

Lake Melville:

Avativut, Kanuittailinnivut
(Our Environment, Our Health)

SUMMARY FOR
POLICYMAKERS

Nunatsiavut Government
2016



Credit: Rodd Laing

Above: Members of Lake Melville: Avativut, Kanuittailinnivut field research team collecting sediment samples in Lake Melville

Cover photo: Fishing in Lake Melville, an estuary that is downstream of the Muskrat Falls development and critical for Inuit traditional land use, food and culture.
Credit: Charlie Flowers.

Introduction

Lake Melville is an ecologically and culturally significant subarctic estuary located mostly within Labrador Inuit territory. It is central to Inuit subsistence and well-being and has supported a thriving Inuit society for centuries. Nalcor Energy, the provincial energy corporation of the Government of Newfoundland and Labrador, is currently developing the first phase of the Lower Churchill hydroelectric project – the Muskrat Falls dam and reservoir – upstream from Lake Melville. During the project environmental assessment (EA) and subsequent approvals by federal and provincial governments, however, little was known about potential downstream impacts on Lake Melville and the surrounding Inuit population. The EA panel concluded that this knowledge gap was compounded by Nalcor's decision to exclude Lake Melville from the EA and from detailed study. Nalcor based this decision on their prediction that there would be no measurable impacts downstream.

The Lake Melville: *Avativut, Kanuittailinnivut* research program was initiated by the Nunatsiavut Government, the Labrador Inuit self-government body, to fill this knowledge gap. Independent research by a team of expert scientists from Canada and the United States carried out an extensive field program and data synthesis using state-of-the-art research methods to develop an authoritative understanding of key processes and dynamics in the estuary. The primary research objective was to understand if and how Muskrat Falls would impact the Lake Melville ecosystem and Inuit who depend on it for their well-being. A secondary objective was to anticipate the potentially compounding impacts of changing climate. The research findings are documented in the Lake Melville: *Avativut, Kanuittailinnivut* Scientific Report and provide the scientific basis for the information presented here.

Among the key report findings is evidence from Harvard University scientists of future significant impacts on methylmercury concentrations in the Lake Melville ecosystem and increased Inuit exposure to methylmercury from Muskrat Falls. These findings are substantially different than predictions presented in the Lower Churchill EA by Nalcor Energy. In light of this new scientific evidence, the Nunatsiavut Government has prepared, in this report, a new set of conclusions with respect to the downstream impacts of Muskrat Falls and stemming from these a set of science-based policy recommendations to protect Inuit health and well-being.



Inuit community of Rigolet.

Why Lake Melville is important

CIMFP Exhibit P-01684

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Home to thousands of Inuit

- Thousands of Inuit living on the shores of Lake Melville depend on it for subsistence harvesting and as critical travel infrastructure
- Cultural and historical significance for Inuit reflected in the inclusion of most of Lake Melville within the Labrador Inuit Settlement Area and provision of special Inuit harvesting rights (under Schedule 12-E of land claim) over the remaining portion

Ecologically significant

- Identified as an “Ecologically and Biologically Significant Area” by the Canadian Science Advisory Secretariat, with notably high productivity and species diversity
- Provides important habitat for numerous fish species, seabirds, ducks, seals, and other marine mammals



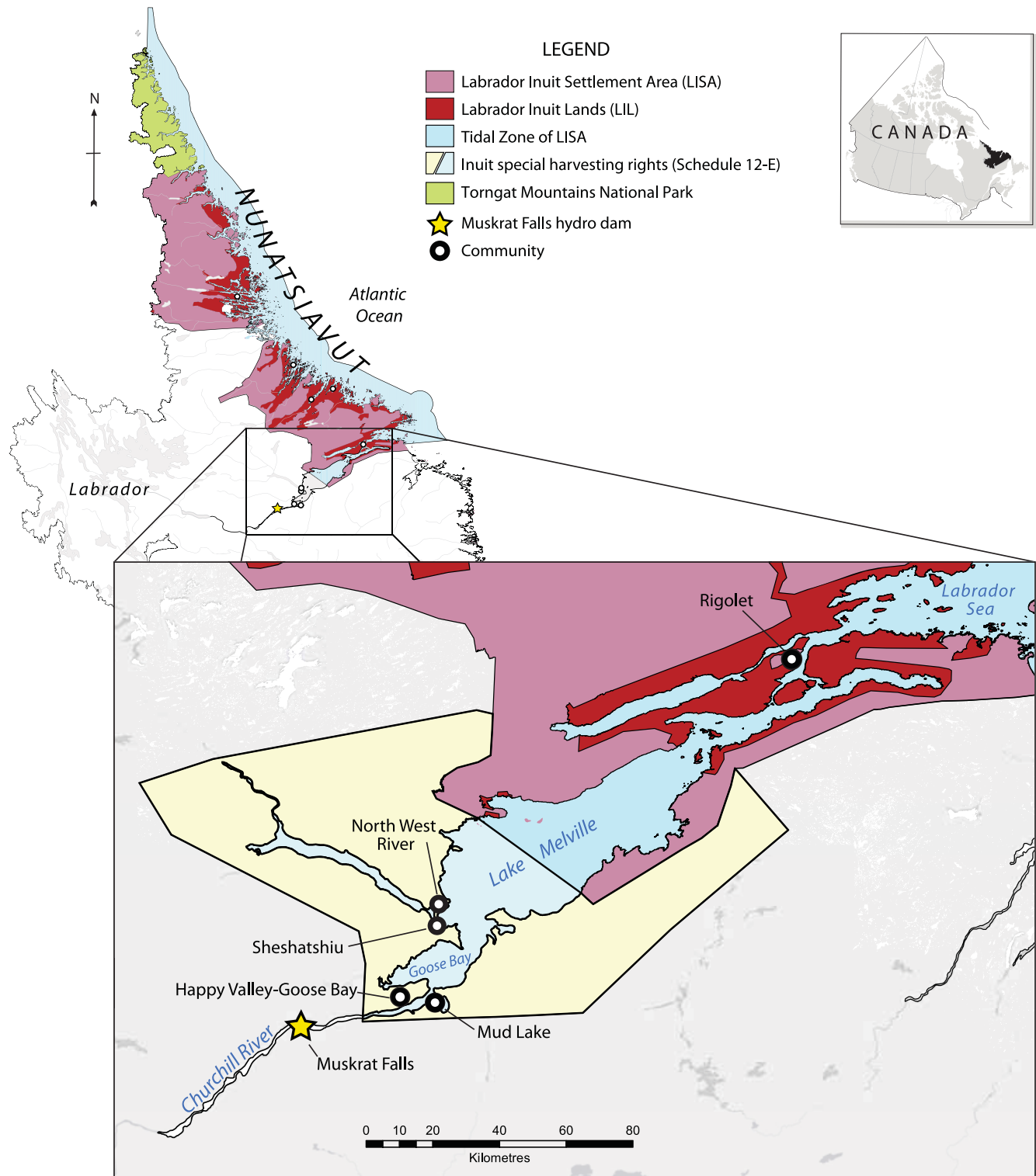
Michael L. Baird
(flickr.bairdphotos.com)



NOAA/Brandon Southall,
SNMFS/OPR



Hans-Petter Fjeld



Lake Melville, surrounding communities and Muskrat Falls in relation to Nunatsiavut (established Labrador Inuit territory). Most of Lake Melville falls within the Labrador Inuit Settlement Area, and Inuit have special harvesting rights over the remainder.



*"It's part of our
culture...we depend on
what we get out there
to sustain us."*

- Rigolet resident

“We’re hungry if we don’t eat our own kind of food, wild food. If we only ate off the store, we’d be hungry all the time.”

–Rigolet resident

“95% of my food is what I eat off of the land.”

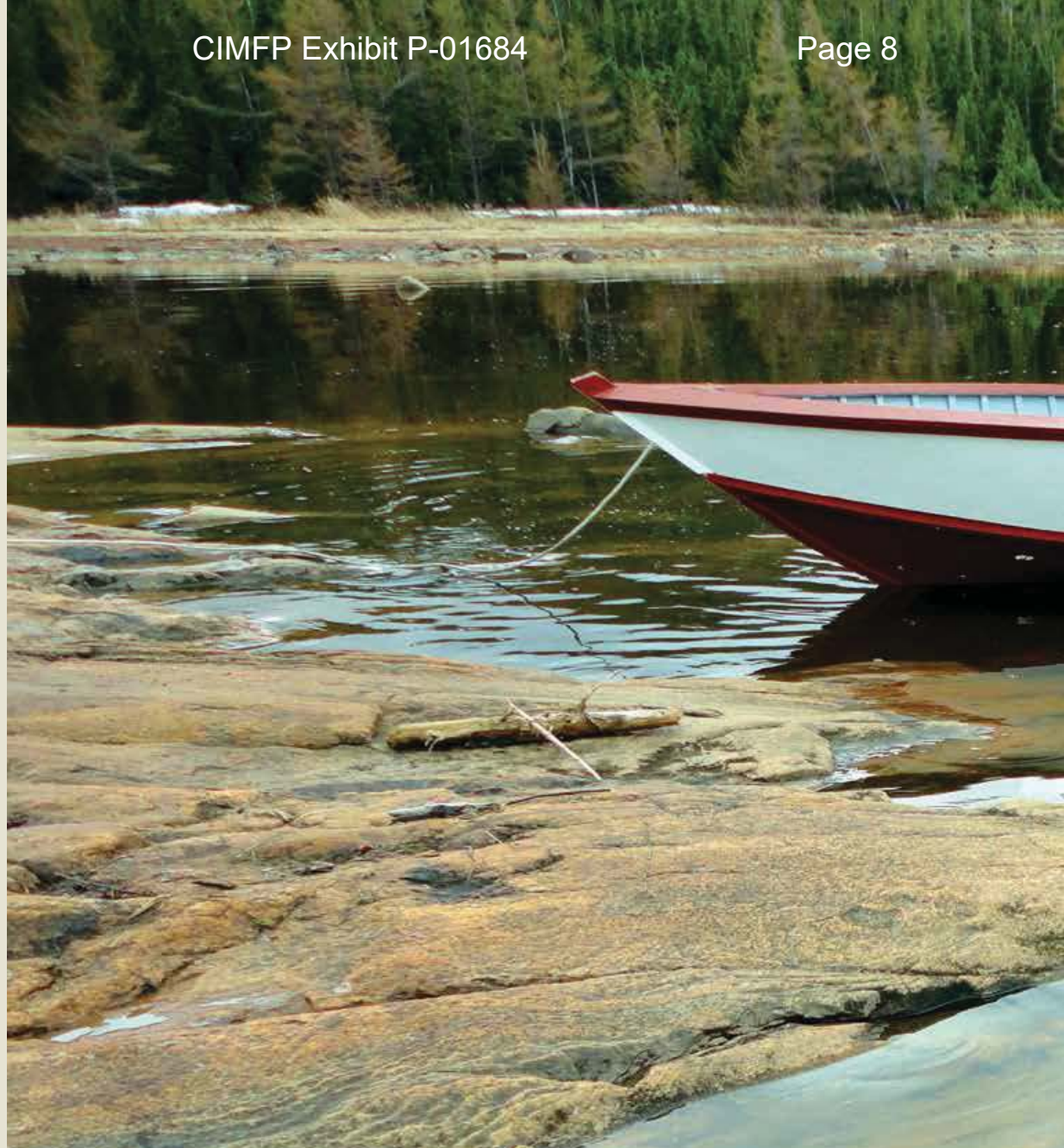
– Rigolet resident



Critical source of country food

- Country foods are at the heart of Inuit health, well-being and culture
- Food from Lake Melville contributes significant nutritional benefits; evidence shows that on days when country foods are consumed, Inuit diets have significantly less fat, carbohydrates, and sugar, and more protein and essential micronutrients (such as vitamins A, D, E, and B6; riboflavin; iron; zinc; copper; magnesium; manganese; phosphorus; potassium; and selenium)¹
- Harvesting puts food on the table in a region with high market food costs and almost 5 times the food insecurity rates of the general Canadian population

¹ Kuhnlein et al., 2004



Lake Melville is very important to us, and the watersheds that connect or flow into Lake Melville. It's been a part of our lives and our families' lives as long as anyone can go back... [It] keeps us healthy, it connects us to the land, it gives us our food, it gives us our identity.

-Rigolet resident







Credit: Build Films

CIMFP Exhibit P-01684

Why methylmercury is of critical concern to Inuit

Methylmercury is toxic to humans

- Primarily a central nervous system toxin
- Chronic exposure from consumption of aquatic foods has been associated with brain impairment in children, including IQ deficits, attention deficit behavior, and reductions in verbal function and memory
- The developing fetus is most vulnerable to effects
- In adults, dietary exposure can affect cardiovascular (heart and blood) health, immune health, and hormone function

Muskrat Falls under construction (Fall 2015)

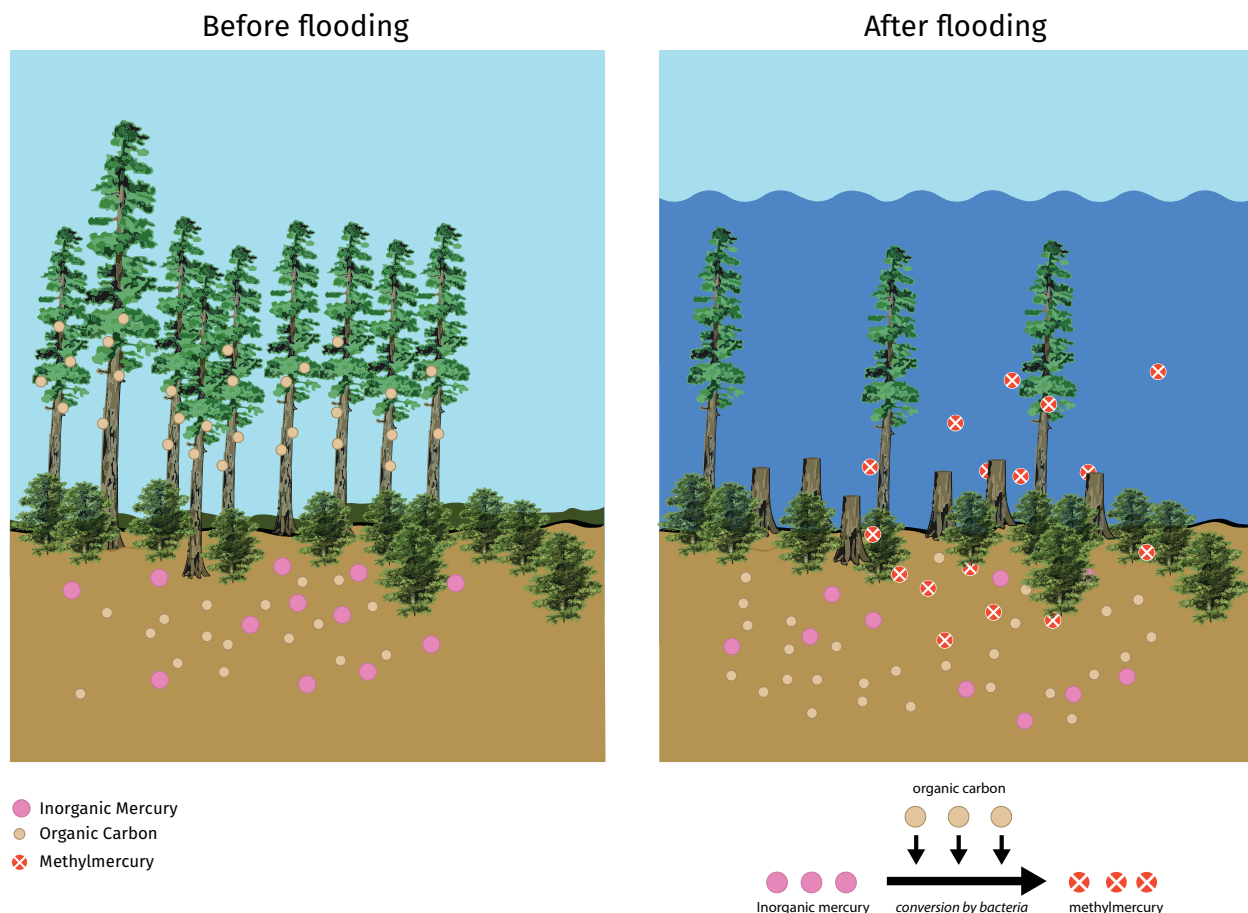
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Reservoir flooding increases methylmercury production

Reservoir flooding creates an ideal environment for specialized bacteria to convert naturally-occurring inorganic mercury to methylmercury, fueled by organic carbon from decomposing vegetation

- Methylmercury is naturally formed from inorganic mercury by specialized bacteria, a process that is dramatically enhanced during reservoir flooding
- Bacterial production of methylmercury is fuelled by abundant organic carbon from decomposing vegetation in reservoirs
- The amount of methylmercury produced is directly related to the available organic carbon content of reservoirs derived from flooded soils and vegetation

How flooding increases methylmercury production

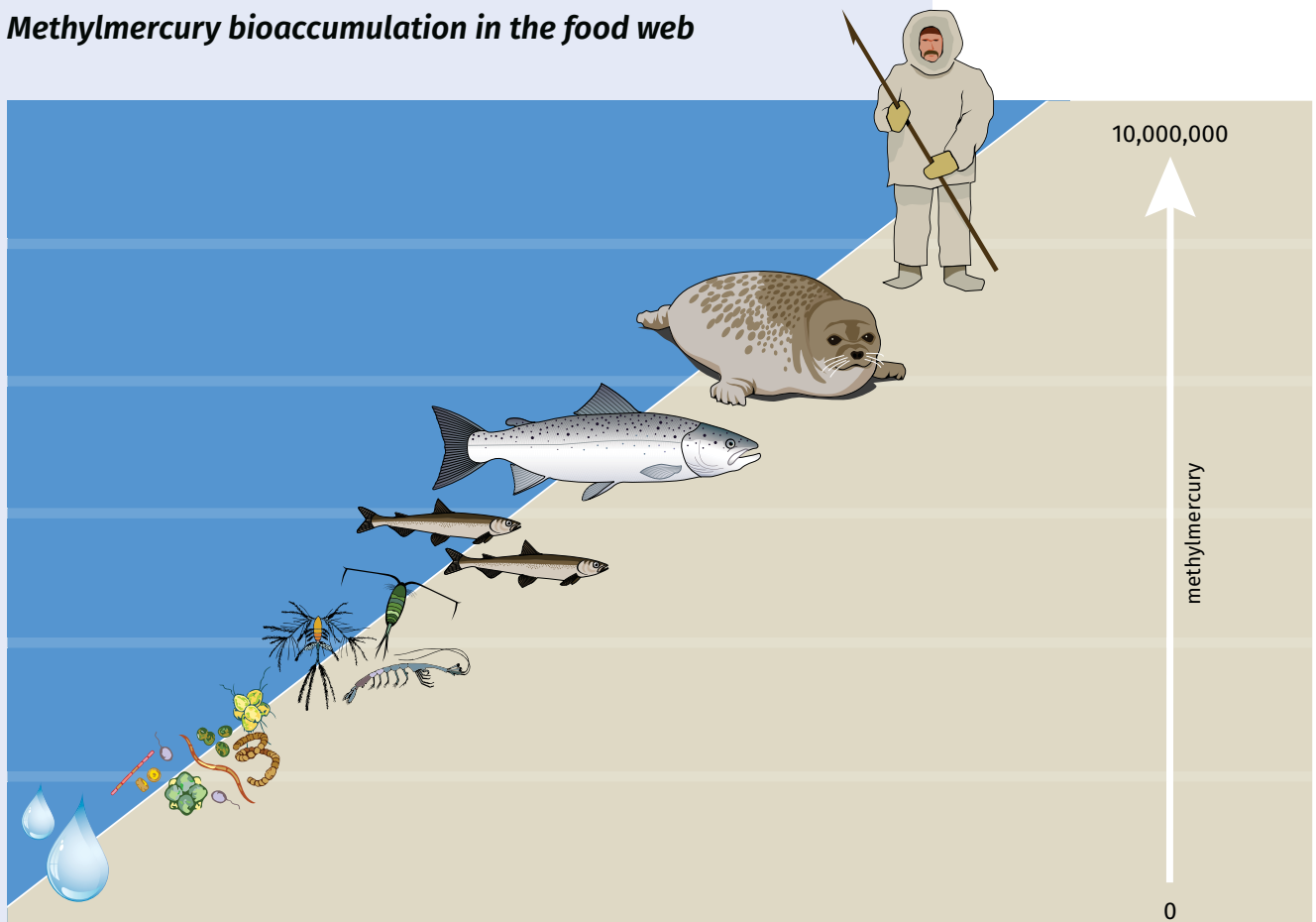


Methylmercury bioaccumulates in aquatic food webs

- Methylmercury accumulates in higher concentrations up through the aquatic food web such that levels in fish and marine mammals are usually up to ten million times higher than the water they live in. The largest bioaccumulation increase is at the lowest levels – plankton – in the food web
- Increased biological concentrations of methylmercury can be sustained for decades after initial flooding

After entering plankton at the base of the food web, methylmercury bioaccumulates (builds up in species) and biomagnifies (concentrates in the aquatic food web) as species consume other species.

Methylmercury bioaccumulation in the food web





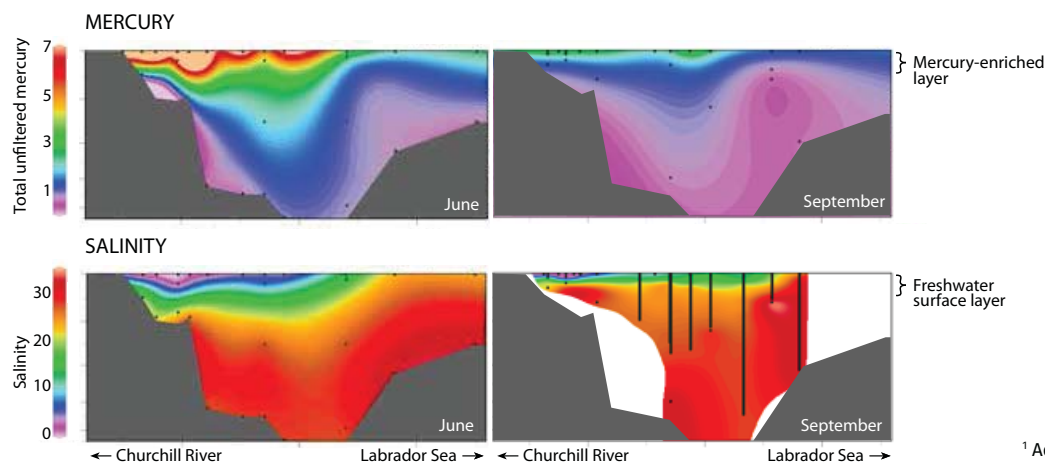
What the Lake Melville scientific research program told us

1. Lake Melville is a primary methylmercury producer

- In contrast to Nalcor's assumption that Lake Melville dilutes methylmercury concentrations, the Harvard study demonstrates that Lake Melville is a primary producer of methylmercury in the water column
- Most of the methylmercury currently measured in Lake Melville is converted from inorganic mercury by specialized bacteria in the surface freshwater layer

2. Rivers have a major impact on methylmercury levels in Lake Melville

- By far the largest source of inorganic mercury to Lake Melville is from rivers, with the Churchill River being the primary contributor
- Mercury and methylmercury contributed by rivers are concentrated in the surface freshwater layer of Lake Melville



Cross-section of Lake Melville that shows elevated mercury levels in the freshwater layer derived from Churchill River inputs¹

¹ Adapted from Schartup et al., 2015



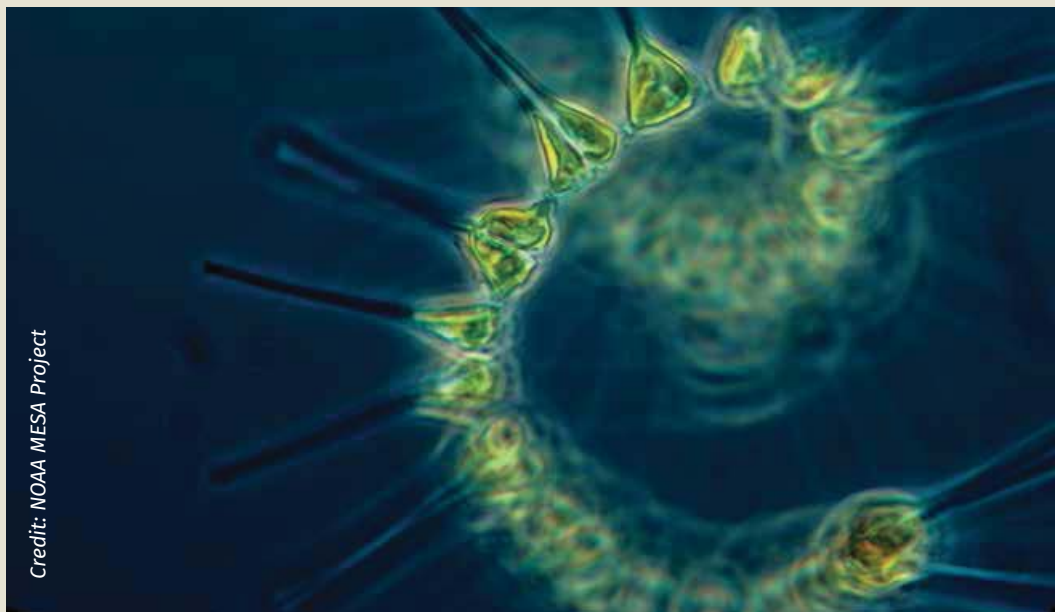
Churchill River

3. Rivers have a major impact on organic carbon in Lake Melville

- University of Manitoba study findings show that rivers are the largest source of organic carbon to Lake Melville, which is the base of the food web and supports microbial communities including those responsible for methylmercury conversion in the water column
- The majority of the suspended sediment load and terrestrial particulate organic carbon from rivers is carried beyond Goose Bay into the main basin of Lake Melville
- The supply of organic carbon to Lake Melville has increased in recent decades, most likely related to changes in Churchill River flow because of the Upper Churchill development 300 km upstream, showing sensitivity in the lake to river changes upstream

4. Lake Melville is uniquely efficient at magnifying methylmercury

- Highest methylmercury concentrations and bioaccumulation factors occur in plankton living in a thin surface plume of freshwater that extends from the mouth of the Churchill River across almost the entire length of Lake Melville to the Narrows at Rigolet
- This intense microbial and plankton activity, supported by thin layers of organic material near the base of the freshwater layer and fueled by organic carbon entering from rivers, enhances methylmercury production and its rapid uptake into the food web



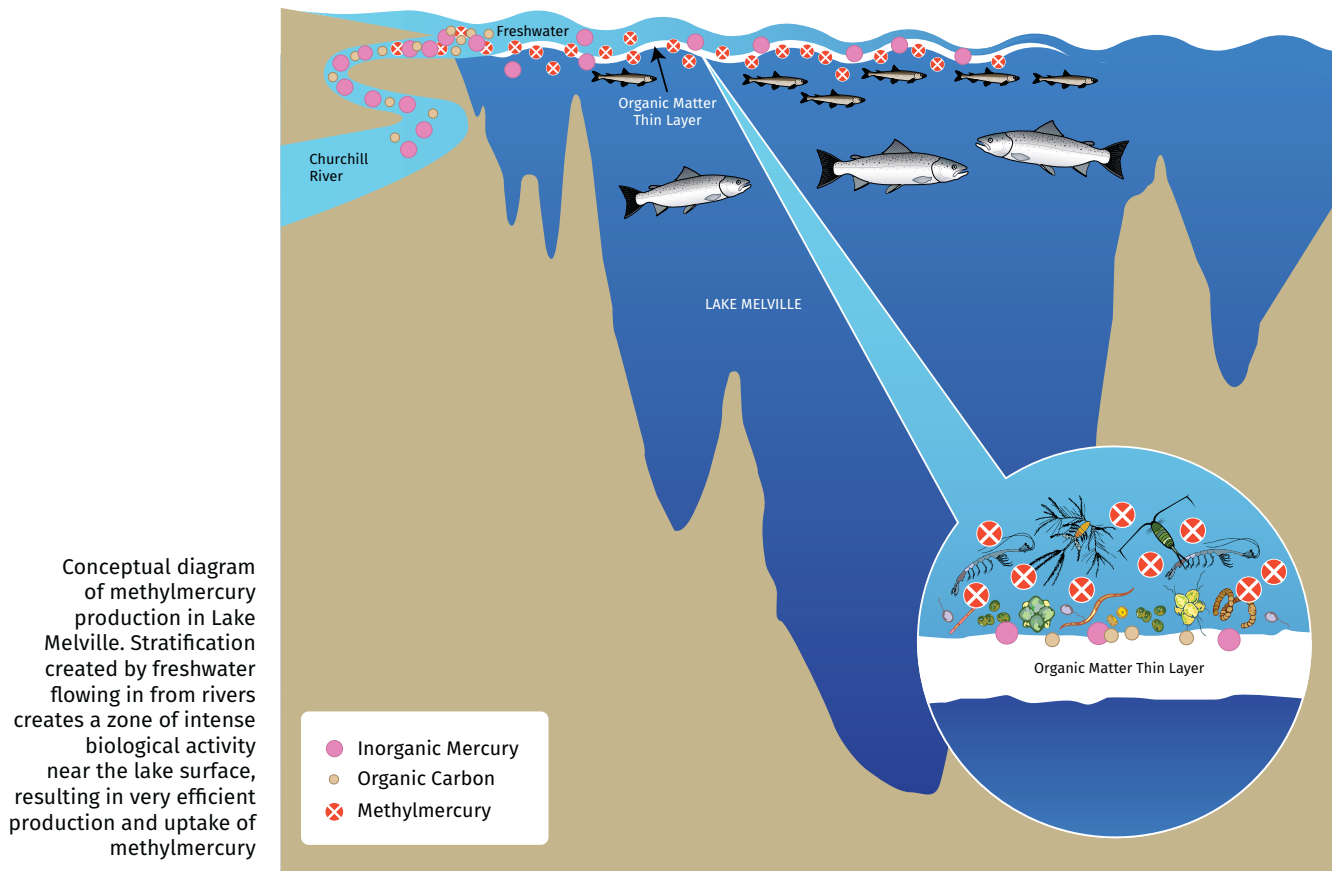
Credit: NOAA MESA Project



Credit: Matt Wilson/Jay Clark, NOAA NMFS AFSC

Phytoplankton (upper) and zooplankton (lower) under a microscope

Stratification and methylmercury bioaccumulation in Lake Melville



5. Methylmercury exposures of Inuit living around Lake Melville are currently higher than the Canadian population

- The median mercury level measured in hair (a reliable measure of methylmercury) in the 655 Inuit individuals sampled was roughly 2 to 2.5 times that of the general Canadian population
- Locally-caught wildlife represents a large fraction of food consumed by Inuit and contributes ~70% of their total methylmercury exposure
- Methylmercury exposures were higher in Rigolet and North West River than Happy Valley-Goose Bay (including Mud Lake)

6. Flooding will cause a sharp rise in methylmercury production in the reservoir within 120 hours that can remain elevated for decades

- Experimentally flooded soils from the future Muskrat Falls reservoir area showed a spike in methylmercury concentrations within 72 hours, and a 14-fold increase in methylmercury concentrations within 120 hours
- Elevated levels of methylmercury are anticipated to last decades

7. Muskrat Falls expected to double suspended sediment and terrestrial organic carbon inputs to Lake Melville

- Calculations by the University of Manitoba science team show that Muskrat Falls could double the amount of suspended sediment and terrestrial organic carbon carried by the Churchill River to Lake Melville, the majority of which is likely to be carried beyond Goose Bay into central Lake Melville

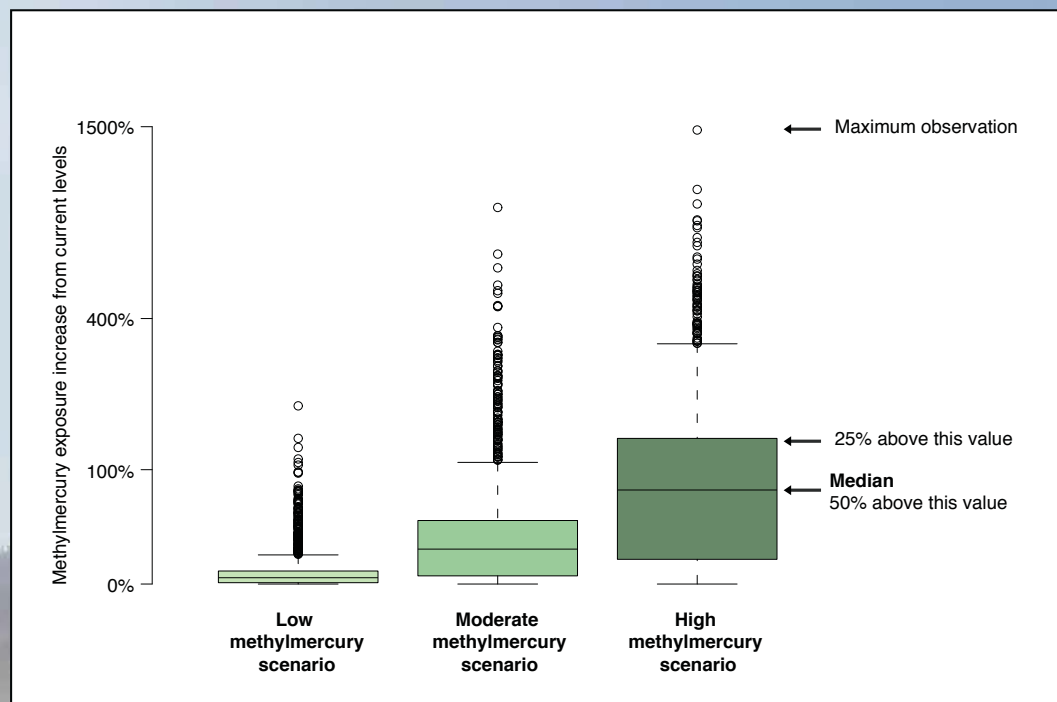
8. Methylmercury exposures for Inuit will increase post-Muskrat Falls flooding

- The Harvard science team constructed three outcomes for Muskrat Falls reservoir flooding assuming different levels of reservoir clearance to calculate potential increases in methylmercury levels in Lake Melville and changes in Inuit exposure to methylmercury

Flooding scenario	Reservoir clearance assumptions
Low methylmercury scenario	Removal of topsoil , vegetation & trees; rapid decomposition of methylmercury in river (low transport into Lake Melville)
Moderate methylmercury scenario	Partial clearance of trees & brush, moderate decomposition in river (moderate transport into Lake Melville)
High methylmercury scenario	Partial clearance of trees & brush; little decomposition in river (high transport into Lake Melville)

- Even under the low methylmercury scenario, which requires complete removal of topsoil, vegetation and trees, and rapid decomposition of methylmercury in the river before it reaches Lake Melville, there will be an overall increase in Inuit methylmercury exposure
- Under the high methylmercury scenario, methylmercury exposure for some individuals who consume greater amounts of country foods may increase by up to 1500%

Modelled changes in methylmercury exposures for Inuit due to Muskrat Falls flooding



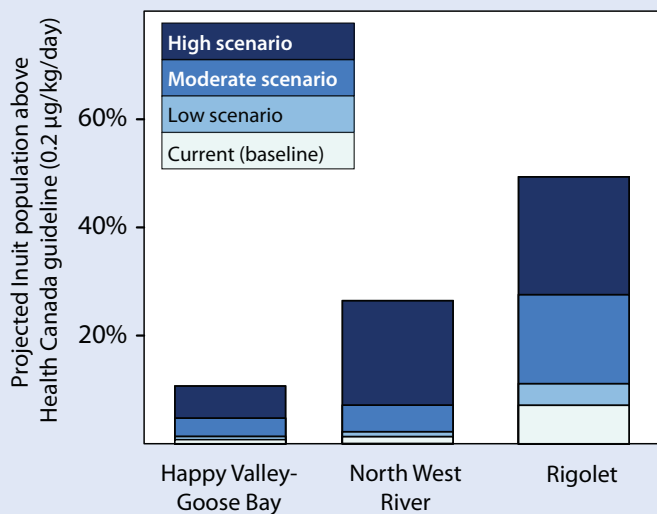
Modelled changes in methylmercury exposure for Inuit living around Lake Melville under the three Muskrat Falls reservoir-flooding scenarios¹

¹ Adapted from Calder et al., in prep

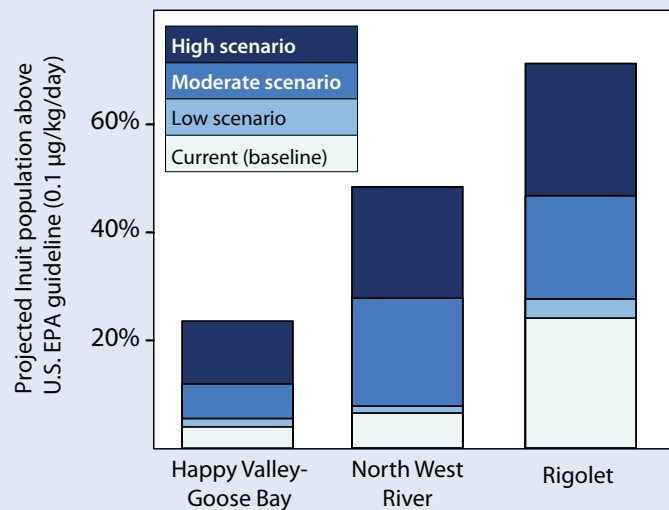
9. Hundreds of Inuit will be exposed to methylmercury above regulatory guidelines

- The number of Inuit who will potentially exceed the most conservative Health Canada guideline for methylmercury exposure ranges from 32 individuals if the reservoir is completely cleared, including topsoil, to over 200 individuals if only partial clearance of trees and brush occurs
- Using the U.S. Environmental Protection Agency (EPA) methylmercury guideline, which given the health risks is more conservative for human exposure, the number of individual exceedences in the Inuit population around Lake Melville increases to over 50 under the low and over 400 under the high methylmercury scenarios
- Rigolet residents, who reside within the Labrador Inuit Settlement Area, are at higher risk of increased mercury exposure compared with Inuit living in other lake Melville communities due to their greater reliance on locally harvested food; under the high methylmercury scenario, 46% and 66% of the community would exceed the most conservative Health Canada and U.S. EPA guidelines, respectively

Percentage of Inuit to exceed most conservative Health Canada guideline



Percentage of Inuit to exceed U.S. EPA guideline



Percentage of Inuit living around Lake Melville projected to exceed **Health Canada (left)** and **U.S. EPA (right)** methylmercury guidelines under the three Muskrat Falls reservoir-flooding scenarios¹

¹Adapted from Calder et al., in prep

Young beneficiary
on the land in
Lake Melville

Credit: Charlotte Wolfrey



Conclusions and Recommendations

Conclusion 1: Scientific evidence demonstrates that Nalcor's downstream impact predictions are false and based on incorrect assumptions.

Nalcor's claim that "Goose Bay dilutes any effects originating from upstream to 'no measurable effects,'" was based on limited information, and has been proven incorrect by scientific measurements. Scientific evidence demonstrates both that there will be substantial downstream impacts, and also that Nalcor's premise for predicting no downstream impacts was false.

The Harvard study shows that instead of diluting methylmercury, Lake Melville is a primary producer of methylmercury, and concentrates it in the biologically active surface layer where it is rapidly taken up in the food web. The University of Manitoba study shows that rather than being diluted and blocked, the majority of sediments and organic carbon in the estuary are carried by the Churchill River plume east of Goose Bay into central Lake Melville. These findings are based on extensive measurements of Lake Melville sediments, water, and plankton. Some of the key differences between Nalcor's claims during the EA and approaches and findings of the Lake Melville research program university science teams are detailed in a table at the end of this report.

Sample from Lake Melville

Conclusion 2: Under the current plan to only partially clear trees and brush in the reservoir, the Muskrat Falls dam will have significant adverse impacts on Inuit health, harvesting and consumption of country foods and Treaty rights in the Labrador Inuit Settlement Area. These impacts are much greater than previously assessed.

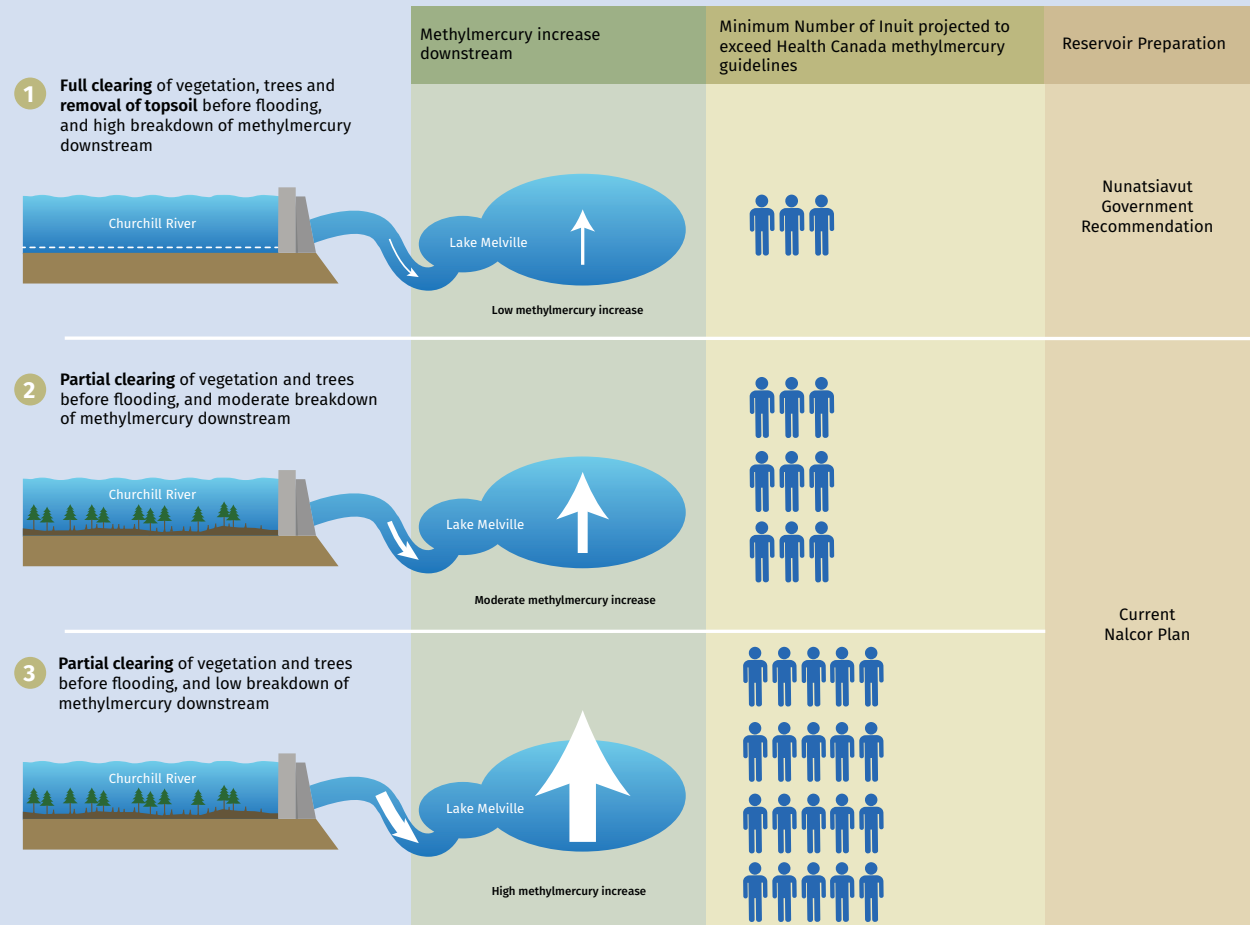
Conclusion 3: Mitigation of downstream methylmercury impacts of Muskrat Falls is possible. Full clearing of wood, brush, vegetation, and topsoil from the reservoir area before flooding will result in significantly lower increases in methylmercury exposure for Inuit in the Lake Melville area than may be expected under the current plan to only partially clear the reservoir.

RECOMMENDATION 1:

Governments require Nalcor to fully clear the Muskrat Falls reservoir of wood, brush, vegetation, and topsoil before flooding to mitigate as much as possible increases in methylmercury exposures for downstream Inuit populations, building on recommendation 4.5 of the Lower Churchill EA panel. Until full clearing is carried out, Muskrat Falls reservoir flooding must not be allowed.

Muskrat Falls flooding scenarios and downstream impacts; the current plan is projected to fall within scenario 2 or 3

 = 10 People



Conclusion 4: Even with full clearance of the Muskrat Falls reservoir, an increase in methylmercury exposure for Inuit downstream can be expected.

Under all reservoir clearance scenarios, the Muskrat Falls dam will increase Inuit exposure to methylmercury. Nalcor's proposed mitigation plan to simply issue consumption advisories is a flawed health protection strategy. A comprehensive review of impacts of contaminants on Inuit health⁴ revealed that changes in country food consumption as a result of contamination have complex and adverse health consequences for Inuit, such as:

- Loss of essential nutrients in country foods that are not generally replaced when individuals switch away from their traditional diet, resulting in: i) increased obesity and risk of chronic disease; ii) increased total fat, saturated fat, and sucrose consumption above recommended levels; and iii) decreased intake of vitamins A, D, E, B6, and riboflavin and of minerals.
- Loss and disruption to cultural, social, psychological, economic, and spiritual benefits of harvesting, sharing, and consuming country foods.

The EA panel concluded that Muskrat Falls would have *significant adverse effects* on traditional harvesting and country food consumption by Labrador Inuit should consumption advisories be required in Goose Bay and Lake Melville, and recommended that "...if the downstream effect assessment (Recommendation 6.7) indicates that consumption advisories would be required for Goose Bay or Lake Melville, Nalcor enter into negotiations prior to impoundment."⁵



Credit: Charlie Flowers



Credit: Iris Allen

⁴ Donaldson et al., 2013

⁵ Joint Review Panel, 2011, p. 238



RECOMMENDATION 2: Governments require Nalcor to negotiate an Impact Management Agreement with the Nunatsiavut Government to the satisfaction of all parties before Muskrat Falls reservoir flooding and subsequent adverse downstream impacts occur, consistent with recommendation 13.9 of the Lower Churchill EA panel.

Conclusion 5: Current monitoring plans for downstream impacts of Muskrat Falls are inadequate for the protection of Inuit health.

The current Environmental Effects Monitoring Plan is based on prior predictions by Nalcor of no measurable impacts of Muskrat Falls in Lake Melville and consists of spatially and temporally limited water sampling and minimal mercury sampling of fish and seals. These predictions are no longer valid. New measurements and modelling that anticipate significant increases in methylmercury exposure for Inuit require a more sophisticated and rigorous monitoring program. Independent expertise is required to review and utilize the scientific findings from the Lake Melville research program in the design of a new, holistic monitoring regime. Such an expert panel should also address outstanding questions raised by this new research that have monitoring and legislative implications, such as expected impacts of elevated methylmercury exposures on fish and seal health in Lake Melville.



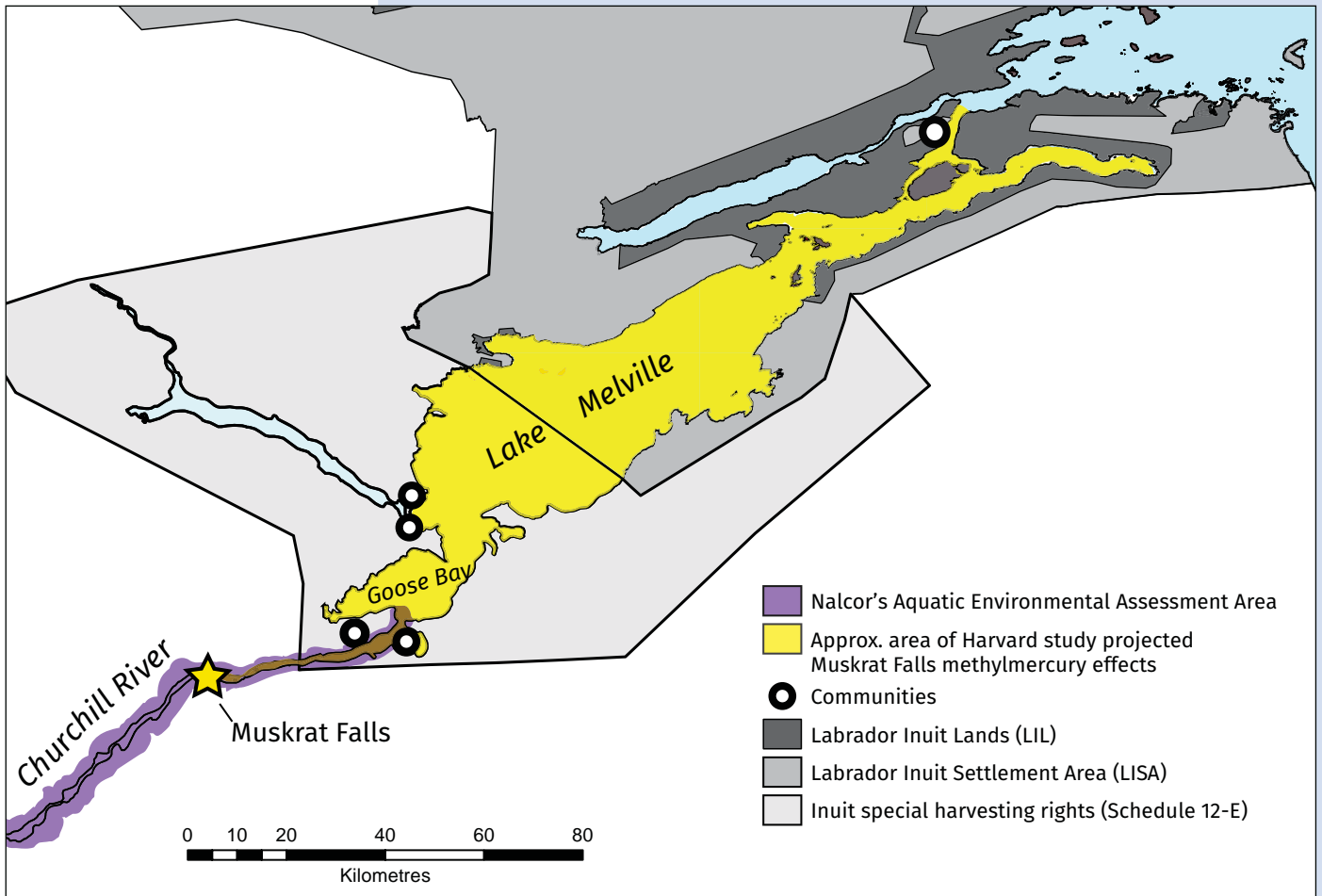
Credit: Rodd Laing

Lake Melville field research program in action



Credit: Rodd Laing

RECOMMENDATION 3: Governments require Nalcor to establish an independent Expert Advisory Committee of recognized experts, including from the academic community, to advise on mitigation measures and the design and audit of a rigorous, credible, and predictive monitoring program related to downstream impacts of Muskrat Falls using the best available scientific and Inuit knowledge.



Comparison of Nalcor's aquatic environmental assessment area, beyond which no measurable effects were predicted, and approximate area of projected Muskrat Falls methylmercury effects from the Harvard study

Conclusion 6: Lack of Inuit involvement and decision-making authority related to monitoring and environmental management of Muskrat Falls is inconsistent with the significant adverse impacts expected on Inuit lands, rights, and health.

Currently, Inuit have no decision-making authority related to any aspect of Muskrat Falls as Nalcor did not predict adverse effects downstream. Evidence now demonstrates that Muskrat Falls will have significant adverse effects on harvesting and consumption of country foods and human health in the Labrador Inuit Settlement Area, where Inuit have jurisdiction. Inuit jurisdiction and rights are not recognized or reflected in the current monitoring and management regime for Muskrat Falls.

RECOMMENDATION 4: Governments require Nalcor to grant Inuit joint decision-making authority over downstream environmental monitoring and management of Muskrat Falls through the creation of an Environmental Management Board, to which the Expert Advisory Committee on monitoring would report.

Table of differences between Nalcor and Lake Melville research program science

	Nalcor and consultants	Lake Melville research program
Scope	<p>Nalcor has claimed that impacts from hydroelectric development will not extend past Goose Bay and has therefore excluded Lake Melville from the environmental assessment.</p> <p><i>Lake Melville is not included within the Assessment Area as there will be no change in flow or salinity, water temperature, ice or other physical disturbance beyond the mouth of the Churchill River from this Project. (Nalcor Energy, 2009, p. 2-16)</i></p> <p><i>Goose Bay dilutes any effects originating from upstream to “no measureable effects” level on the key indicators (KI). (Nalcor Energy, 2011, p. 3)</i></p>	<p>Schartup et al. (2015) and Calder et al. (in prep) have focused on the downstream environment and the mechanisms that make it vulnerable to changes in freshwater inputs.</p> <p><i>Ambient MeHg [methylmercury] concentrations in the upper few meters of the estuarine water column are enriched from riverine inputs rather than water-column methylation relative to deeper waters within the stratified low-salinity surface layer. (Schartup et al., 2015, p. 2)</i></p> <p>Kamula and Kuzyk (2016) have focused on the sediment and organic carbon sources, flows, and distribution in Lake Melville, finding that the Churchill River is the largest source of sediment and terrestrial particulate organic carbon to the downstream estuary with most of it being transported by the river plume past the Narrows at Goose Bay.</p>
Impacts of hydropower on upstream methylmercury	<p>Assessments commissioned by Nalcor have been limited by a lack of data.</p> <p>Harris et al. (2010) predicted that post-flooding methylmercury levels in the Churchill River would increase by 60%. However, this study assumed a baseline level roughly double that subsequently measured and reported by Schartup et al. (2015). Therefore, the relative increase of methylmercury in the water column after flooding is underestimated.</p> <p>Impacts on biological organisms are disconnected from the biogeochemistry of the system.</p> <p>Nalcor Energy (2010) uses flow rate and flooded area to adapt data from Quebec and Manitoba and proposes that after flooding, methylmercury in fish downstream from Muskrat Falls will increase by 220% to 500%. The physical characteristics of the environment (e.g., carbon content) are not considered.</p>	<p>Schartup et al. (2015) and Calder et al. (in prep) use direct measurements and develop an integrated environmental model.</p> <p>Estimates for post-flooding methylmercury levels are based on the carbon content of the system and design parameters of the reservoir and are compared to measured pre-flooding concentrations. This increase is propagated through the food web. Post-flooding methylmercury concentrations are thus derived mechanistically.</p>

	Nalcor and consultants	Lake Melville research program
Methylmercury in Lake Melville	<p>Nalcor has not evaluated impacts on methylmercury in the Lake Melville food web, to our knowledge.</p> <p>Oceans Ltd. (2010) implemented a dispersion model to characterize the transport of methylmercury discharged by the Churchill River. This study has two primary limitations:</p> <ul style="list-style-type: none"> • the model design likely overestimates vertical mixing and therefore underestimates methylmercury levels in upper layers of Lake Melville (acknowledged by authors); and • the Churchill River is taken to be the only source of total mercury and methylmercury, and there is no support for the chemical processes responsible for the estuarine mercury cycle. <p>The Oceans Ltd. study cannot be considered to model mercury dynamics in Lake Melville.</p>	<p>Schartup et al. (2015) identified that stratification in Lake Melville enhances sensitivity in Lake Melville's food web to changes in the Churchill River.</p> <p>Subsequent work (Calder et al. in prep) quantifies the impact of changes in the Churchill River on freshwater and marine species.</p>
Baseline exposures to methylmercury	<p>Nalcor's study of current exposure to methylmercury is limited by low Inuit participation levels.</p> <p>Golder Associates (2015) recruited 293 individuals from Churchill Falls, Happy Valley-Goose Bay, Mud Lake, North West River and Sheshatshiu into a dietary survey and hair sampling program. Two-thirds (196/293) of the participants reported membership in an Aboriginal organization, predominantly in the communities of North West River and Sheshatshiu. The study was carried out in the winter (November 2014 to February 2015), which is known to be a period of low consumption of country foods.</p> <p>Hair mercury levels suggest that predominantly Aboriginal communities are more highly exposed than the general Canadian population but largely below regulatory guidelines.</p>	<p>High Inuit survey participation captures high variability in current diets and methylmercury exposures.</p> <p>Calder et al. (in prep) recruited 1,145 individuals from Happy Valley-Goose Bay (including Mud Lake), North West River and Rigolet into a dietary survey and hair sampling program carried out in three seasons over one year (2014). All participants were Inuit or the spouse or child of Inuit.</p> <p>This study revealed wide ranges in diet and exposures across seasons, communities and demographic groups. Relatively high enrollment was therefore necessary to adequately characterize the Inuit population.</p>

	Nalcor and consultants	Lake Melville research program
Methylmercury exposures following flooding	<p>No conclusions on post-flooding methylmercury exposures for Inuit can be drawn from Nalcor's commissioned studies.</p> <p>Golder Associates (2011) assessed potential future exposures in Churchill Falls, Happy Valley-Goose Bay (including Mud Lake), North West River and Sheshatshiu. The study used a quantity called 'hazard quotient' (HQ) to compare methylmercury exposures to Health Canada's provisional tolerable daily intake (pTDI), where pTDI = 0.20 µg/kg/day for women and children and 0.47 µg/kg/day for everyone else.</p> <p>Baseline (current) and post-flooding HQs were derived for these communities, but only (predominantly Innu) Sheshatshiu has Aboriginal-specific post-flooding HQ values. Across demographic strata and excluding infants, the range of HQs is expected to rise from 0.8–4 to 2–11 in Sheshatshiu.</p> <p>Baseline data are presented for (predominantly Inuit) North West River, but only four households participated and one was excluded as an "outlier" (14 locally-caught fish meals per day). Inuit account for 27.5% of participants in communities other than Sheshatshiu, but participation is not reported on a community-specific basis. Post-flooding values for other Aboriginal populations are not presented.</p> <p>The results for Sheshatshiu suggest that Aboriginal populations face substantial increases in methylmercury exposures. However, no inferences can be drawn about the high-end consumers of any ethnicity or about exposures among Inuit.</p>	<p>Calder et al. (in prep) simulates post-flooding exposures under a range of scenarios with emphasis on the populations at greatest risk.</p> <p>Under the scenario where carbon-rich surface soil is not removed before flooding, median exposures may increase by nearly 50% to greater than 100%. Roughly 10 to 20% of Inuit living around Lake Melville are expected to exceed the Health Canada pTDI after flooding compared to 4% at baseline. The 95th percentile (roughly 150 Inuit in the Lake Melville region) may increase from roughly the pTDI at baseline by roughly 350%.</p> <p>Removal of surface soil and litter is likely to substantially reduce the magnitude of methylmercury production. It may reduce by roughly two thirds the number of Inuit expected to exceed the Health Canada pTDI (0.2 µg/kg/day).</p>

	Nalcor and consultants	Lake Melville research program
Sediments and organic carbon in Lake Melville	<p>Nalcor's claims regarding sediment and organic carbon in Lake Melville are limited by lack of data.</p> <p>Nalcor claimed that Goose Bay dilutes effects originating from upstream to no measurable effects based on the premise that transport between Goose Bay and the main Lake Melville basin is "blocked" at the shallows:</p> <p><i>...the shallows at Goose Bay Narrows act as a hydraulic control that slow exchange with Lake Melville...Water, TSS [total suspended solids] and plankton are progressively "diluted" going downstream from Muskrat Falls and most sediment will settle out along the way; the Narrows will further "block" sediment, plankton, and fish to some degree. (Nalcor Energy 2011, p. 3)</i></p> <p>This assertion is hampered by limited data: All of Nalcor's component studies for the EA related to sediments were restricted to the main stem of the Churchill River (AMEC 2008; Minaskuat 2007, 2008; Northwest Hydraulic Consultants 2008) apart from one, which was limited to the Goose Bay estuary (AMEC-BAE 2001). This latter study found that total suspended solids migrate into Goose Bay and Lake Melville (AMEC-BAE 2001; Nalcor Energy 2009b), which seems to contradict Nalcor's main claim above.</p>	<p>Empirical sediment data shows a strong influence of the Churchill River organic carbon in Lake Melville.</p> <p>Through a study of sediment cores, Kamula and Kuzyk (2016) found that the Churchill River is the largest source of sediment and terrestrial particulate (larger-sized) organic carbon to Goose Bay and Lake Melville, with 74% of the river's suspended sediment load and 62% of the terrestrial (land-derived) particulate organic carbon being carried beyond the Narrows at Goose Bay and into Lake Melville. Mass accumulation rates from studying sediment cores show the greatest accumulation of sediment on the east side of Goose Bay Narrows, in the western part of Lake Melville's main basin. In this location, total organic carbon in surface sediment was three times greater than at a nearby core site in Goose Bay. This indicates that sediment is being carried in suspension eastward in the surface waters of the Churchill River plume through Goose Bay Narrows where currents are fast and flow direction is consistently eastward (seaward) during both ebb and flood tide.</p>

	Nalcor and consultants	Lake Melville research program
Historical sediment inputs to Lake Melville	<p>Lack of historical data has led to a limited understanding of the past influences of hydro development on organic carbon and sediments in Lake Melville.</p> <p>Sparse data has hampered understanding of past development effects. In a commissioned study, Northwest Hydraulic Consultants (2008) stated that:</p> <p><i>Winokapau Lake [~50 km downstream from the Upper Churchill development, ~250 km upstream from Goose Bay] is a very extensive and permanent feature, which has acted and continues to act to trap all sediment incoming from upstream sources. Winokapau Lake thus represents an upstream boundary for all historical downstream sediment transport. (p. 4)</i></p> <p>However, the authors acknowledge that influences of changes in discharge on sediments were outside the scope of their study.</p>	<p>Sediment record shows likely influence of past hydro development on organic carbon inputs to Lake Melville.</p> <p>By studying sediment cores, Kamula and Kuzyk (2016) found a small but significant increase in terrestrial organic carbon over the last four decades in the western end of Lake Melville's main basin, even though this area is quite removed from the river mouths. It is likely that the Churchill River, as the strongest source of terrestrial organic carbon to Lake Melville, has played a role in this increase. Specifically, changes in the flow and drainage area of the Churchill River from the Upper Churchill hydro development starting in the 1970s could have released terrestrial organic matter thus likely increasing the delivery of particulate organic carbon to Lake Melville, at least for some period until the system readjusted. Other land use changes within the watershed may have also contributed to the observed increase of organic carbon in the sediment record.</p>

	Nalcor and consultants	Lake Melville research program
Sediments and organic carbon following flooding	<p>Environmental assessment boundary limited study of downstream effects of flooding on sediments and organic carbon.</p> <p>In a commissioned study, AMEC (2008) found that the majority (97%) of the Muskrat Falls reservoir has a Soil Erosion Potential rating of high to very high and the majority (72%) of the area downstream of Muskrat Falls has a Soil Erosion Potential rating of high:</p> <p><i>Erosion and the ongoing undermining of the post construction/impoundment shoreline will continue, potentially for decades until the redevelopment of a stable shoreline. (AMEC 2008, p. iv)</i></p> <p>AMEC (2008) estimated that under the most likely scenario, sediment inflow will increase from 1 million m³/year below Muskrat Falls to 1.67 million m³/year near the mouth of the river. Using a bulk density of 2600 kg/m³, this equals an increase to about 43.5 x 10⁸ kg sediment per year.</p> <p>However, restriction of this study to the main stem of the Churchill River and lack of study of sediment and organic carbon cycling in Lake Melville meant that effects of this increase on the estuary were not investigated.</p>	<p>Majority of increased sediment and organic carbon loads after flooding likely to flow into main basin of Lake Melville.</p> <p>Using shoreline erosion assumptions from Muskrat Falls reported by Amec (2008), calculations by Kamula and Kuzyk (2016) show that suspended sediment inputs of the Churchill River to Lake Melville may increase from 25.2 x 10⁸ kg to 49.5 x 10⁸ kg per year, while terrestrial particulate organic carbon inputs may increase from 18.4 10⁶ kg to 24.3 x 10⁶ kg per year. This would continue until the shoreline readjusts, over a longer, unknown timescale, potentially decades. This calculation, which agrees with the estimate in Amec (2008), assumes half of the eroded soil and organic matter remains trapped in the reservoir and sand bars downstream. To put this in perspective, the mass budget developed by Kamula and Kuzyk suggests this is a doubling of the annual loads. Furthermore, based on current mass accumulation rates, the majority of these loads are likely to flow past Goose Bay into the main basin of Lake Melville.</p>

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