Keeyask Generation Project

Aquatic Effects Monitoring Plan

Mercury in Fish Flesh from Gull Lake in 2014 Report

AEMP-2016-11

KEEYASK

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KEEYASK GENERATION PROJECT

AQUATIC EFFECTS MONITORING REPORT

Report #AEMP-2016-11

MERCURY IN FISH FLESH FROM GULL LAKE IN 2014

Prepared for

Manitoba Hydro

By

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SUMMARY

Background

The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan to monitor the effects of construction and operation of the Keeyask Generating Station (GS) on the environment. Besides measuring the accuracy of the predictions made and actual effects of the GS on the environment, monitoring results will provide information on how construction and operation of the GS will affect the environment and if more needs to be done to reduce harmful effects.

Construction of the Keeyask GS began in mid-July 2014. During August and September, the flow in the north and central channels of Gull Rapids was blocked off and all the flow was diverted to the south channel. Cofferdams were constructed in the north and central channels and these channels were dewatered by fall (see construction site map below). The combination of high natural flows in the Nelson River and diversion of flow resulted in water levels on Gull Lake increasing about 1.3 m at the water level monitoring site at Caribou Island. The rise in water levels resulted in flooding along the shoreline and in low-lying areas.

Fish mercury is one of the key components for monitoring because it affects the suitability of fish for consumption by people. Flooding of the Keeyask reservoir is predicted to increase mercury levels in fish in Gull Lake and Stephens Lake, though the increase in Stephens Lake will be much less than when the lake was first created by construction of the Kettle GS in the early 1970s.

This report provides the results of mercury concentrations measured in jackfish, pickerel, and whitefish from Gull Lake in 2014. Fish samples collected at this time represent pre-construction conditions because the flooding that began in mid-July 2014 at Gull Lake could not have affected the average mercury level in these large-bodied fish collected in September, as there is a delay between flooding and when mercury begins to accumulate in measureable amounts in the flesh of large-bodied fish.

Why is the monitoring being done?

Monitoring in 2014 was done to partially fulfill (year one of two) the requirement in the Manitoba *Environment Act* Licence issued for the Keeyask Generation Project (the Project), which states that the KHLP has to measure mercury levels in fish twice more before the Project goes into operation.

The monitoring in 2014 will help to answer the following question:

- Have mercury concentrations in jackfish, pickerel, and whitefish remained unchanged in Gull Lake in 2014 compared to concentrations measured during environmental studies for the Project?

Map of instream structures at the Keeyask Generating Station site, June 2015.

Frozen pickerel muscle sample being prepared for mercury analysis.

What was done?

Jackfish, pickerel and whitefish were in Gull Lake in September 2014. Yellow Perch were also targeted for monitoring but none were caught in 2014.

Thirty-one jackfish, 38 pickerel and four whitefish were captured. Fish were measured for length and weight and a structure to determine the fish's age was collected. A piece of muscle was taken from each fish for mercury analysis. Mercury was measured at a certified laboratory in Winnipeg.

Using the mercury concentration measured in each fish, the average mercury concentration of all fish from each species was calculated. This concentration is referred to as the arithmetic mean. Because the concentration of mercury in fish typically increases with the length of the fish, a second value was calculated that adjusts the concentration to a standard fish length (550 mm for jackfish, 400 mm for pickerel, 350 mm for whitefish). This value is called the standard mean. Comparison of mercury concentrations between years and waterbodies based on a standard mean is more reliable than the arithmetic mean since the standard mean accounts for differences in the size of fish sampled each year. Standard means can only be calculated if the fish that were sampled show an increase in mercury concentration with fish length. Therefore a standard mean is not always available.

What was found?

Standard means of mercury concentration in fish collected from Gull Lake in 2014 were 0.34 ppm in jackfish, 0.32 ppm in pickerel, and 0.02 ppm in whitefish. A comparison of the results for 2014 with past results shows that:

- Mercury concentrations in whitefish have always been low and have not changed much over time.
- Average mercury concentrations in pike and pickerel caught in 2014 were higher than average values measured during the environmental studies for the Project (2001, 2002 and 2006). With the exception of pickerel in 2002, the difference was statistically significant in all years.

What does it mean?

Mercury concentrations measured in 2014 are higher than measured during the Project environmental studies. This means that mercury concentrations can change due to factors in the environment, not necessarily related to a specific development.

What will be done next?

Fish mercury concentrations from Gull Lake will be monitored again in 2016 to fulfill the *Environment Act* Licence requirement to collect additional mercury data before the reservoir is formed. After the reservoir is created, the AEMP states that mercury concentrations in fish in the reservoir (currently Gull Lake) and Stephens Lake will be monitored annually for several years.

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The collection of biological samples described in this report was authorized by Manitoba Conservation and Water Stewardship, Fisheries Branch, under terms of the Scientific Collection Permit #18-14 (Gull Lake 2014).

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1.0 INTRODUCTION

Construction of the Keeyask Generation Project (the Project), a 695 megawatt hydroelectric generating station (GS) and associated facilities, began in July 2014. The Project is located at Gull Rapids on the lower Nelson River in northern Manitoba where Gull Lake flows into Stephens Lake, 35 km upstream of the existing Kettle GS (Map 1).

Construction of the north channel rock groin took place between August 5 and 29, 2014. Gull Lake levels increased approximately 1.5 m between August 5-29 due to an increase in flow on the Nelson River as well as the rock groin construction. By October 5, the water level on Gull Lake was approximately 1.3 m higher than the level before construction began on July 14 when the flows on the river were roughly the same (Manitoba Hydro 2015). The amount of inundated land associated with the water level increases during this period is not known but likely included the nearshore areas of much of Gull Lake and some localized areas in and around Gull Rapids, as well as low-lying areas that extended further inland.

The *Keeyask Generation Project: Response to EIS Guidelines*, completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the aquatic environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs is provided in the *Keeyask Generation Project Environmental Impact Statement: Aquatic Environment Supporting Volume* (AE SV). These documents are jointly referred to as the Keeyask Environmental Impact Statement (EIS). As part of the licencing process for the Project, an Aquatic Effects Monitoring Plan (AEMP) was developed detailing the monitoring activities of various components of the aquatic environment, including fish mercury concentrations, for the construction and operation phases of the Project.

The primary parameter of concern for the mercury monitoring program is the concentration of total mercury in fish skeletal muscle from the following species: Lake Whitefish (*Coregonus clupeaformis*), Northern Pike (*Esox lucius*), Walleye (*Sander vitreus*), and 1-year-old Yellow Perch (*Perca flavescens*). The first three species are sampled because they are important in domestic, commercial, and recreational fisheries and form the primary pathway by which humans ingest (methyl)mercury. Juvenile Yellow Perch were included because mercury concentrations in these young fish will respond more quickly (*i.e.*, within a year) to changes in mercury availability in the ecosystem than the older individuals typically sampled for the three large-bodied species. These older fish integrate and reflect temporal changes in the supply of mercury over longer time scales. (*i.e.*, several years). Furthermore, young perch are not known to undertake extensive movements and more likely represent “local” conditions of mercury availability and bioaccumulation.

The waterbodies included in the fish mercury component of the AEMP are Gull Lake/Keeyask reservoir, Stephens Lake, Split Lake, and the Aiken River. In the event that mercury concentration in fish from Stephens Lake should exceed predicted maximum concentrations by

more than 10%, the fish mercury monitoring program will be extended further downstream on the Nelson River by sampling within the Long Spruce Forebay.

This report provides results for mercury monitoring in Lake Whitefish, Northern Pike and Walleye (Yellow Perch were not captured) collected in 2014 from Gull Lake. This sampling was conducted in partial fulfillment of the requirement in the *Environment Act* Licence to measure mercury levels in fish twice more before the Project was in operation. The record of mercury concentrations for Lake Whitefish, Northern Pike, and Walleye from Gull Lake (1982–2006) was reviewed as part of the Keeyask EIS (KHLP 2012). The current report will build upon this timeline of fish mercury concentrations, adding results from the 2014 sampling.

The key questions to be answered about mercury in fish in relation to monitoring completed in 2014 are:

- What are the concentrations of mercury in Northern Pike, Walleye and Lake Whitefish caught in Gull Lake prior to reservoir flooding and how have concentrations changed since studies completed for the Keeyask EIS?
- How do mercury concentrations in Northern Pike, Walleye and Lake Whitefish compare to established benchmark values to assess if fish are acceptable for commercial marketing?

For ease of reading, Northern Pike and Lake Whitefish are also referred to as pike and whitefish in this report.

2.0 METHODS

2.1 FIELD COLLECTIONS

The 2014 sampling program was conducted using methodologies similar to those used in previous Keeyask Environmental Studies sampling programs conducted on Gull Lake between 1999 and 2006. Lake Whitefish, Northern Pike, and Walleye were collected from several sites within Gull Lake from September 1 to 16, 2014 (Map 2). Because of the difficulties obtaining Lake Whitefish from Gull Lake, one fish captured at Pahwaybanik Bay approximately 5 km to the west of the lake was included in the sample for Gull Lake. Fish were captured using single panel gill nets measuring 25 yards (22.9 m) long by 6 feet (1.8 m) deep with (stretched) mesh sizes of 2, 3, or 4.25 inch (51, 76, 108 mm). Gill nets were checked at least every 24 hours.

To be consistent with the methodology described in earlier Manitoba fish mercury monitoring programs (Jansen and Strange 2007) and in the fish mercury component of CAMP (CAMP 2014), a broad size range of fish was collected. A tally of the fish captured within each consecutive 50 mm length interval (starting at 100 mm) was kept aiming for an equal distribution of lengths classes within a target size of 36 fish per species. Upon capture, large-bodied fish were measured for fork length (±1 mm) and total weight. Weight of fish weighing less than 2000 g was recorded to ±1 g on a digital balance; heavier fish were weighed on a pan balance (±25 g). Bony structures were removed from fish for age analysis: cleithra were collected from Northern Pike, and otoliths were removed from Lake Whitefish and Walleye. A portion of axial muscle weighing between 10 and 40 g was removed from each fish anterior to the caudal (tail) fin for mercury analysis. The muscle with skin attached was wrapped tightly with commercial “cling-wrap”, placed in a mercury-free, internally and externally labelled Whirl-Pac bags or Zip-lock bags, and stored on ice until it could be frozen. Frozen tissue samples were shipped to the North/South office in Winnipeg for inventorying, storage, and further processing.

2.2 LABORATORY DETERMINATIONS

Frozen tissue samples were shipped to the ALS Laboratory Group laboratory in Winnipeg considering a holding time requirement between fish capture and analysis of less than one year. Fish muscle samples were analyzed for mercury between January 20 and 28, 2015. The skin on the one side of the muscle sample and a thin surface layer of the exposed muscle tissue on the opposite side was sliced away before the remaining sample was homogenized (see below). This procedure helped to ensure that the percentage of water in the muscle sample was representative of the original sample taken from the fish.

Mercury analysis was performed using an adaptation of US EPA Method 200.3 “Sample Procedures for Spectrochemical Determination of Total Recoverable Elements in Biological

Tissues". In preparation, tissue samples were homogenized and sub-sampled prior to "HotBlock" digestion with nitric and hydrochloric acids, in combination with repeated additions of hydrogen peroxide. Analysis was by atomic fluorescence spectrophotometry, adapted from US EPA Method 245.7. Samples of two different standard (certified) reference materials (SRM) were typically analyzed with each sample run (Table 1):

- apple leaves (https://www-s.nist.gov/srmors/certificates/archive/ 1515.%20July% 202,%201991.pdf; last accessed 7 February, 2016;
- lobster hepatopancreas (TORT-3; National Research Council Canada, NRC; http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/certificates/tort_3.html;last accessed 27 January, 2016); and
- fish protein (DORM-4; NRC; http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/ certificates/ dorm_4 .html; last accessed 27 January, 2016).

Homogenate of submitted fish tissues samples were also run for quality control purposes. Mean mercury concentrations obtained from the SRMs were within 1% of the mean certified value for apple leaves, within 17% for TORT-3 and within 20% for DORM-4. The mean percentage deviation of replicate homogenate analyses was 5.1% with a range of 2.3 -11.3% (Table 1).

Dried ageing structures of all fish were prepared and analyzed using a variety of techniques. Pike cleithra were cleaned and examined under reflected light aided by a magnified ring light. Whitefish and Walleye otoliths were cracked by scoring the secured bone cross wise across the focus with a scalpel until it snapped. The cracked plane of the otolith was then lightly polished with a bench lathe, toasted in an alcohol filled Bunsen burner, and inserted into plasticine with the cracked edge (treated with clearing medium) facing up prior to viewing under a microscope with reflected light.

2.3 DATA ANALYSIS

A condition factor (K) was calculated for each fish as:

$$K = W \times 10^5 / L^3$$

where: W = total weight (g); and
L = fork length (mm).

Fish obtained in different years from a group of lakes will invariably differ in mean size between years and lakes. Because fish accumulate mercury over their life time, older and, normally, larger individuals have higher levels than younger, smaller fish (Green 1986; Evans *et al.* 2005). In addition to calculating arithmetic mean mercury concentrations (also referred to as arithmetic means), mean mercury concentrations have been standardized to a common fish length under earlier Manitoba fish mercury monitoring programs (Jansen and Strange 2007, CAMP 2014) to facilitate comparisons for the same species of fish between years from one waterbody or

between different waterbodies in a given year. The standard lengths used for Northern Pike, Walleye, and Lake Whitefish were 550, 400, and 350 mm, respectively.

Length standardized mean mercury concentrations (also referred to as standard means) were calculated from unique regression equations, by species and river location, based on the analysis of logarithmic transformations of muscle mercury concentration and fork lengths using the following relationship:

$Log_{10}[Hg] = a + b\ (Log_{10}\ L)$

where: [Hg] = muscle mercury concentration (µg/g or ppm);
L = fork length (mm);
a = Y-intercept (constant); and
b = slope of the regression line (coefficient).

To present data in more familiar units, all standardized means and their measures of variance presented in the tables and figures have been retransformed to arithmetic values.

Because one of the objectives of the sampling program was to evaluate potential changes in mercury concentrations in fish from Gull Lake over time, the results for 2014 were compared to data collected in previous years.

Differences in mean length, weight, and age of fish species between locations (and years) were ascertained employing one-way analysis of variance (ANOVA). If F-values were significant, differences between individual means were confirmed by Holm-Sidak's pairwise multiple comparison tests. If normality of data distribution or equality of variances could not be achieved by logarithmic transformation of the data, Kruskal-Wallis one-way ANOVA on ranks was performed, applying Dunn's method for pairwise multiple comparisons. In all cases, significance was established at $p \leq 0.05$. Actual probabilities values are stated in the text if $P < 0.05$. Differences in standardized mean mercury concentrations between locations or years were established if the 95% confidence limits (CL) of two means did not overlap. Statistical analyses were completed using Sigma Plot V. 11.0 (SSI 2008) and the plyr package version 1.8 (Wickham 2011) for R Version 2.15.0 (R Development Core Team 2012).

Mercury concentrations were also compared to benchmarks specified in the AEMP (see following section).

2.4 BENCHMARKS

The Keeyask AEMP identified the following benchmarks for comparison with monitored fish mercury concentrations from Project area waterbodies:

- The 0.5 ppm total mercury Health Canada standard for commercial marketing of freshwater fish in Canada (Health Canada 2007a, b), which also represents the Manitoba guideline for mercury in fish for the protection of human consumers (MWS 2011).

- A 0.2 ppm total mercury guideline instituted as a “safe consumption limit” for people eating “large quantities of fish” for subsistence purposes (Wheatley 1979); and
- The 0.033 ppm methylmercury Canadian and Manitoba tissue residue guidelines of for the protection of wildlife consumers of aquatic biota (CCME 1999 with more recent updates; MWS 2011)

Whereas the 0.5 ppm standard applies to the suitability of fish for commercial marketing in Canada (*i.e.*, the general public consuming store-bought fish), the 0.2 ppm guideline was established to provide practical advice to people who frequently consume wild fish. However, Health Canada no longer uses the 0.2 ppm guideline for unrestricted domestic consumption. Instead, the agency uses the provisional Tolerable Daily Intake (TDI) of 0.47 µg methylmercury per kilogram of body weight per day (kg-bw/day) for adults, and 0.2 µg methylmercury per kg-bw/day for women of childbearing age (Health Canada 2010) in human health risk assessments. The TDI approach does not result in a simple number for a fish mercury concentration as the exposure to mercury varies both with the human consumer and with the amount, species and size of fish consumed. Therefore, the TDI approach does not provide a benchmark suitable for use in environmental effects monitoring when only (mean) fish mercury concentrations for a particular year are available for the assessment. To address questions regarding suitability of fish for human consumption, data collected by this fish mercury monitoring study is being provided to the Mercury and Human Health Implementation Group, established by the KHLP. One of the tasks of this group is to develop consumption guidelines based on mercury concentrations in locally caught fish for people who consume large amounts of fish.

Since selecting the 0.033 ppm benchmark guideline for the protection of wildlife consumers of aquatic biota for the EIS, the Canadian Council of Ministers of the Environment has ceased the development of further tissue residue guidelines for the protection of wildlife consumers of aquatic biota (N. Burgess, *pers. comm*. 2015), as their guideline will be exceeded by a substantial portion of fish from lower trophic levels and almost all adult predatory fish routinely monitored in Manitoba (CAMP 2014) and elsewhere in Canada (Depew *et al*. 2013). For this reason, the tissue residue guideline of 0.033 ppm methylmercury for the protection of wildlife consumers of aquatic biota that was originally selected is no longer an appropriate benchmark to use for the Keeyask Generation Project.

Given that the 0.2 ppm and 0.033 guidelines are no longer supported by the agencies that identified them, only the 0.5 ppm Health Canada standard for the commercial marketing of fish will be used as a benchmark for the assessment of fish mercury concentrations in the AEMP.

3.0 RESULTS

3.1 SAMPLE DESCRIPTION AND BIOLOGICAL DATA

Thirty-one Northern Pike and 38 Walleye were captured for mercury analysis, which was close to the target number of 36 of each species (Table 2). However, only four Lake Whitefish and no Yellow Perch were captured at Gull Lake in 2014. Relatively high water levels prevented the use of gillnets in shallow littoral areas (a favourite habitat of 1-year old perch), which were generally obstructed by trees and other coarse terrestrial vegetation. Whitefish are not abundant in Gull Lake (KHLP 2012) and it has been difficult to catch the target number for mercury monitoring in previous years. Except for two pike, all fish analyzed for mercury were aged (Table 2).

Mean age of whitefish, pike and Walleye analyzed for mercury differed substantially between the three species, whitefish being three to almost four years older than the other two species (Table 2). While ANOVA on ranks indicated that these overall differences between the three species were significant, pairwise multiple comparisons did not identify any significant differences in the age of particular species pairs.

The mean length of 498 mm (Table 2) of the four very large whitefish analyzed for mercury from Gull Lake was 42% larger than the standard length for the species (350 mm). Similarly, the average length of pike sampled for mercury analysis (707 mm; Table 2) was 29% larger than the species' standard length of 550 mm; only one individual was less than 550 mm in length (Figure 2). Walleye mean length (391 mm; Table 2) and standard length (400 mm) were similar. Large differences between sample mean length and standard length often occur when the overall catch for a species is relatively small, as was the case for whitefish from Gull Lake in 2014. Biological data for individual fish are presented in Appendix 1.

3.2 MERCURY CONCENTRATIONS

3.2.1 RESULTS FOR 2014

Length standardized mean mercury concentrations of fish collected from Gull Lake in 2014 ranged from 0.02 ppm in the benthivorous Lake Whitefish to 0.32 and 0.34 ppm in the two piscivorous species, Northern Pike and Walleye, respectively (Table 3). The standard mean for whitefish was calculated despite the fact that the relationship between mercury concentration and fish length was not significant (p=0.059; also see Figure 1). Using the standard mean for whitefish is appropriate because it provides a more realistic comparison to previous results from Gull Lake than the arithmetic mean given that the four fish in the 2014 sample were very large (see Section 4.1). Similar to whitefish, the arithmetic mean for pike was substantially higher than

the standard mean for the species. As with whitefish, this difference is because most of the individuals included in the sample for mercury analysis were much larger than the standard length used to calculate the standard mean for this species (Section 3.1). When comparing mercury concentrations between the three species, arithmetic means of pike were significantly higher than those of Walleye and whitefish, whereas the relatively small Walleye had statistically similar mean concentrations compared to the very large whitefish.

Except for the arithmetic mean of pike, the standard means and arithmetic means of all three species were below the 0.5 ppm Health Canada standard for commercial sale of fish (Table 3). The arithmetic mean of pike (0.57 ppm) exceeded the standard mainly because 19 (*i.e.*, 61% of the sample) of the larger individuals had mercury concentrations higher than 0.5 ppm, reaching a maximum concentration of 1.1 ppm in an individual measuring 865 mm (Figure 1). Mercury levels in nine of the 38 Walleye (25%) analyzed exceeded the Health Canada standard, with one fish of 540 mm length reaching 1.2 ppm (Figure 1).

3.2.2 COMPARISONS TO OTHER YEARS

Data as far back as 1982 were evaluated as part of the Keeyask EIS. Walleye and pike from Gull Lake have been analyzed for mercury since 1982 and mercury data for whitefish exist since 1999 (Figure 2). However, there are large time intervals during which no information on mercury exists (*i.e.*, 1983–1998 and 2007–2013), limiting the interpretation of the existing record.

Standard means of pike and Walleye declined from the relatively high (> 0.5 ppm) and highly variable (for pike) concentrations recorded in 1982 to 1999 and further to 2001 (Figure 2). Standard means for both pike (0.21–0.23 ppm) and Walleye (0.19–0.26 ppm) were low for the three samples taken between 2001 and 2006 and that were used in the EIS to represent baseline concentrations (KHLP 2012, Section 7E.1). The current (2014) standard means of 0.34 ppm for pike and 0.32 ppm for Walleye are higher than all of the respective values for 2001, 2002, and 2006 (Figure 2). These differences are significant, except for Walleye in 2002.

Standard means of whitefish from Gull Lake have been statistically similar at or below 0.08 ppm since measurements were first collected in 1999 (Figure 2).

4.0 DISCUSSION

Mercury concentrations measured in 2014 were significantly higher for Northern Pike and Walleye than recorded during studies reported in the EIS (*i.e.*, 2001, 2002, and 2006) for all years except Walleye in 2002. As noted in Section 1.0, start of construction in July 2014 resulted in flooding along Gull Lake; however, this flooding could not have affected concentrations of mercury in pike and Walleye by the time fish were collected in September because mercury concentrations do not immediately increase in larger (older) fish that are higher up the food chain.

Significant increases in fish mercury concentrations, in pike and Walleye since the mid 2000s were also observed in Split and Stephens lakes (Jansen 2010a, b; Manitoba Hydro and the Province of Manitoba 2015), and the Aiken River (Jansen 2010a, 2016). The observed increases in Split and Stephens lakes were first recorded in 2007 and have persisted until the most recent sampling in 2013 and 2015, respectively (CAMP 2014 and unpubl. data). This observation suggests that the increase in mercury levels observed in pike and Walleye from Gull Lake is part of a more wide-spread change in fish mercury concentrations.

In contrast, mercury concentrations in Lake Whitefish measured in 2014 are not different from those recorded during the EIS studies. However, the small sample size (4 fish) precludes definitive conclusions.

Despite the increase in mercury concentrations, the standard means of all species remain within the Health Canada standard for the commercial sale of fish. Due to the large size of pike sampled in 2014, the arithmetic mean (average concentration of fish in sample) was greater than the Health Canada standard.

5.0 CONCLUSION AND NEXT STEPS

Mercury concentrations in Walleye and Northern Pike measured in 2014 are higher than recorded during the EIS studies, indicating that mercury concentrations can change due to factors in the environment not necessarily related to a specific development.

Average concentrations for Walleye and Lake Whitefish are lower than the Health Canada standard for the commercial sale of fish in Canada. The average concentration (arithmetic mean) of pike is above this standard.

Fish mercury concentrations from Gull Lake will be monitored again in 2016 to fulfill the *Environment Act* Licence requirement to collect additional mercury data before the reservoir is formed. After the reservoir is created, the AEMP states that mercury concentrations in fish in the reservoir (currently Gull Lake) and Stephens Lake will be monitored annually for several years.

6.0 REFERENCES

Balogh, S. J., E. B. Swain and Y.H. Nollet. 2006. Elevated methylmercury concentrations and loadings during flooding in Minnesota rivers. Science of the Total Environment 368: 138-148.

Bodaly, R. A., W. A. Jansen, A. R. Majewski, R. J. P. Fudge, N. E. Strange, A. J. Derksen, and D. J. Green. 2007. Post-impoundment time course of elevated mercury concentrations in fish in hydroelectric reservoirs of northern Manitoba, Canada. Archives of Environmental Contamination and Toxicology 53:379-389.

CAMP (Coordinated Aquatic Monitoring Program). 2014. Three year summary report (2008–2010). Report prepared for the Manitoba/Manitoba Hydro MOU Working Group by North/South Consultants Inc., Winnipeg, MB.

CCME (Canadian Council of Ministers of the Environment). 1999. Canadian environmental quality guidelines. Canadian Council of Ministers of the Environment, Winnipeg, MB; updated to 2015.

Depew, D. C., N. M. Burgess, M. R. Anderson, R. Baker, S. P. Bhavsar, R. A. Bodaly, C. S. Eckley, M. S. Evans, N. Gantner, J. A. Graydon, K. Jacobs, K. E. LeBlanc, V. I. St. Louis, and L. M Campbell. 2013. An overview of mercury concentrations in freshwater fish species: A national fish mercury dataset for Canada. Canadian Journal of Fisheries and Aquatic Sciences 70: 1–16 pp.

Evans, M.S, W. L. Lockhart, L. Doetzel, G. Low, D. Muir, K. Kidd, G. Stephens, and J. Delaronde. 2005. Elevated mercury concentrations in fish in lakes in the Mackenzie River basin: the role of physical, chemical, and biological factors. Science of the Total Environment 351-352: 479-500.

Government of Alberta. 2009. Alberta Health and Wellness: Common questions about methylmercury levels in Alberta fish. Government of Alberta, Edmonton, AB, 2 p.

Green, D. J. 1986. Summary of fish mercury data collected from lakes on the Rat Burntwood and Nelson River systems, 1983 1985. Manitoba Natural Resources, Fisheries Branch MS Report No. 86 06, 359 pp.

Grieb, T. M., C. T. Driscoll, S. P. Gloss, C. L. Schofield, G. L. Bowie and D. B. Porcella, D.B. 1990. Factors affecting mercury accumulation in fish in the upper Michigan peninsula. Environmental Toxicology and Chemistry 9: 919–930.

Health Canada. 2007a. Human health risk assessment of mercury in fish and health benefits of fish consumption. Health Canada: Bureau of Chemical Safety, Food Directorate, Health Products and Food Branch, Ottawa, Ont., 70 pp.

Health Canada. 2007b. Updating the existing risk management strategy for mercury in fish. Health Canada: Bureau of Chemical Safety, Food Directorate, Health Products and Food Branch, Ottawa, Ont., 45 pp.

Health Canada. 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (Trvs) and Chemical-Specific Factors, Version 2.0, Prepared by Contaminated Sites Division, Safe Environments Directorate, 59 pp.

Jansen, W. 2010a. Fish mercury concentrations in the Keeyask study area, 2009. A report prepared for Manitoba Hydro by North/South Consultants Inc., Report # 09-05, 32 pp.

Jansen, W. 2010b. Mercury in fish from six Manitoba lakes and reservoirs: Results from 2007-2008 sampling and an update of time trends of monitoring data. Report prepared for Manitoba Hydro by North/South Consultants Inc., 44 pp.

Jansen, W. 2016. Mercury in fish flesh from the Aiken River in 2015. Keeyask Generation Project Aquatic Effects Monitoring Report #AEMP-2016-10. A report prepared for Manitoba Hydro by North/South Consultants Inc., June 2016.

Jansen, W., and N. Strange. 2007. Mercury in fish from northern Manitoba reservoirs: results from 1999-2005 sampling and a summary of all monitoring data for 1970 2005. Report prepared by North/South Consultants for Manitoba Hydro, 102 pp.

Johnston, T. A., R. A. Bodaly, M. A. Latif, R. J. P. Fudge and N. E. Strange. 2001. Intra and interpopulation variability in maternal transfer of mercury to eggs of walleye (*Stizostedion vitreum*). Aquatic Toxicology 52: 73-85.

KHLP (Keeyask Hydropower Limited Partnership). 2012. Keeyask Generation Project: Environmental impact statement. Supporting volume-Aquatic Environment. Keeyask Hydropower Limited Partnership, Winnipeg, MB.

KHLP. 2015. Keeyask Generation Project Mercury and Human Health Risk Management Plan. Winnipeg, Manitoba.

Lockhart, W.L., J. F. Uthe, A. R. Kenney, and P. M. Mehrle. 1972. Methylmercury in northern pike (*Esox lucius*): distribution, elimination, and some biochemical characteristics of contaminated fish. Journal of the Fisheries Research Board of Canada 29: 1519–1523.

Manitoba Hydro and the Province of Manitoba. 2015. Regional Cumulative Effects Assessment for Hydroelectric Developments on the Churchill, Burntwood and Nelson River Systems: Phase II Report. Winnipeg, MB. xxx + 4459 pp.

Mergler, D., H. A. Anderson, L. H. M. Chan, K. R. Mahaffey, M. Murray, M. Sakamoto and A. H. Stern. 2007. Methylmercury exposure and health effects in humans: A worldwide concern. Ambio 36: 3–11.

MWS (Manitoba Water Stewardship). 2011. Manitoba water quality standards, objectives, and guidelines. Water Science and Management Branch, MWS Report 2011-01, November 28, 2011; 67 pp.

R Development Core Team. 2012. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Rolfhus, K. R., J. Hurley, R. A. Bodaly, and G. Perrine. 2015. Production and retention of methylmercury in inundated boreal forest soils. Environmental Science & Technology 46:3482–3489.

Schetagne, R., J. Therrien and R. Lalumiere. 2003. Environmental monitoring at the La Grande complex-evolution of fish mercury levels. Summary report 1978–2000. Direction Barrages et Environnement, Hydro-Québec Production and Groupe conseil GENIVAR Inc., Montreal, QC. 185 pp.

Sorensen, J. A., L. W. Kallemeyn, and M. Sydor. 2005. Relationship between mercury accumulation in young of the year yellow perch and water level fluctuations. Environmental Science & Technology 39: 9237–9243.

SSI (Systat Software Inc.) 2008. Sigma Plot V. 11.0 ; San Jose, California.

Van Walleghem, J. L. A., P. J. Blanchfield and H. Hintelmann. 2007. Elimination of mercury by yellow perch in the wild. Environmental Science and Technology 41: 5895–5901.

Wheatley, B. 1979. Methylmercury in Canada; Exposure of Indian and Inuit Residents to methylmercury in the Canadian Environment. Mercury Program Findings to December 31, 1978. Medical Services Branch, Health and Welfare Canada, Ottawa, Ont., 200 pp.

Wickham, H. 2011. The Split-Apply-Combine Strategy for Data Analysis. Journal of Statistical Software, 40(1), 1-29. URL http://www.jstatsoft.org/v40/i01/.

Willacker, J. J., C. A. Eagles Smith, M. A. Lutz, M. T. Tate, J. M. Lepak, and J. T. Ackerman. 2016. Reservoir and water management influence fish mercury concentrations in the western United States and Canada. Science of the Total Environment http://dx. doi:10.1016/j.scitotenv.2016.03.050.

6.1 PERSONAL COMMUNICATIONS

Barth, Cam. 2016. Aquatic Biologist, North/South Consultants Inc., Winnipeg, MB. Oral communication with Wolfgang Jansen, North/South Consultants Inc., Winnipeg, MB, April 5, 2016.

Burgess, Neil. 2015. Wildlife Toxicologist. Environment Canada, Mount Pearl Newfoundland and Labrador. Telephone correspondence with Wolfgang Jansen, North/South Consultants Inc., Winnipeg, MB, May 7, 2015.

TABLES

Table 1: Comparison of total mercury concentrations (ppm; mean ± expanded uncertainty[1]) of certified reference materials (SRM): apple leaves (1515, National Institute of Standards & Technology, NIST); lobster hepatopancreas (TORT-3; National Research Council Canada, NRC), and fish protein (DORM-4; NRC) with results obtained by ALS Environmental in Winnipeg in conjunction with fish muscle analyses for Gull Lake in 2014; RPMD represents the relative percentage difference between the sample mean and the SRM mean; Replicates refers to the percentage difference between first and second sample of replicate analyses of muscle sample digests.

Statistic	Apple leaves	TORT-3	DORM-4	Replicates
	(0.044 ± 0.004)[2]	(0.292 ± 0.022)[3]	(0.41 ± 0.055)[4]	(% difference)
Mean	0.044	0.268	0.336	5.3
Range	0.040–0.048	0.255–0.275	0.306–0.365	2.3–11.3
n[5]	5	5	6	2
RPMD (%)	0.90	9.1	19.7	n/a

1. Expanded uncertainty is the sum of a 95% confidence limit and an allowance for systematic error between analytical methods and/or sample variation (*i.e.*, batches, bottles).
2. See www-s.nist.gov/srmors/certificates/archive/1515.%20July%202,%201991.pdf; last accessed 27 January, 2016.
3. See http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/certificates/tort_3.html; last accessed 27 January, 2016.
4. See http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/certificates/dorm_4.html; last accessed 27 January, 2016.
5. n represents the number of analyses.

Table 2: Mean (± SE) fork length, round weight, condition factor (K), and age of Lake Whitefish, Northern Pike, and Walleye from Gull Lake in 2014.

Species	Waterbody	Length (mm)	n	Weight (g)	n	K	n	Age (years)	n
Lake Whitefish	Gull Lake	497.5 ± 19.1	4	2299.8 ± 385.9	4	1.80 ± 0.15	4	11.8 ± 2.2	4
Northern Pike	Gull Lake	706.9 ± 17.1	31	2774.4 ± 231.2	31	0.73 ± 0.02	31	7.1 ± 0.4	29
Walleye	Gull Lake	391.3 ± 18.5	38	904.1 ± 129.7	38	1.15 ± 0.02	38	8.6 ± 1.2	38

Table 3: Mean arithmetic (± SE) and standardized (95% confidence limits, CL) mercury concentration (ppm) of Lake Whitefish, Northern Pike, and Walleye from Gull Lake in 2014.

Species	Waterbody	n	Arithmetic	SE	Standard	95% CL
Lake Whitefish	Gull Lake	4	0.225	0.060	0.015 [1]	0.001–0.265
Northern Pike	Gull Lake	31	0.570	0.038	0.339	0.275–0.417
Walleye	Gull Lake	38	0.362	0.044	0.324	0.294–0.357

1. The regression for fish mercury concentration on fish length was just not significant (p=0.059).

FIGURES

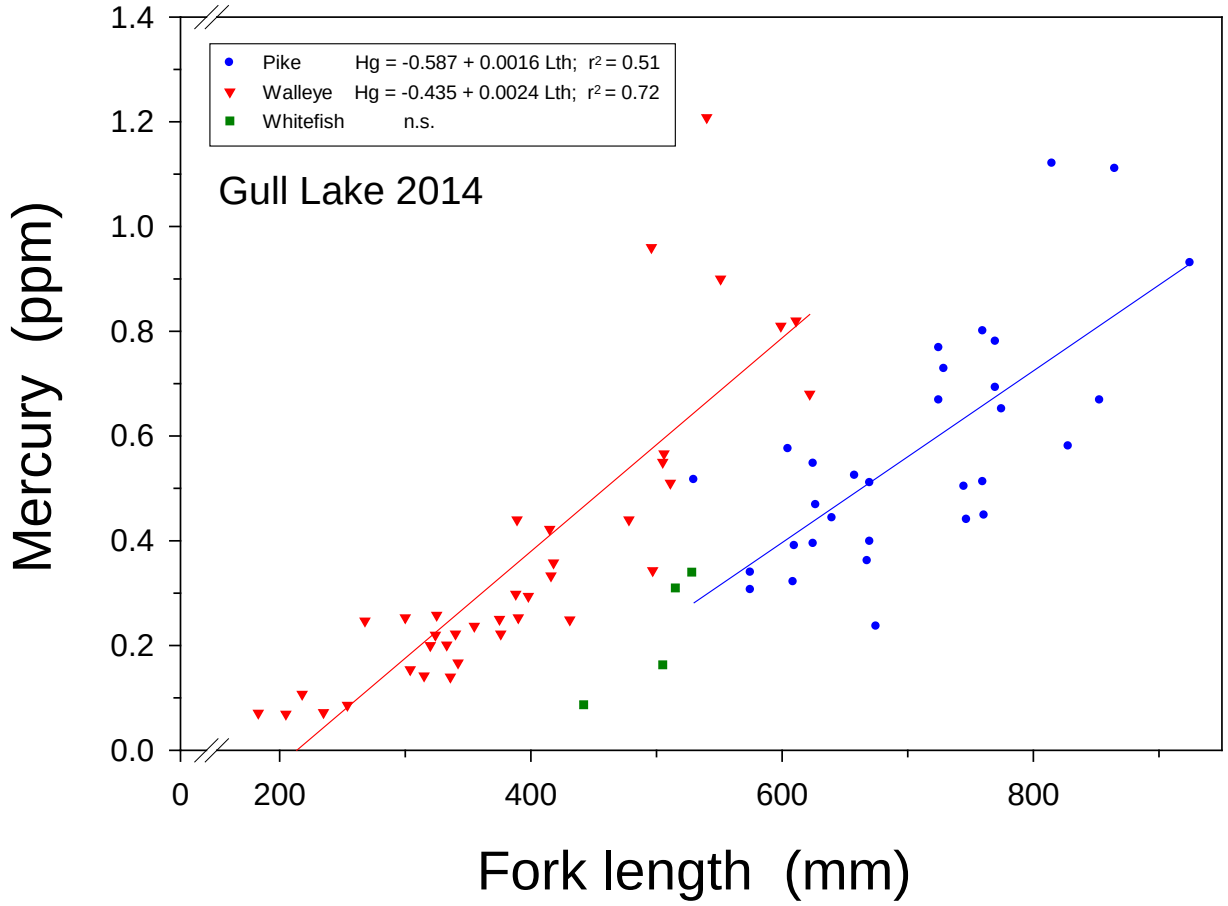
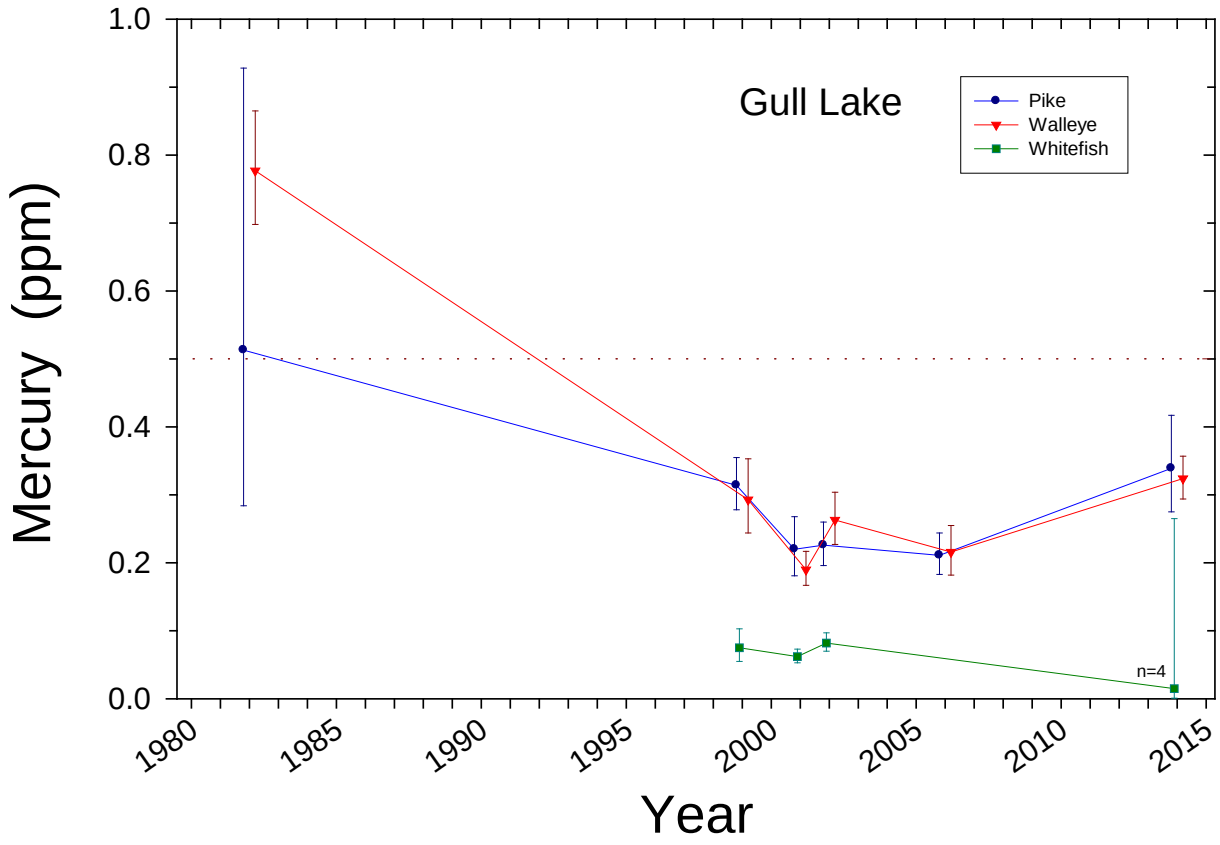


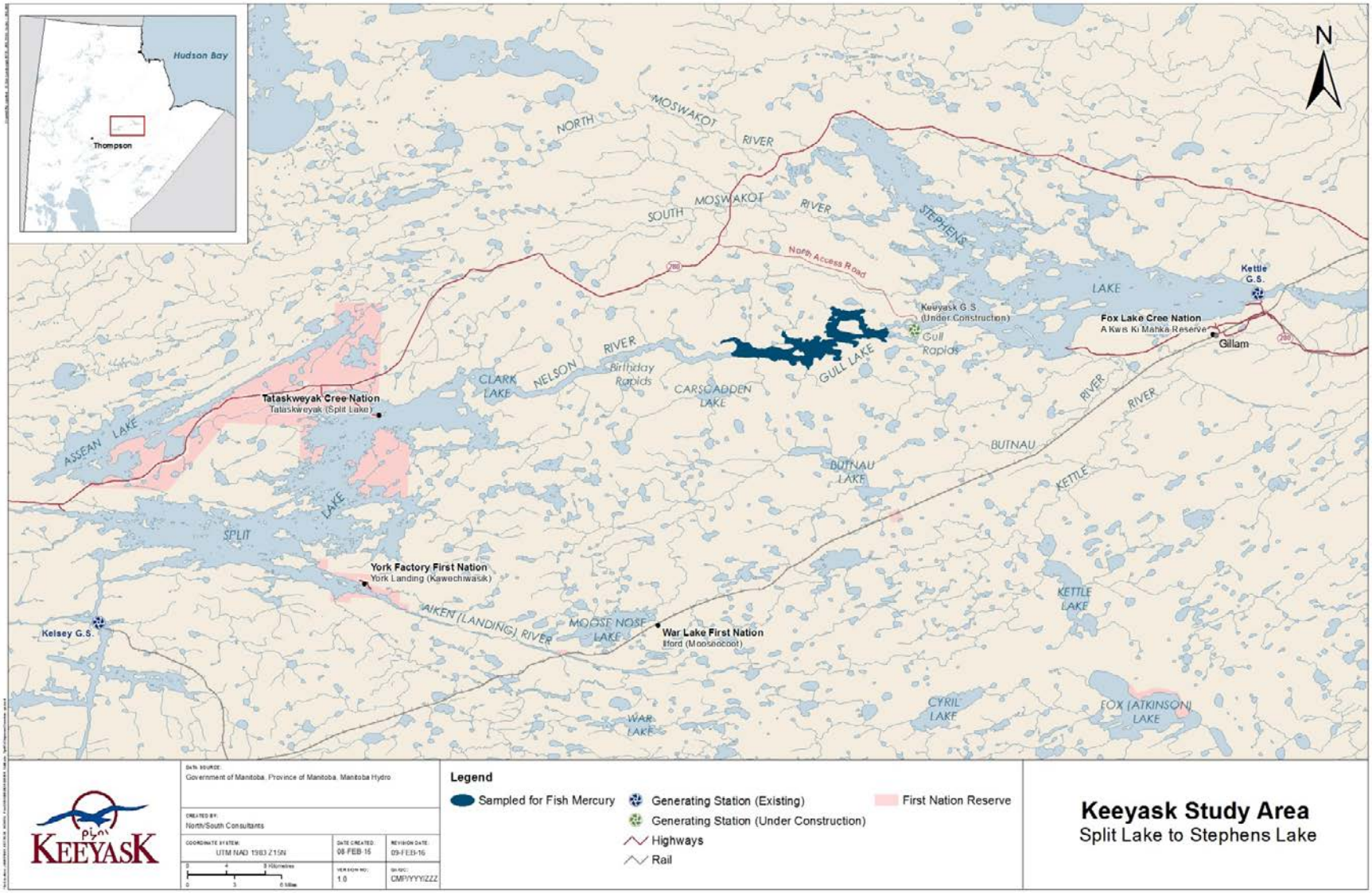
Figure 1: **Relationship between mercury concentration and fish length for Northern Pike Walleye, and Lake Whitefish captured from Gull Lake in September 2014. Significant regression lines are shown.**



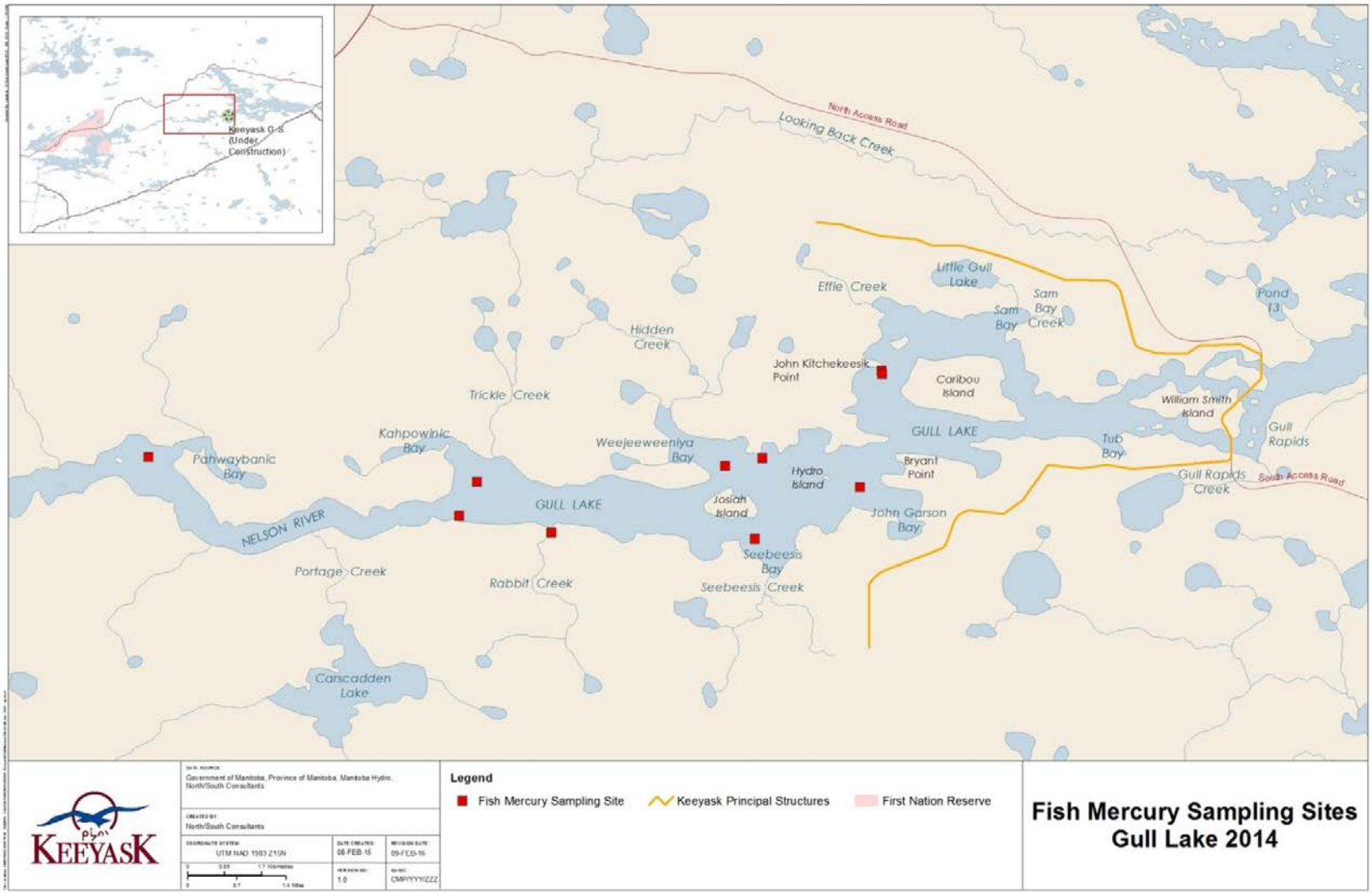
The relationship between fish length and mercury concentration was just not significant (p=0.059) for whitefish in 2015; the arithmetic mean was 0.225 ppm. The stippled line indicates the 0.5 ppm Health Canada standard.

Figure 2: Mean (95% confidence limits, CL) length standardized muscle mercury concentrations of Northern Pike, Walleye, and Lake Whitefish from Gull Lake for years 1982–2014.

MAPS



Map 1: Map of the Keeyask study area showing hydroelectric development and the fish mercury sampling area in 2014.



Map 2: Map of Gull Lake showing sampling sites for fish mercury in 2014.

APPENDICES

APPENDIX 1:
MUSCLE MERCURY CONCENTRATIONS AND BIOLOGICAL DATA FOR FISH FROM GULL LAKE IN 2014

Table A1-1: Definitions of codes used in Appendix tables. 25
Table A1-2: Muscle mercury (Hg) concentrations and other biological data for Lake Whitefish, Northern Pike, and Walleye from Gull Lake in 2014.....26

Table A1-1: Definitions of codes used in Appendix tables.

Term	Code	Definition
Date		Sampling date
Species	NRPK	Northern Pike
	WALL	Walleye
Sex	F	Female
	M	Male
Maturity (Mat)	0	Immature
	1	Mature
Length		Fork length
Weight		Round weight
K		Condition factor

Table A1-2: Muscle mercury (Hg) concentrations and other biological data for Lake Whitefish, Northern Pike, and Walleye from Gull Lake in 2014.

Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	K	Sex	Mat	Age (yr)	Hg (ppm)
90	2014	10-Sep	GN-04	LKWF	442	1249	1.446	-	-	7	0.087
Hg20	2014	1-Sep	Hg20	LKWF	505	2200	1.708	-	-	9	0.163
Hg21	2014	1-Sep	Hg21	LKWF	515	2950	2.160	-	-	16	0.310
Hg22	2014	1-Sep	Hg22	LKWF	528	2800	1.902	-	-	15	0.340
60	2014	9-Sep	GN-02	NRPK	609	1442	0.638	-	-	5	0.321
143	2014	11-Sep	GN-05	NRPK	815	3700	0.683	-	-	10	1.060
305	2014	14-Sep	GN-20	NRPK	575	1341	0.705	-	-	4	0.306
346	2014	15-Sep	GN-24	NRPK	670	2130	0.708	-	-	8	0.398
379	2014	16-Sep	GN-27	NRPK	668	2263	0.759	-	-	7	0.361
380	2014	16-Sep	GN-27	NRPK	640	1976	0.754	-	-	7	0.443
381	2014	16-Sep	GN-27	NRPK	627	1813	0.736	-	-	-	0.468
382	2014	16-Sep	GN-27	NRPK	729	2801	0.723	-	-	8	0.728
383	2014	16-Sep	GN-27	NRPK	675	2243	0.729	-	-	5	0.236
384	2014	16-Sep	GN-27	NRPK	625	1574	0.645	-	-	6	0.547
385	2014	16-Sep	GN-27	NRPK	770	2949	0.646	-	-	-	0.780
386	2014	16-Sep	GN-27	NRPK	575	1475	0.776	-	-	5	0.339
Hg1	2014	11-Sep	Hg1	NRPK	770	3150	0.690	-	-	9	0.692
Hg10	2014	1-Sep	Hg10	NRPK	658	1700	0.597	-	-	6	0.524
Hg11	2014	1-Sep	Hg11	NRPK	865	5300	0.819	-	-	10	1.110

Table A1-2: Muscle mercury (Hg) concentrations and other biological data for Lake Whitefish, Northern Pike, and Walleye from Gull Lake in 2014 (continued).

Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	K	Sex	Mat	Age (yr)	Hg (ppm)
Hg12	2014	1-Sep	Hg12	NRPK	625	1750	0.717	-	-	5	0.394
Hg13	2014	1-Sep	Hg13	NRPK	610	1575	0.694	-	-	6	0.390
Hg14	2014	1-Sep	Hg14	NRPK	670	2450	0.815	-	-	6	0.510
Hg15	2014	1-Sep	Hg15	NRPK	761	3800	0.862	-	-	6	0.448
Hg16	2014	1-Sep	Hg16	NRPK	853	5150	0.830	-	-	9	0.668
Hg17	2014	1-Sep	Hg17	NRPK	725	2250	0.590	-	-	6	0.668
Hg18	2014	1-Sep	Hg18	NRPK	760	3075	0.700	-	-	13	0.800
Hg19	2014	1-Sep	Hg19	NRPK	745	3250	0.786	-	-	7	0.503
Hg2	2014	1-Sep	Hg2	NRPK	775	4700	1.010	-	-	8	0.651
Hg3	2014	1-Sep	Hg3	NRPK	925	5250	0.663	-	-	8	0.930
Hg4	2014	1-Sep	Hg4	NRPK	747	3200	0.768	-	-	7	0.440
Hg5	2014	1-Sep	Hg5	NRPK	725	2850	0.748	-	-	8	0.768
Hg6	2014	1-Sep	Hg6	NRPK	828	5250	0.925	-	-	9	0.580
Hg7	2014	1-Sep	Hg7	NRPK	530	950	0.638	-	-	5	0.516
Hg8	2014	1-Sep	Hg8	NRPK	605	1350	0.610	-	-	5	0.575
Hg9	2014	1-Sep	Hg9	NRPK	760	3300	0.752	-	-	9	0.512
19	2014	9-Sep	GN-01	WALL	324	370.0	1.088	-	-	3	0.220
20	2014	9-Sep	GN-01	WALL	416	818.0	1.136	-	-	5	0.333
21	2014	9-Sep	GN-01	WALL	415	829.6	1.161	-	-	7	0.422
22	2014	9-Sep	GN-01	WALL	506	1644.2	1.269	-	-	13	0.566
24	2014	9-Sep	GN-01	WALL	390	822.1	1.386	-	-	8	0.253

Table A1-2: Muscle mercury (Hg) concentrations and other biological data for Lake Whitefish, Northern Pike, and Walleye from Gull Lake in 2014 (continued).

Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	K	Sex	Mat	Age (yr)	Hg (ppm)
25	2014	9-Sep	GN-01	WALL	388	661.4	1.132	-	-	6	0.298
26	2014	9-Sep	GN-01	WALL	540	1772	1.125	-	-	25	1.208
27	2014	9-Sep	GN-01	WALL	375	609	1.155	-	-	5	0.250
28	2014	9-Sep	GN-01	WALL	333	399.2	1.081	-	-	4	0.201
29	2014	9-Sep	GN-01	WALL	418	861.7	1.180	-	-	6	0.358
30	2014	9-Sep	GN-01	WALL	355	472.3	1.056	-	-	5	0.237
32	2014	9-Sep	GN-01	WALL	268	208.2	1.082	-	-	4	0.247
37	2014	9-Sep	GN-01	WALL	300	294.8	1.092	-	-	5	0.253
39	2014	9-Sep	GN-02	WALL	342	416.0	1.040	-	-	4	0.167
40	2014	9-Sep	GN-02	WALL	398	710.0	1.126	-	-	5	0.294
41	2014	9-Sep	GN-02	WALL	497	1441.0	1.174	-	-	8	0.343
42	2014	9-Sep	GN-02	WALL	551	2080	1.243	-	-	24	0.900
43	2014	9-Sep	GN-02	WALL	505	1476.0	1.146	-	-	10	0.550
44	2014	9-Sep	GN-02	WALL	496	1546.0	1.267	-	-	28	0.960
46	2014	9-Sep	GN-02	WALL	235	130.0	1.002	-	-	2	0.072
47	2014	9-Sep	GN-02	WALL	431	1140.0	1.424	-	-	6	0.249
48	2014	9-Sep	GN-02	WALL	205	86.6	1.005	-	-	2	0.069
49	2014	9-Sep	GN-02	WALL	218	110.0	1.062	-	-	2	0.107
59	2014	9-Sep	GN-02	WALL	254	180.0	1.098	-	-	2	0.086
280	2014	14-Sep	GN-19	WALL	304	277.6	0.988	-	-	4	0.154
282	2014	14-Sep	GN-19	WALL	478	1511.0	1.384	-	-	23	0.440

Table A1-2: Muscle mercury (Hg) concentrations and other biological data for Lake Whitefish, Northern Pike, and Walleye from Gull Lake in 2014 (continued).

Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	K	Sex	Mat	Age (yr)	Hg (ppm)
292	2014	14-Sep	GN-20	WALL	611	2574	1.128	-	-	17	0.820
294	2014	14-Sep	GN-20	WALL	389	628.0	1.067	-	-	6	0.440
296	2014	14-Sep	GN-20	WALL	376	516.0	0.971	-	-	5	0.222
297	2014	14-Sep	GN-20	WALL	340	409.0	1.041	-	-	5	0.222
298	2014	14-Sep	GN-20	WALL	336	448.0	1.181	-	-	4	0.140
299	2014	14-Sep	GN-20	WALL	315	342.0	1.094	-	-	4	0.142
300	2014	14-Sep	GN-20	WALL	325	348.0	1.014	-	-	4	0.258
303	2014	14-Sep	GN-20	WALL	320	363.0	1.108	-	-	4	0.200
330	2014	15-Sep	GN-23	WALL	599	3194	1.486	-	-	25	0.810
335	2014	15-Sep	GN-23	WALL	183	67.0	1.093	-	-	1	0.071
Hg23	2014	1-Sep	Hg23	WALL	622	2775	1.153	-	-	17	0.680
Hg24	2014	1-Sep	Hg24	WALL	511	1825	1.368	-	-	17	0.510

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