# KEEYASK GENERATION PROJECT
## ENVIRONMENTAL IMPACT STATEMENT

## SOCIO-ECONOMIC ENVIRONMENT,
## RESOURCE USE AND HERITAGE RESOURCES
## SUPPORTING VOLUME

# APPENDIX 5C
# HUMAN HEALTH RISK ASSESSMENT

# REVISED APRIL 2013

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# APPENDIX 5C

# Human Health Risk Assessment of the Mercury from the Proposed Keeyask Generation Project

**FINAL REPORT**

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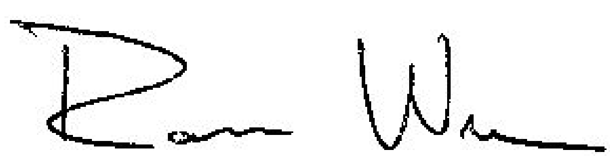


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# EXECUTIVE SUMMARY

The Mercury and Human Health Technical Working Group, participating in the environmental assessment (EA) for the Keeyask Generation Project requested Wilson Scientific Consulting Inc. (Wilson Scientific) to complete a human health risk assessment (HHRA) to address current and potential increased mercury in the environment that may result if the proposed Keeyask Generation Project proceeds. The HHRA was to consider the traditional uses of the land by the various First Nation communities in the study area. In addition, the most recent scientific evidence on health effects from mercury was to be part of the assessment.

The methods used to estimate human health risks were based on risk assessment procedures cited by Health Canada, the World Health Organization (WHO) and the US Environmental Protection Agency (US EPA).

The items of main concern were:

- Consumption of country (wild) foods (*i.e.*, fish, wild game, waterfowl and wild plants); and
- Ingestion and direct contact with surface water.

The water bodies of primary interest for this assessment were Gull and Stephens lakes. The HHRA was greatly assisted by Keeyask Cree Nations' representatives who shared their knowledge regarding types and locations of country foods and food consumption patterns. In addition, it should be noted that the HHRA did not measure mercury concentrations in food or people but instead relied upon present and estimated post-impoundment concentrations in water and foods that have been provided by other experts (*i.e.*, fish and surface water mercury concentrations provided by North/South Consultants Inc.; wild game mercury concentrations by Wildlife Resource Consulting Services MB Inc.; and waterfowl concentrations of mercury estimated by TetrES Consultants Inc. [now known as Stantec]).

The key conclusions of the HHRA are as follows:

1. Hazard Quotient values greater than 1 are predicted from consumption of certain fish under both the present conditions and the predicted post-impoundment conditions. Under post-impoundment conditions, Hazard Quotient values increase since the mercury concentrations in various fish are estimated to increase. The fish with the predicted highest increase in mercury concentrations are from Gull Lake and include northern pike (0.22 µg/g to just over 1 µg) and walleye (0.23 µg/g to just over 1 µg/g) while the increase in lake whitefish would be less (0.07 µg/g to just below 0.2 µg/g). The same species from Stephens Lake would be impacted less than fish from Gull Lake. Although Hazard Quotient values greater than 1 are predicted from certain fish based on consumption frequencies, it is stressed that this does not automatically mean that the consumption of these fish needs to be restricted. Issuance of consumption advisories is a complex issue that requires evaluation of the benefits and risks. Manitoba Health and Health Canada have committed to working with the KCNs and Manitoba Hydro on consumption advisories in a separate process.
2. No Hazard Quotient values greater than 1 are predicted from consumption of wild game or waterfowl under current or post-impoundment conditions. Muskrat is the only mammal that was predicted to have increased tissue concentrations of mercury following impoundment; however, the increases are considered to be very minor (*i.e.*, 0.02 µg/g under baseline conditions versus 0.04 µg/g under post-impoundment conditions). No measurable changes in mercury tissue concentrations under post-impoundment conditions in moose, beaver and snowshoe hare were predicted by Wildlife Resource Consulting Services. In the case of waterfowl, Stantec Consultants estimate that these may mirror changes in whitefish concentrations; however, no Hazard Quotient values greater than 1 were predicted from consumption of waterfowl.
3. Mercury concentrations in surface water do not pose unacceptable risks from contact or drinking under present or post-impoundment conditions (*i.e.*, risks are considered to be negligible). Typical total mercury surface water concentrations

are predicted to remain less than the currently used analytical method detection limit (*i.e.*, less than 0.05 µg/L as compared to the Canadian Drinking Water Guideline of 1 µg/L).

4. No conclusions can be provided on consumption of wild plants or gull eggs since discipline experts have not been able to estimate mercury concentrations either presently or under post-impoundment conditions.

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# HUMAN HEALTH RISK ASSESSMENT OF THE MERCURY FROM THE PROPOSED KEEYASK GENERATION PROJECT

## 1.0 INTRODUCTION

The Mercury and Human Health Technical Working Group (the Technical Working Group) for the Keeyask Generation Project requested that Wilson Scientific Consulting Inc. (Wilson Scientific) complete a human health risk assessment (HHRA) to address current and potential increased methylmercury (mercury) concentrations in the environment that may result if the proposed Keeyask Generation Project is approved. The specific questions that the HHRA needed to address were:

1. What are the risks from consumption of fish under present conditions?
2. If the proposed project is approved, what are the risks to persons consuming:
    a. Fish?
    b. Wild game?
    c. Waterfowl?
    d. Wild plants?
    e. Water?

The HHRA also needed to consider the domestic uses of the land by the various local First Nation communities. In addition, the most recent scientific evidence on health effects from mercury was required to be part of the assessment.

It is important to note that through a formal agreement with the Keeyask Cree Nations (KCNs), they participated in the environmental assessment (EA) for the Keeyask Generation Project; as part of the EA, a Mercury and Human Health Technical Working Group was established with representatives from the KCNs and Manitoba Hydro and their respective consultants. The First Nations consisted of representatives from:

- Tataskweyak Cree Nation
- War Lake First Nation
- Fox Lake Cree Nation
- York Factory First Nation

The Mercury and Human Health Technical Working Group played an important role in providing guidance and knowledge on traditional use of the land that has been incorporated into this HHRA.

This report outlines the methods, results, conclusions and recommendations of the HHRA and is organized as follows:

- Section 2 of the report introduces mercury as a chemical of potential concern, and the concept of HHRA;
- Section 3 summarizes the site setting and relevant documents that provide information cited in the HHRA;
- Section 4 provides methods used to complete the HHRA;
- Section 5 provides the results;
- Section 6 provides a discussion of the results including an uncertainty analysis;
- Section 7 provides the overall conclusions of the HHRA; and
- Appendix 5C-1 provides detailed technical information, worked example calculations and detailed risk estimates.

# 2.0 MERCURY AND HUMAN HEALTH RISK ASSESSMENT

## 2.1 WHAT IS MERCURY?

Mercury is a metal that naturally occurs in very small quantities in the soil, water, plants, animals, etc. in the Keeyask Project area as well as many other parts of Canada. Mercury can be found in various forms categorized as follows:

- Elemental mercury (a shiny silver-coloured liquid that slowly evaporates at room temperature and more rapidly when heated to moderate temperatures);
- Inorganic mercury (a form of mercury that results when elemental mercury combines with sulphur, chlorine or oxygen to form "mercury salts"); and
- Methyl mercury (a form of mercury that results when elemental mercury combines with carbon to form "organic mercury" and is naturally present in very small quantities in all foods, but almost always highest in carnivorous fish).

## 2.2 WHAT ARE TYPICAL SOURCES OF MERCURY?

Mercury is used by humans in a wide-variety of industrial processes and commercial products. Metallic mercury is used to produce chlorine gas and caustic soda. In consumer products, metallic mercury can be found in thermometers, dental fillings, batteries and fluorescent lights. Inorganic mercury salts can sometimes be found in various anti-septic creams and ointments. In terms of exposure to people, the vast majority of exposure is in the form of methyl mercury through the consumption of fish.

Although mercury occurs naturally in the environment, human activities may result in increased exposures. Human-contributed sources of mercury exposures include:

- Releases of mercury into the air from combustion processes such as coal-fired power generation, metal mining, metal smelting operations and waste incineration;

- Disposal of mercury containing products (*e.g.*, fluorescent lights, batteries, thermostats, barometers, switches and relays) into landfill sites and subsequent leaching into the environment; and
- Flooding of soils for new dam sites (this can result in mercury from flooded soils releasing mercury into the aquatic food chain).

### 2.3 HOW ARE CANADIANS EXPOSED TO MERCURY?

Canadians may be exposed to mercury from activities that include:

- Eating fish flesh of any kind. Fish consumption typically represents the greatest source of exposure to most Canadians. Fish with the highest muscle mercury concentrations tend to be the large and long-lived predatory fish; however, essentially all fish contain some levels of mercury. Fish in some lakes in Canada have naturally high concentrations of mercury and it is not an issue that is totally restricted to impoundments. Also, some marine fish often contain elevated concentrations of mercury. A list of fish with relatively high mercury concentrations includes the following:
    - Fresh and frozen tuna;
    - Canned albacore tuna (other canned tuna do not typically contain as much mercury);
    - Lake trout;
    - Burbot;
    - Walleye (or pickerel);
    - Jackfish (or pike);
    - Shark;
    - Swordfish;
    - Marlin;
    - Orange roughy; and
    - Escolar (a type of mackerel that is commonly used in sushi);

- Eating fish from localized areas impacted by mercury releases (concentrations also tends to be greatest in the larger, long-lived predatory fishes);
- Breathing vapours in air from spills, incinerators and industrial operations that release mercury into the air;
- Breathing mercury vapours that are released into a person's mouth during dental treatments (mercury amalgams used as fillings for cavities); and
- Use of medical treatments which contain mercury (various topical ointments and creams).

### 2.4 WHAT ARE THE HEALTH EFFECTS ASSOCIATED WITH MERCURY?

The health effects of concern depend on the form of mercury and the duration and magnitude of exposures. If the exposure is of elevated concentrations for a long duration, all forms of mercury may cause health effects to the nervous system. Methyl mercury (primarily from fish consumption) and elemental mercury (primarily from inhalation of vapours) tend to have greater ability to cause health effects than inorganic mercury due to an increased ability of these forms to cross body tissues and enter the nervous system. Important aspects of mercury toxicology include the following:

- Health effects primarily associated with methyl mercury have included damage to the brain (*e.g.*, motor skills, irritability, shyness, tremors, changes in vision/hearing, memory problems, decreased IQ);
- Health effects primarily associated with inorganic mercury have been associated with the kidneys, gastrointestinal damage and autoimmune effects. Mercury salts can cause blisters and ulcers on the lips and tongue. Rashes, excessive sweating, irritability, tremors, muscle weakness and high blood pressure have also been noted in persons exposed to elevated concentrations of inorganic mercury;
- Health effects primarily associated with elemental mercury, such as vapours, have included hand tremors and memory problems;

- Short-term exposures to high levels of metallic mercury (primarily as vapours) may be associated with effects that include lung damage, nausea, vomiting, diarrhea, blood pressure, increased heart rate and skin rashes, and eye irritation; and
- Although there is some evidence of mercury causing cancer in animals at elevated exposures, there is not considered to be adequate evidence to conclude that mercury is a human carcinogen and most health agencies do not consider it necessary to consider the cancer endpoint in establishing safe levels of exposure.

Fortunately, mercury in most foods, consumer products, and the environment are at concentrations not great enough to cause the health effects listed above.

It is also noted that in order for mercury to cause toxicity, it must be absorbed. For example, if a child accidentally swallowed liquid mercury from a broken thermometer, it is unlikely that much of the ingested mercury would be absorbed into the body; however, mercury could enter the body via inhalation of vapours from the spill.

### 2.5 WHO IS MOST SENSITIVE TO MERCURY EXPOSURES?

Generally speaking, young children and pregnant women (or women of child-bearing age) (due to the potential harmful effects on the developing fetus) are of primary concern to health agencies with respect to mercury exposure; however, persons of any age may experience health effects if the exposures are great enough. Consequently, health authorities can have different recommendations for minimizing exposures depending upon the segment of the population a person may represent. For example, many health agencies recommend that pregnant or breastfeeding women and young children restrict their consumption of certain types of fish containing high concentrations of mercury; however, most health agencies also agree that consumption of fish is an important part of the diet and these agencies stress that consumption of fish containing low concentrations of mercury represent a healthy part of the diet for pregnant and breastfeeding women (as well as for young children).

## 2.6 IF MERCURY IS TOXIC, HOW IS ANY EXPOSURE SAFE?

Although mercury exposure is associated with some serious health effects, there are certain exposures considered to be "safe" and without appreciable health risks to the general public. Because mercury is ubiquitous in the global environment, health agencies around the world have dedicated considerable effort in determining mercury exposure rates considered to be acceptable. This process has allowed health agencies to recommend that people continue to consume fish because the benefits outweigh the risks.

Using a risk assessment approach, it is possible that no unacceptable health risks may exist from mercury even when concentrations in the environment are considered to be elevated above normal levels. This conclusion is most common when persons are not receiving elevated exposures to the mercury (despite its presence at elevated concentrations in the environment). Situations that can result in a conclusion of "no appreciable risk" from elevated mercury concentrations in the environment include:

- The mercury is found in environmental media with which people do not often come into contact (*e.g.,* located in subsurface soils that do not leach into groundwater and are not releasing appreciable mercury vapours);
- The mercury is found in a food (or foods) that people are not consuming or are consuming infrequently;
- The mercury is found in a form in the environment that is not very soluble and, therefore, cannot readily be absorbed into the body even when it is consumed (*i.e.,* it is in a form that is not very bioavailable); and
- The mercury is found in environmental media at concentrations that people regularly contact; however, the concentrations are low enough that exposures are still below levels considered to be acceptable by agencies such as the World Health Organization and Health Canada.

In such cases, it may be possible to arrive at conclusions that indicate acceptable risks from mercury even though elevated concentrations are present in the environment.

Nevertheless, in all cases, conclusions must be based on a careful analysis supported by the available science (*e.g.*, risk assessment).

### 2.7 WHAT ARE ACCEPTABLE CONCENTRATIONS OF MERCURY IN FOOD?

For mercury occurring in commercial fish sold at the retail level, Health Canada (2007) provides a guideline of 0.5 µg/g (wet weight). Similarly, the European Community (2006) provides a maximum permissible mercury concentration of 0.5 µg/g (wet weight) for most fish but then allows up to 1.0 µg/g (wet weight) for a list of specific fish that includes northern pike (*Esox lucius*). It needs to be stressed that these maximum permissible concentrations are specific to commercial fish.

In the case of fish consumed for subsistence purposes, there is no official recommendation available from either Health Canada or WHO. Part of the difficulty in establishing acceptable concentrations of mercury is that fish (*i.e.*, often the major source of mercury exposure) has tremendous nutritional benefits.

Health Canada (2007) has noted the following:

> *"It is considered essential that any communications to the public include information on the health benefits of fish consumption alongside information on the risks of methylmercury exposure so that citizens can consider both the benefits and risks in reaching their own decisions about appropriate fish consumption. Studies on the nutritional benefits of fish are supportive of efforts to influence consumers' behaviour by modifying the types of fish regularly chosen rather than by decreasing overall fish consumption."*

Notwithstanding the above, provincial and federal health authorities have the ultimate responsibility for making consumption recommendations and this HHRA avoids providing final advice on recommendations on how much fish and country foods are safe to consume.

In the case of other foods (*i.e.*, wild game, waterfowl and plants), no health agency recommendations were identified for allowable mercury content.

## 2.8 WHAT IS HUMAN HEALTH RISK ASSESSMENT?

Human health risk assessment is a process that is accepted by Canadian and international health agencies for evaluating the potential for chemical, biological and physical agents to cause adverse health effects in people. Although it is desirable to minimize exposures to some environmental chemicals, exposures to chemicals and physical agents cannot be avoided in many circumstances. Potentially harmful chemicals and physical agents can exist naturally, and there were exposures prior to modern civilization. This is also true for mercury. Regulatory agencies across Canada and around the world have adopted risk assessment as a scientifically-defensible tool for the evaluation of potential health risks to chemicals and physical agents. Examples of regulatory agencies that currently use risk assessment to assist in making health-based decisions include the World Health Organization, US Environmental Protection Agency and Health Canada.

Risks from environmental chemicals and physical agents are normally evaluated using the same principles and fundamentals that regulatory agencies use to develop standards to protect the general public from unacceptable risks for soil, water, air and food. It is stressed that there are uncertainties in risk assessment and it is virtually impossible to prove complete safety in almost anything that is evaluated. Consequently, risk assessment normally comments on the reasonable likelihood of adverse health effects in people exposed to various environmental chemicals or physical agents rather than providing absolute certainties of no adverse health effects.

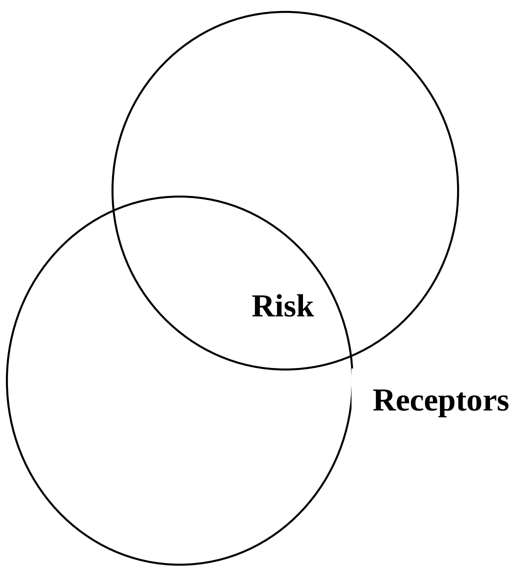
It should also be noted that most health agencies and scientists contend that risk assessment is much more likely to overestimate than underestimate risks. Due to the various uncertainties in risk assessment, health agencies tend to use large safety factors and default assumptions that result in overestimation of health risks. Further details on the HHRA methods are provided in Sections 4 and 5 of this report while some of the particularly important concepts are discussed below.

*Basic Elements Required for Risk to Exist*

One of the basic tenets of risk assessment is that in order for human health risks to exist the following elements must be present:

- A person (or receptor) is present in the area of concern;
- A chemical is present in the area of concern; and
- An exposure pathway must exist that allows a person (or persons) to be exposed.

For example, if a non-volatile chemical (such as lead) was present in subsurface soil and not leaching into groundwater, there would be virtually no risk from this chemical (as long as persons were not digging in the soil) as exposure pathways would not exist. However, as soon as persons dig in the subsurface soil, an exposure pathway would be open and exposures could then potentially exist.




*Dose-Response Relationships*

A second important fundamental of risk assessment is that the magnitude of risk is proportional to both the magnitude of exposure and the inherent potency of the chemical. Most health agencies agree that there are acceptable or "safe" levels of exposures unlikely to cause adverse health effects for even the most potent chemicals (*e.g.*, there are acceptable levels of exposure to chlorinated dioxins from pulp and paper effluent, benzo[a]pyrene from car exhaust, aflatoxin in peanut butter and various chemicals in a cup of coffee). Likewise, some seemingly innocuous chemicals may pose unacceptable risks if consumed in excess quantities (*e.g.*, although quite rare, people have become ill or even died from consumption of excessive amounts of water [due to electrolyte imbalance] or over consumption of Vitamin A from polar bear livers and carrot juice). In other words, there can be acceptable levels of the most hazardous substances and unacceptable levels of the most innocuous substances. Thus, for virtually all chemicals and physical agents that may be harmful to people, the principle of dose-response relationships apply.

According to the dose-response principle, as the level of exposure increases, the probability and/or magnitude of adverse health effects also increase. An important exception to this theory, however, is for exposure rates that are so low that adverse health effects are not expected to be observed until dose rates increase above a certain threshold of exposure. For example, certain minerals such as iron and zinc are required in our diet and are not expected to cause adverse health effects at levels at or below our recommended daily allowances for proper health and fitness. It is only when these levels are exceeded that the adverse health effects begin to increase with increasing levels of exposure.

The principle that the magnitude of risk is in proportion to the level of exposure and the potency of the chemical can be summarized as follows:

*Risk = Magnitude of Exposure x Toxicity of the Chemical*

Human health risks were estimated using the concept of dose-response relationships to the maximum extent possible in this report.

*Important Terms Used in Human Health Risk Assessment*

Scientific terminology is commonly used to describe human health risks from chemicals and physical agents. Some of the more important terms in the context of the human health risk assessment are provided below.

*Tolerable Daily Intake (TDI):* The daily amount of exposure that is considered unlikely to cause adverse health effects in the general population (including sensitive individuals). Tolerable Daily Intakes are usually provided as daily dose rates in units of mass of chemical per kilogram of body weight of a person per day (*e.g.*, the Tolerable Daily Intake for methyl mercury exposure to pregnant women is 0.2 µg of methyl mercury/kg body weight/day such that a 60 kilogram pregnant woman should not exceed 12 µg of methyl mercury per day). Other terms that are similar in meaning are the Acceptable Daily Intake (used by the World Health Organization) and Reference Dose (used by the US Environmental Protection Agency). Health Canada-derived Tolerable Daily Intakes are meant to protect all members of the general public including First Nation individuals.

*Hazard Quotient:* Used to estimate risks for non-carcinogens, Hazard Quotient values can be estimated according to the following formula:

$$\textit{Hazard Quotient} = \frac{\textit{Estimated Exposure } (\mu g/kg \textit{ body weight/day})}{\textit{Tolerable Daily Intake } (\mu g/kg \textit{ body weight/day})}$$

A Hazard Quotient value that is less than 1 indicates that exposures are less than the Tolerable Daily Intake and, thus, adverse health effects are unlikely. A Hazard Quotient value that is greater than 1 indicates a situation where chemical exposure rates may exceed the acceptable rate and, thus, may indicate excessive or unacceptable risks. In all cases, however, Hazard Quotients require careful consideration of the underlying assumptions and uncertainties before final conclusions are made.

*Incremental Lifetime Cancer Risk:* An estimate of the increased level of cancer risk posed by exposure to a carcinogen at a site. Incremental Lifetime Cancer Risks can be estimated according to the following formula:

$$ILCR = Lifetime\ Daily\ Exposure\ (\mu g/kg/day) \times Potency\ Factor\ (\mu g/kg/day)^{-1}$$

In many parts of Canada, an Incremental Lifetime Cancer Risk estimate that is less than or equal to one in one hundred thousand ($1 \times 10^{-5}$) is normally considered to be acceptable while an Incremental Lifetime Cancer Risk greater than this value generally indicates that clean-up or some other form of risk reduction/management is required. In all cases, however, interpretation of Incremental Lifetime Cancer Risk estimates requires consideration of the overall risk assessment process and assumptions to ensure conclusions on risks are not misrepresented.

It is noted that neither Health Canada nor the World Health Organization considers mercury to be a carcinogenic substance. Consequently, it was not necessary to estimate Incremental Lifetime Cancer Risks due to mercury exposures.

*Some Limitations to Human Health Risk Assessment*

With the above principles in mind, there are some important limitations to the HHRA process that need to be considered. Firstly, an HHRA is completed as a science-based toxicological evaluation of the possibility for risks posed by chemicals. As a result, this toxicological evaluation does not cover all elements of health that local First Nations may be concerned about. To evaluate non-toxicological indicators of health, a different approach would be required that may involve other expertise (*e.g.*, sociologists, social scientists, spiritual leaders, etc.). Although the proposed Keeyask Project may affect health indicators not related to toxicological outcomes, only the toxicological evaluation of the potential for physical disease was the focus of the HHRA. No conclusions have been made about mental, emotional or spiritual health in this document.

Finally, risk assessment carries with it uncertainties and it is never possible to ensure absolute safety. Daily events may present exposures to chemicals and physical agents including: eating burned food (exposure to polycyclic aromatic hydrocarbons), consuming chlorinated drinking water (exposure to chlorinated organic chemicals), using environmentally friendly compact fluorescent lights (exposure to mercury), breathing indoor air of homes with carpeting (exposure to volatile organic compounds) and using electrical appliances that release electromagnetic fields. These exposures are associated with similar uncertainties. Although it is possible to estimate risks that may be associated with each of these individual activities, there is a level of uncertainty that exists despite our best efforts.

Overall, risk assessment is recognized as a scientifically-defensible tool that provides a methodology for evaluating potential risks from chemicals and physical agents; however, uncertainty is an element of risk assessment that cannot be avoided. Due to the existence of these uncertainties, a conservative approach is typically applied in risk assessment and this approach tends to overestimate risks and, thus, minimize the potential for adverse health effects.

# 3.0 SUMMARY OF ENVIRONMENTAL CONCENTRATIONS USED IN THE HHRA

The focus of the HHRA was on the Keeyask Cree Nations (KCNs) communities since these people would have the greatest amount of exposure from country foods under both present and post-impoundment conditions. Nevertheless, similar methods and results would be expected for members of the general public who fish and hunt at similar rates as the KCNs within the Project area. The KCNs were assumed to be exposed to mercury from consumption of various local foods including fish, wild game, waterfowl and wild plants. Two scenarios were considered:

- Present conditions (*i.e.,* based on fish mercury data collected from 2001-2009).
- Post-impoundment conditions point in time when mercury concentration is predicted to reach peak concentrations in fish (it has been estimated in Keeyask Hydropower Limited Partnership [2011a,b] that this could occur approximately 3-7 years after impoundment).

The water bodies of primary interest were Gull and Stephens lakes. The HHRA did not measure mercury concentrations in food or people but relied on measured present and estimated post-impoundment concentrations in water and foods provided by other experts (*i.e.,* fish and surface water mercury concentrations by North/South Consultants Inc.; wild game mercury concentrations by Wildlife Resource Consulting Services MB Inc.; and waterfowl concentrations of mercury estimated by TetrES Consultants Inc. (now known as Stantec). Results of the various studies on mercury concentrations in fish, wild game, plants and water are critical input parameters used to assess human health risks. The reader is referred to Keeyask Hydropower Limited Partnership (2011a,b) for specific discussion on these concentrations and potential variability with time.

### 3.1 CONCENTRATION OF MERCURY IN FISH

The Aquatic Environment Supporting Volume (AE SV), Section 7.2) provides the present (up to year 2006) and predicted future concentrations of mercury in fish muscle and the reader is referred to that section for full details of historic, current, and potential future fish mercury concentrations in the Keeyask study area. To increase the sample size of fish mercury concentrations for the HHRA, particularly to strengthen the power of analysis for fish length-class specific exposure levels, available data from Stephens Lake for 2007 and 2009 were included.

For consideration in the HHRA, members of the Mercury and Human Health Technical Working Group arranged for a workshop in October 2009 with Members of local First Nations (known as the Keeyask Cree Nations). In this workshop, persons in the communities discussed how often and how much of each food type was consumed. The detailed results of this workshop are provided in the October 2009 memo provided by InterGroup Consultants. Although numerous fish species are available for consumption in the Keeyask area, the key fish species that are most frequently consumed by resource users and that will mainly contribute to human mercury exposure are:

- Lake whitefish;
- Northern pike (also known as jackfish);
- Walleye (also known as pickerel); and
- Lake sturgeon.

Table 3-1 provides a summary of the total mercury concentrations in fish muscle tissue that were used in the HHRA and referred to as present concentrations (AE SV Section 7.2). It is noted that NSC has indicated that present mercury concentrations in lake sturgeon are based on only 13 fish from one location (Gull Lake).

Total mercury in fish was assumed to exist as methylmercury as recommended by Health Canada (2007). It is noted that there is considerable variability in the portion of total mercury that will exist as methylmercury (Health Canada [2007] cites a range of 30 to 95% as methylmercury). Nevertheless, Health Canada (2007) recommends that HHRA consider the mercury in fish to be present only as methylmercury.

**Table 3-1: Total Mercury in the Muscle Tissue of Length-Standardized* Fish from Gull and Stephens Lakes: Present (2001-2006 for Gull Lake, 2001-2005 for Stephens Lake) Concentrations**

| Fish species | Mercury Concentration in Fish Muscle (for Standardized Size)* (µg/g; wet weight) | |
|---|---|---|
| | Gull Lake | Stephens Lake |
| Lake whitefish | 0.07 | 0.09 |
| Northern pike | 0.22 | 0.26 |
| Walleye | 0.23 | 0.29 |
| Lake sturgeon | 0.20 | No measurements currently available |

* Standard lengths: lake whitefish 350 mm; northern pike 550 mm; walleye 400 mm, lake sturgeon 1,300 mm. Individual mercury concentrations will be dependent upon the size of the fish with the smaller fish having generally lower concentrations than bigger fish.

To estimate maximum mercury concentrations in whitefish, pike, and walleye following impoundment, NSC have used various modeling approaches (AE SV, Section 7.2.2). Based on the modeling results and taking into account the strength and weaknesses of the different models used, NSC considered the best estimates of maximum post-impoundment concentrations would be equal to the values provided in Table 3-2. No model is available to predict maximum post-impoundment mercury concentrations in lake sturgeon, and the values included in Table 3-2 are “best guess” estimates by the author of the Fish Quality section of the Aquatics Environment SV (North South Consultants, *pers. comm*. 2010).

Based on this evaluation, it is evident that the mercury concentrations of certain fish may increase markedly following impoundment while other fish would be much less affected. Northern pike and walleye from Gull Lake would be the most affected fish species while the whitefish from Stephens Lake is predicted to have the lowest increase in mercury concentration following impoundment.

**Table 3-2: Total Mercury in the Muscle Tissue of Length-Standardized* Fish from Gull and Stephens Lakes: Predicted Maximum Post-Impoundment Concentrations**

| Fish Type | Average Estimated Mercury Concentration in Fish Muscle (for Standardized Size)* (µg/g; wet weight) | |
|---|---|---|
| | Gull Lake | Stephens Lake |
| Whitefish | 0.19 | 0.15 |
| Northern pike | 1.0 | 0.50 |
| Walleye | 1.0 | 0.50 |
| Sturgeon | 0.30 | 0.25 |

* Standard lengths: lake whitefish 350 mm; northern pike 550 mm; walleye 400 mm, lake sturgeon 1,300 mm. Individual mercury concentrations would be dependent upon the size of the fish with the smaller fish having generally lower concentrations than bigger fish.

### 3.2 CONCENTRATION OF MERCURY IN WILD GAME

The Terrestrial Environment Supporting Volume (TE SV) (Section 8) provides the present and future concentrations of mercury in wild game tissue compiled by Wildlife Resource Consulting Services MB Inc. (WRCS) and the reader is referred to that section for full details of the measured and predicted concentrations.

As discussed earlier, members of the Mercury and Human Health Technical Working Group arranged for a workshop in October 2009 with members of the KCNs communities. In this workshop, persons in the communities discussed how often and how much of each food type was consumed. Although numerous wild game species can be consumed, the key species of concern (based on frequency of consumption and likelihood to accumulate mercury) are as follows:

- Beaver;
- Muskrat;
- Moose; and
- Snowshoe hare.

Table 3-3 provides a summary of the mercury concentrations in muscle tissue of wild game that were used in the HHRA for present concentrations. Mercury in wild game was estimated as total mercury concentrations (*i.e.*, present in both inorganic and methylmercury forms).

**Table 3-3: Total Mercury in the Muscle Tissue of Wild Game Collected from the Project Area: Present Concentrations**

| **Species** | **Total Mercury as an Average Concentration in Muscle (µg/g; wet weight)** | **Range of Total Mercury Concentration in Muscle (µg/g; wet weight)** |
|---|---|---|
| Beaver | 0.01 | <0.01 – 0.05 |
| Muskrat | 0.02 | <0.01 – 0.06 |
| Moose | 0.07* | <0.01–0.17 |
| Snowshoe Hare | 0.05* | <0.01–0.12 |

* Mercury concentration in moose and snowshoe hare was only a literature estimate and may have greater uncertainty than other species for which measured values were obtained from the study area.

In the case of the mercury concentrations in wild game following impoundment, Wildlife Resource Consulting Services considered the best estimate of concentrations during the maximum year post-impoundment would be equal to the values provided in Table 3-4. Mercury in wild game was estimated as total mercury concentrations.

**Table 3-4: Total Mercury in the Muscle Tissue of Wild Game from the Project Area: Predicted Maximum Post-Impoundment Concentrations**

| **Species** | **Total Mercury Concentration in Muscle (µg/g; wet weight)** | **Most Likely Range in Total Mercury Concentration in Muscle (µg/g; wet weight)** |
|---|---|---|
| Beaver | 0.01 | <0.01 – 0.05 |
| Muskrat | 0.04 | <0.01 – 0.12 |
| Moose | 0.07* | <0.01–0.17 |
| Snowshoe Hare | 0.05* | <0.01–0.12 |

* Mercury concentration in moose and snowshoe hare was a literature based estimate and likely has greater uncertainty than other species for which measured concentrations were obtained from the study area

Based on this evaluation, it is evident that wild game would not be expected to be greatly impacted by the proposed impoundment. Beaver, moose and snowshoe hare would not be predicted to have any measurable change in mercury tissue concentrations while muskrat would be only expected have an increased concentration of 0.04 µg/g (although this is a doubling of concentrations, it is still an increase of only 0.02 µg/g).

### 3.3 CONCENTRATION OF MERCURY IN WATERFOWL

The TE SV (Section 8 and Appendix 8A) provide the present and future concentrations of mercury in waterfowl tissue compiled by Stantec and the reader is referred to that section for full details of the measured and predicted concentrations. Although various species of waterfowl can be consumed, the waterfowl assessed were (based on frequency of consumption and likelihood to accumulate mercury):

- Ducks (*e.g.*, mallard, ring-necked duck, teal, golden eye); and
- Gull eggs.

Table 3-5 provides a summary of the mercury concentrations in muscle tissue of ducks that were used in the HHRA of present concentrations. As described in TE SV (Section 8), Stantec has estimated that concentrations of mercury in ducks would be similar to or less than concentrations measured in local whitefish. Stantec has indicated that there is no information on mercury concentrations that may result in gull eggs and, as a result, could not provide an estimate of present concentrations for use in the HHRA. All mercury in ducks was assumed to exist as methylmercury (*i.e.*, mirrored lake whitefish concentrations).

**Table 3-5: Total Mercury in Waterfowl from the Project Area: Present Concentrations**

| Taxon | Mean Mercury Concentration (µg/g; wet weight) | |
|---|---|---|
| | Gull Lake | Stephens Lake |
| Duck | ≤0.07 | ≤0.09 |
| Gull eggs | No measurements currently available | No measurements currently available |

* Mercury concentration in ducks was an estimate where concentrations were assumed to be similar to or less than concentrations found in whitefish.

In the case of the mercury concentrations in waterfowl following impoundment, Stantec considered the best estimate of concentrations during the maximum year post-impoundment to equal the values provided in Table 3-6. Once again, Stantec has estimated that concentrations of mercury in ducks would be similar to or less than concentrations in whitefish and, consequently, the mercury levels provided in Table 3-6 for ducks are those previously provided for whitefish.

Based on this evaluation, it is evident that the increases in mercury concentrations in ducks are expected to be relatively modest following impoundment. No estimates are provided for gull eggs and, consequently, these would need to be directly measured in the field if further information is required.

**Table 3-6: Total Mercury in Waterfowl in the Project Area: Predicted Maximum Post-Impoundment Concentrations**

| Taxon | Mean Mercury Concentration (µg/g; wet weight) | |
|---|---|---|
| | Gull Lake | Stephens Lake |
| Duck | ≤0.19 | ≤0.15 |
| Gull eggs | No estimates available | No estimates available |

* Mercury concentration in ducks was an estimate where concentrations were assumed to be similar to or less than concentrations found in whitefish.

### 3.4 CONCENTRATION OF MERCURY IN WILD PLANTS

Although many types of wild plants can be consumed from the Project area, the key plants that were identified from discussions with the KCNs community Members are:

- Northern tea (also known as Labrador tea);
- Blueberries; and
- Seneca root.

There was no information available on present mercury concentrations in these plants. Nor were future concentration estimates provided for post-impoundment conditions. Consequently, these would need to be directly measured in the field if further information was required.

### 3.5 CONCENTRATION OF MERCURY IN SURFACE WATER

The AE SV (Section 2) provides a description of the present concentrations of mercury in surface water as well as an assessment of effects of the Project on concentrations in surface water in the study area and the reader is referred to that section for additional detail. The following provides a summary of this information presented in the AE SV.

Mean total mercury concentrations measured in Gull and Stephens lakes were less than the current analytical method detection limit of 0.05 µg/L. The maximum measured total mercury concentration for the entire study area (Split Lake to the Nelson River estuary) was 0.32 µg/L (site NR-5 August 2003). Mercury has been detected across the study area and at three sites (GT1, NR5, and NR6) concentrations have occasionally exceeded the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOG) for freshwater aquatic life of 0.1 µg/L; however, all samples were within the Manitoba drinking water guideline of 1 µg/L.

Table 3-7 provides a summary of the measured total mercury concentrations in surface water that were used in the HHRA of present concentrations.

**Table 3-7: Total Mercury Measured in the Surface Water from the Project Area: Present Concentrations**

| Mean Total Mercury Concentration in Surface Water (µg/L) | |
|---|---|
| **Gull Lake** | **Stephens Lake** |
| Less than 0.05 | Less than 0.05 |

Project-related increases in mercury in surface water are not expected to exceed 0.05 µg/L or to cause or contribute to exceedences of the drinking water quality guideline in, or downstream of, the Keeyask reservoir (see Table 3-8). Based on modeling results and literature regarding measured concentrations of mercury in Manitoba and Ontario reservoirs, it is expected that total mercury concentrations would not exceed 0.05 µg/L; this value was therefore used as a conservative value in the HHRA. Concentrations of mercury are expected to remain below the Manitoba PAL water quality guideline and below the analytical detection limits employed in this study from the combined effects of peatland disintegration and flooding. Mercury was not detected in the Nelson River between Clark and Stephens lakes and the predicted average increases due to peatland disintegration and flooding are expected to be too small to exceed the analytical detection limit. However, during periods where organic particulate materials are notably elevated as a result of resuspension or peatland disintegration (*i.e.*, stochastic events), total mercury concentrations may be higher than existing conditions. Effects on Stephens Lake are also not expected to exceed total mercury concentrations of 0.05 µg/L.

**Table 3-8: Total Mercury in Surface Water from the Project Area: Predicted Mean Post-Impoundment Concentrations**

| Mean Total Mercury Concentration in Surface Water (µg/L) | |
|---|---|
| **Gull Lake** | **Stephens Lake** |
| Less than 0.05 | Less than 0.05 |

# 4.0 HHRA METHODOLOGY

## 4.1 INTRODUCTION

As mentioned earlier, the focus of the HHRA was on the KCNs communities but similar findings would be expected for members of the general public who frequently fish and hunt. These First Nations were assumed to be exposed to mercury from consumption of various local foods including fish, wild game, waterfowl and wild plants. Two scenarios were considered:

- Present conditions; and
- Post-impoundment conditions at the point in time when mercury concentration is predicted to reach peak concentrations in fish.

The methods used to estimate human health risks were primarily based on risk assessment provided by Health Canada, the World Health Organization (WHO) and the United States Environmental Protection Agency (US EPA). Important documents that have been used to estimate risks include the following:

- Health Canada. 2010a. (draft) Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment of Chemicals ($DQRA_{CHEM}$). Contaminated Sites Division, Safe Environments Programme, Health Canada, Ottawa, ON.
- Health Canada. 2010b. Toxicological Reference Values, Estimated Daily Intakes, or Dietary Reference Values for Trace Elements.
- Health Canada. 2009a. (draft) Federal Contaminated Site Risk Assessment in Canada – Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA).
- Health Canada. 2009b. Federal Contaminated Site Risk Assessment in Canada – Part IV: Spreadsheet Tool for Human Health Preliminary Quantitative Risk Assessment (PQRA).

- Health Canada. 2007. Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption.
- Health Canada. 2004. Canadian Handbook on Health Impact Assessment.

Briefly, exposures to mercury were estimated based on a variety of assumptions relating to the use of areas and the possible dietary habits (*i.e.,* consumption of animals and plants) of people in the vicinity of the site. The toxicological literature was then reviewed to identify exposure rates for mercury that have been determined by international health agencies to be acceptable or "safe" (or more specifically, exposure rates without appreciable risks of adverse effects). The next step in the risk assessment was a comparison of the estimated exposure rates to the dose rates considered acceptable or "safe" for humans for the various consumption scenarios considered in the assessment.

Risks from historic exposures that may have occurred in previous decades were not evaluated in the assessment of off-site receptors. Instead, the focus of the exposure assessment was on exposures that may possibly occur under present and post-impoundment use.

In addition, it should be noted that health agencies have undertaken blood and hair analysis for mercury in the KCNs communities in the Keeyask study area in the 1990s. These data are confidential and were not available to Wilson Scientific for inclusion in this HHRA. As discussed by the Mercury and Human Health Technical Working Group, community specific data were available, in summary form at the community level (*i.e.,* no individual results), to each community by request directly to Health Canada.

The methods used to complete the risk assessment are described in detail in the following sections.

## 4.2 PROBLEM FORMULATION

### *4.2.1 Chemicals of Potential Concern*

The HHRA focused on mercury as the main chemical of potential concern. Mercury was evaluated since it has appreciable potential to accumulate in the environment at concentrations that could affect food and other sources. Mercury can enter the aquatic food chain and prompt fish consumption advisories following reservoir creation. It should be emphasized that mercury occurs naturally in many foods, particularly predatory fish at the top of the food chain. Nevertheless, it is clear that some fish concentrations of mercury are expected to increase appreciably following impoundment.

### *4.2.2 Receptors of Concern*

The Keeyask study area is used for a variety of purposes including the traditional collection of foods by the KCNs community Members. Persons participating in such activities could be of any age. Consistent with Health Canada (2009a; 2010a) guidance, the most sensitive toddler (ages 0.5 to four years) was the key receptor used to evaluate risks to mercury in the Keeyask area. Other receptors included women of childbearing age and adult males.

### *4.2.3 Assumed Receptor Characteristics*

To the extent possible, receptor characteristics were based on data specific to the Canadian population. Values used in the risk assessment were based primarily on recommendations provided by Health Canada (2009a; 2010a). Other sources such as CCME (2006), Richardson (1997) and other published scientific literature were also considered.

*Body Weight*

For body weight, the values recommended in Health Canada (2009a; 2010a) were considered for the assessment of child and adult receptors.

Accordingly, the following values were selected as receptor characteristics in the assessment:

| | |
|---|---|
| Younger Child (ages 0.5-4 yrs): | 16.5 kg (Health Canada 2009a; 2010a); |
| Women of Child-bearing Age: | 60 kg (Health Canada 2009a; 2010a); |
| Adults: | 70.7 kg (Health Canada 2009a; 2010a). |

It is noted that Health Canada (2009a; 2010a) has different age groups for consideration than provided in Manitoba Water Stewardship (2007) (*i.e.*, the latter focuses upon children under 12 years of age). Nevertheless, the consumption information provided by the KCNs representatives was for toddlers and, consequently, the Health Canada (2009a; 2010a) information was used.

*Water Consumption Rate*

Water consumption rates for the various human receptor types recommended by Health Canada (2009a; 2010a) were used in the exposure assessment.

Accordingly, the following values were selected as receptor characteristics in this assessment as the drinking water consumption estimates:

| | |
|---|---|
| Younger Child (ages 0.5-4 yrs): | 0.6 L/day (Health Canada 2009a; 2010a); |
| Adults: | 1.5 L/day (Health Canada 2009a; 2010a). |

*Skin Surface Area*

In the case of skin surface area available for contact with surface water, Health Canada (2009a; 2010a) has adopted values recommended by Richardson (1997) for the whole body surface area.

The following values were selected as receptor characteristics in the assessment:

| | |
|---|---|
| Younger Child (ages 0.5-4 yrs): | 0.60 $m^2$ (whole body) (Health Canada 2009a; 2010a) |
| Adults: | 1.8 $m^2$ (whole body) (Health Canada 2009a; 2010a). |

*Time Spent at the Site*

For traditional land use, it was assumed that these persons would spend seven days per week, 52 weeks per year for their entire life at the site. These estimates are not from literature sources but instead are based on input from the KCNs, professional judgment and acceptable practice in HHRA (*i.e.*, use of conservative estimates).

The following values were selected as receptor characteristics in the assessment:

| | |
|---|---|
| Traditional Land Use: | 7 days per week, 52 weeks per year for 80 years (professional judgment) |
| Country Foods Consumer: | Various rates of consumption for an entire lifetime (see below). |

*Country Foods Consumption*

The term "country foods" refers to foods that are not bought in stores or grown in home gardens or farms but instead are collected from the environment. Country foods (or wild foods) include fish, wild game, waterfowl and wild plants.

The scientific literature contains an appreciable amount of information on the rate of country (wild) food consumption by First Nation communities in Canada. Although this information provides excellent sources for consideration, use of such data has limitations since rates of country (wild) food consumption vary from locale to locale. As a result, it is preferable to have site-specific information on the rates of consumption when such estimates are available.

For consideration in the HHRA, members of the Mercury and Human Health Technical Working Group arranged for a workshop in October 2009 with members of the KCNs. In this workshop, persons in the communities discussed how often and how much of each food type was consumed. The detailed results of this workshop are provided in the October 2009 memo provided from InterGroup Consultants. According to this memorandum, the most common food types and rate of consumption are provided below.

It is recognized that the fish serving sizes provided in Table 4-1 represent quite large serving sizes compared to those typical, as identified by Health Canada. These serving sizes were determined through consultations with KCNs representatives at the October 2009 workshop. It is possible that many persons would consume smaller portion sizes or may eat foods at a lower frequency. It is noted that in the case of fish consumption, different consumption rates are used by Manitoba Water Stewardship (2007) for recreationally angled fish (i.e., 114 g per serving for 30 kg children and 227 g per serving for 60 kg women of child-bearing age); however, the KCNs provided assurance that the increased serving size for fish was applicable to their habits.  Consequently, the information provided by the KCNs was used to estimate risks.

**Table 4-1: Assumed Consumption Rates of Various Country (Wild) Foods Consumed by the Keeyask Cree Nations Communities**

| Food Type | Serving Size for Young Child | Serving Size for Adult | Frequency of Consumption |
|---|---|---|---|
| Fish | | | |
| Whitefish | 100 g (or 3.5 ounces)* | 400 g (or 14 ounces) | Three times per week |
| Northern pike | 100 g (or 3.5 ounces) | 400 g (or 14 ounces) | Three times per week |
| Walleye | 100 g (or 3.5 ounces) | 400 g (or 14 ounces) | Three times per week |
| Sturgeon | 100 g (or 3.5 ounces) | 400 g (or 14 ounces) | Three times per week |
| Wild Game | | | |
| Beaver | 57 g (or 2 ounces) | 200 g (or 7 ounces) | Three times per week |
| Muskrat | 57 g (or 2 ounces) | 200 g (or 7 ounces) | One time per week |
| Moose | 100 g (or 3.5 ounces) | 400 g (or 14 ounces) | Five times per week |
| Snowshoe hare | 57 g (or 2 ounces) | 200 g (or 7 ounces) | One time per week |
| Waterfowl | | | |
| Duck | 57 g (or 2 ounces) | 200 g (or 7 ounces) | One time per week |

* One ounce = 28.4 grams

The above information was used to estimate exposures to mercury that persons may receive from the consumption of various country (wild) foods. Using the period of exposure that may result in the greatest daily exposure over a period of one week, the daily intake rate was estimated for each of the food groups. For example, in the case of sturgeon which is consumed only in spring and fall, risk estimates are based on the period that it is consumed three times per week. This is considered to be a conservative assumption because it does not distinguish risks from foods consumed on a seasonal basis versus those consumed all year round. Nevertheless, no health agencies were identified that provide recommendations for addressing short-term exposures to methylmercury and, thus, this approach was conservatively adopted.

It is noted that the KCNs communities also identified the following country foods as a concern:

- Gull eggs;
- Wild plants:
  - Northern tea;
  - Blueberries; and
  - Seneca roots

However, as noted in Section 3, there are no estimates of mercury concentrations in these animals or plants either presently or that would occur following impoundment. Consequently, these foods were not further evaluated in the quantitative HHRA. It is recommended that these foods be part of future monitoring if information on risks from consumption is desired.

### *4.2.4 Exposure Pathways of Concern*

The exposure pathways for the off-site receptors are receptor-dependent. In the case of traditional land use, the exposure pathways evaluated included:

- Ingestion of surface water from Gull Lake or Stephens Lake; and
- Dermal contact with surface water from Gull Lake or Stephens Lake.

In the case of the country (wild) foods consumers, risks from consumption of the following food groups were estimated:

- Fish:
    - Whitefish;
    - Northern pike;
    - Walleye; and
    - Sturgeon.
- Wild Game:
    - Beaver;
    - Muskrat;
    - Moose; and
    - Snowshoe hare;
- Waterfowl:
    - Ducks.

#### *4.2.5 Conceptual Model*

Based on the information provided in the previous section and following the guidance from Health Canada and various other international health agencies, conceptual models were developed to illustrate the receptors and exposure pathways identified for evaluation of risks to off-site receptors.

As discussed earlier, it is usually not possible to evaluate every individual and/or exposure pathway present; however, if the most sensitive receptors and most important pathways are evaluated, it can safely be concluded that other receptors and exposure pathways not considered would be adequately addressed by the result and conclusions of the HHRA. Consequently, the conceptual models summarized here have been developed with this objective in mind.

For the persons using the area for traditional land uses, the receptors and exposure pathways are provided in Table 4-2. Once again, the consumption of country (wild) foods was addressed as a separate pathway (see below).

**Table 4-2: Conceptual Model for Traditional Land Use**

| Critical receptor | | Exposure pathways | |
|---|---|---|---|
| | Infant | | Soil Ingestion |
| X | Toddler | | Soil dermal absorption |
| | Child | | Particulate inhalation |
| | Teen | | Vapour inhalation |
| X | Adult | X | Water dermal exposure |
| | | X | Water ingestion |
| | | X | Wild plant ingestion |
| | | X | Fish ingestion |
| | | X | Wild game ingestion |

X – Requires evaluation in the human health risk assessment

## 4.3 EXPOSURE ASSESSMENT

### *4.3.1 Environmental Concentrations*

As discussed earlier, receptors were assumed to consume country (wild) foods that include wild game, fish and plants. In addition, receptors were assumed to be exposed to surface water. The assumed concentrations of mercury in the various country (wild) foods and surface water are discussed in sections below.

**Assumed Concentrations of Mercury in Fish**

As identified by the Mercury and Human Health Technical Working Group, consumption of the following fish species was the primary concern to human health:

- Lake whitefish;
- Northern pike;
- Walleye; and
- Lake sturgeon.

Section 3.1 provides the measured and predicted concentrations of mercury in fish tissue that were used in the HHRA. The HHRA was based on the mean concentrations of mercury in fish tissue (current concentrations were measured while future concentrations were predicted).

The mercury concentrations reported in section 3.1 are specific to a standardized length of the various fish species. Because mercury concentrations are generally positively related to fish length, fish that are larger than the specified standard length usually have greater concentrations while smaller fish have lower concentrations. The standard lengths used here are based on the approximate size of fish that would typically be caught and eaten. Therefore, using mercury concentrations from fish of this size provides the best average estimate of mercury exposure to people over the long-term.

**Assumed Concentrations of Mercury in Wild Game**

As identified by the Mercury and Human Health Technical Working Group, consumption of the following wild game species were the primary concern to human health:

- Beaver;
- Muskrat;
- Moose; and
- Snowshoe hare.

Section 3.2 provides the measured and estimated concentrations of mercury in wild game tissue that were used in the HHRA. Similar to that discussed for fish, the HHRA of wild game consumption was based on the mean concentrations of mercury.

It is noted that other wild game species may be consumed by First Nations that were not directly evaluated in the HHRA. In most cases, these species would likely have similar or lower concentrations of mercury than those assumed in the HHRA. For example, caribou are consumed from the area but caribou would be expected to have lower concentrations of mercury than moose because they spend less time in the area (*i.e.*, larger home range) and less time in contact with aquatic habitat. Consequently, it is likely that risks from such foods would be even lower than from the wild game evaluated in the HHRA. Nevertheless, it will be recommended that a program is established whereby hunters may submit tissue samples of any species of wild game that they have hunted in the area for mercury analysis. In this manner, the mercury content of other country (wild) foods can be monitored.

**Assumed Concentrations of Mercury in Waterfowl**

As identified by the Mercury and Human Health Technical Working Group, consumption of the following waterfowl species was the primary concern to human health:

- Ducks; and
- Gull eggs.

Section 3.3 provides the assumed concentrations of mercury in ducks. As discussed earlier, no estimate of mercury concentrations in gull eggs was possible for either present or future scenarios. Consequently, gull eggs would need to be monitored if risk estimates from this food group are required.

It is noted that other waterfowl may be consumed by the KCNs that were not directly evaluated in the HHRA (*e.g.*, geese). In the case of geese, they would likely have similar or lower concentrations of mercury than those assumed in the HHRA (due to their mainly plant-based diet, geese have a lower ability to accumulate mercury than ducks). Consequently, it is likely that risks from geese would be lower than from the ducks evaluated in the HHRA. Nevertheless, it will be recommended that a program is established whereby hunters may submit tissue samples of any species of waterfowl that they have hunted in the area for mercury analysis. In this manner, the mercury content of other country (wild) foods can be monitored.

### Assumed Concentrations of Mercury in Wild Plants

As identified by the Mercury and Human Health Technical Working Group, consumption of the following wild plant species was the primary concern to human health:

- Northern tea;
- Blueberries; and
- Seneca root.

As discussed earlier, no estimates of mercury concentrations in wild plants were available for either present or post-impoundment scenarios. Consequently, wild plants would need to be monitored if risk estimates from this food group is required and it will be recommended that a program be established whereby food gatherers may submit tissue samples of species of edible plants that have been gathered for mercury analysis. In this manner, the mercury content of wild plants can be monitored.

### Assumed Concentrations of Mercury in Surface Water

The approach for estimating potential human exposure to off-site receptors was based on measured water concentrations at the current time and estimated water concentrations that would occur at the maximum time following impoundment. As discussed previously in Section 3.5, the surface water concentrations were largely compiled from data presented in the AE SV, Section 2.5.2. Briefly, North/South Consultants have indicated that both present and post-impoundment concentrations of mercury in surface water would be expected to be less than the method detection limit of 0.05 µg/L. For the purposes of the HHRA, it was assumed that mercury would be found in surface water at a concentration equal to the method detection limit of 0.05 µg/L.

### *4.3.2 Mathematical Equations Used to Estimated Exposures*

As discussed earlier, the exposures that off-site receptors may receive were estimated for the following pathways:

- Ingestion of surface water;
- Dermal contact with surface water (bathing or swimming); and
- Consumption of country foods (wild game, fish and plants).

The mathematical equations used to estimate exposures from these pathways are discussed in Appendix 5C-1. Some of the other important concepts applied in the exposure assessment approach are discussed below.

#### 4.3.2.1 Exposure Amortization

As noted earlier, the number of weeks assumed for the exposure duration of concern was important to the outcome of the risk assessment. Essentially, it is important that the exposure data match as closely as possible the toxicological data (*i.e.*, toxicity reference values [TRVs]) in terms of exposure duration.

For assessment of risks from mercury, no lifetime exposure amortization was completed for less than lifetime exposures. Although it was previously stated that persons spend 80 years of their lifetime at the site, this timeframe does not play a role in estimation of risks to the non-carcinogens. According to Health Canada guidance, any exposure that lasts more than three months is considered to be chronic in duration and lifetime exposure amortization is typically appropriate for exposures that last longer than this duration. With the above in mind, it was considered appropriate and consistent with Health Canada guidance to amortize exposures that occur two times per week over the entire week. Although it is likely that receptors will have lower exposures in the winter than in the summer (due to snow cover and potentially reduced use of off-site areas in some cases), the HHRA did not consider this in the quantitative evaluation.

As a result, the HHRA has been completed for exposures that occur during the season where the exposure took place (*i.e.*, exposures that occur over a one or two month period were not spread out over the entire year).

#### 4.3.2.2 Bioavailability Assessment

As shown in the Appendix 5C-1 calculations, bioavailability was used to estimate the fraction of exposure that may actually enter a person's body. Bioavailability is an important factor that allows for the comparison of exposures via multiple routes. For example, bioavailability allows the risk assessment to compare health risks from dermal exposures to TRVs established for oral exposure routes. For the purposes of the HHRA, the bioavailability of mercury in food was assumed to be 100%. For dermal absorption from surface water, mercury was assumed to have a permeability constant of $1 \times 10^{-5}$ m/hr as recommended by Health Canada (2009b).

### 4.4 TOXICITY ASSESSMENT

Toxicological data were available from regulatory agencies such as Health Canada, US EPA and the World Health Organization. In the case of mercury, the following TRVs were used:

- Tolerable Daily Intake (TDI) for methyl mercury = 0.2 µg/kg bw/day (for children, women of child bearing age) and 0.47 µg/kg bw/day (for other members of the general population) (Health Canada, 2010b).
- TDI for total mercury = 0.57 µg/kg bw/day for all persons (based on WHO [2010] provisional tolerable weekly intake of 4 µg/kg/week).

For mercury in fish and waterfowl, all mercury was assumed to be present as methylmercury since most experts would agree that the vast majority of mercury would be present in this form. For mercury in wild game and wild plants, mercury was assumed to be present as total mercury since information is not readily available on the mercury form in muscle tissue and, thus, was compared to the WHO/Health Canada total mercury toxicity reference value. Appendix 5C-1 provides additional details regarding these TRVs.

### 4.5 RISK CHARACTERIZATION

Risks were estimated as Hazard Quotient values according to the following formula:

$$\textit{Hazard Quotient} = \frac{\textit{Estimated Exposure } (\mu g/kg \textit{ body weight/day})}{\textit{Tolerable Daily Intake } (\mu g/kg \textit{ body weight/day})}$$

With respect to Health Canada guidance for foods, a Hazard Quotient value of 1 is typically considered to be the maximum acceptable exposure that will not be associated with unacceptable risks (Health Canada 2004). Although a Hazard Quotient value of 0.2 is considered to be acceptable for contaminated soils (when environmental concentrations represented by the arithmetic means are considered) (Health Canada 2009a, 2010a), this value is not typically used for evaluation of foods. Indeed, there are numerous precedents where Health Canada has considered Hazard Quotient values of 1 to be acceptable (especially when food sources are considered). Consequently, a Hazard Quotient value of 1 was used as the acceptable risk for mercury.

Since mercury is not evaluated as a carcinogen by most health agencies (*e.g.*, Health Canada, World Health Organization and US Environmental Protection Agency), it was not necessary to estimate cancer risks.

# 5.0 RESULTS

The results of the risk assessment for receptors exposed to mercury are provided in the sections below. Worked examples of the risk calculations are provided in Appendix 5C-1.

## 5.1 RISKS FROM CONSUMPTION OF FISH

Risks from consumption of fish were estimated for the present conditions and for the possible post-impoundment scenario. Based on information provided by the KCNs communities, all fish were assumed to be consumed at a frequency of three meals per week with a serving size of 100 g (3.5 ounces) per meal for toddlers and 400 g (14 ounces) per meal for adults. These rates of consumption were used at the request of the KCNs and are considered to represent upper bound exposures (especially in regard to serving size). Nevertheless, the HHRA considered these values in order to ensure a conservative assessment and address all concerns of the KCNs communities.

It is recognized that certain fish are only consumed at certain times of the year (*e.g.*, sturgeon are only consumed in the spring and the fall). Nevertheless, this less than continuous exposure is not quantitatively considered in the HHRA because the key concern regarding methylmercury is developmental toxicity. Developmental toxicants sometimes only require a couple of weeks of exposure to illicit adverse effects and the fact that a pregnant woman only consumed a certain country (wild) food for a few weeks during pregnancy would not necessarily be a mitigating factor that would diminish the potential developmental toxicity.

Although Hazard Quotient values greater than 1 are predicted from certain fish and consumption frequencies, it is stressed that this does not automatically mean that the consumption of these types of fish need to be restricted altogether. There are numerous fish in Gull and Stephen Lakes that have mercury concentrations that are considered to be low (less than 0.2 ppm) and very low (less than 0.1 ppm).

Even though Hazard Quotient values greater than 1 can theoretically be predicted from consumption of large amounts of these fish, many scientists would consider that there is no reason to advise the First Nations that the consumption of the low and very low mercury concentration fish needs to be unduly restricted. There are numerous health advantages to a fish-based diet, particularly for northern Aboriginal communities where healthy and affordable alternatives are often lacking; consequently it is anticipated that the benefits of eating fish will also be considered in preparing consumption recommendations. As requested by Health Canada and Manitoba Health, this HHRA does not provide consumption advice. Manitoba Health and Health Canada have committed to providing their opinion on this issue to the KCNs and Manitoba Hydro as a separate undertaking.

### *5.1.1 Present Conditions*

Table 5-1 provides the risk estimates for consumption of fish under present conditions. Using the methods discussed previously, the key results of the risk analysis of present conditions include the following:

- In evaluation of the results of the HHRA, it is important to consider that relatively high rates of fish consumption were assumed.
- Toddlers and women of childbearing age had risks that were two to three times higher than adult males and Elders consuming the same fish species. This is mainly because the TDI for methylmercury is approximately 2.5 times lower for toddlers/women of child bearing age than for adults.
- The greatest risks were estimated from consumption of northern pike and walleye due to their higher tissue mercury concentrations relative to other fish species. These two predatory fish species have mean mercury concentrations that are greater than 0.2 µg/g but less than 0.5 µg/g and various health agencies have recommended that young children and women of childbearing age may want to restrict consumption of fish to a meal or so per week when mercury concentrations are in this range.

- Risks from consumption of lake whitefish were the lowest due to their low mercury concentrations; however, consumption of three large meals per week could still result in Hazard Quotient values that exceed the acceptable value.
- In the case of lake sturgeon in Gull Lake, these fish presently contain arithmetic mean mercury concentrations equal to 0.2 µg/g (the relationship between mercury concentration and fish length was not significant and standardized means should not be used; see AE SV (Appendix 7A). Consumption of three large meals per week could result in Hazard Quotient values that exceed the acceptable value.

Based on the results, frequent consumption of large meals of certain types of fish may exceed the acceptable Hazard Quotient. It should be noted that the adult Hazard Quotient values would have been lower in Table 5-1 if a more common serving size of 150 grams per meal was used (*i.e.*, 150 grams is the serving size commonly assumed by Health Canada). Indeed, the Hazard Quotient values for adults (both women of childbearing age and adult males and all Elders) would have been about 2.5 times lower than provided in Table 5-1; however, for toddlers, Health Canada policy uses a serving size of 106 g/meal and a body weight of 14 kilograms such that Hazard Quotient values would have been about 20% higher than provided in Table 5-1. Nevertheless, the information on serving sizes obtained directly from the communities is considered to supersede the Health Canada recommendations.

Notwithstanding the above, it is anticipated that the benefits of eating fish will be considered along with the Hazard Quotient values in determining fish consumption recommendations. As requested by Health Canada and Manitoba Health, this HHRA does not provide consumption advice and instead these agencies will provide this advice as a separate undertaking.

**Table 5-1: Risk Estimates from Consumption of Fish: Present Conditions**

| Fish Species | Standardized Concentration* (µg/g, wet weight) | Hazard Quotient from Consumption of Three Large Meals per Week (Acceptable Value = 1)*** | | |
|---|---|---|---|---|
| | | Toddlers | Women of Childbearing Age | Adult Males and All Seniors |
| Gull Lake | | | | |
| Lake Whitefish | 0.07 | 0.9 | 1.0 | 0.4 |
| Northern Pike | 0.22 | 2.8 | 3.1 | 1.1 |
| Walleye | 0.23 | 3.0 | 3.3 | 1.2 |
| Lake Sturgeon** | 0.20 | 2.6 | 2.8 | 1.0 |
| Stephens Lake | | | | |
| Lake Whitefish | 0.09 | 1.3 | 1.4 | 0.5 |
| Northern Pike | 0.26 | 3.5 | 3.8 | 1.4 |
| Walleye | 0.29 | 4.2 | 4.7 | 1.7 |
| Lake Sturgeon | No measurements currently available | No estimates currently available | No estimates currently available | No estimates currently available |

* Standard lengths: lake whitefish 350 mm; northern pike 550 mm; walleye 400 mm,
Individual mercury concentrations would be dependent upon the size of the fish with the smaller fish having generally lower concentrations than bigger fish.
** Arithmetic mean concentration.
*** Based on information provided by local First Nation communities, all fish were assumed to be consumed at a frequency of three meals per week with a serving size of 100 g for toddlers and 400 g for adults.

Table 5-2 provides the risk estimates from consumption of various sizes and species of fish in terms of Hazard Quotient values of three large meals/week under present conditions. The table illustrates the influence of the size of fish by species that result in Hazard Quotient values either less than or greater than 1. For example, lake whitefish from Gull Lake consumed by women of child-bearing age can range from a Hazard Quotient value of 0.6 for the smallest category fish (< 300 mm) to 2.1 for the largest category fish (> 450 mm).

**Table 5-2: Risk Estimates from Consumption of Fish for Various Fish Size Classes: Present Conditions**

| Species | Fish Size Class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lake Whitefish | | | Northern Pike | | | Walleye | | |
| | <300 mm | 300-450 mm | >450 mm | <400 mm | 400-800 mm | >800 mm | <400 mm | 400-550 mm | >550 mm |
| **Gull Lake** | | | | | | | | | |
| Mean concentration of mercury in tissue (µg/g; wet weight) | 0.042 | 0.071 | 0.149 | 0.129 | 0.270 | 0.789 | 0.117 | 0.394 | 0.688 |
| Hazard Quotient from Three Large Meals per Week for Toddlers | 0.5 | 0.9 | 1.9 | 1.7 | 3.5 | 10.1 | 1.5 | 5.1 | 8.9 |
| Hazard Quotient from Three Large Meals per Week for Women of Child Bearing Age | 0.6 | 1.0 | 2.1 | 1.8 | 3.8 | 11.2 | 1.7 | 5.6 | 9.7 |
| Hazard Quotient from Three Large Meals per Week for Adult Males/ All Seniors | 0.2 | 0.4 | 0.8 | 0.7 | 1.4 | 4.0 | 0.6 | 2.0 | 3.5 |
| **Stephens Lake** | | | | | | | | | |
| Mean concentration of mercury in tissue (µg/g; wet weight) | 0.070 | 0.094 | 0.154 | 0.096 | 0.318 | 1.07 | 0.183 | 0.422 | 0.716 |
| Hazard Quotient from Three Large Meals per Week for Toddlers | 0.9 | 1.2 | 2.0 | 1.2 | 4.1 | 13.8 | 2.4 | 5.4 | 9.2 |
| Hazard Quotient from Three Large Meals per Week for Women of Child Bearing Age | 1.0 | 1.3 | 2.2 | 1.4 | 4.5 | 15.1 | 2.6 | 6.0 | 10.1 |
| Hazard Quotient from Three Large Meals per Week for Adult Males/ All Seniors | 0.4 | 0.5 | 0.8 | 0.5 | 1.6 | 5.4 | 0.9 | 2.1 | 3.6 |

### *5.1.2 Post-Impoundment Conditions*

Table 5-3 provides the risk estimates for consumption of fish that would occur under post-impoundment conditions. These risk estimates are based on the peak concentrations that would occur following impoundment and assuming consumption of fish of standard size (*i.e.*, lake whitefish = 350 mm; northern pike = 550 mm; walleye = 400 mm; and, lake sturgeon = 1,300 mm). Key results of the risk analysis include the following:

- The greatest risks were estimated from consumption of northern pike and walleye from Gull Lake due to tissue concentrations of mercury predicted to reach or slightly exceed 1.0 µg/g (Keeyask Hydropower Limited Partnership, 2012a).
- In the case of northern pike and walleye from Stephens Lake and lake sturgeon from either Stephens Lake or Gull Lake, these fish are predicted to have mercury concentrations that are greater than 0.2 µg/g but less than or equal to 0.5 µg/g.
- Risks from lake whitefish from Gull Lake and Stephens Lake were the lowest of the fish evaluated; however, consumption of three large meals per week could still result in Hazard Quotient values that exceed the acceptable value.

As noted earlier, as requested by Health Canada and Manitoba Health, this HHRA does not provide consumption advice and instead these agencies will provide this advice as a separate undertaking.

**Table 5-3: Risk Estimates from Consumption of Fish: Post-Impoundment Conditions**

| Fish Species | Assumed Concentration* (µg/g, wet weight) | Hazard Quotient from Consumption of Three Large Meals per Week (Acceptable Value = 1)*** | | |
|---|---|---|---|---|
| | | Toddlers | Women of Childbearing Age | Adult Males and All Seniors |
| Gull Lake | | | | |
| Lake Whitefish | 0.19 | 2.4 | 2.7 | 1.0 |
| Northern Pike | 1.0 | 12.9 | 14.2 | 5.1 |
| Walleye | 1.0 | 12.9 | 14.2 | 5.1 |
| Lake Sturgeon** | 0.30 | 3.9 | 4.2 | 1.5 |
| Stephens Lake | | | | |
| Lake Whitefish | 0.15 | 1.9 | 2.1 | 0.8 |
| Northern Pike | 0.50 | 6.4 | 7.1 | 2.5 |
| Walleye | 0.50 | 6.4 | 7.1 | 2.5 |
| Lake Sturgeon | 0.25 | 3.2 | 3.5 | 1.3 |

* Standard lengths: lake whitefish 350 mm; northern pike 550 mm; walleye 400 mm,
Individual mercury concentrations would be dependent upon the size of the fish with the smaller fish having generally lower concentrations than bigger fish. Nevertheless, NSC (North South Consultants pers. comm. 2010) concluded that there was not sufficient information to do a length-class specific analysis of mercury concentrations for the post-impoundment scenario.
** Arithmetic mean concentration.
*** Based on information provided by local First Nation communities, all fish were assumed to be consumed at a frequency of three meals per week with a serving size of 100 g for toddlers and 400 g for adults.

If impoundment occurs, it will be important that fish consumption recommendations for fish be communicated to local First Nations people through community health practitioners.

### *5.1.3 Health Effects from Consuming Fish at Rates Greater than Hazard Quotient Values of One*

This section addresses the potential health effects that could be associated with persons who consume fish at rates greater than Hazard Quotient values greater than one.

Both the present and post-impoundment conditions have estimated certain scenarios with Hazard Quotient values greater than one.

#### 5.1.3.1 Present Conditions

Under present conditions, it is apparent that persons could have elevated Hazard Quotient values for certain fish. The key concern is consumption of larger northern pike and walleye by women of childbearing age and young children. Nevertheless, potential unacceptable risks could affect persons of any age if unrestricted consumption of the larger fish occurred on a frequent basis.

Blood and hair measurements are a well known and accurate method for estimating both exposure and risks from methylmercury in fish. To evaluate potential health risks, the Health Canada approach has been employed whereby mercury hair concentrations less than 5 ppm (or 20 µg/L in blood) are considered to be in the "normal range" while concentrations between 5 and 25 ppm (25 to 100 µg/L in blood) are in the "increasing risk" range and concentrations above 25 ppm (or 100 µg/L in blood) are considered to be "at risk" levels (INAC 2009). In addition to these broad classifications, the following tissue concentrations would be close to known effects levels from the literature:

- Health Canada (1998) and US EPA (2011) have indicated that maternal mercury concentrations of 10 ppm in hair and/or 58 µg/L in blood are generally equal to the threshold for a 5% increased risk of developmentally delayed children. Although there have been no clear-cut clinical abnormalities in children born to mothers with mercury concentrations above 10 ppm in hair or 58 µg/L in blood, there have been effects on language, attention and memory that have been reported to be mercury-related.

- US EPA (2011) has developed a Benchmark Dose Level (BMDL05) (the lower 95% confidence limit of the BMD05) of 59 µg/L in maternal blood for neurological effects in children. This blood concentration would result in a doubling of the number of children with a neurological response at the fifth percentile of the population.

- Axelrad et al. (2007) has estimated that mercury concentrations of 1 ppm in maternal hair may be associated with a 0.18 IQ point decrement in children (i.e., 10 ppm may be associated with a 1.8 IQ point decrement); however, it is unclear if Axelrad et al. (2007) appropriately controlled for other factors and this relationship has not yet been used by any major health agency. It is stressed there can be a great number of everyday factors that can affect IQ at rates much greater than 1.8 IQ (as summarized in Wilson et al. [2005][1] a person's environment may affect their IQ by 20 to 25 points) and, thus, the proper context should be provided to a potential 1.8 IQ decrement at 10 ppm.
- In addition to the comparison of these literature-effect levels, it is possible that to compare the exposure to the Inuit in the Canadian Arctic. INAC (2009) data indicate that only 2% of Nunavut/Inuit women sampled between 2005 and 2007 had blood levels of mercury greater than 20 µg/L.

It is beyond the scope of this analysis to attempt to predict the blood and hair levels of mercury that may currently be present in the communities due to fish consumption. We understand that the KCNs communities have a dialogue with health agency officials regarding such testing but this information is considered to be private medical information that is not to be used in this HHRA. With the above noted, the greatest Hazard Quotient under present conditions when expressed for standardized length was estimated to be 4.7 for women of childbearing age (as shown in Table 5-1). It is not clear that actual adverse health effects would occur at such exposures and, instead, it is only clear that a desired margin of safety would be intruded upon. Nevertheless, it is stressed that Hazard Quotient values of 4.7 are not desirable and would place women and their developing babies in the "increasing risk" that has been defined by Health Canada. Consequently, there is importance to making good decisions regarding fish consumption under the present scenario since there would be much lower risks for women of

[1] As summarized in Wilson *et al.* (2005), example of factors that may each cause an IQ decrement of three points or more include: socio-economic status (SES); parent's education, family size and child's position in family; enriched pre-school and breast feeding. Furthermore, it is noted that the standard deviation on an IQ test is three points.

childbearing age consuming lake whitefish or smaller northern pike and walleye (*i.e.*, fish with mercury concentrations less than 0.2 µg/g and in the case of lake whitefish less than 0.1 µg/g).

In addition to the effects on development, there have been concerns regarding cardiovascular effects of mercury. Clinical effects in adults have included increased blood pressure. Roman *et al.* (2011) have indicated that a dose-response relationship could be developed for methylmercury exposure and acute myocardial infarction; however, at the current time, we are not aware of any recognized relationship that can be quantified and applied to the results of this risk assessment. Moreover, in two very large US cohorts, Mozaffarian *et al.* (2011) found no evidence of any clinically relevant adverse effects of mercury exposure on coronary heart disease, stroke, or total cardiovascular disease. Consequently, at the current time, the effect of mercury on cardiovascular risk remains unclear.

Overall, there is a recognized risk of children being born who later do not perform as well in various mental tasks. In addition, there is the potential for other health effects that may include cardiovascular effects. Ideally, it would be prudent for persons to attempt to lower exposures through good choices of fish consumption. On the other hand, there could also be risks from persons not consuming fish (since fish can be such an important source of nutrients)[2]. As a result, it is stressed that this information should be used to make informed choices about fish consumption.

#### 5.1.3.2 Post-Impoundment Conditions

There is potential for unacceptable health risks for persons who decide to frequently consume fish from Gull and Stephens lakes under post-impoundment conditions. For example, there would be greater risks associated with the consumption of northern pike and walleye from Gull Lake. On the other hand, there could also be health risks if persons choose not to consume fish and instead substitute less healthy foods in their diet. Thus, it

[2] The health effects of not eating fish have not been quantified in this HHRA report.

is important that persons should be encouraged to use, to the maximum extent possible, the programs that enable use of lakes unaffected by the Project.

Similar to that discussed for present-day conditions, it is beyond the scope of this analysis to attempt to predict the blood and hair levels of mercury that may be present in the communities following impoundment with maximum Hazard Quotient values of 14.2 (for women of childbearing age). Future hair and blood concentrations would be expected to follow fish mercury concentrations (for which we have estimated levels) but would also be dependent on how many and which people choose to use the lakes unaffected by the Project versus Gull Lake versus Stephens Lake (all unknown variables). Nevertheless, it should be apparent that for persons frequently consuming fish at mercury concentrations of 1 µg/g (*i.e.,* Hazard Quotient values up to 14.2 for women of childbearing age), exposures would be classified in the Health Canada "at risk" range. For women of childbearing age who continue to consume Gull Lake northern pike or walleye at 1.2 kilograms of northern pike or walleye (1.0 ppm for standardized size) per week, it could be expected that hair and blood concentrations would exceed the previously described known effects levels from the literature (main concerns would be developmental effects in children and potential cardiovascular effects in adults). Such populations would be considered to be in the Health Canada "at risk" range. In addition, such concentrations would be greater than the majority of Nunavut/Inuit women sampled between 2005 and 2007 by INAC (2009) (*i.e.,* only two percent had blood levels of mercury greater than 20 µg/L).

It is noted that this Hazard Quotient was estimated by assuming that a 60 kg woman of childbearing age consumes 1.2 kg of northern pike or walleye per week on a consistent basis. If a woman consumed less fish, the exposure and risk values would accordingly decrease. For example, if a woman of childbearing age consumed serving sizes of seven ounces rather than 14 ounces (but still at a rate of three meals of northern pike or walleye per week), the Hazard Quotient values would be halved (*i.e.,* Hazard Quotient values of

7.1). Such halving would place women of childbearing age in the "increasing risk" range of exposure (rather than in the "at risk" range).

Although these levels of exposures are of concern, it is important to recognize that these are not estimates of blood and hair concentrations that will occur in the community as a whole. First of all, there are programs in the Adverse Effects Agreements to enable the KCNs to access lakes unaffected by the Project that will provide an alternate source of fish and, thus, if the people use these programs, it should not be a health concern. In addition, these estimates apply to consumption of 1.2 kg of northern pike or walleye from Gull Lake per week on a consistent basis. Appreciably lower hair and blood levels would be associated with less frequent consumption of the same fish. It is also noted that accumulation of such levels takes several weeks of such consumption, such that lower blood and hair concentrations would be associated with lower frequencies of consumption of fish from Gull Lake.

Overall, it is considered to be important that persons follow fish consumption recommendations provided by health authorities; and for the KCNs, to utilize the programs to access areas unaffected by the Project under post-impoundment conditions. If persons frequently consume certain fish from Gull and Stephens lakes following impoundment, individuals could be in the "at risk" range of tissue concentrations. On the other hand, under the programs in the Adverse Effects Agreements to enable the KCNs to access lakes unaffected by the Project, there would be no adverse effects or unacceptable risks if persons follow health authority recommendations. This information should be used to make informed choices about fish consumption with special emphasis on the consumption of fish from unaffected lakes during the post-impoundment elevation in fish concentrations.

### 5.2 RISKS FROM CONSUMPTION OF WILD GAME

Risks from consumption of wild game (beaver, muskrat, moose and snowshoe hare) were estimated for the present and post-impoundment conditions. Based on information provided by the KCNs communities, the following consumption rates of wild game were assumed:

- Moose was assumed to be consumed at a frequency of five meals per week with a serving size of 100 g (3.5 ounces) per meal for toddlers and 400 g (14 ounces) per meal for adults.
- Beaver was assumed to be consumed at a frequency of three meals per week with a serving size of 57 g (two ounces) per meal for toddlers and 200 g (seven ounces) per meal for adults.
- Muskrat and snowshoe hare were assumed to be consumed at a frequency of 1 meal per week with a serving size of 57 g (two ounces) per meal for toddlers and 200 g (seven ounces) per meal for adults.

These rates of consumption were used at the request of the KCNs and are considered to represent upper bound exposures. It is recognized that some wild game are only consumed at certain times of the year (*e.g.*, muskrat and beaver are mostly consumed in the colder months). Similar to that discussed for fish consumption, less than continuous exposure was not quantitatively considered in the HHRA because the key concern regarding mercury is developmental toxicity. In addition, although moose are mainly harvested in the fall, the meat is stored in a freezer and can be consumed all year. As a result, the risks from consumption of the various forms of wild game were not adjusted for less than all year round consumption patterns.

### *5.2.1 Present Conditions*

Table 5-4 provides the risk estimates for consumption of wild game under present conditions. Key results of the risk analysis include the following:

- Consumption of wild game at present concentrations of total mercury is not associated with unacceptable risks. The greatest risks were estimated from consumption of moose; however, five times per week consumption of large serving sizes resulted in Hazard Quotient values approximately equal to 0.5.

- Even lower Hazard Quotient values were estimated from consumption of muskrat, beaver and snowshoe hare (due to a combination of lower total mercury concentrations, less consumption frequency and smaller serving sizes).

Based on the results, consumption of large meals of any wild game does not pose unacceptable health risks under present conditions. As noted in Section 3, there is some uncertainty in regard to the moose and snowshoe hare concentrations of mercury and it is recommended that monitoring of these species be completed to ascertain that the assumed mercury concentrations were reasonable.

**Table 5-4: Risk Estimates from Consumption of Wild Game: Present Conditions**

| Wild Game Species | Assumed Concentration* (µg/g, wet weight) | Hazard Quotient (Acceptable Value = 1)** | | |
|---|---|---|---|---|
| | | Toddlers | Women of Childbearing Age | Adult Males and All Seniors |
| Beaver | 0.01 | 0.03 | 0.02 | 0.02 |
| Muskrat | 0.02 | 0.02 | 0.02 | 0.01 |
| Moose* | 0.07 | 0.5 | 0.29 | 0.24 |
| Snowshoe hare* | 0.05 | 0.04 | 0.04 | 0.03 |

* Mercury concentration in moose and snowshoe hare was only a literature estimate and may have greater uncertainty than other species for which measured values were obtained from the study area
** Hazard Quotient estimated assuming either five meals per week for moose, three meals per week for beaver or 1 meal per week for snowshoe hare/muskrat

### *5.2.2 Post-Impoundment Conditions*

Table 5-5 provides the risk estimates for consumption of wild game that would occur under post-impoundment conditions. In some cases, it is important to realize that these risk estimates are based on very high rates of wild game consumption (*i.e.*, moose was assumed to be consumed at a frequency of five meals per week with a serving size of 100 g per meal for toddlers and 400 g per meal for adults).

Key results of the risk analysis include the following:

- In the case of moose, beaver and snowshoe hare, the concentrations of total mercury in the tissue of these animals would not be expected to change post-impoundment (i.e., Hazard Quotient less than 1). As a result, there is no change in risk from consumption of these animals and risks are estimated to remain acceptable.
- In the case of muskrat, the risks from consumption were estimated to be acceptable for the post-impoundment scenario (i.e., Hazard Quotient less than 1) even though total mercury concentrations may increase from 0.02 µg/g to 0.04 µg/g.

It is noted that some aquatic mammals such as otter and mink may experience appreciably higher increases in total mercury concentrations than the mammals considered in the HHRA. However, consultation has indicated that these mammals are not consumed by the KCNs communities. Nevertheless, it should be clear that risks from consumption of such aquatic mammals were not considered in the HHRA.

It is also noted that certain other wild game has not been considered in the HHRA. For example, the HHRA has not evaluated consumption of lynx, bear or caribou. These animals are not expected to have higher concentrations of mercury than the wild game considered in the HHRA (*i.e.,* the animals considered in the HHRA will have more direct contact with the aquatic ecosystem and/or more potential to accumulate mercury). In addition, these animals are not consumed as frequently as the animals considered in the HHRA. Since risks were acceptable from consumption of the wild game that was more likely to contribute risks from mercury, it can be conservatively concluded that risks would be even lower and, therefore, acceptable for these other animals not formally considered in the HHRA.

Overall, based on the results (see Table 5-5), consumption of large meals of any wild game does not pose unacceptable health risks under post-impoundment conditions. As noted in Section 3, there is some uncertainty in regard to the moose and snowshoe hare concentrations of mercury and it is recommended that monitoring of these species be completed to ascertain that the assumed mercury concentrations were reasonable.

**Table 5-5: Risk Estimates from Consumption of Wild Game: Post-Impoundment Conditions**

| Wild Game Species | Assumed Concentration* (µg/g, wet weight) | Hazard Quotient (Acceptable Value = 1)** | | |
|---|---|---|---|---|
| | | Toddlers | Women of Childbearing Age | Adult Males and All Seniors |
| Beaver | 0.01 | 0.03 | 0.02 | 0.02 |
| Muskrat | 0.04 | 0.03 | 0.03 | 0.03 |
| Moose* | 0.07 | 0.5 | 0.29 | 0.24 |
| Snowshoe hare* | 0.05 | 0.04 | 0.04 | 0.03 |

* Mercury concentration in moose and snowshoe hare were based on a literature estimate and may have greater uncertainty than other species for which measured values were obtained from the study area
** Hazard Quotient estimated assuming either five meals per week for moose, three meals per week for beaver or 1 meal per week for snowshoe hare/muskrat

### 5.3 RISKS FROM CONSUMPTION OF WATERFOWL

Risks from consumption of waterfowl (*i.e.*, ducks) were estimated for the present and post-impoundment conditions. Based on information provided by the KCNs communities, ducks were assumed to be consumed at a frequency of 1 meal per week with a serving size of 57 g (two ounces) per meal for toddlers and 200 g (seven ounces) per meal for adults. These rates of consumption were used at the request of the KCNs.

It is recognized that ducks are only consumed at certain times of the year (*i.e.*, mostly in the spring and fall). Similar to that discussed for fish consumption, less than continuous exposure was not quantitatively considered in the HHRA because the key concern regarding mercury is developmental toxicity. In addition, duck meat could be placed in a freezer and can be consumed all year. As a result, the risks from consumption of waterfowl were not adjusted for less than all year round consumption patterns.

Finally, it is noted that the mercury present in duck tissue was assumed to be methylmercury rather than total mercury. Consequently, the more conservative methylmercury TRV (i.e., 0.2 µg/kg bw/day for sensitive populations) was used rather than the 0.57 µg/kg bw/day that the WHO has recommended for use when mercury is not present in fish and shellfish. Although this is considered to be conservative, the avian experts have indicated that the mercury concentrations in waterfowl are expected to mirror the whitefish concentrations and that no further information on mercury speciation was available. If monitoring of waterfowl indicates that the mercury is not present as methylmercury, it would be possible to adjust these risk estimates (*i.e.*, even lower risks would be predicted).

### *5.3.1 Present Conditions*

Table 5-6 provides the risk estimates for consumption of waterfowl under present conditions. Key results of the risk analysis include the following:

- Consumption of waterfowl at present concentrations of total mercury is not associated with unacceptable risks.
- Even lower Hazard Quotient values would be estimated from consumption of other waterfowl (such as geese) (due to a combination of lower total mercury concentrations and possibly less consumption frequency).
- No risk estimate was available for gull eggs since no estimate of the mercury concentration of these eggs was available. To provide an estimate of risks from eggs, monitoring of gull eggs would likely be required.

Based on the results, consumption of duck and other waterfowl does not pose unacceptable health risks under present conditions. No estimate can be provided on the risks from consumption of gull eggs. As noted in Section 3, there is some uncertainty in regard to the duck concentrations of mercury and it is recommended that monitoring of these species be completed to ascertain that the assumed mercury concentrations were reasonable.

**Table 5-6: Risk Estimates from Consumption of Waterfowl: Present Conditions**

| Fish Species | Assumed Concentration* (µg/g, wet weight) | Hazard Quotient (Acceptable Value = 1)** | | |
|---|---|---|---|---|
| | | Toddlers | Women of Childbearing Age | Adult Males and All Seniors |
| Gull Lake | | | | |
| Duck | 0.07 | 0.17 | 0.17 | 0.06 |
| Stephens Lake | | | | |
| Duck | 0.09 | 0.22 | 0.21 | 0.08 |

* Mercury concentration in duck was assumed to be similar to that estimated for lake whitefish
** Hazard Quotient estimated assuming 1 meal per week

### *5.3.2 Post-Impoundment Conditions*

Table 5-7 provides the risk estimates for consumption of waterfowl that would occur under post-impoundment conditions. Key results of the risk analysis include the following:

- In the case of ducks from Stephens Lake, a small increase in methylmercury concentration is predicted. As a result, there is no or little change in risk from consumption of these ducks and risks are estimated to remain acceptable.
- In the case of ducks from Gull Lake, the risks from consumption were estimated to be acceptable under post-impoundment conditions (i.e., Hazard Quotient less than 1) even though total mercury concentrations may increase from 0.07 µg/g to 0.19 µg/g.

It is also noted that certain other waterfowl has not been considered in the HHRA. For example, the HHRA has not evaluated consumption of geese. Geese are not expected to have higher concentrations of mercury than the ducks considered in the HHRA. Since risks were acceptable from consumption of ducks, it can be safely concluded that risks would be even lower and, therefore, acceptable for geese even though it was not formally considered in the HHRA.

Overall, based on the results, consumption of waterfowl would not pose unacceptable health risks under post-impoundment conditions. As noted in Section 3, there is some uncertainty in regard to duck concentrations of mercury and it is recommended that monitoring of these species should be completed to ascertain that the assumed mercury concentrations were reasonable.

**Table 5-7: Risk Estimates from Consumption of Waterfowl: Post-Impoundment Conditions**

| Fish Species | Assumed Concentration* (µg/g, wet weight) | Hazard Quotient (Acceptable Value = 1)** | | |
|---|---|---|---|---|
| | | Toddlers | Women of Childbearing Age | Adult Males and All Seniors |
| Gull Lake | | | | |
| Duck | 0.19 | 0.47 | 0.45 | 0.16 |
| Stephens Lake | | | | |
| Duck | 0.15 | 0.37 | 0.35 | 0.13 |

* Mercury concentration in duck was assumed to be similar to that predicted for lake whitefish
** Hazard Quotient estimated assuming 1 meal per week

## 5.4 RISKS FROM CONSUMPTION OF WILD PLANTS

The KCNs communities identified the following plants as primary concern:

- Northern tea;
- Blueberries; and
- Seneca root.

As discussed earlier in Section 3.4, no estimates of mercury concentrations in wild plants are available under either present or post-impoundment conditions. Consequently, no risk estimates are available from consumption of wild plants. If risk estimates are required, it will likely be necessary to collect samples from the study area.

## 5.5 RISK FROM CONTACT WITH SURFACE WATER

The final media of concern that was evaluated in the HHRA was surface water. For the purposes of the HHRA, it was assumed that the KCNs communities would consume surface water as their drinking water source. In addition, it was assumed that the communities would use the water for bathing/swimming. For both the present and post-impoundment scenarios, mercury was assumed to be present in surface water at a concentration equal to the method detection limit of 0.05 µg/L.

### *5.5.1 Present Conditions*

Table 5-8 provides the risk estimates from contact with surface water under present conditions. Key results of the risk analysis include the following:

- Present surface water concentrations (less than method detection limit of 0.05 µg/L) are appreciably lower than the Canadian Drinking Water Guideline of 1 µg/L for total mercury.
- Hazard Quotient from ingestion and dermal contact with surface water is not associated with unacceptable risks.

Based on the results, contact with surface water does not pose unacceptable health risks under present conditions.

**Table 5-8: Risk Estimates from Contact with Surface Water: Present Conditions**

| Route of Concern | Assumed Concentration* (µg/L) | Hazard Quotient (Acceptable Value = 1) | | |
|---|---|---|---|---|
| | | Toddlers | Women of Childbearing Age | Adult Males and All Seniors |
| Drinking (direct ingestion) | 0.05 | 0.0032 | 0.0022 | 0.0019 |
| Bathing/swimming (dermal) | 0.05 | 0.000032 | 0.000026 | 0.000022 |
| Total | | 0.0032 | 0.0022 | 0.0019 |

* Mercury concentration in surface water was assumed to equal the method detection limit

### *5.5.2 Post-Impoundment Conditions*

Table 5-9 provides the risk estimates from contact with surface water under post-impoundment conditions. Key results of the risk analysis include the following:

- No changes in surface water concentrations of mercury are expected under post-impoundment conditions (i.e., surface water concentrations would be expected to remain less than method detection limit of 0.05 µg/L).
- Hazard Quotient from ingestion and dermal contact with surface water is not associated with unacceptable risks.

Based on the results, contact with surface water would not pose unacceptable health risks under post-impoundment conditions.

**Table 5-9: Risk Estimates from Contact with Surface Water: Post-Impoundment Conditions**

| Route of Concern | Assumed Concentration* (µg/L) | Hazard Quotient (Acceptable Value = 1) | | |
|---|---|---|---|---|
| | | Toddlers | Women of Childbearing Age | Adult Males and All Seniors |
| Drinking (direct ingestion) | 0.05 | 0.0032 | 0.0022 | 0.0019 |
| Bathing/swimming (dermal) | 0.05 | 0.000032 | 0.000026 | 0.000022 |
| Total | | 0.0032 | 0.0022 | 0.0019 |

* Mercury concentration in surface water was assumed to equal the method detection limit

## 5.6 CHEMICAL INTERACTION ASSESSMENT OF VARIOUS FORMS OF MERCURY

A final consideration in the HHRA involves estimation of risks for persons who may be involved in multiple activities. For example, what are the health risks for a person who is exposed to surface water (mercury primarily as inorganic) and also consumes country (wild) foods? Or, what are the health risks for a person who consumes multiple types of country (wild) foods?

In the case of adding mercury-related risks from surface water exposures to consumption of country (wild) foods, the combination of these activities will not change the conclusions. As illustrated previously in Tables 5-8 and 5-9, it is expected that risks from mercury due to contact with surface water would be associated with a Hazard Quotient value of 0.0032 for toddlers (and even less for other age groups). When this Hazard Quotient is added to the values associated with consumption of fish, wild game or waterfowl, the sum of the Hazard Quotient values remains essentially unchanged in all cases.

When the Hazard Quotient of 0.0032 from surface water is added to the values associated with consumption of certain fish, the sum of the Hazard Quotient values will remain above 1 for various consumption scenarios; however, there is no reason to recommend that persons consuming fish should avoid using the surface water (and vice versa). In past guidance from international health agencies (such as Health Canada and the World Health Organization), consumption advice to the general public has typically allowed for exposures from fish to contribute a Hazard Quotient value of 1 from methylmercury, irrespective of other forms of mercury exposures.

In the case of interactive effects from consumption of multiple country (wild) foods, it is clear that fish consumption is the dominant contributor in terms of risks. Although moose consumption also theoretically contributes a Hazard Quotient of 0.5, this is based on a person consuming large amounts of moose on a daily basis and, thus, it is likely that their fish consumption would drop under such circumstances. In addition, it has not been confirmed that the mercury concentrations of 0.07 µg/g for moose muscle tissue would actually occur at the study area. Finally, mercury concentrations in moose tissues was predicted to be essentially unaffected by impoundment. Nevertheless, the possible implications of cumulative exposure is discussed in greater detail below.

There are too many possible combinations to fully evaluate all possible interactions that may occur. As an alternative, the percentage of the TDI that 1 meal per week of each food group would represent was estimated as shown below. In completing these calculations, the meal sizes provided earlier were used:

- Toddler fish and moose meal = 100 g;
- Toddler beaver/muskrat/snowshoe hare/duck meal = 57 g;
- Adult fish and moose meal = 400 g; and
- Adult beaver/muskrat/snowshoe hare/duck meal = 200 g.

Once again, it should be noted that these represent rather large portion sizes for adults and Health Canada often uses a fish serving size of 200 g in most of their evaluation of adults (while in the case of the toddler, the 100 g is similar to Health Canada policy).

### *5.6.1 Present Conditions*

As discussed above, the percentage of the TDI that 1 meal per week of each food would represent was estimated for present conditions and is provided in Table 5-10. As shown in this table, some food combinations would likely result in exposures exceeding the TDI under present conditions and, indeed, some foods by themselves (*i.e.*, northern pike and walleye) could result in exposures exceeding the TDI if consumed on a once per week basis under present conditions. Nevertheless, health authority advice should be sought before determining if these foods should be avoided under present day conditions.

**Table 5-10: Risk Estimates from Mercury for Combined Sources: Present Conditions**

| Food | % of TDI Used Based on 1 Meal per Week | | |
|---|---|---|---|
| | Toddlers | Women of Childbearing Age | Other Members of the General Population |
| **Gull Lake** | | | |
| Lake whitefish | 30 | 33 | 12 |
| Northern Pike | 94 | 104 | 37 |
| Walleye | 99 | 108 | 39 |
| Lake sturgeon | 86 | 94 | 34 |
| Duck | 17 | 17 | 6 |
| Beaver | 3 | <1 | <1 |
| Muskrat | <1 | <1 | <1 |
| Moose | 10 | 12 | 10 |
| Snowshoe hare | 4 | 4 | 3 |
| **Stephens Lake** | | | |
| Lake whitefish | 40 | 42 | 15 |
| Northern Pike | 110 | 123 | 44 |
| Walleye | 120 | 137 | 49 |
| Lake sturgeon | No estimate available | No estimate available | No estimate available |
| Duck | 17 | 17 | 6 |
| Beaver | <1 | <1 | <1 |
| Muskrat | 2 | 2 | 1 |
| Moose | 10 | 12 | 10 |
| Snowshoe hare | 4 | 4 | 3 |

### *5.6.2 Post-Impoundment Conditions*

Under post-impoundment conditions, the percentage of the TDI that 1 meal per week of each food would represent is provided in Table 5-11. As shown in this table, some food combinations will likely result in exposures exceeding the TDI under present conditions and, indeed, some foods by themselves (*i.e.*, northern pike and walleye) could result in exposures exceeding the TDI if consumed on a once per week basis from either Gull Lake or Stephens Lake under post-impoundment conditions.

Another alternative to reduce mercury exposures would be consumption of fish from appropriate lakes unaffected by the Project. However, even from pristine lakes unaffected by the Project, it will be necessary to consider size and species of fish for persons desiring to reduce their mercury exposures (*i.e.*, certain fish from these offset lakes may have mercury concentrations that warrant consumption recommendations).

**Table 5-11: Risk Estimates from Mercury for Combined Sources: Post-Impoundment Conditions**

| Food | % of TDI Used Based on 1 Meal per Week | | |
|---|---|---|---|
| | Toddlers | Women of Childbearing Age | Other Members of the General Population |
| **Gull Lake** | | | |
| Lake whitefish | 80 | 90 | 32 |
| Northern Pike | 430 | 470 | 170 |
| Walleye | 430 | 470 | 170 |
| Lake sturgeon | 130 | 140 | 50 |
| Duck | 47 | 45 | 16 |
| Beaver | <1 | <1 | <1 |
| Muskrat | 3 | 3 | 3 |
| Moose | 10 | 12 | 10 |
| Snowshoe hare | 4 | 4 | 3 |
| **Stephens Lake** | | | |
| Lake whitefish | 60 | 71 | 25 |
| Northern Pike | 210 | 240 | 85 |
| Walleye | 210 | 240 | 85 |
| Lake sturgeon | 110 | 118 | 42 |
| Duck | 37 | 35 | 13 |
| Beaver | <1 | <1 | <1 |
| Muskrat | 3 | 3 | 3 |
| Moose | 10 | 12 | 10 |
| Snowshoe hare | 4 | 4 | 3 |

# 6.0 DISCUSSION AND UNCERTAINTY ANALYSIS

The HHRA was completed using a series of upper-bound assumptions that are intended to over-estimate actual health risks and thereby ensure a conservative assessment. Given the conservative assumptions used in this assessment, it is quite possible that actual risks may be substantially lower than estimated here. Nevertheless, certain assumptions were key determinants in the acceptability of risks. The following sensitivity analysis discusses some of the most important assumptions that had key influences on the risk assessment.

*Mercury Concentrations in the Environment*

One source of uncertainty is the concentrations of mercury in surface water and country (wild) foods that persons may be exposed to through their typical daily activities. The HHRA relied heavily on present and post-impoundment concentrations that have been measured or predicted by other disciplines. The prediction of the magnitude and extent of the changes in environmental concentrations was considered to be beyond the scope of the HHRA.

In the case of fish concentrations, the largest uncertainty with the most substantial impact on how much people can eat is for mercury concentrations in northern pike and walleye (*i.e.*, the NSC modeled post-impoundment estimates range from 0.81-1.33 µg/g and 0.83-1.46 µg/g). In addition, it is noted that there was particular uncertainty reported by the other disciplines in the mercury concentrations in the tissues of the following animals:

- Moose;
- Lake sturgeon;
- Snowshoe hare; and
- Ducks and geese.

It is anticipated that continued monitoring of concentrations can be used as a direct measure of the impact that present conditions and impoundment would have on mercury concentrations. Nevertheless, there remain uncertainties and, in all cases, future environmental monitoring and risk management should be used to determine if environmental concentrations increase beyond those assumed in the HHRA.

*Toxicity Reference Values*

The approach that health agencies use to estimate acceptable or "safe" levels of exposure are typically very conservative and employ considerable safety factors to ensure protection of the general population. It is unlikely that such regulatory agency-derived exposure limits would underestimate health risks. Overall, the TRVs for methylmercury and total mercury used in this assessment represent dose rates that are unlikely to present unacceptable health risks and may actually overestimate health risks.

*Country (Wild) Foods Consumption Rates*

Highly conservative estimates of country (wild) foods consumption were assumed for the HHRA. The rate of country (wild) foods consumption was provided directly by members of the KCNs communities as high-end estimates of food consumption. As a result, it is considered unlikely that these consumption rates underestimate exposures.

*Overall Uncertainty in the Risk Assessment*

Overall, it is unlikely that human health risks have been underestimated in the risk assessment and it is quite possible that already low risks have been overestimated. The potential combination of upper bound estimates of consumption patterns and conservative TRVs likely resulted in an overestimate of actual risks. Nevertheless, it is still possible (but not likely) that risks may have been underestimated for certain receptors in some cases. The two main conditions where risks may have been underestimated would include:

- Any situations where environmental sampling or modeling has underestimated mercury concentrations either currently or that would occur following impoundment; and
- Any situations where people are not accurately represented by the assumed receptor assumptions.

Risk management measures should be undertaken to ensure that neither of the conditions described above occur. If such conditions do occur, additional risk analysis would be recommended to address potential increases in human health risks.

# 7.0 CONCLUSIONS

For fish from Gull and Stephens lakes, the present arithmetic mean mercury concentrations of lake whitefish are less than 0.1 µg/g while northern pike and walleye have an arithmetic mean concentration of approximately 0.3 µg/g. Nevertheless, potential unacceptable risks are estimated from these fish when Hazard Quotient values are the only consideration used. In the case of wild game, moose meat concentrations of mercury are largely unknown for the study area but have been estimated to perhaps be in the range of 0.07 µg/g while muskrat, beaver and snowshoe hare would have concentrations of mercury in muscle tissue in the range of 0.01 to 0.05 µg/g, depending on the species.

Under post-impoundment conditions, the mercury concentrations of fish in Gull Lake and Stephens Lake will increase. Specifically, during years of maximum mercury concentrations in fish (perhaps 3 to 7 years post-impoundment; refer to Keeyask Hydropower Limited Partnership [2012a,b] for specific discussion on patterns of variation), the concentrations of mercury in fish and ducks from Gull Lake may increase by 0.5 to five times (smallest increase was in lake sturgeon and lake whitefish while greatest increase was in northern pike and walleye) while the concentrations of mercury from Stephens Lake would be more modest (perhaps 0.3 to 0.7 times increase). In the case of waterfowl, it is possible that fish eating ducks may experience an increase in mercury concentrations; however, the increase is not expected to result in Hazard Quotient values greater than 1. The mercury concentrations of wild game tissues consumed by the KCNs (*i.e.,* beaver, muskrat, moose or snowshoe hare) are expected to be essentially unaffected by the impoundment.

The key conclusions of the HHRA are as follows:

1. Hazard Quotient values greater than 1 are predicted from consumption of certain fish under both the present conditions and the predicted post-impoundment conditions. Under post-impoundment conditions, Hazard Quotient values increase since the mercury concentrations in various fish are estimated to increase. The

fish with the predicted highest increase in mercury concentrations are from Gull Lake and include northern pike (0.22 µg/g to just over 1 µg) and walleye (0.23 µg/g to just over 1 µg/g) while the increase in lake whitefish would be less (0.07 µg/g to just below 0.2 µg/g). The same species from Stephens Lake would be impacted less than fish from Gull Lake. There are currently numerous fish in Gull and Stephen lakes that have mercury concentrations that are considered to be low (less than 0.2 ppm) and very low (less than 0.1 ppm). This is expected to change after impoundment.Issuance of consumption advisories is a complex task that requires evaluation of the benefits and risks of fish consumption. Manitoba Health and Health Canada have committed to working with the KCNs and Manitoba Hydro on consumption advisories in a separate process.

2. No Hazard Quotient values greater than 1 are predicted from consumption of wild game or waterfowl under current or post-impoundment conditions. Muskrat is the only mammal that was predicted to have increased tissue concentrations of mercury following impoundment; however, the increases are considered to be very minor (*i.e.*, 0.02 µg/g under baseline conditions versus 0.04 µg/g under post-impoundment conditions). No measurable changes in mercury tissue concentrations under post-impoundment conditions in moose, beaver and snowshoe hare were predicted by Wildlife Resource Consultants. In the case of waterfowl, Stantec estimate that these may mirror changes in lake whitefish concentrations; however, no Hazard Quotient values greater than 1 were predicted from consumption of waterfowl.

3. Mercury concentrations in surface water do not pose unacceptable risks from contact or drinking under present or post-impoundment conditions (*i.e.*, risks are considered to be negligible). Typical total mercury surface water concentrations are predicted to remain less than the currently used analytical method detection limit (*i.e.*, less than 0.05 µg/L as compared to the Canadian Drinking Water Guideline of 1 µg/L).

4. No conclusions can be provided on consumption of wild plants or gull eggs since discipline experts have not been able to estimate mercury concentrations either presently or under post-impoundment conditions.

## STATEMENT OF LIMITATIONS

This report has been prepared by Wilson Scientific Consulting Inc. (Wilson Scientific) for the sole benefit of InterGroup Consultants Limited (InterGroup) and Manitoba Hydro. Any use that a third party makes of this report, or any reliance on decisions made based on it, is the responsibility of such third parties. Wilson Scientific accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

The information and conclusions contained in this report are based upon work undertaken by trained professional staff in accordance with generally accepted scientific practices current at the time the work was performed.

Any site-specific information provided by InterGroup, Manitoba Hydro or other parties has been assumed by Wilson Scientific to be accurate. Conclusions presented in this report should not be construed as legal advice.

This risk assessment was undertaken exclusively for the purpose outlined herein and was limited to those contaminants, exposure pathways, receptors, and related uncertainties specifically referenced in the report. This work was specific to the site conditions and land use considerations described in the report. This report cannot be used or applied under any circumstances to another location or situation or for any other purpose without further evaluation of the data and related limitations.

This report describes only the applicable risks associated with the identified environmental hazards, and is not intended to imply a risk-free site. Should any conditions at the site be observed or discovered that differ from those at the sample locations, or should the land use surrounding the identified hazards change significantly, Wilson Scientific requests that to be notified immediately to reassess the conclusions provided herein.

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# APPENDIX 5C-1-1: DETAILED TECHNICAL INFORMATION, WORKED EXAMPLE RISK CALCULATIONS AND DETAILED RISK ESTIMATES

# APPENDIX 5C-1-1: DETAILED TECHNICAL INFORMATION, WORKED EXAMPLE RISK CALCULATIONS AND DETAILED RISK ESTIMATES

## 5C-1-1 Introduction

This appendix provides detailed technical information on the human health risk assessment (HHRA). The appendix includes the following:

- Section 5C-1-2 provides the mathematical equations used to estimate exposures.
- Section 5C-1-3 provides worked examples of the risk calculations for various scenarios.
- Section 5C-1-4 provides information on the toxicological reference values selected for the HHRA.
- Section 5C-1-5 provides the detailed results of the HHRA (results expressed on an exposure pathway basis)

## 5C-1-2 Mathematical Equations Used to Estimate Exposures

As discussed earlier, the exposures that receptors may receive were estimated for the following pathways:

- Ingestion of surface water.
- Dermal contact with surface water.
- Ingestion of country foods.

The mathematical equations used to estimate exposures from these pathways are discussed in greater detail below.

Estimation of Exposure from Ingestion of Surface Water

In order to estimate exposure from ingestion of surface water, the following Health Canada (2009a; 2010a) equation was applied:

$$EWG = \frac{C_W \times IR_W \times RAF_{Oral} \times D_2 \times D_3}{BW}$$

where:

| | | |
|---|---|---|
| EWG | = | exposure from the water ingestion pathway (µg/kg body weight/day) |
| $C_W$ | = | water chemical concentration (µg/L) |
| $IR_W$ | = | water ingestion rate of person (L/day) |
| $RAF_{Oral}$ | = | relative bioavailability fraction via the ingestion route (chemical specific) |
| $D_2$ | = | days per week exposed/7 days (unitless) |
| $D_3$ | = | weeks per year exposed/52 weeks (unitless) |
| BW | = | body weight of person (kg) |

Estimation of Exposure from Dermal Contact with Drinking Water

Dermal contact with surface water was another pathway of exposure that was quantitatively evaluated in the HHRA. Dermal exposure was estimated according to the following Health Canada (2009a; 2010a) equation:

$$EDW = \frac{C_w \times SA_B \times PC \times D_1 \times D_2 \times D_3}{BW}$$

where:

| | | |
|---|---|---|
| EDS | = | exposure from the dermal pathway for drinking water (µg/kg/day) |
| $C_W$ | = | water chemical concentration (µg/L) |
| $SA_B$ | = | surface area of the entire body ($m^2$) |
| PC | = | permeability constant (m/hr) (chemical specific) |
| $D_1$ | = | hours per day exposed to water (hr/day) |
| $D_2$ | = | days per week exposed/7 days (unitless) |
| $D_3$ | = | weeks per year exposed/52 weeks (unitless) |
| BW | = | body weight of person (kg) |
| UCF | = | unit correction factor (1,000 $L/m^3$) |

Estimation of Exposure from Ingestion of Country Food

In order to estimate exposure from consumption of country food, the following Health Canada (2009a; 2010a) equation was applied:

$$EFG = \frac{C_F \times IR_F \times RAF_{Oral} \times D_2 \times D_3}{BW}$$

where:

| | | |
|---|---|---|
| EFG | = | exposure from the country food ingestion pathway (µg/kg body weight/day) |
| $C_F$ | = | food chemical concentration (µg/g) |
| $IR_F$ | = | food ingestion rate of person (g/day) |

| | | |
|---|---|---|
| $RAF_{Oral}$ | = | relative bioavailability fraction via the ingestion route (chemical specific) |
| $D_2$ | = | days per week exposed/7 days (unitless) |
| $D_3$ | = | weeks per year exposed/52 weeks (unitless) |
| BW | = | body weight of person (kg) |

### 5C-1-3 Worked Example Risk Calculations

#### 5C-1-3.1 Worked Example #1: Risks Posed to a Person Using Surface Water

In this worked example, risks posed to a woman of child-bearing age using surface water from mercury are estimated. To estimate exposures and risks, a surface water concentration of 0.05 µg/L (equal to the method detection limit) was assumed.

<u>Estimation of Risks from Ingestion of Surface Water</u>

In order to estimate exposure from surface water, the following equation was applied:

$$EWG = \frac{C_W \times IR_W \times RAF_{Oral} \times D_2 \times D_3}{BW}$$

where:

| | | |
|---|---|---|
| EWG | = | exposure from the water ingestion pathway (µg/kg body weight/day) |
| $C_W$ | = | water chemical concentration (0.05 µg/L) |
| $IR_W$ | = | water ingestion rate of person (1.5 L/day) |
| $RAF_{Oral}$ | = | relative bioavailability fraction via the ingestion route (1.0) |
| $D_2$ | = | days per week exposed/7 days (1.0) |
| $D_3$ | = | weeks per year exposed/52 weeks (1.0) |
| BW | = | body weight of person (60 kg) |

Under this scenario, the estimated exposure to mercury from surface water ingestion was estimated to be 0.0012 µg/kg bw/day.

The Hazard Quotient from this route was then estimated as follows:

$$\textit{Hazard Quotient} = \frac{\textit{Estimated Exposure } (0.0012\ \mu g/kg\ bw/day)}{\textit{Tolerable Daily Intake } (0.57\ \mu g/kg\ bw/day)}$$

Thus, the Hazard Quotient value from surface water ingestion was estimated to be 0.0021.

Estimation of Risks from Dermal Contact with Drinking Water

Dermal contact with drinking water was another pathway of exposure that was quantitatively evaluated in the HHRA. Dermal exposure was estimated according to the following Health Canada (2009a) equation:

$$EDW = \frac{C_w \times SA_B \times PC \times D_1 \times D_2 \times D_3}{BW}$$

where:

| | | |
|---|---|---|
| EDS | = | exposure from the dermal pathway for drinking water (µg/kg/day) |
| $C_W$ | = | water chemical concentration (0.05 µg/L) |
| $SA_B$ | = | surface area of the entire body (1.8 $m^2$) |
| PC | = | permeability constant (1 x $10^{-5}$ m/hr) |
| $D_1$ | = | hours per day exposed to water (1 hr/day) |
| $D_2$ | = | days per week exposed/7 days (1.0) |
| $D_3$ | = | weeks per year exposed/52 weeks (1.0) |
| BW | = | body weight of person (60 kg) |
| UCF | = | unit correction factor (1000 L/$m^3$) |

Under this scenario, the estimated exposure to mercury from dermal contact with surface/drinking water was estimated to be 0.000015 µg/kg bw/day.

The Hazard Quotient from this route was then estimated as follows:

$$\text{Hazard Quotient} = \frac{\text{Estimated Exposure (0.000015 µg/kg bw/day)}}{\text{Tolerable Daily Intake (0.57 µg/kg bw/day)}}$$

Thus, the Hazard Quotient value from dermal contact with drinking water was estimated to be 0.000026.

**Estimation of Risks from All Surface Water Exposures**

Summing the risks from all exposure routes, the following Hazard Quotient was estimated:

| | |
|---|---|
| Hazard Quotient from ingestion of drinking water | 0.0021 |
| Hazard Quotient from dermal contact with drinking water | 0.000026 |
| Sum of all Hazard Quotients | 0.0021 |

### 5C-1-3.2 Worked Example #2: Risks Posed from Consumption of Walleye

In this worked example, risks posed to the young child receptor from consumption of post-impoundment walleye from Gull Lake are estimated. It was assumed that the young toddler consumed walleye at a rate of one time per week (serving size = 100 g).

To estimate exposures and risks, the following environmental concentrations were assumed:

- Methylmercury concentration in walleye (peak year post-impoundment) = 1.0 µg/g

In order to estimate exposure from consumption of walleye, the following equation was applied:

$$EFG = \frac{C_F \times IR_F \times RAF_{Oral} \times D_2 \times D_3}{BW}$$

where:

| | | |
|---|---|---|
| EFG | = | exposure from the country food ingestion pathway (µg/kg body weight/day) |
| $C_F$ | = | food chemical concentration (1.0 µg/g) |
| $IR_F$ | = | food ingestion rate of person (100 g/week or 14.3 g/day) |
| $RAF_{Oral}$ | = | relative bioavailability fraction via the ingestion route (1.0) |
| $D_2$ | = | days per week exposed/7 days (1.0) |
| $D_3$ | = | weeks per year exposed/52 weeks (1.0) |
| BW | = | body weight of person (16.5 kg) |

Under this scenario, the estimated exposure to methylmercury from consumption of walleye was estimated to be 0.87 µg/kg bw/day.

The Hazard Quotient from this route was then estimated as follows:

$$\text{Hazard Quotient} = \frac{\text{Estimated Exposure (0.87 µg/kg bw/day)}}{\text{Tolerable Daily Intake (0.2 µg/kg bw/day)}}$$

Thus, the Hazard Quotient value from consumption of walleye at a rate of once per week during the peak year following impoundment was estimated to be 4.3 for the young toddler.

### 5C-1-4 Toxicological Reference Values Used in the HHRA

As discussed in the Main Report, toxicological reference values were selected using Health Canada guidance.  The rationale for the selected TRVs is provided below.

***Mercury, Methyl***

Health Canada (2010b) recommends the following TDIs for methyl mercury:

- 0.2 μg/kg body weight/day for sensitive members of the general population (i.e., pregnant women, women of child-bearing age, infants and young children)

- 0.47 μg/kg body weight/day for non-sensitive member of the general population

Health Canada (1998; 2002) proposed an interim revised TDI of 0.2 μg/kg body weight/day for sensitive members of the population. The proposed interim revision of the TDI was based on a studies completed in human populations consuming fish in New Zealand, Republic of Seychelles and the Faroe Islands. The endpoint of primary concern was related to neurological development of children born to women consuming large amounts of fish with elevated methyl mercury concentrations. Based on these studies, Health Canada (1998) developed a benchmark dose of dietary intake equal to 1 μg/kg body weight/day that was felt to represent a dose where no adverse effects were observed. With the application of a 5-fold uncertainty factor to this benchmark dose, Health Canada then proposed an interim TDI for pregnant women, women of child-bearing age, and infants of 0.20 μg/kg body weight/day. Health Canada (1998; 2002) advised that this should be regarded as a temporary measure only and revised guidance may still be developed. For non-sensitive members of the general population, Health Canada (2010) cited a TDI of 0.47 μg/kg body weight per day.  These TDIs were assumed to be protective of adverse health effects from methyl mercury.

***Mercury, Inorganic***

For evaluation of mercury when it is not present in fish, the human health risk assessment has relied on the recommendations of WHO (2010).  WHO (2010) Committee established a provisional tolerable weekly intake (PTWI) for inorganic mercury of 4 μg/kg bw.  WHO (2010) indicated that this PTWI for inorganic mercury was considered applicable to dietary exposure to total mercury from foods other than fish and shellfish. WHO (2010) also indicated that this was applicable to the whole population and did not indicate that risks would be additive with methylmercury exposures (i.e., WHO [2010] concluded that the upper limits of estimates of average dietary exposure to total mercury from foods other than fish and shellfish for adults (1 µg/kg bw per week) and for children (4 µg/kg bw per week) were at or below the PTWI for inorganic mercury and did not indicated a requirement to sum the methylmercury exposures). Consequently, this PTWI was used as the source of the TDI. To estimate a TDI, the PTWI was simply divided by 7 days. Consequently, a TDI of 0.57 µg/kg bw/day was estimated. This value was used to estimate risks from total mercury present in foods other than fish and shellfish and from mercury present in surface water.

In summary, the following Tolerable Daily Intakes were used to evaluate the neurological potential of inorganic of mercury:

- Total mercury TDI of 0.57 µg/kg bw/day for young children and women of child-bearing age;
- Total mercury TDI of 0.57 µg/kg bw/day for the rest of the population.

**5C-1-5 Detailed Risk Estimates**

The risk estimates for the various receptors and issues of concern are provided in Tables 5C-1-1 to 5C-1-7.

**Table 5C-1-1 Preliminary Risk Estimates from Mercury Due to Consumption of Country Foods: Baseline Conditions at Gull Lake**

| Food Item | Assumed Concentration (ug/g wet weight) | Proposed Consumption Frequency (meals per week) | Serving Size for Toddler (ounces) | Serving Size for Adult (ounces) | HQ for Toddlers | HQ for Women of Childbearing Age | HQ for Adult Males and All Seniors |
|---|---|---|---|---|---|---|---|
| ***Fish*** | | | | | | | |
| Lake Whitefish | 0.07 | 3 | 3.5 | 14 | 0.9 | 1.0 | 0.4 |
| Jackfish (pike) | 0.22 | 3 | 3.5 | 14 | 2.8 | 3.1 | 1.1 |
| Pickerel (walleye) | 0.23 | 3 | 3.5 | 14 | 3.0 | 3.3 | 1.2 |
| Lake Sturgeon | 0.2 | 3 | 3.5 | 14 | 2.6 | 2.8 | 1.0 |
| ***Birds*** | | | | | | | |
| Duck | 0.07 | 1 | 2 | 7 | 0.17 | 0.17 | 0.06 |

HQ = Hazard Quotient

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**Table 5C-1-2 Preliminary Risk Estimates from Mercury Due to Consumption of Country Foods: Baseline Conditions at Stephens Lake**

| Food Item | Assumed Concentration of Mercury (ug/g wet weight) | Assumed Consumption Frequency (meals per week) | Serving Size for Toddler (ounces per meal) | Serving Size for Adult (ounces per meal) | HQ for Toddlers | HQ for Women of Childbearing Age | HQ for Adult Males and All Seniors |
|---|---|---|---|---|---|---|---|
| ***Fish*** | | | | | | | |
| Lake Whitefish | 0.09 | 3 | 3.5 | 14 | 1.2 | 1.3 | 0.5 |
| Jackfish (pike) | 0.26 | 3 | 3.5 | 14 | 3.3 | 3.7 | 1.3 |
| Pickerel (walleye) | 0.29 | 3 | 3.5 | 14 | 3.7 | 4.1 | 1.5 |
| ***Birds*** | | | | | | | |
| Duck | 0.09 | 1 | 2 | 7 | 0.22 | 0.21 | 0.08 |

HQ = Hazard Quotient

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**Table 5C-1-3 Preliminary Risk Estimates from Mercury Due to Consumption of Country Foods: Post-Impoundment Conditions at Gull Lake**

| Food Item | Assumed Concentration of Mercury (ug/g wet weight) | Assumed Consumption Frequency (meals per week) | Serving Size for Toddler (ounces per meal) | Serving Size for Adult (ounces per meal) | HQ for Toddlers | HQ for Women of Childbearing Age | HQ for Adult Males and All Seniors |
|---|---|---|---|---|---|---|---|
| ***Fish*** | | | | | | | |
| Lake Whitefish | 0.19 | 3 | 3.5 | 14 | 2.4 | 2.7 | 1.0 |
| Jackfish (pike) | 1.0 | 3 | 3.5 | 14 | 12.9 | 14.2 | 5.1 |
| Pickerel (walleye) | 1.0 | 3 | 3.5 | 14 | 12.9 | 14.2 | 5.1 |
| Lake Sturgeon | 0.3 | 3 | 3.5 | 14 | 3.9 | 4.2 | 1.5 |
| ***Birds*** | | | | | | | |
| Duck | 0.19 | 1 | 2 | 7 | 0.47 | 0.45 | 0.16 |

HQ = Hazard Quotient

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**Table 5C-1-4 Preliminary Risk Estimates from Mercury Due to Consumption of Country Foods: Post-Impoundment Conditions at Stephens Lake**

| Food Item | Assumed Concentration of Mercury (ug/g wet weight) | Assumed Consumption Frequency (meals per week) | Serving Size for Toddler (ounces per meal) | Serving Size for Adult (ounces per meal) | HQ for Toddlers | HQ for Women of Childbearing Age | HQ for Adult Males and All Seniors |
|---|---|---|---|---|---|---|---|
| ***Fish*** | | | | | | | |
| Lake Whitefish | 0.15 | 3 | 3.5 | 14 | 1.9 | 2.1 | 0.8 |
| Jackfish (pike) | 0.5 | 3 | 3.5 | 14 | 6.4 | 7.1 | 2.5 |
| Pickerel (walleye) | 0.5 | 3 | 3.5 | 14 | 6.4 | 7.1 | 2.5 |
| Lake Sturgeon | 0.25 | 3 | 3.5 | 14 | 3.2 | 3.5 | 1.3 |
| ***Birds*** | | | | | | | |
| Duck | 0.15 | 1 | 2 | 7 | 0.37 | 0.35 | 0.13 |

HQ = Hazard Quotient

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**Table 5C-1-5 Preliminary Risk Estimates from Mercury Due to Consumption of Country Foods: Baseline Conditions**

| Food Item | Assumed Concentration of Mercury (ug/g wet weight) | Assumed Consumption Frequency (meals per week) | Serving Size for Toddler (ounces per meal) | Serving Size for Adult (ounces per meal) | HQ for Toddlers | HQ for Women of Childbearing Age | HQ for Adult Males and All Seniors |
|---|---|---|---|---|---|---|---|
| ***Mammals*** | | | | | | | |
| Beaver | 0.01 | 3 | 2 | 7 | 0.03 | 0.02 | 0.02 |
| Muskrat | 0.02 | 1 | 2 | 7 | 0.02 | 0.02 | 0.01 |
| Moose | 0.07 | 5 | 3.5 | 14 | 0.53 | 0.58 | 0.49 |
| Rabbit* | 0.05 | 1 | 2 | 7 | 0.04 | 0.04 | 0.03 |

* Concentrations of mercury in rabbit have only been evaluated semi-quantitatively at the current time

HQ = Hazard Quotient

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**Table 5C-1-6 Preliminary Risk Estimates from Mercury Due to Consumption of Country Foods: Future Conditions**

| Food Item | Assumed Concentration of Mercury (ug/g wet weight) | Assumed Consumption Frequency (meals per week) | Serving Size for Toddler (ounces per meal) | Serving Size for Adult (ounces per meal) | HQ for Toddlers | HQ for Women of Childbearing Age | HQ for Adult Males and All Seniors |
|---|---|---|---|---|---|---|---|
| ***Mammals*** | | | | | | | |
| Beaver | 0.01 | 3 | 2 | 7 | 0.03 | 0.02 | 0.02 |
| Muskrat | 0.04 | 1 | 2 | 7 | 0.03 | 0.03 | 0.03 |
| Moose | 0.07 | 5 | 4 | 14 | 0.53 | 0.58 | 0.49 |
| Rabbit* | 0.05 | 1 | 2 | 7 | 0.04 | 0.04 | 0.03 |

* Concentrations of mercury in rabbit have only been evaluated semi-quantitatively at the current time

HQ = Hazard Quotient

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**Table 5C-1-7 Risk Estimates for Traditional Land Use - Based on Total Mercury Surface Water Concentrations (Present and Future Assumed to Equal 0. 05 ug/L)**

| Receptor of Concern | Assumed Surface Water Conc (ug/L) | HQ dermal - surface water | HQ - ingestion of drinking water | HQ all routes of surface water contact |
|---|---|---|---|---|
| Toddler | 5.0E-02 | 0.000032 | 0.0032 | 0.0032 |
| Woman of Childbearing Age | 5.0E-02 | 0.000026 | 0.0022 | 0.0022 |
| Adult Male | 5.0E-02 | 0.000022 | 0.0019 | 0.0019 |

HQ = Hazard Quotient