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Technical Memorandum

Date: July 19, 2018
To: Peter Madden, Nalcor Energy
From: Randy Baker
Our File: NE 18-01

RE: Summary of Post-Exposure Human Health Risk Assessment from Methylmercury in Seafood in Goose Bay and Lake Melville, Labrador

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Objective

The objective of this Technical Memo is to summarize the effects of updated methylmercury (MeHg) modelling and predicted increases in key aquatic species on the Human Health Risk Assessment (HHRA). Dillon Consulting Ltd. completed the initial HHRA on MeHg prepared for Nalcor Energy (Nalcor) in 2016 (Dillon 2016). This provisional update incorporates the most recent science on the manufacture and release of MeHg from the Muskrat Falls Reservoir downstream of the lower Churchill River to Goose Bay and Lake Melville. Based on this, we discuss the implications for human health based on predicted changes in MeHg concentrations in fish and marine mammals. A complete review and update of the 2016 HHRA will be completed by Dillon later in 2018.

Background and Assumptions

In 2016, Dillon completed a full HHRA to determine baseline human health risks from exposure to MeHg in country and store-bought foods consumed by residents of four study area communities prior to creation of the Muskrat Falls Reservoir on the lower Churchill River (the Project). These were Happy Valley-Goose Bay, North West River, Mud Lake and Sheshatshiu.

Various food ingestion-based exposure pathways were assessed for males and females of all age classes in each of the above communities. In all, 293 community members underwent a dietary survey (DS), food consumption rate questionnaire and a human biomonitoring program (HBP), involving human hair sampling and analysis for MeHg.

The Dillon (2016) HHRA used standard methods developed and endorsed by Health Canada (2007, 2010a, 2010b), incorporating reasonable levels of conservatism in its various approaches, models and assumptions to overestimate exposure to MeHg and quantify potential risk to humans. Several lines of evidence were followed that comprised the main outcomes of the HHRA including:

- Calculated human health risk estimates for each of the assessed human receptors (e.g., toddlers, teenagers, adults), in the communities above, expressed as hazard quotients (HQs; i.e., the estimated exposure to MeHg divided by the toxicological reference value(s) (TRVs) for MeHg);
- The relative proportion of MeHg exposure that is attributed to country food vs store-bought food (e.g., tinned tuna);
- Appropriate consideration of safety factors and assumptions with respect to data variability and uncertainty;
- Comparison of local aquatic biota tissue concentration against regulatory standards; and
- Evaluation and consideration of measured human biomonitoring data such as hair MeHg values relative to Health Canada guidance.

The reader is encouraged to consult the Dillon (2016) HHRA for a full explanation of the approach, procedures, assumptions and conclusions. These have not substantially changed since the initial assessment was made and their assessment of current risk is still valid. Note also that while the health benefits of consuming country foods (e.g., fish, seals, game) was recognized by the HHRA, this was not balanced against exposure risk; health benefits were considered as part of forthcoming consumption advice.

The Dillon (2016) HHRA concluded that "t*here is a low to negligible potential for human health risk resulting from MeHg exposure, and a negligible potential for human health risk resulting from inorganic Hg*(mercury) *exposure*. *The calculated MeHg and inorganic Hg exposures and risks are similar to what would be expected in numerous communities in North America where food consumption patterns comprise the ingestion of both store-bought foods and country food items that are of aquatic origin*". Note that the Dillon (2016) HHRA also considered inorganic mercury (Hg); given that virtually all environmental exposure to MeHg is via dietary sources of fish, shellfish and marine mammals (Health Canada 2007, 2010a, 2010b) this update focuses only on MeHg. The exposure scenario for inorganic Hg is unchanged since 2016.

It is noteworthy that the Dillon (2016) HHRA considered *current* health risks, prior to Project-related changes, while recognizing the concern expressed by the downstream communities with respect to increased potential for health risks due to higher MeHg exposure. As a result, on behalf of Nalcor, there was a commitment to comprehensive monitoring and a science-based risk management program, if warranted. Concerns expressed by Indigenous communities were further heightened following publication of the Calder et al. (2016) study, purporting that risks to human health from MeHg exposure were significantly higher than forecast.

As noted above, this Memorandum acknowledges that two of the key baseline HHRA program components consisted of a dietary survey and hair sampling in all study area communities except Rigolet. Results of these two components provided critical information to the HHRA regarding current patterns and level of risk from MeHg exposure. Work by Calder et al. (2016) also incorporated dietary surveys and hair MeHg monitoring at Rigolet and showed only slightly higher reliance on country foods and hair mercury concentrations (see the July 2018 Human Health PPT Presentation for further details). This information is still current and accurate and helps to inform perspective on both current and predicted risk.

Disclaimer

Note that due to circumstances beyond the control of Mr. R. Willis of Dillon Consulting, the main author of the 2016 HHRA, was unable to update the HHRA at this time. Thus, Azimuth was engaged to provide this expertise in the interim. Azimuth has considerable experience addressing human health risks related to MeHg from previous projects and this document follows on from the Dillon (2016) HHRA to incorporate more recent findings related to predicted changes in MeHg concentrations in key species in Goose Bay and Lake Melville. The Dillon (2016) HHRA will be revised at a later date.

2018 Update – Background Information

As noted above, this Technical Memorandum updates the key 2016 HHRA findings by incorporating the most recent investigations from the documents listed below. In this update, we have also predicted the change in tissue MeHg concentration in the most frequently consumed species by local residents in Goose Bay and Lake Melville. Risk predictions have been updated relative to baseline using the most recent tissue MeHg data from monitoring programs, bringing to bear the best available science to predict changes in MeHg in downstream species. With respect to risk predictions, rather than calculating a HQ (i.e., by comparing the ratio of what *could be* eaten relative to what <u>is</u> eaten based on local surveys), we have determined the incremental risk using Health Canada's total daily intake (TDI; Health Canada 2010a) value for MeHg. We calculated the difference in number of seafood meals that can be consumed at post-inundation peak MeHg values relative to baseline while remaining within Health Canada guidelines. This format provides similar but more relevant and meaningful information that Indigenous community members and other stakeholders can understand and base decisions on. There are four main documents from which these predictions are based:

1. **Harris and Hutchinson July 2018** – Predicted changes to MeHg concentrations generated within Muskrat Falls were made using a combination of mechanistic modeling predictions based on results of ResMerc and empirical data from the FLUDEX experiment at the Experimental Lakes Area (ELA) in Ontario. These results were used to predict MeHg concentrations in both surface (i.e., upper 20 m epilimnion and mixing zone) and deeper (>20 m hypolimnion) water in Goose Bay and Lake Melville. Predicted relative increases above existing concentrations were used as an indication of the potential relative increase in biota. For example, if water concentrations increased 50%, so would biota concentrations. Because fish exposure to MeHg is integrated over time, a brief increase in water concentration would not translate into the same relative increase

in biota. Predicted increases in water were therefore averaged over three years in order to predict increases in biota MeHg.

2. **Baird 3-D Hydrodynamic Modeling July 2018** – Baird used high-resolution Delft3D hydrodynamic modeling in Goose Bay and Lake Melville to make conservative predictions regarding the export of MeHg from the reservoir over time, accounting for a variety of factors including dilution as well as losses of MeHg due to photodegradation and settling. The models used five-year predictions of excess (i.e., over and above baseline) MeHg leaving the lower Churchill River to be dispersed in the marine environment. Estimates of excess MeHg concentrations in Goose Bay and Lake Melville were then used in calculations of the relative increases in water column MeHg concentrations above baseline.
3. **AMEC Foster-Wheeler (AMEC) July 2018** – This document summarizes life history and habitat use for key species identified as being important in the diet of local communities harvesting wildlife species in Goose Bay and Lake Melville. This summary also recognizes local Traditional Ecological Knowledge. Application of life history and diet information is used to determine the relative degree to which biota may be exposed to water where MeHg has increased in Lake Melville, post-impoundment. The degree of both spatial and temporal overlap of each species within the zone of exposure was used to prorate the magnitude of exposure, relative to baseline. That is, where, when and for how long a species resides and feeds in either Goose Bay and western and eastern Lake Melville determines exposure and the magnitude of increase in tissue MeHg concentration. The peak increase in MeHg concentrations in water over three years was used to determine the maximum degree to which biota may theoretically respond. The conservative assumption was made that biota tissue concentrations would increase in relative proportion to the increase in water MeHg concentrations for species 'fully exposed' to water with higher MeHg. There is a reasonable amount of conservatism built into this assumption, so as to not underestimate the potential magnitude of change.
4. **Azimuth Consulting Group February 25, 2018** – Evaluation of MeHg production by Muskrat Falls Reservoir and implications for Lake Melville – A top-down, mass-balance approach. This document, makes the case that the biomass of the estuarine/marine environment is considerably greater than the freshwater environment and will nearly entirely dampen any downstream changes in water or biota due to reservoir creation. While this argument has not been brought to bear in hydrodynamic or export models (ResMerc or FLUDEX), or on risk predictions, this should be considered.

2018 Update – Risk Characterization

Dillon (2016) concluded that HQ values suggest a negligible to low potential for human health risk among residents of the study area communities under baseline conditions, particularly given the conservative assumptions used in the HHRA. However, the HHRA did not predict future risk because an estimate of the magnitude of change in tissue MeHg was not available at the time.

Tissue MeHg concentrations of aquatic organisms will only increase if an individual spends a meaningful amount of time feeding within the zone of exposure in Goose Bay and Lake Melville.

Thus, as noted above, life history features of aquatic biota reportedly consumed by local residents must be considered. Although some species were reported as being consumed by some residents (AMEC 2018), several of these were not considered further in the risk analysis for the following reasons:

- lake trout (*Salvelinus namaycush*) - are not present outside of the river mouth and are very rare within the lower portion of the river (i.e. Muskrat Falls reservoir area)
- Atlantic salmon (*Salmo salar* - both anadromous and land-locked) - the landlocked form is very rare within the lower portion of the river (i.e., Muskrat Falls reservoir area) and anadromous returning salmon from the Labrador Sea cease feeding as they enter freshwater of Lake Melville
- Atlantic cod (*Gadus morhua*) - this species has not been documented within Lake Melville
- Capelin (*Mallotus villosus*) - this species has only rarely been observed in Lake Melville since the early 1970s
- Arctic char (*Salvelinus alpinus*) - This species is not found in the lower Churchill River below the Labrador Plateau and only rarely observed in Lake Melville and typically found beyond the Narrows at the eastern end of Lake Melville.

Only three species are abundant, frequently consumed and exposed to changes in MeHg in water in Goose Bay and Lake Melville. These are brook trout (*S. fontinalis*), rainbow smelt (*Osmerus mordax*) and ringed seal (*Phoca hispida*) and are the only species considered in this provisional update to the HHRA. **Table 1** depicts the mean baseline tissue MeHg concentration for each of the three species, the increase factor predicted for Goose Bay and Lake Melville (AMEC 2018) and the predicted post-impoundment increase in MeHg.

Table 1. Mean baseline[1] MeHg concentration (mg/kg) in Goose Bay (GB) and Lake Melville (LM) and increase factor for post-impoundment peak MeHg concentration for key species.

Species	Baseline [MeHg] mg/kg in GB / LM	Increase Factor in GB / LM	Post-Impoundment Peak MeHg (mg/kg)
Brook trout	0.07 / 0.04	1.8 x / 1.2 x	0.13
Rainbow smelt	0.04 / 0.02	2.1 x / 1.5 x	0.06
Ringed seal pup	0.09 LM only	1.2 x	0.11
Ringed seal adult	0.62 LM only	1.2 x	0.74

1 From AMEC (2018)

Note that these values represent the peak three-year increase in water MeHg concentration in Goose Bay and Lake Melville to acknowledge life history features (AMEC 2018) and that time is required to reach equilibrium in key downstream species.

The Health Canada provisional tolerable daily intake (pTDI) for MeHg is a benchmark of acceptable exposure for chronic oral exposure from all sources over a lifetime without harmful

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effect. Two TDIs for MeHg have been issued by Health Canada, one TDI for the general population and a second to protect 'sensitive' receptors such as women of child-bearing age and children less than 12 years of age. These are stated as a dose of 0.47 µg and 0.20 µg MeHg/kg body weight/day (µg/kg bw/d) respectively (Health Canada 2010a).

To determine the number of weekly seafood servings that can be safely consumed over a lifetime for different receptor groups this simple equation is used:

Servings/Week = (pTDI x body weight (kg) x 7 days) / (Fish [MeHg] x Serving Size gm)

The Dillon (2016) HHRA used locally derived body weights for toddlers, children, teens and adults, by gender (male, female) from the communities. For example, on average, adult males weighed 83 kg, while adult females weighed 70 kg. The assumed average serving size for adults was approximately 170 g, less than for seal meat (193 g). Gender and age-specific serving sizes were used to more accurately estimate dose.

Retaining these site-specific values and using the above equation, we determined the total number of servings per week, by species, by age and gender, that is permissible under Health Canada guidance for a lifetime exposure. **Table 2** presents the total number of weekly servings under current baseline conditions and for the peak three-year period in the years following full impoundment of the Muskrat Falls Reservoir.

Based on results presented in **Table 2** (below) a considerable number of seafood meals are permissible per week under both baseline and post-impoundment scenarios without an effect to humans. For example, an adult can currently safely consume 23 meals per week of brook trout, diminishing to 13 meals per week post-impoundment from Goose Bay. In Lake Melville, this is currently 40 weekly meals, diminishing to 32 meals post-impoundment. Relatively fewer meals are permissible for 'sensitive' receptors such as children and women of child-bearing age. Diet of adult seal muscle is more restrictive, with 3 weekly meals pre-impoundment, diminishing to 2 at peak post-impoundment. To provide perspective using tinned tuna as an example, the number of weekly servings of tuna is more restrictive, at about half what can be consumed from locally harvested species.

The large number of permissible weekly servings of fish and seal pups is due to the very low baseline MeHg concentrations in Goose Bay and Lake Melville and the relatively low increase in tissue MeHg predicted for all key receptors, based on the work by Harris and Hutchinson (2018), Baird (2018) and AMEC (2018).

Summary and Conclusions

In summary, there is an extremely low likelihood of risk to human health from consumption of seafood from Goose Bay or Lake Melville at peak mercury levels in a post-impoundment scenario. Note that the projected increase of tissue MeHg by ~20% does <u>not</u> account for the effect of the large downstream biomass (i.e., the 'biomass effect') of Lake Melville (Azimuth 2018) which would further considerably diminish the predicted downstream increase. Thus, the original conclusions of the Dillon (2016) HHRA remain valid and are further strengthened by this quantitative assessment and provisional update to examine post-inundation MeHg concentrations in seafood and their implications for human consumption.

Literature Cited

Amec Foster Wheeler. 2017. Aquatic environmental effects monitoring program 1998 to 2016 baseline conditions Muskrat Falls. Prepared for Nalcor Energy by AMEC, St. John's NL. August 2017.

Amec Foster Wheeler. 2018. Predicted increases in fish MeHg muscle tissue concentrations in Goose Bay and Lake Melville. Prepared for Nalcor Energy by AMEC, St. John's NL. July 2018.

Brunton. A. 2018. Model analysis of Goose Bay and Lake Melville hydrodynamics and transport of methylmercury from Muskrat Falls Reservoir. Baird Technical Memorandum to R. Harris. July 2018.

Calder, R.S.D., A.T. Schartup, M. Li, A.P. Valberg, P.H. Balcom, and E.M. Sunderland. 2016. Future Impacts of Hydroelectric Power Developments on Methylmercury Exposures of Canadian Indigenous Communities. Environ. Sci. Technol. 50(23): 13115-13122.

Harris, R.C. and D. Hutchinson. 2018. Updated analysis of methylmercury increases in Muskrat Falls Reservoir. Technical Memorandum to P. Madden (Nalcor), July 2018.

Health Canada. 2007. Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption. Ottawa, ON, Health Canada, Health Products and Food Branch, Food Directorate, Bureau of Chemical Safety.

Health Canada. 2010a. Federal Contaminated Site Risk Assessment In Canada. Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0. Safe Environments, Contaminated Sites Division, Ottawa, ON.

Health Canada. 2010b. Federal Contaminated Site Risk Assessment In Canada. Supplemental Guidance on Human Health Risk Assessment for Country Foods ($HHRA_{Foods}$). Safe Environments, Contaminated Sites Division, Ottawa, ON.

Schartup, A.T., P. H. Balcom, A.L. Sorensen, K.J. Gosnell, R.S.D. Calder., R.P. Mason and E.M. Sunderland. 2016. Freshwater discharges drive high levels of methylmercury in Arctic marine biota. PNAS 112(38): 11789-11794.

Table 2. Weekly seafood servings that can be consumed without exceeding Health Canada's pTDI for MeHg.

		Average[1] peak MeHg concentration	Toddler	Child	Female Teen	Women of Child Bearing Age	Male Teen	Other Adult
		Age	7 mo. - 4 y	5 - 11 y	12 - 19 y	> 20 y	12 - 19 y	> 20 y
Species	**Location**	Serving Size mg MeHg/kg wet wt	75	100	150	163	150	170
Brook Trout	**Goose Bay - Baseline**	**0.07**	**4**	**7**	**8**	**10**	**19**	**23**
	Goose Bay Post-Impoundment	**0.12**	**2**	**4**	**5**	**6**	**11**	**13**
Brook Trout	**Lake Melville - Baseline**	**0.04**	**8**	**12**	**14**	**18**	**33**	**40**
	Lake Melville- Post-Impoundment	**0.05**	**6**	**10**	**11**	**14**	**27**	**32**
Rainbow Smelt	**Goose Bay - Baseline**	**0.02**	**15**	**25**	**28**	**36**	**67**	**80**
	Goose Bay - Post-Impoundment	**0.04**	**7**	**12**	**14**	**17**	**32**	**38**
Rainbow Smelt	**Lake Melville - Baseline**	**0.04**	**8**	**12**	**14**	**18**	**33**	**40**
	Lake Melville - Post-Impoundment	**0.06**	**5**	**8**	**9**	**12**	**22**	**27**
Ringed seal (pup)	**Lake Melville - Baseline**	**0.09**	**4**	**6**	**6**	**8**	**15**	**18**
	Lake Melville - Post-Impoundment	**0.11**	**3**	**5**	**5**	**7**	**13**	**15**
Ringed seal (adult)	**Lake Melville - Baseline**	**0.62**	**0.5**	**1**	**1**	**1**	**2**	**3**
	Lake Melville - Post-Impoundment	**0.74**	**0.4**	**1**	**1**	**1**	**2**	**2**

Notes

1 Arithmetic means of target size fish (AMEC 2018) after 3-year exposure; Seal serving size is 193 gm