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Mercury in Fish Flesh from the Aiken River in 2018 Report AEMP-2019-09





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KEEYASK

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2018-2019

KEEYASK GENERATION PROJECT

AQUATIC EFFECTS MONITORING PLAN

REPORT #AEMP-2019-09

MERCURY IN FISH FLESH FROM THE AIKEN RIVER IN 2018

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. During the winter, a cofferdam was constructed extending into the south channel. During the spring of 2015, flows in the Nelson River decreased and water level on Gull Lake went down to pre-construction high water levels.

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 and Stephens lakes, 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. The average concentration of mercury in fish in upstream waterbodies such as Split Lake and the Aiken River (known locally as the Landing River) could be affected if a large proportion of the fish in these waterbodies also spend extended periods in the Keeyask reservoir. Given that fish moving out of the Keeyask reservoir are expected to form only a small proportion of the fish in Split Lake and the Aiken/Landing River, no measurable effects to average mercury concentrations of fish collected from these waterbodies are predicted. Sampling is being conducted to confirm this prediction.

This report provides mercury concentrations measured in jackfish and pickerel from the Aiken/Landing River near York Landing and Ilford in 2018. Fish samples collected at this time represent conditions during Keeyask construction, which started in July 2014.



KEEYASK GENERATION PROJECT



Satellite Imagery - October 12th, 2018

Map of instream structures at the Keeyask Generating Station site, October 2018.



Why is the monitoring being done?

The monitoring in 2018 was done to answer several questions:

- What are mercury concentrations in jackfish and pickerel, two domestically and commercially important species, at two locations on the Aiken/Landing River (York Landing and Ilford) during the construction phase of the Keeyask Project?
- Have mercury concentrations in jackfish and pickerel remained unchanged at these two locations in 2018 compared to previous study years?



Freshly caught jackfish awaiting processing for muscle samples for mercury analysis.

What was done?

Jackfish and pickerel were captured near York Landing and Ilford in May 2018 (see map below). Thirty-six fish of each species were taken from each location. 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.





Frozen pickerel muscle sample being prepared for mercury analysis.

Using the mercury concentration measured in each fish, the average mercury concentration of all fish from each species (pickerel or jackfish) and location (York Landing or Ilford) 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 (400 mm for pickerel, 550 mm for jackfish). This value is called the standard mean. Comparison of mercury concentrations between years and waterbodies based on a standard mean is more meaningful 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.





Map of the Aiken (Landing) River showing sampling sites for fish mercury in 2018.



What was found?

Mercury concentrations of jackfish and pickerel were positively related to fish length and standard means could be calculated. The standard means of fish sampled in 2018 ranged from 0.33–0.34 ppm in jackfish and from 0.33–0.37 ppm in pickerel. The arithmetic means for both species from both locations ranged from 0.23–0.36 ppm.

A comparison of the results for 2018 with past results (see figure below) shows that:

- Standard mean mercury concentrations for both fish species in 2018 were similar to concentrations measured during 2009, 2012, and 2015 at York Landing and Ilford.
- Standard means of pickerel and jackfish from both locations in 2018 continue to be higher than concentrations measured during the studies for the EIS (2002 to 2006).

What does it mean?

These relatively stable mercury concentrations of jackfish and pickerel during the period 2009–2018 are similar to what has been observed for these two species at other on-system waterbodies in the Keeyask area. Currently, there is no indication of any effect of Keeyask GS construction on fish mercury levels in the Aiken/Landing River.



Mercury concentrations measured in fish during the study period.





Aiken/Landing River approximately 400 m downstream of sampling site 3.

What will be done next?

Fish mercury concentrations at York Landing and Ilford will be monitored again in three years according to the schedule in the Keeyask AEMP.



ACKNOWLEDGEMENTS

We would like to thank Manitoba Hydro for the opportunity and resources to conduct this study.

The following members of War Lake First Nation (WLFN) and York Factory First Nation (YFFN) are thanked for their local expertise and assistance in conducting the field work: John Laliberty (WLFN), Gary Spence (WLFN), Nathanael Beardy (YFFN), and Jared Wastecicoot (YFFN).

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 #22-18).



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1.0 INTRODUCTION

The Keeyask Generation Project (the Project) is a 695-megawatt (MW) hydroelectric generating station currently under construction in northern Manitoba. 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).

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). 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 for the construction and operation phases of the Project.

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 and Stephens lakes, 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. The average concentration of mercury in fish in upstream waterbodies such as Split Lake and the Aiken River¹ could be affected if a large proportion of the fish in these waterbodies also spend extended periods in the Keeyask reservoir. Given that fish moving out of the Keeyask reservoir are expected to form only a small proportion of the fish in Split Lake and the Aiken River, no measurable effects to average mercury concentrations of fish collected from these waterbodies are predicted. Sampling is being conducted to confirm this prediction.

The waterbodies included in the fish mercury component of the AEMP are Gull Lake/Keeyask reservoir, Stephens Lake, Split Lake, and the Aiken River, a tributary of Split Lake. 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 Northern Pike (*Esox lucius*) and Walleye (*Sander vitreus*) collected in spring 2018 from the Aiken River. Mercury data from these two piscivorous species in the Aiken River were first collected during environmental studies for the Project in 2002 and 2003, and some more limited data are also available from earlier years. In response to War Lake First Nation (WLFN) and York Factory First Nation (YFFN) members'

¹ The Aiken River is also known locally as the Landing River but will be referred to as the Aiken River for the remainder of this report.



concerns with respect to mercury in fish flesh, a study was initiated in 2006 to monitor mercury concentrations in Northern Pike and Walleye on a three-year cycle until such time as there was (or was not) an indication of change.

The monitoring in 2018 was done to answer several questions:

- What are mercury concentrations in Northern Pike and Walleye at two locations on the Aiken River (York Landing and Ilford) during the construction phase of the Keeyask Project?
- Are mercury concentrations measured in these two species in 2018 unchanged from previous measurements?
- How do recent mercury concentrations compare to benchmarks established in the AEMP?

Results from post-EIS fish mercury sampling in 2009, 2012, and 2015 have been reported in Jansen (2010), Jansen (2012), and Jansen (2016a), respectively. The current report builds upon the 2002 to 2015 timeline of fish mercury concentrations, adding results from the 2018 sampling.

For ease of reading, Northern Pike is also referred to as pike in this report.



2.0 METHODS

2.1 FIELD COLLECTIONS

The 2018 sampling program was conducted using methodologies similar to those used in previous sampling programs conducted between 2002 and 2015. Northern Pike and Walleye were collected from two locations in the Aiken River: near the communities of York Landing and Ilford (in the following referred to as "from" or "at" York Landing/Ilford).

Pike and Walleye were collected for mercury analysis from several sites at York Landing from May 21 to 22, 2018 and at Ilford from May 23 to 25, 2018 (Map 2). At both locations, pike and Walleye were captured by angling.

To be consistent with the methodology described in earlier Manitoba fish mercury monitoring programs (Jansen and Strange 2007), 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 length classes within a target sample size of 36 fish per species. Upon capture, fish were measured for fork length (± 1 mm) and total weight. Weight was recorded to ± 25 g on a pan balance. A measuring board was not available during sampling at York Landing and fish length was measured with a flexible tape at an accuracy of ≤ 5 mm.

Fish were also examined internally to determine sex and maturity, and bony structures were removed for age analysis: dorsal spines were taken from Walleye, and cleithra were collected from Northern Pike. 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 or Zip-lock bag, 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. The 2018 Aiken River samples were analyzed for mercury between September 1 and October 1, 2018. 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 absorption spectrophotometry, adapted from US EPA Method 245.7 using a Teledyne Leeman Labs (Hudson, NH, USA) M-7600 analyzer.

Samples of fish protein (DORM-4; NRC; http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/ certificates/ dorm_4 .html; last accessed 19 December, 2018) certified reference material (CRM) were typically analyzed with each sample run (Table 1). Further quality control consisted of analysis of a laboratory control sample (LCS) with each sample run. The LCS consisted of a mercury-free liquid spiked with 0.01 ppm total mercury. In addition, several replicate analyses of the homogenates of submitted fish tissues samples were conducted for quality control purposes. Differences between measured and target concentrations for the CRM and the LCS, and between duplicate sample analyses were expressed as relative percentage mean difference.

Mean mercury concentrations obtained for DORM-4 were 28.4% lower than the certified value (*i.e.*, 71.6% recovery) (Table 1). ALS.Global applies a target value for DORM-4 of 0.322 mm since 2018 (Appendix 1). Using this concentration, the recovery of mercury from DORM-4 analyzed together with the Aiken River fish samples was 96.5% of the target concentration.

Mercury concentrations obtained for the LCS were on average 5.3% below the target concentration (Table 1). The mean deviation of replicate homogenate analyses was 7.0% with a range of 0.8–12.1% (Table 1).

Dried ageing structures of all fish were prepared and analyzed using a variety of techniques. Walleye dorsal spines were coated in epoxy and sectioned with a Struers microtome saw. Sections were then fixed on glass slides with Cytoseal 280 and fish ages were determined by examining the slides with a Wild M3 dissecting microscope. Pike cleithra were cleaned and examined under 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) and CAMP (CAMP 2017) 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 and Walleye are 550 and 400 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 (μ g/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 standard means and their measures of variance presented in the tables and figures have been retransformed to arithmetic values (*i.e.*, inverse log).

Because one of the objectives of the 2018 sampling program was to evaluate potential changes in mercury concentrations in fish from the Aiken River over time, the results for 2018 were compared to data collected in previous years.

Differences in mean length, weight, condition, 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 $p \le 0.05$. Actual probabilities values are stated in the text if p < 0.05. 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).



2.4 BENCHMARKS

The Keeyask AEMP identified three benchmarks for comparison with monitored fish mercury concentrations from Project area waterbodies. Two of the benchmarks were previously dropped as they were no longer appropriate as discussed in Jansen (2016a, b). Going forward, comparisons of mercury in fish to the 0.5 ppm total mercury Health Canada standard for commercial marketing of freshwater fish in Canada (Health Canada 2007a, b) will no longer be carried out, since the standard applies to fish that are bought in stores and not to subsistence consumers.

Data from this report are shared with the Keeyask Mercury and Human Health Implementation Group for their consideration.



3.0 RESULTS

3.1 SAMPLE DESCRIPTION AND BIOLOGICAL DATA

Mercury concentrations were obtained from 72 Northern Pike and 72 Walleye caught in the Aiken River in 2018. The target sample size of 36 fish of each species caught was achieved at both York Landing and Ilford. All fish analyzed for mercury were aged (Table 2).

Mean length of Northern Pike (ANOVA on ranks, p=0.045) and Walleye (ANOVA, p<0.001) analyzed for mercury differed significantly between the two sampling locations, with fish captured at York Landing being longer (Table 2). Similar statistically significant differences in pike length between the two locations have consistently been found in previous sampling years (*i.e.*, 2006–2015). For Walleye, fish from York Landing have mainly been longer than those caught at Ilford, but the difference in length was only significant for one of the five sampling years between 2006 and 2018.

Pike and Walleye analyzed for mercury from each location in 2018 were, in general, not as long as those caught in previous sampling years since 2002. However, the differences in fish length in 2018 were only significant for fish caught at Ilford, where the length of pike in 2018 was significantly less than in 2015, and Walleye were significantly shorter in 2018 compared to 2006, 2009, and 2015 (ANOVA on ranks, p<0.05).

The mean length of pike analyzed for mercury from York Landing in 2018 was moderately (23 mm) smaller than the standard length for the species (550 mm), whereas pike from Ilford were 83 mm smaller than the standard length (Table 2). Walleye from York Landing in 2018 were slightly (5 mm) longer than the standard length for the species (400 mm); whereas, the mean length of their conspecifics from Ilford was 32 mm smaller than the standard length

The difference in the weight of pike caught from Ilford and York Landing in 2018 was not significant (ANOVA on ranks, p=0.099), mainly because of the large variability in the weight of fish caught at York Landing (Table 2). The weight of Walleye was also similar between locations (ANOVA on ranks, p=0.177). These results fit the general pattern observed for both species in previous years since 2002, when occasional, large differences in the weight of pike and Walleye captured at York Landing and Ilford were not significant between locations, with the exception of pike caught in 2006.

The condition of pike in 2018, where condition is a surrogate of how fat or skinny a fish is, was similar at York Landing and Ilford (Table 2), and is consistent with the condition observed for all previous sampling years since 2006. In contrast, Walleye captured at Ilford and analyzed for mercury in 2018 were in significantly (ANOVA, p<0.001) better condition than their conspecifics from York Landing. Such significant differences in Walleye condition have been observed in



most of the previous sampling years; however, the capture location of fish with the higher K value has been inconsistent.

Walleye from York Landing and Ilford were of similar (ANOVA on ranks, p=0.778) age in 2018 (Table 2); Pike age was also similar (ANOVA, p=0.223) when comparing the two locations (Table 2). However, age differed significantly (ANOVA, p<0.001) between the two species captured at each location, with Walleye being approximately 1.5 years older than pike. These results are consistent with those collected in past years on the Aiken River.

Biological data for individual fish caught are presented in Appendix 3.

3.2 MERCURY CONCENTRATIONS

3.2.1 RESULTS FOR 2018

The relationship between mercury concentration and fish length was significant for Northern Pike and Walleye from both locations (Figure 1), and length standardized mean mercury concentrations could be calculated. The standard means of pike were similar at York Landing (0.342 ppm) and Ilford (0.332 ppm; Table 3). The standard mean for pike from Ilford was almost 50% higher than the arithmetic mean (Table 3), which is a result of the smaller mean length of the pike analyzed for mercury (Table 2) compared to the standard length of the species (see Section 3.1). The standard mean of Walleye from Ilford (0.371 ppm) was slightly higher than the mean of their conspecifics captured at York Landing (0.332 ppm) (Table 3).

Maximum concentrations observed in 2018 were 0.88 ppm in pike and 1.08 ppm in Walleye (Figure 1). Mercury concentrations for all fish are presented in Appendix 3.

3.2.2 COMPARISONS TO OTHER YEARS

Prior to 2002, Walleye and pike from the Aiken River at Ilford have been analyzed for mercury since 1978 and at York Landing only in 1982 (Appendix 2). Until 2002, sample sizes were small (3–8 fish) for both species and a standard mean could be calculated only three times. Since 2002, a lack of a significant relationship between length and mercury concentration and thereby an inability to calculate a standard mean has occurred three times, for Walleye in 2003 (both locations) and 2015 (York Landing) (Figure 2).

Considering the above limitations, the mean concentrations in pike from Ilford, which are mostly arithmetic means, fluctuated from 0.20–0.40 ppm between 1978 and 1998 (Appendix 2). Concentrations in Walleye from Ilford exhibited a similar temporal pattern, although arithmetic means were always lower compared to pike, ranging from 0.08–0.24 ppm (Appendix 2).



Mean length-standardized mercury concentrations slightly decreased from 2002/2003 to 2006 in pike from both locations and Walleye from York Landing (very few Walleye were sampled from Ilford in 2003). Standard means then increased by between 0.06 and 0.15 ppm in 2009 and have remained higher at both locations in 2012, 2015, and 2018 when compared to 2006 (Figure 2). Thus, standard means have generally been similar to each other over the past 9 years (2009–2018) and have been generally higher than mean concentrations reported for years 2002–2006 in the EIS.



4.0 **DISCUSSION**

Length standardized mean mercury concentrations of Northern Pike and Walleye from locations near Ilford and York Landing on the Aiken River in 2018 have remained similar compared to fish sampled in years between 2009 and 2015. All standard means of pike and Walleye increased between 2006 and 2009 and have remained higher compared to standard means measured during EIS studies (2002–2006).

These general, temporal patterns in mercury concentrations of pike and Walleye from the Aiken River are similar to results from other Keeyask Project on-system waterbodies. For example, increases in standard means of pike and Walleye from Split and Stephens lakes observed between 2005 and 2007 have persisted (with some fluctuations in Split Lake) until 2015/2016 (Jansen 2018). Collectively, the temporal pattern of changes in mercury in fish from in these waterbodies has been interpreted as part of a more wide-spread change in fish mercury concentrations in the region (Jansen 2016b).



5.0 CONCLUSION AND NEXT STEPS

The key question to be answered about mercury in fish in relation to the mercury in fish monitoring completed in 2018 was:

• What is the concentration of mercury in Northern Pike and Walleye caught in the Aiken River during the construction of the Keeyask GS but prior to Keeyask reservoir flooding and how has it changed since it was measured for the Keeyask EIS?

The length-standardized mean mercury concentrations of fish sampled from the Aiken River at York Landing and Ilford in 2018 ranged from 0.33–0.34 ppm in Northern Pike and from 0.33–0.37 ppm in Walleye. These standard means have remained similar compared to the last three previous sampling periods between 2009 and 2015 but are generally higher than standard means recorded during the EIS studies between 2002 and 2006.

Mercury concentrations in Northern Pike and Walleye will be sampled again in the Aiken River at York Landing and Ilford in 2021.



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TABLES



Table 1:Comparison of total mercury concentrations (ppm; mean ± expanded
uncertainty¹) of certified reference material (SRM) fish protein (DORM-4;
National Research Council Canada, NRC) with results obtained by ALS
Environmental in Winnipeg in conjunction with fish muscle analyses for the
Aiken River in 2018; RPMD represents the relative mean percentage
difference between the sample mean and the target concentration; Replicates
refers to the difference between first and second sample of replicate analyses
of muscle sample digests.

01-11-11-	DORM-4	LCS	Replicates
Statistic	$(0.412 \pm 0.036)^2$	(0.10) ³	(% difference)
Mean	0.310	0.097	6.9
Range	0.293-0.339	0.091–0.107	0–12.1
n ⁴	7	7	6
RPMD (%)	28.4	5.3	n/a

1. The expanded uncertainty (U_{CRM}) in the certified value is equal to U = kuc where uc is the combined standard uncertainty calculated according to the JCGM Guide and k is the coverage factor. It is intended that U_{CRM} encompasses every aspect that reasonably contributes to the uncertainty of the measurement.).

2. See https://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/certificates/dorm_4.html; last accessed 18 December, 2018; Note that ALS applies an internal standard concentration of 0.322 ppm total mercury for quality control purposes (see Appendix 1).

3. ALS internal Laboratory Control Sample; liquid spiked with total mercury to a concentration of 0.1 ppm; no measure of variance available.

4. n represents the number of analyses.



Table 2:Mean (± SE) fork length, round weight, condition factor (K), and age of Northern Pike and Walleye from two
locations on the Aiken River in 2018.

Species	Location	n	Length (mm)	Weight (g)	к	Age (years)
Northern Pike	York Landing	36	526.6 ± 19.1	981.3 ± 98.5	0.61 ± 0.02	4.8 ± 0.2
	llford	36	467.1 ± 10.5	675.7 ± 37.3	0.65 ± 0.02	4.3 ± 0.1
Walleye	York Landing	36	404.6 ± 6.9	618.9 ± 27.6	0.92 ± 0.02	6.2 ± 0.2
	llford	36	367.9 ± 5.0	556.3 ± 21.8	1.10 ± 0.02	6.1 ± 0.2

Table 3:Mean arithmetic (± SE) and standardized (95% confidence limits, CL) mercury concentration (ppm) of NorthernPike and Walleye from two locations on the Aiken River in 2018.

Species	Location	n	Arithmetic	SE	Standard	95% CL
Northern Pike	York Landing	36	0.359	0.075	0.342	0.294–0.398
	llford	36	0.227	0.049	0.332	0.253-0.436
Walleye	York Landing	36	0.361	0.055	0.332	0.297–0.371
	llford	36	0.335	0.027	0.371	0.332–0.415



FIGURES





Figure 1: Relationship between mercury concentration and fish length for Northern Pike and Walleye captured from the Aiken River at York Landing (YL) and Ilford (IF) in May 2018. Significant regression lines and equations are shown; note logarithmic scale.





An asterisk indicates that the relationship between fish length and mercury concentration was not significant and the arithmetic mean was used; n represents sample size (only shown if n < 10).

Figure 2: Mean (±95% confidence limits, CL) length standardized muscle mercury concentrations of Northern Pike and Walleye from the Aiken River at York Landing (YL) and Ilford (IF) for years 2002–2018.



MAPS





Map 1: Map of the Keeyask study area showing hydroelectric development and highlighting the Aiken River.





Map 2: Map of the Aiken (Landing) River showing sampling sites for fish mercury in 2018.



APPENDICES



APPENDIX 1: TARGET CONCENTRATION OF DORM-4 CERTIFIED REFERENCE MATERIAL USED BY ALS ENVIRONMENTAL.

Hi Wolfgang,

I had a chance to look into your concerns regarding ALS' decision to use the long term mean of 0.322 mg/kg to calculate the target for DORM-4, instead of the agency limit of 0.412 mg/kg.

CRM certified targets are for the total content of an analyte in a reference material and does not necessarily mean all digestion methods will achieve a total recovery. The certificate for DORM-4 shows what instrumental method(s) were used to determine the concentration but does not provide the digestion type. The digestion itself is what determines how thoroughly a sample is broken down, therefore how much metal is extracted. The tissue digestion performed at ALS is an environmental digestion following EPA 200.3. This digest is not as aggressive as one using such acids as perchloric or hydrofluoric.

Refer to the attached for a chart of CRM recoveries. Both Vancouver and Winnipeg have very similar results for DORM-4 with hundreds of points each. Edmonton has a smaller sample set with only 19 points in their average. There are CRMs with targets both below and above the DORM-4 target that have acceptable recoveries. This leads us to believe that the concentrations for DORM-4 were obtained through a different, perhaps more aggressive procedure.

We are confident that our digestion and analytical processes are reliable. This is supported by the various CRMs that are analyzed as well as the other Quality Control samples that are routinely analyzed for this test.

Regards,

Christine Mason Senior Analyst Winnipeg, Canada





e-mail attachment: CRM Recoveries

Certified reference material mercury tissue data; results from ALS Labs.

CRM name	Location	Date Range	Mean % Recovery	Certified Target mg/kg
Apple leaf	Vancouver	July2015–Mar2018	94.4	0.0404
Dolt-4	Vancouver	Oct2012–Jan2013	90	2.58
Oyster 1566B	Vancouver	Jan2016-May2017	89.8	0.0344
Peach leaf 1547	Vancouver	May2015-Jan2018	95.2	0.031
Dorm-4	Vancouver	Sep2017–Mar2018	80.7	0.412
Pine needle 1575A	Vancouver	Nov2016-Sep2017	95.2	0.0329
Apple leaf	Winnipeg	Jan2013-Dec2016	99.3	0.044
Dorm-4	Winnipeg	Sep2016-Mar2018	80.5	0.412
Tort-3	Winnipeg	Sep2016-Mar2018	88.9	0.292
Dorm-4	Edmonton	May2013-Nov2015	91.5	0.412



APPENDIX 2:

MEAN (±95% CONFIDENCE LIMITS, CL) LENGTH STANDARDIZED MUSCLE MERCURY CONCENTRATIONS OF NORTHERN PIKE AND WALLEYE FROM THE AIKEN RIVER AT YORK LANDING (YL) AND ILFORD (IF) FOR YEARS 1978–2018.





An asterisk indicates that the relationship between fish length and mercury concentration was not significant and the arithmetic mean was used; n represents sample size (only shown if n <10).



APPENDIX 3: MUSCLE MERCURY CONCENTRATIONS AND BIOLOGICAL DATA FOR FISH FROM THE AIKEN RIVER IN 2018

Table A3-1:	Definitions of codes used in Appendix tables	. 29
Table A3-2:	Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at York Landing in 2018	. 30
Table A3-3:	Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at Ilford in 2018.	. 33



Table A3-1: Definitions of codes used in Appendix tables.

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



Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	к	Sex	Mat	Age (yr)	Hg (ppm)
1	2018	21-May	1	NRPK	455	475	0.504	Female	1	4	0.151
2	2018	21-May	2	NRPK	555	1000	0.585	Female	1	5	0.432
3	2018	21-May	2	NRPK	535	950	0.620	Female	1	5	0.323
4	2018	21-May	2	NRPK	380	400	0.729	Male	0	4	0.139
5	2018	21-May	2	NRPK	470	625	0.602	Female	1	5	0.192
6	2018	21-May	2	NRPK	455	500	0.531	Female	0	3	0.119
7	2018	21-May	2	NRPK	705	2450	0.699	Female	1	7	0.596
8	2018	21-May	2	NRPK	555	925	0.541	Female	1	5	0.459
9	2018	21-May	2	NRPK	535	900	0.588	Male	0	6	0.562
10	2018	21-May	2	NRPK	635	1200	0.469	Female	1	6	0.460
11	2018	21-May	2	NRPK	670	1950	0.648	Female	1	6	0.265
16	2018	21-May	2	NRPK	275	200	0.962	Male	0	2	0.134
19	2018	21-May	2	NRPK	565	1000	0.554	Male	0	6	0.551
22	2018	21-May	2	NRPK	440	500	0.587	Male	1	4	0.133
23	2018	21-May	2	NRPK	635	1250	0.488	Female	1	5	0.611
24	2018	21-May	2	NRPK	425	450	0.586	Female	0	3	0.157
25	2018	21-May	3	NRPK	430	500	0.629	Female	1	4	0.183
26	2018	21-May	3	NRPK	320	200	0.610	Male	0	2	0.105
27	2018	21-May	3	NRPK	420	550	0.742	Male	1	5	0.157
28	2018	21-May	3	NRPK	470	600	0.578	Female	1	3	0.602
29	2018	21-May	3	NRPK	550	800	0.481	Male	1	6	0.748
30	2018	21-May	3	NRPK	695	2000	0.596	Female	1	6	0.535
31	2018	21-May	3	NRPK	715	2150	0.588	Female	1	6	0.289
59	2018	21-May	3	NRPK	420	500	0.675	Male	1	4	0.125
66	2018	22-May	4	NRPK	405	475	0.715	Male	1	4	0.175
67	2018	22-May	4	NRPK	430	600	0.755	Female	1	5	0.244

 Table A3-2:
 Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at York Landing in 2018.



Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	К	Sex	Mat	Age (yr)	Hg (ppm)
68	2018	22-May	4	NRPK	495	800	0.660	Female	1	4	0.182
69	2018	22-May	4	NRPK	670	1675	0.557	Male	1	4	0.545
70	2018	22-May	4	NRPK	460	700	0.719	Female	1	3	0.146
71	2018	22-May	4	NRPK	570	1200	0.648	Female	1	5	0.878
72	2018	22-May	4	NRPK	660	1725	0.600	Male	1	5	0.462
73	2018	22-May	4	NRPK	605	1300	0.587	Male	1	6	0.496
74	2018	22-May	4	NRPK	700	1900	0.554	Female	1	8	0.795
75	2018	22-May	4	NRPK	500	725	0.580	Male	0	4	0.297
76	2018	22-May	4	NRPK	650	1550	0.564	Female	1	8	0.540
77	2018	22-May	4	NRPK	480	600	0.543	Female	0	3	0.144
12	2018	21-May	2	WALL	380	550	1.002	Female	1	7	0.280
13	2018	21-May	2	WALL	470	800	0.771	Male	1	7	0.407
14	2018	21-May	2	WALL	435	825	1.002	Male	0	7	0.177
15	2018	21-May	2	WALL	455	850	0.902	Male	0	7	0.471
17	2018	21-May	2	WALL	480	850	0.769	Female	1	9	1.080
18	2018	21-May	2	WALL	430	725	0.912	Male	1	7	0.348
20	2018	21-May	2	WALL	470	825	0.795	Male	1	8	0.349
21	2018	21-May	2	WALL	400	550	0.859	Male	0	7	0.264
33	2018	21-May	3	WALL	425	650	0.847	Male	1	6	0.401
34	2018	21-May	3	WALL	335	400	1.064	Male	1	5	0.228
35	2018	21-May	3	WALL	450	850	0.933	Male	1	8	0.418
36	2018	21-May	3	WALL	355	475	1.062	Male	0	5	0.206
37	2018	21-May	3	WALL	370	475	0.938	Male	1	5	0.392
39	2018	21-May	3	WALL	450	950	1.043	Female	1	7	0.365
40	2018	21-May	3	WALL	405	550	0.828	Male	0	5	0.321
41	2018	21-May	3	WALL	400	525	0.820	Male	0	6	0.484
43	2018	21-May	3	WALL	380	500	0.911	Male	1	6	0.278

 Table A3-2:
 Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at York Landing in 2018 (continued).



Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	К	Sex	Mat	Age (yr)	Hg (ppm)
44	2018	21-May	3	WALL	390	450	0.759	Male	1	5	0.293
45	2018	21-May	3	WALL	420	625	0.844	Male	1	5	0.487
46	2018	21-May	3	WALL	455	800	0.849	Male	1	6	0.279
47	2018	21-May	3	WALL	350	450	1.050	Male	1	6	0.255
48	2018	21-May	3	WALL	395	500	0.811	Male	1	5	0.385
49	2018	21-May	3	WALL	410	600	0.871	Male	1	7	0.519
50	2018	21-May	3	WALL	355	480	1.073	Male	1	5	0.244
51	2018	21-May	3	WALL	355	400	0.894	Male	0	7	0.652
53	2018	21-May	3	WALL	415	650	0.909	Male	1	6	0.423
54	2018	21-May	3	WALL	440	725	0.851	Male	1	7	0.336
55	2018	21-May	3	WALL	385	500	0.876	Male	1	7	0.289
56	2018	21-May	3	WALL	380	525	0.957	Male	1	6	0.360
57	2018	21-May	3	WALL	440	725	0.851	Male	1	7	0.500
60	2018	22-May	4	WALL	320	400	1.221	Male	1	5	0.185
61	2018	22-May	4	WALL	455	975	1.035	Female	1	8	0.309
62	2018	22-May	4	WALL	375	550	1.043	Male	0	5	0.306
63	2018	22-May	4	WALL	370	475	0.938	Male	1	4	0.200
64	2018	22-May	4	WALL	370	500	0.987	Male	0	5	0.255
65	2018	22-May	4	WALL	395	600	0.974	Male	1	5	0.247

 Table A3-2:
 Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at York Landing in 2018 (continued).



Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	К	Sex	Mat	Age (yr)	Hg (ppm)
90	2018	23-May	5	NRPK	380	475	0.866	Male	0	3	0.055
91	2018	23-May	5	NRPK	550	1025	0.616	Female	1	5	0.525
92	2018	23-May	5	NRPK	470	825	0.795	Male	0	6	0.106
93	2018	23-May	5	NRPK	360	500	1.072	Male	0	3	0.144
94	2018	23-May	5	NRPK	470	650	0.626	Male	0	6	0.406
95	2018	23-May	5	NRPK	335	400	1.064	Male	0	2	0.039
96	2018	23-May	5	NRPK	450	650	0.713	Male	0	3	0.145
97	2018	23-May	5	NRPK	455	650	0.690	Female	1	3	0.141
98	2018	23-May	5	NRPK	505	800	0.621	Male	0	5	0.213
111	2018	23-May	5	NRPK	480	800	0.723	Male	0	5	0.343
112	2018	24-May	5	NRPK	520	850	0.605	Male	1	4	0.345
113	2018	24-May	5	NRPK	480	800	0.723	Female	1	5	0.243
125	2018	24-May	5	NRPK	515	900	0.659	Female	1	7	0.088
129	2018	24-May	5	NRPK	455	700	0.743	Female	1	4	0.195
131	2018	25-May	5	NRPK	465	550	0.547	Female	1	4	0.157
132	2018	25-May	5	NRPK	375	300	0.569	Male	0	2	0.121
133	2018	25-May	5	NRPK	505	800	0.621	Female	1	5	0.078
134	2018	25-May	5	NRPK	485	750	0.657	Female	1	4	0.161
135	2018	25-May	5	NRPK	465	600	0.597	Male	0	5	0.270
136	2018	25-May	5	NRPK	490	700	0.595	Female	1	4	0.115
137	2018	25-May	5	NRPK	550	650	0.391	Male	1	4	0.361
138	2018	25-May	5	NRPK	520	900	0.640	Male	1	7	0.690
139	2018	25-May	5	NRPK	610	1250	0.551	Female	1	8	0.394
140	2018	25-May	5	NRPK	470	650	0.626	Male	0	6	0.329
141	2018	25-May	5	NRPK	450	550	0.604	Male	0	4	0.325
142	2018	25-May	5	NRPK	435	500	0.607	Female	1	3	0.208

 Table A3-3:
 Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at Ilford in 2018.



Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	к	Sex	Mat	Age (yr)	Hg (ppm)
144	2018	25-May	5	NRPK	305	150	0.529	Male	0	2	0.034
145	2018	25-May	5	NRPK	590	1250	0.609	Female	1	4	0.456
146	2018	25-May	5	NRPK	470	550	0.530	Female	1	3	0.156
147	2018	25-May	5	NRPK	460	550	0.565	Female	1	4	0.210
148	2018	25-May	5	NRPK	440	500	0.587	Female	1	5	0.189
149	2018	25-May	5	NRPK	500	750	0.600	Male	1	5	0.303
150	2018	25-May	5	NRPK	470	650	0.626	Male	1	5	0.229
151	2018	25-May	5	NRPK	468	600	0.585	Female	1	4	0.153
152	2018	25-May	5	NRPK	462	600	0.608	Male	0	3	0.078
153	2018	25-May	5	NRPK	405	500	0.753	Male	0	4	0.179
80	2018	23-May	5	WALL	345	400	0.974	Male	1	5	0.334
81	2018	23-May	5	WALL	350	500	1.166	Male	1	6	0.324
82	2018	23-May	5	WALL	412	750	1.072	Female	1	6	0.310
83	2018	23-May	5	WALL	325	375	1.092	Male	1	6	0.313
84	2018	23-May	5	WALL	340	450	1.145	Male	1	6	0.273
85	2018	23-May	5	WALL	370	550	1.086	Male	1	6	0.427
86	2018	23-May	5	WALL	365	552	1.135	Male	1	6	0.340
87	2018	23-May	5	WALL	342	450	1.125	Male	1	6	0.322
88	2018	23-May	5	WALL	380	600	1.093	Male	1	6	0.383
89	2018	23-May	5	WALL	380	500	0.911	Male	1	7	0.414
99	2018	23-May	5	WALL	404	850	1.289	Male	1	7	0.481
100	2018	23-May	5	WALL	350	600	1.399	Male	1	6	0.344
101	2018	23-May	5	WALL	350	500	1.166	Male	1	5	0.227
102	2018	23-May	5	WALL	360	525	1.125	Male	1	6	0.167
103	2018	23-May	5	WALL	360	600	1.286	Male	1	6	0.271
104	2018	23-May	5	WALL	370	600	1.185	Male	1	7	0.361
105	2018	23-May	5	WALL	340	500	1.272	Male	1	6	0.303

 Table A3-3:
 Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at Ilford in 2018 (continued).



Eich #	Voor	Data	Sito	Species	Length	Weight	V	Sov	Mot		
FISH #	real	Date	Sile	species	(mm)	(g)	ĸ	Sex	IVIAL	Age (yr)	ну (ррпт)
106	2018	23-May	5	WALL	365	600	1.234	Male	0	5	0.267
107	2018	23-May	5	WALL	350	500	1.166	Male	1	5	0.231
108	2018	23-May	5	WALL	430	900	1.132	Male	1	7	0.399
109	2018	23-May	5	WALL	400	650	1.016	Male	1	7	0.452
110	2018	23-May	5	WALL	408	725	1.067	Male	1	6	0.448
114	2018	24-May	5	WALL	350	525	1.224	Male	1	6	0.486
115	2018	24-May	5	WALL	348	500	1.186	Male	1	5	0.318
116	2018	24-May	5	WALL	340	400	1.018	Male	1	6	0.344
117	2018	24-May	5	WALL	428	700	0.893	Female	1	8	0.325
118	2018	24-May	5	WALL	380	600	1.093	Male	1	8	0.396
119	2018	24-May	5	WALL	360	450	0.965	Male	1	5	0.281
120	2018	24-May	5	WALL	368	550	1.104	Male	1	5	0.278
121	2018	24-May	5	WALL	385	600	1.051	Male	1	8	0.301
122	2018	24-May	5	WALL	395	650	1.055	Male	1	8	0.471
123	2018	24-May	5	WALL	358	475	1.035	Male	1	5	0.236
126	2018	24-May	5	WALL	320	325	0.992	Male	1	5	0.277
128	2018	24-May	5	WALL	350	450	1.050	Male	1	6	0.353
130	2018	24-May	5	WALL	330	375	1.043	Male	1	5	0.216
143	2018	25-May	5	WALL	438	750	0.893	Female	1	7	0.400

Table A3-3:Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River
at Ilford in 2018 (continued).

