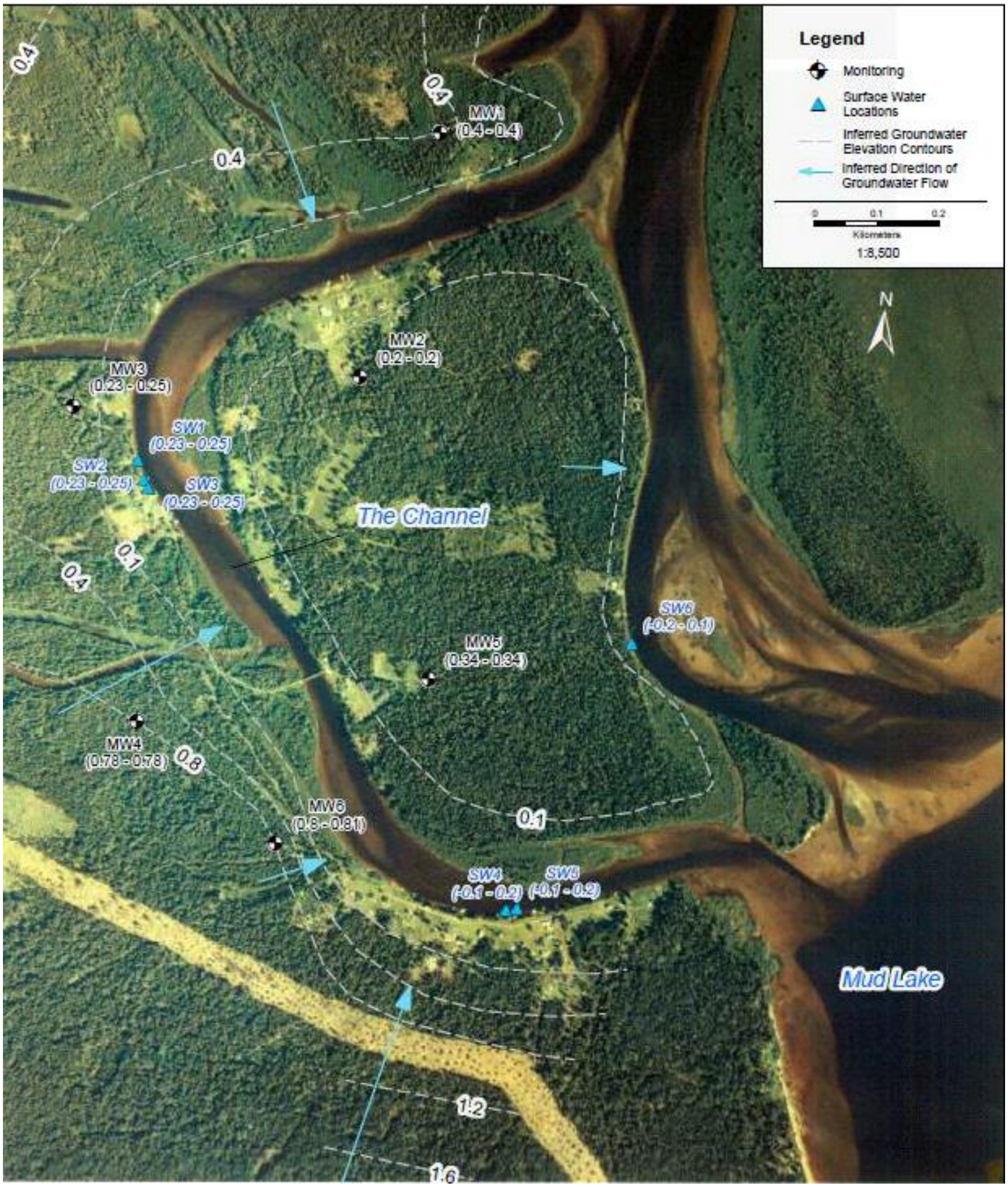

Figure 7-2 Groundwater flow directions under high tide conditions (October 4, 2009 data)

Figure 7-3 Groundwater Wells and Sampling Points

8 MUD LAKE GROUNDWATER SAMPLING EEM

The sole purpose of this Mud Lake Groundwater EEM program is to meet the commitment made during the Panel Hearings for the 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 described above, the modelling and studies completed to date indicate two key points:

1) The potential for saltwater intrusion into the lower Churchill River during reservoir filling is not predicted to occur with a maintenance flow of 552m^3/s (30% MAF) (Figure 7-1).
2) Baseline drinking water salinity measurements obtained from the tap water samples were 2 orders of magnitude less than baseline salinity measurements of the Churchill River, indicating that there is no existing interaction between the Churchill River and the shallow groundwater aquifer used by local water wells.

However, to be precautionary, saltwater intrusion will be monitored using real-time conductivity data. Based on a complex formula used for conversion of specific conductance to salinity (Perkin and Lewis 1980), a specific conductance value of 14,600 µS/cm (at a conservatively low water temperature of 5^{o}C) will be used to indicate a salinity of 14 PSU. At this value, the water is becoming more saline. A water temperature of 5^{o}C was chosen as a conservative value to be used in the conversion equation. Temperature influences the conductivity in that cooler water temperatures create lower conductance. An exceedance of 14,600 µS/cm would trigger the potential that saltwater is migrating upriver. This monitoring will continue during reservoir filling.

Daily during the head pond diversion and full impoundment, the Real Time Water Quality Station located in the Churchill River and English Point will be monitored on a daily basis for changes in specific conductivity that indicate saltwater intrusion.

If the real time water quality monitoring indicates the water was becoming more saline, LCP will initiate a water sampling program in the community of Mud Lake as follows:

- Baseline water samples will be collected at 15 houses within the community of Mud Lake and analyzed for general chemistry and metals. Where possible, all aerators, tap screens, hoses, filters of other attachments will be removed from the faucet prior to turning on the cold water. The flow rate will be increased to full, or as high as practical, to allow the system to purge. Laboratory supplied bottles will be placed under the faucet, and the cold water opened at a flow rate sufficient to allow collection of the sample without flushing out preservatives inside the sample bottles.
- Water samples will be submitted to an accredited laboratory for general chemistry and metal analyses. During sampling and transport, the samples will be stored in coolers equipped with several frozen ice packs to maintain sample storage temperature as close to 4°C as possible.

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

Event	Date (Approx.)	Time of sampling	Method	Sampling Parameters
Baseline Data Collection	Summer 2010 Summer 2014	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	Quarter 4, 2016	Daily during head pond diversion	Real Time Water Quality Network portal accessed daily – Churchill River at English Point	Specific conductivity
Full impoundment	Quarter 3, 2017	Daily during impoundment	Real Time Water Quality Network portal accessed	Specific conductivity

			daily for the station – Churchill River at English Point	

8.1 MUD LAKE CONSULTATION

Residents of Mud Lake will be provided the results of the program through the following methods:

- Presentation at a LCP Community Liaison Committee (CLC) meeting where the Mud Lake representative is present.
- Provision of a monitoring report via the Project website and hard copies via the CLC.
- If required, personal communication to each resident where the results of the salinity sampling raised concern and exceeded guidelines.

9 REPORTING

A report will be prepared post head pond diversion creation and post-impoundment in 2016 and 2017, respectively, summarizing the results of the Mud Lake drinking water analysis EEM program. The results of these EEM reports will be submitted to all required regulators including the provincial Department of Environment and Conservation.

10 CONTINGENCY

At this time, contingency plans are not anticipated in relation to changes in drinking water at Mud Lake based on the modelling completed by Hatch, including the mitigation for 30% compensation flow. In addition, the findings of the Amec study that the baseline drinking water salinity measurements obtained from the tap water samples were two orders of magnitude less than baseline salinity measurements of the Churchill River, indicating that there is no existing interaction between the Churchill River and the shallow groundwater aquifer used by local water wells.

However, if any effects on the drinking water in Mud Lake are found to be attributable to the project, contingencies will be provided through alternate means as deemed necessary.

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.

AMEC. 2013a. Lower Churchill Hydroelectric Development Freshwater Fish and Fish Habitat Compensation Plan. Prepared for Nalcor Energy. St. John’s, NL.

AMEC. 2013b. Lower Churchill Hydroelectric Development Aquatic Environmental Effects Monitoring Program; Muskrat Falls. Prepared for Nalcor Energy. St. John’s, NL.

Bobbitt, J. and S. Akenhead. 1982. Influence of controlled discharge from the Churchill River on the oceanography of Groswater Bay, Labrador. Can. Tech. Rep. Aquat. Sci. 1097: 43p.

Cardosa, D. and B. deYoung. 2002. Historical hydrographic data from Goose Bay, Lake Melville and Groswater Bay, Labrador 1950-1997. Physics and Physical Oceanography Data Report 2002-2. Memorial University of Newfoundland.

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

Hatch, 2008b. Salt Water Intusion 3D Model Study Addendum No. 1. Prepared for Newfoundland and Labrador Hydro Lower Churchill Project. January 2009.

JWEL (Jacques Whitford Environmental Limited). 2001. Biological Study of the Goose Bay Estuary. Prepared for Newfoundland and Labrador Hydro, St. John’s, NL.

Oceans Ltd. 2010. Modeling the dispersion of mercury and phosphorus in Lake Melville. Technical Memorandum prepared for LCP Energy, St. John’s, NL.

Perkin, R. G. and E. L. Lewis. 1980. The Practical Salinity Scale 1978: Fitting the data. IEEE J. Oceanic Eng. OE-5: 9–16.