SECTION 8

WILDLIFE AND MERCURY

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8.0 WILDLIFE AND MERCURY

8.1 GENERAL INTRODUCTION

Mercury is a heavy metal that occurs naturally in plants, animals, air, water, sediments, bedrock, and soil (Environment Canada 2000). When soils are flooded by natural or anthropogenic events (*e.g.*, hydroelectric reservoir creation), soil-bound inorganic mercury is released into the aquatic ecosystem. Once in the aquatic environment, bacteria living in the water will inadvertently consume inorganic mercury while feeding on decomposing organic matter. Through bacteria digestion processes, inorganic mercury is converted to the organic, cell-binding form called methylmercury (MeHg; Health Canada 2007). Since this form is readily absorbed into the tissues of animals (it has a strong affinity for proteins), and has low elimination rates (especially in fish), it can potentially have negative effects on animal health due to **biomagnification** (DesGranges *et al.* 1999).

The following section provides information on the potential effects of mercury on the terrestrial wildlife community (referred to as 'wildlife') in the Keeyask region. For information on the interaction of mercury and people, including how increases in mercury may affect human consumption of fish and wildlife, see Section 5 of the Socioeconomic Supporting Volume (SE SV). For information on mercury in water, aquatic invertebrates, and fish, see the Aquatic Environment Supporting Volume (AE SV).

The introduction to pathways and potential effects used to describe general Project linkages are outlined in Section 8.1.1. The general approach and the methodology used to describe the existing environment and to predict Project effects on bird and mammal mercury concentrations are outlined in Section 8.2. Detailed descriptions of the existing environment and effects assessment are described for birds in Section 8.3 and for mammals in Section 8.4. For each major section on birds and mammals, a description of the environmental setting, including an overview of historical mercury concentrations where available, and current trends is provided. Construction and operation effects and potential mitigation measures are discussed separately under birds and then mammals. Residual impacts, cumulative impacts, and monitoring and follow-up are provided in Sections 8.3.4.2 to 8.3.4.5 for birds, and Sections 8.3.4.3 to 8.3.4.6 for mammals.

8.1.1 Introduction to Pathways and Potential Effects

In Manitoba lakes and reservoir water, methylmercury naturally occurs at low concentrations (*i.e.*, 0.8-2.0 parts per trillion [ppt]; AE SV). If the Project is developed, background mercury concentrations in the Keeyask reservoir water would increase due to the flooding of organic soils and release of soil bound mercury. While the actual increase of dissolved inorganic mercury in the water would be small, the biomagnifications process would lead to an increase in the concentration of methylmercury in the aquatic food chain. As lower **trophic level** organisms (*e.g.*, aquatic insects, clams, fish) are consumed by higher trophic level organisms (*e.g.*, ducks, river otters), methylmercury is passed on, leading to the **bioaccumulation** of methylmercury in higher trophic level organisms. Since methylmercury is not easily removed from the tissues of most animals (birds being the exception), it has the potential to negatively affect a range of organisms including mammals and birds. This is particularly true of long-lived higher trophic level organisms whose diets chiefly consist of large-bodied fish (Braune *et al.* 1999; Scheuhammer 1995). For example, larger predatory fish that occupy a higher trophic level in the aquatic food chain (*e.g.*, northern pike, walleye (also known as pickerel in the SE SV)) contain higher levels than smaller fish (AE SV). Terrestrial animals that consume top predatory fish would likely have even higher amounts of mercury in their tissues (*e.g.*, muscle, liver) than top predatory fish due to bioaccumulation.

As methylmercury moves further up the food chain it biomagnifies and can have negative effects on the health of wildlife, particularly higher-trophic **piscivorous** birds and mammals (*e.g.*, loons and river otters; Wren 1986; Scheuhammer *et al.* 2007). At certain concentrations, mercury levels have been shown to negatively affect the health and reproductive ability of some species. For instance, concentrations of 0.5 μg/g[1] of mercury in the muscle tissues of mallards have caused a decline in the number of eggs laid (Heinz 1976b). For common loon, mercury concentrations of 1.6 μg/g in muscle tissue have been shown to cause a reduction in the number of territories established and in the number of eggs laid (Barr 1986). While wild birds may carry high levels of mercury in their tissues (including brain, liver and muscle), levels are very rarely high enough to be lethal.

For mink, ingesting mercury concentrations of 0.08 μg/kg/day have been shown to result in mortality, weight loss, and behavioral changes (NALCOR 2009a). Using this value and scaling for body-size, ingesting mercury concentrations of 0.07 μg/kg/day are expected to result in adverse effects including mortality, weight loss and behavioural changes (NALCOR 2009a).

8.2 GENERAL APPROACH AND METHODOLOGY

Generally, the approach taken for the impact assessment of mercury concentrations in birds and mammals was similar to the approach applied for other terrestrial components. The assessment comprised two major components: a description of the existing conditions in the Project area to provide the foundation for assessing the potential effects of the Project on bird and mammal mercury concentrations; and an impact assessment in which potential effects of the Project on bird and mammal mercury concentrations were described.

The assessment focused on aquatic and riparian birds and mammals of domestic importance for resource users (*i.e.*, Canada goose, mallard, beaver, muskrat). Osprey, mink and river otter are at the top of the aquatic food web and represent the worst-case scenario in terms of bird and mammal mercury concentrations. In addition, other wildlife species (*e.g.*, scoter, scaup, terns, moose, caribou) and other resources of domestic importance (*i.e.*, eggs) for resource users were reviewed for mercury to provide background information and to gain a better understanding of mercury in the aquatic and terrestrial environment at different trophic levels.

Different approaches were used to describe existing conditions in the environmental setting for birds and mammals. Where field data were not available for birds, literature was used to approximate baseline values in the Keeyask Study Area. The existing conditions for mammal species including beaver, muskrat,

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[1] μg/g (micro grams per gram) is equivalent to ppm (parts per million)

mink and river otter were defined over a period of six years (2003-2008). The six-year period was necessary to collect sufficient data to characterize the Regional Study Area. Other species of domestic interest included moose and caribou, where a limited number of samples were collected in 2010/11. Existing mercury concentrations were also determined for mammals from off-system areas that will serve as regional comparison areas to monitor natural fluctuations or trends in mammal mercury concentrations against which corresponding changes in the Local and Regional Study Areas can be compared.

The environmental setting included a description of historical information where available to provide an overview of how wildlife mercury concentrations have changed over time and background data against which future changes can be evaluated. Long-term data were not available for birds. Point-in-time references for river otter and mink were examined for Stephens Lake, and comparison including Southern Indian Lake, Wuskwatim Lake, and Split Lake in northern Manitoba (Environment Canada 1987).

Potential impacts of the Project on mercury concentrations in mallard, Canada goose, bald eagle, osprey, muskrat, beaver, mink and river otter were assessed by modeling expected concentrations by:

- Using a predictive model from the scientific literature; and
- Using historic and recent data from nearby reservoirs (*i.e.*, Southern Indian Lake and Stephens Lake) as proxies for the future Keeyask reservoir.

The possible concentration of mercury levels in birds, and the duration of elevated mercury concentrations in birds and mammals were estimated based on model estimates from fish in the Gull Lake and Stephens Lake area (AE SV). Fish information sources used for the assessment were linked to information obtained from the EIS studies, predictions generated for the Physical Environment Supporting Volume (PE SV) and Section 2 (Water and Sediment Quality) of the AE SV, and scientific literature pertaining to hydroelectric development in Manitoba and elsewhere.

The potential impacts of the Project on mercury levels in bald eagle, osprey, river otter and mink were assessed using a **risk characterization approach**. This approach uses exposure and toxicity assessments to link a chemical of potential concern, in this case methylmercury (MeHg), with adverse ecological effects (NALCOR 2009a). The **hazard quotient** (HQ), the ratio of "the average concentration of mercury being ingested" to a "known concentration where adverse effects may occur (**toxicity reference value** (TRV)," was calculated in order to predict whether MeHg will have adverse effects to top-level bird and mammal predators in the Local Study Area, specifically the Keeyask reservoir and Stephens Lake. Potential wildlife health effects were assessed further using the scientific literature.

8.2.1 Study Area

Mammal sampling for mercury studies was conducted in the Keeyask region, with the majority of sampling contained within Zone 6 (see Section 7, Map 7-1), which is an area of approximately 30,500 km^2 .Samples were also collected outside this zone for comparison purposes. Refer to Section 1 (Introduction) of the TE SV for a detailed description of the study areas in the Keeyask region.

For the effects assessment of mercury in wildlife, the Local Study Area is defined as Zone 4 (2,215 km²) and the Regional Study Area is defined as Zone 5 (14,160 km²).

8.3 BIRDS AND MERCURY ASSESSMENT

8.3.1 Introduction

Mercury is a naturally occurring element that can enter aquatic environments through the flooding of soils. Bacteria in the water consume inorganic mercury inadvertently while feeding on and decomposing organic matter. Through bacterial digestion of organic matter, methylation of mercury occurs, producing organic methylmercury (MeHg; Health Canada 2007). Since this form is readily absorbed into the tissues of animals (it has a strong affinity for proteins), and has low elimination rates (especially in fish), it can biomagnify and potentially have negative effects on the health of birds (DesGranges *et al.* 1999).

In Manitoba lakes and reservoir water, methylmercury naturally occurs at low concentrations (*i.e.*, 0.8-2.0 parts per trillion [ppt]; (AE SV). When land is flooded as a result of reservoir creation, mercury concentrations often increase, potentially putting birds that feed on aquatic organisms at risk of developing mercury related health problems.

Plants do not present a significant source of methylmercury to birds that consume them as plants are at the bottom of the food chain (*i.e.*, lower trophic level organisms) and consequently take up and retain only minute levels of methylmercury (Scheuhammer 1995). Aquatic invertebrates and small fish tend to contain slightly higher levels of methylmercury in their tissues in comparison to plants. Larger predatory fish that are higher up on the aquatic food chain (*e.g.*, [1]northern pike, walleye) contain even higher levels (Scheuhammer 1995). Animals at higher trophic levels have the potential to acquire a greater body burden of mercury than animals at lower trophic levels due to the bioaccumulation of methylmercury through the food chain (Scheuhammer 1995; Braune *et al.* 1999). As methylmercury moves up the food chain it biomagnifies and becomes more toxic to birds, especially long-lived higher-trophic piscivorous birds (*e.g.*, loons; Sheuhammer *et al.* 2007).

The primary avenue for the transfer of mercury to birds is through consumption of methylmercury–contaminated aquatic organisms (*e.g.*, invertebrates, fish). Thus, birds with diets consisting of aquatic organisms, such as waterbirds (*e.g.*, ducks, loons, terns), piscivorous raptors (*e.g.*, ospreys and eagles) and some species of songbirds (*e.g.*, swallows, northern waterthrush), are potentially at risk of accumulating high levels of methylmercury in their tissues in environments where mercury levels are elevated (Gerrard and St. Louis 2001). While high mercury levels (*e.g.*, 0.5 ppm in muscle tissue) can have negative effects on the health and reproductive ability of some bird species, levels encountered in the wild are very rarely high enough to be lethal to birds (Evers *et al.* 2005).

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[1] ppm (parts per million) is equivalent to µg/g (micro grams per gram)

8.3.2 Approach and Methodology

Studies measuring the existing mercury levels in birds have not occurred within the Regional Study Area. Instead, information from previous scientific studies conducted across Canada, as well as background levels in fish species from Gull Lake, provide a baseline estimate for existing mercury levels in birds using aquatic environments within the Local Study Area (Langis *et al.* 1999; Braune *et al.* 1999 and Braune and Malone 2006).

Studies have shown that certain fish and bird species that consume a similar diet, or share similar feeding habits, display comparable levels of mercury in their muscle tissue (DesGranges *et al.* 1998; Schetagne *et al.* 1999; Gerrard and St. Louis 2001; Hydro-Quebec 2007). For example, while northern pike consume a diet consisting mainly of fish, they will also consume amphibians, ducklings and other organisms when available. Northern pike diet is not unlike the diet of common merganser, a bird that consumes small fish (<10 cm), crustaceans, amphibians and small mammals. While both merganser and pike diets are similar, they differ in that pike consume larger-bodied fish and therefore have potential to bioaccumulate higher levels of mercury than mergansers. As a result, mercury burdens in mergansers would likely be similar to but less than mercury levels in pike. Comparatively, mercury body burdens in birds that consume larger-bodied fish (*e.g.*, northern pike), will likely be higher than levels observed and/or predicted for northern pike due to the bioaccumulation of mercury in higher trophic level organisms.

Using fish as indicators of mercury in birds that share similar feeding habits (Table 8-1) and foraging habitat (*e.g.*, Gull Lake) is one of the methods used to establish background estimates for mercury in birds using the Local Study Area. Results from Canada-wide studies that measured mercury levels in birds add support to levels extrapolated from Gull Lake northern pike, walleye and lake whitefish.

Table 8-1: Comparison of Fish and Waterbird Diets

Species	**Mature Whitefish**	**Mallard**	**Ring-necked Duck**	**Common Goldeneye**	**Lesser Scaup, White-winged Scoter**
Diet	Small fish, fish eggs, aquatic insect larvae, clams, snails	Insect larvae, aquatic invertebrates, plants	Plant seeds, submergent vegetation, snails, insects, aquatic invertebrates	Crustaceans (crab, shrimp), aquatic invertebrates (*e.g.*, insect larvae)	Aquatic invertebrates (*e.g.*, amphipods), mollusks (mussels, snails)
Species	**Northern Pike, Walleye**	**Common Merganser**	**Common Tern**	**Ring-billed Gull, Herring Gull**	**Loon**
Diet	Fish, crayfish, frogs, mice, ducklings, leeches, worms	Small fish (<10 cm) crustaceans, aquatic invertebrates, amphibians, small mammals, plants	Small fish, insects, crustaceans	Fish, other birds, bird eggs, garbage, carrion	Yellow perch, white sucker

8.3.3 Environmental Setting

8.3.3.1 Waterbirds

Waterbirds include waterfowl, gulls, terns, grebes, herons, pelicans and cormorants. Waterfowl include dabbling ducks (*e.g.*, mallard, teal, pintail), diving ducks (*i.e.*, bay [*e.g.*, scaup, ring-necked ducks], sea ducks [*e.g.*, scoter, goldeneye]), geese and swans. These birds eat a diet consisting of foods that are low on the food chain such as sedges, insects, molluscs and occasionally small fish (Bellrose 1976). Because these prey species have not accumulated appreciable amounts of methylmercury, waterfowl preying upon them have low potential to acquire the levels of methylmercury that would have negative effects on either their health or the health of those that consume them (Braune *et al.* 1999; Braune and Malone 2006).

The waterfowl group also includes mergansers, a species of duck that feeds primarily on fish. Since fish are higher trophic level organisms, mergansers have greater potential of accumulating higher levels of methylmercury than other duck species that consume lower trophic level organisms (*e.g.*, aquatic invertebrates).

Mercury levels in waterfowl have been reported for various sites located across Canada (Braune *et al.* 1999; Langis *et al.* 1999; Braune and Malone 2006). However, mercury levels reported for waterfowl species are often highly variable due to differences between sites where samples were taken (Table 8-2). Due to this variability, these estimates can function as a benchmark by which to compare levels of mercury in birds but not necessarily as predictors of mercury burdens in birds using a particular area of interest (*e.g.*, Keeyask Project Area). Instead, existing mercury levels in fish using the area of interest can function as better predictors of mercury levels in birds (Schetagne *pers. comm.* 2009). Therefore, mercury levels in waterbird species using the Regional Study Area were based on the mercury levels measured in local fish populations inhabiting Gull Lake and Stephens Lake (Table 8-3). Background levels in fish using these lakes were between 0.07-0.09 ppm in whitefish tissue (consumer of crustaceans, snails, insects), and between 0.22-0.29 ppm in northern pike and walleye tissue (Table 8-4).

Based on their feeding habits and diet of deep-water (benthic) invertebrates and fish, benthivorous whitefish can be used to estimate methylmercury levels in waterbirds that consume similar diets or share similar feeding habits (*e.g.*, scoter; Table 8-4). For strictly herbivorous or herbivorous/benthivorous birds, levels of methylmercury in muscle tissue will likely be less than levels observed in whitefish tissue. Piscivorous northern pike and walleye can be used to estimate methylmercury levels in waterbirds that consume a similar diet of fish (*e.g.*, merganser, loon; Table 8-4). For species with diets that include some fish, levels in pike and walleye can also be used as indicators of methylmercury burdens in bird muscle tissue. In this case, predicted methylmercury levels in birds (*e.g.*, gulls and terns) that consume a mixed diet of fish and other lower trophic level organisms are likely overestimated, as pike and walleye consume a diet primarily of fish (higher trophic level organisms) and thus contain higher levels of methylmercury. In the absence of data on fish species having comparable feeding habits and a diet similar to gulls and terns, pike and walleye data provide useful estimates when used in the right context.

Table 8-2: Mean Total Mercury Concentrations in Muscle Tissue of Waterbirds Using the Quebec Hydroelectric Project Areas (1989-1991 Baseline/Predevelopment Levels)[1] and 123 Sites Located Canada-wide (1987-1995)[2]

Species	Mean Total Mercury Level (ppm) [n=sample size]		
	Quebec Hydroelectric Project Areas[1]		Canada-wide Summary[2] [n=123 sites]
	Notaway-Broadback-Rupert	Grande Baleine	
Strictly Herbivorous			
Canada goose	0.03 (n=26)	0.05 (n=35)	0.03 (n=381)
Herbivorous/benthivorous			
Mallard	0.2 (n=58)	0.16 (n=82)	0.04 (n=800)
Green-winged teal			n/a
Northern pintail			0.06 (n=156)
American wigeon	n/a	n/a	0.02 (n=115)
Benthivorous			
Black scoter	0.71 (n=1)	0.21 (n=69)	0.2 (n=35)
Surf scoter			0.17 (n=66)
White-winged scoter	n/a	n/a	0.11 (n=34)
Mixed			
Greater scaup	0.19 (n=45)	0.21 (n=42)	0.11 (n=63)
Lesser scaup			0.09 (n=165)
Common goldeneye			0.22 (n=135)
Ring-necked duck			0.03 (n=63)
Piscivorous-invertivorous			
Terns	1.09 (n=12)	0.8 (n=20)	n/a
Piscivorous-omnivorous			
Herring gull	1.59 (n=13)	1.03 (n=28)	n/a
Piscivorous			
Common merganser	0.97 (n=50)	0.9 (n=76)	0.61 (n=95)
Red-breasted merganser			0.42 (n=68)
Common loon			0.83 (n=57)

*Source: [1]Langis *et al.* 1999; [2] Braune *et al.* 1999 and Braune and Malone 2006

Table 8-3: Estimates of Existing Total Mercury Concentrations in Muscle Tissue of Waterbirds Based on Existing Levels Measured in Fish Inhabiting Gull Lake and Stephens Lake

Waterbird Species	Bird Feeding Group	Comparable Fish Feeding Group	Fish Species	Total Mercury Levels in Fish (ppm)[1]	Estimated Total Mercury Levels in Birds (ppm)	Canada-Wide Average Total Mercury in Birds (ppm)[2]
Geese	Strictly Herbivorous	n/a	n/a	n/a	0.03	0.03
Mallard, green-winged teal, northern pintail, ring-necked duck	Herbivorous/ benthivorous	Benthivorous	Whitefish	0.07-0.09	<0.07-0.09	0.04
Black scoter, surf scoter, common goldeneye, Scaup	Benthivorous	Benthivorous	Whitefish	0.07-0.09	0.07-0.09	0.13
Tern	Piscivorous-insectivorous	Piscivorous	Northern pike and walleye	0.22-0.29	0.22-0.29	n/a
Herring gull	Piscivorous-omnivorous	Piscivorous	Northern pike and walleye	0.22-0.29	0.22-0.29	n/a
Common merganser, red-breasted merganser, loon	Piscivorous	Piscivorous	Northern pike and walleye	0.22-0.29	0.22-0.29	0.61

Source: [1] Aquatic Environment Supporting Volume, Table 7-2

Within the Gull Lake and Stephens Lake area, both the mercury levels measured in fish and the levels predicted for waterbirds fall within (or just below) the ranges in mercury levels reported for both fish and waterbirds in Quebec (Table 8-4).

Table 8-4: Summary of Total Mercury Concentrations in Muscle Tissue of Fish and Waterfowl and Fish-eating Waterbirds Using the Nottaway-Broadback-Rupert (NBR) and Grande Baleine Hydroelectric Project Areas in Quebec (1989-1991 Baseline/Predevelopment Levels)[1]

	Muscle Mercury Levels (ppm) [n=sample size]					
	Fish		**Birds**			
Project Area	**Benthivorous (*e.g.*, whitefish)**	**Piscivorous (*e.g.*, pike and walleye)**	**Benthivorous (*e.g.*, scoter)**	**Piscivorous-invertivorous (*e.g.*, tern)**	**Piscivorous-omnivorous (*e.g.*, gull)**	**Piscivorous (*e.g.*, loon, merganser)**
NBR, Quebec	0.07-0.36 (n=1,025)	0.33-1.81 (n= 2,229)	0.17 (n=1)	1.1 (n=12)	1.59[1] (n=13)	0.98 (n=50)
Grande Baleine, Quebec	0.08-0.27 (n=309)	0.45 (n=23)	<0.21 (n=69)	0.8 (n=20)	1.03 (n=28)	0.9 (n=76)
Keeyask, Manitoba	0.07-0.091[2]	0.22–0.26[2]	0.07-0.09*	0.22–0.26*	0.22–0.26*	0.22–0.26*

Source: Schetagne and Verdon 1999; Langis *et al.* 1999

[1] High mercury levels explained by preference for carrion (*e.g.*, large dead fish with higher mercury levels) over live fish

[2] Levels measured in fish, 2003 and 2004

* Predicted levels based on mercury levels in fish taken from Split Lake, Gull Lake and Stephens Lake 2003, 2004

8.3.3.2 Piscivorous Raptors

Piscivorous raptors inhabiting the Regional Study Area include osprey and bald eagle. Osprey typically consume a diet exclusively of fish (*e.g.*, sucker, northern pike, walleye) 10-30 cm in length, while bald eagles feed on fish, birds and other animals including carrion (Watson and Pierce 1998). In the wild, osprey live for approximately 15-20 years while bald eagle can live 20-30 years.

Since both osprey and bald eagle are long-lived and at the top of the food chain, they have the potential to accumulate high levels of contaminants including mercury. A study in northern Quebec found that osprey nesting near reservoirs (*e.g.*, La Grande) had high burdens of methylmercury in their muscle tissues (1.79 ppm; DesGranges *et al.* 1998). These levels are similar to those measured in northern pike from La Grande reservoirs (0.8-2.3 ppm in muscle; DesGranges *et al.* 1998). While these levels appear to be high, the number of chicks fledged near reservoirs did not differ from the number of chicks that fledged in natural habitats (*e.g.*, lakes and rivers; DesGranges *et al.* 1998).

Osprey are migratory, breeding in Canada in the spring and summer and over-wintering in central and south America. Based on the analysis of egg tissues, background mercury levels in adult osprey are often low when arriving on the breeding grounds, as methylmercury levels in osprey egg tissues did not differ between those laid near reservoirs and those laid near natural lakes and rivers (DesGranges *et al.* 1998). Osprey chicks raised near reservoirs did, however, accumulate five times higher levels of methylmercury than chicks raised in natural environments. Fortunately the growth of feathers, beginning at 20 days old and completed at 45 days old, provides young chicks with a way in which to store mercury away from living tissues (*e.g.*, liver). However, once fledged, young osprey foraging in reservoirs are at risk to accumulating high levels of methylmercury in living tissues. It is not until young osprey leave the breeding grounds, that mercury exposure decrease substantially. Most of the mercury in young osprey is eliminated during the first winter moult (*i.e.*, two- to three-month half-life of mercury; DesGranges *et al.* 1998).

8.3.3.3 Current Trends

8.3.3.3.1 Mercury Exposure in Birds

Predicting how elevated levels of methylmercury in the aquatic food chain will affect bird communities is a complex process that requires consideration of a number of variables. The degree in which birds are exposed to elevated levels of mercury (Hg) is dependent upon diet and geographic location of breeding, over-wintering and foraging grounds (Becker *et al.* 1994; Evers *et al.* 2005; Scheuhammer *et al.* 2007). The build up of mercury in birds is also related to species longevity as longer-lived species have a greater potential to bioaccumulate higher levels of mercury than shorter-lived species. While exposure rates can be highly variable, so can the rate at which birds remove methylmercury from their tissues. Birds have the ability to mobilize muscle-bound mercury into the blood for transport into feathers and, in the case for egg-laying females, into eggs (Section 8.3.3.3.3).

8.3.3.3.2 Influence of Forage Location on Mercury levels in birds

Mercury exposure rates in birds can vary depending upon the location where foraging takes place. For instance, mercury concentrations in aquatic food chains are generally lower in rivers than lakes due to the flow-through or flushing of water in riverine environments (Evers *et al.* 2005). Lake mercury levels also tend to be higher than river levels because lakes are often subject to flooding during seasonal events (*e.g.*, spring thaw). Seasonal flooding and human induced impoundments can drive levels of methylmercury up through the release of soil-bound mercury and organic material (Evers *et al.* 2005).

Birds that forage for greater periods of time in environments with elevated mercury concentrations are more likely to experience greater mercury accumulation. In northern Quebec, DesGrange *et al.* (1998) found that osprey nesting near and foraging within aquatic environments with elevated mercury concentrations, such as reservoirs associated with hydro-electric development, had higher mercury levels within their tissues than birds living and foraging in neighbouring, undisturbed habitats.

In the Regional Study Area, some species of bird forage and breed within and adjacent to the aquatic habitats anticipated to experience Project-related flooding (*e.g.*, Gull Lake), while other species only utilize the area briefly as a stop-over site during migration. The degree of methylmercury exposure for birds using the Regional Study Area following Project construction is therefore highly dependent upon duration of time spent in affected areas (*e.g.*, Keeyask reservoir, Nelson River immediately downstream of the GS site).

Exposure to food sources with elevated levels of mercury during Project operation could be as little as a few days for migrants to as many as six months for birds breeding along the Nelson River. Within this time, exposure to prey items including aquatic invertebrates, molluscs and small fish containing elevated levels of mercury may be highly variable as birds are mobile and may forage outside of affected areas.

Following impoundment, exposure to methylmercury is anticipated to be higher for the population of birds that breed within the Project Footprint area (*e.g.*, gulls), and/or spend considerable time foraging within the Project Footprint area (*e.g.*, bald eagles) than for individuals of the same species breeding and foraging elsewhere in the Regional Study Area. Increases in background mercury levels within the aquatic food chain are anticipated to be limited to the reservoir and areas of the river downstream to Kettle Generating Station (GS).

8.3.3.3.3 Mercury Depuration in Birds

Ingestion of mercury-contaminated organisms represents the primary source of avian exposure to methylmercury. Following consumption, methylmercury is readily absorbed into the blood and distributed to various tissues including the brain, liver, kidney and muscle where it begins to accumulate over time. Some of these tissues, such as the liver and kidney, are considered to be accumulation end points, where the mercury becomes largely unavailable for remobilization within the body (Evers *et al.* 2005). Methylmercury deposited into muscle tissue however, is available for remobilization through depuration, a natural process that allows birds to partially eliminate various toxins, such as methylmercury, from their bodily tissues (Evers *et al.* 2005).

One of the main pathways of mercury depuration is through feathers, although egg laying, excretion and dilution (*i.e.*, growth) can also decrease body burdens of methylmercury (Furness *et al.* 1986; Braune 1987; Braune and Gaskin 1987; Becker *et al.* 1993; DesGranges *et al.* 1999). During the seasonal feather moult, mercury is remobilised from muscle tissue and carried by the blood into newly developing feathers (Evers *et al.* 2005). Methylmercury ingested through the diet is also readily transferred into growing plumage, where it binds to keratin in the feathers and is transferred out of the body during the next moulting process. At the time of feather growth, when new feathers are receiving blood circulation, feather methylmercury levels are reflective of the body's blood methylmercury levels (Evers *et al.* 2005). When new feathers are fully-grown and blood supply to the feather ceases, the body's blood methylmercury levels will rise (Furness *et al.* 1986). Some of this methylmercury will be carried and deposited into the liver and muscle tissues. Since bird feathers have the ability to act as a sink for methylmercury (over 60% of a bird's body burden of methylmercury can be found in the plumage of some waterbird species), feathers buffer against toxic effects of methylmercury (Braune 1987; Lewis and Furness 1991; DesGranges *et al.* 1998). During periods of feather growth and moult, this depuration process is an efficient method of methylmercury decontamination.

In female adult birds, methylmercury is also depurated into eggs (~20% of total body burden for fish-eating waterbirds; consequently, young chicks are born with an existing mercury body burden (Becker *et al.* 1994; Fournier *et al.* 2002; Heinz and Hoffman 2004; Braune and Malone 2006). The process of mercury depuration into growing feathers is an important decontamination pathway for young chicks as methylmercury is more readily deposited into nestlings' down than developing tissue (Becker *et al.* 1993). Elimination of methylmercury into the growing plumage allows young birds, especially those that feed primarily on aquatic organisms, to partially reduce their pre-existing methylmercury burden prior to accumulating additional mercury through their diet. This process is especially important for young piscivorous birds (*e.g.*, merganser, loon, osprey, eagle) and that feed at higher trophic levels and generally have greater methylmercury body burdens to pass on to their young (Becker *et al.* 1994).

8.3.4 Effects of Mercury on Birds

8.3.4.1 Construction Effects and Mitigation

During construction, it is unlikely that the amounts of methylmercury entering on-system locations will measurably affect the rates of mercury bioaccumulation in fish (AE SV). As a result, a measurable accumulation of methylmercury in birds is not anticipated during construction.

8.3.4.1.1 Residual Effects of Construction

Using the criteria established to determine the significance of Project effects for regulatory purposes, there are no likely residual effects of Project construction on mercury in birds during construction.

8.3.4.2 Operation Effects and Mitigation

Flooding will increase mercury levels in the reservoir. Potential effects on birds are linked to increases in fish mercury concentrations (AE SV) in the Keeyask reservoir and Stephens Lake.

Based on scientific literature, a surrogate model, and scientific judgement, estimated post-Project mercury levels in fish-eating birds are predicted to increase over baseline conditions (Table 8-5) and peak about three to seven years after the reservoir is impounded (following the peak maximum mean concentrations in fish). Mercury levels are expected to decline after about seven years and reach pre-Project levels approximately 20 to 30 years post-Project, following the rate of mercury decline in fish (AE SV). Methylmercury concentrations in herbivores (*e.g.*, geese) are not expected to change as a result of the Project due to the minute quantities of mercury taken up by plants. Small increases in total mercury concentrations will likely occur in some birds (*e.g.*, mallard, lesser scaup) that forage on lower trophic level foods (*e.g.*, aquatic invertebrates, molluscs) found within the reservoir and Stephens Lake. These increases are not expected to have any measureable effects on local populations. Larger increases in total mercury concentrations are expected for some fish-eating birds (*e.g.*, terns, eagles, and osprey) that forage within the Keeyask reservoir and/or Stephens Lake.

Table 8-5: Predicted Total Mercury Concentrations in the Muscle Tissue of Waterbirds Based on Peak Total Mercury Levels Modeled-Predicted for Fish Inhabiting the Keeyask Reservoir

Waterbird Species	Bird Feeding Group	Comparable Fish Feeding Group	Fish Species	Mercury Levels in Fish[1] (ppm)	Estimated Mercury Levels in Birds (ppm)
Canada goose	Strictly Herbivorous	N/A	N/A	N/A	~0.03
Mallard, green-winged teal, northern pintail, ring-necked duck	Herbivorous/ benthivorous	Benthivorous	Whitefish	<0.19	<0.19
Black scoter, surf scoter, common goldeneye, Scaup	Benthivorous	Benthivorous	Whitefish	0.19	0.19
Tern	Piscivorous-insectivorous	Piscivorous	Northern pike and walleye	1.0	1.0
Herring gull	Piscivorous-omnivorous	Piscivorous	Northern pike and walleye	1.0	1.0
Common merganser, red-breasted merganser, loon , osprey	Piscivorous	Piscivorous	Northern pike and walleye	1.0	1.0+
Bald eagle	Piscivorous-omnivorous	Piscivorous	Northern pike and walleye	1.0	1.0+

[1]-Source: Aquatic Environment Supporting Volume, Section 7.2.4.2.2

8.3.4.2.1 Raptors

Bald eagles have a wide and varied diet. However, as a piscivorous bird they often consume larger-bodied fish (Watson and Pierce 1998) containing higher mercury levels (*i.e.*, up to 1.0 µg/g in pike and walleye). An ecological risk characterization for bald eagle indicates that bald eagle is not expected to accumulate enough mercury though the ingestion of fish to experience any adverse effects. However, the HQ of 0.23 (reservoir; Table 8-6) assumes that the only mercury bioaccumulated in local bald eagle populations is from the Bird Regional Study Area.

Ospreys are piscivorous and consume a diet entirely of fish. Though osprey have been observed in the Regional Study Area, they are not considered common. Observations of osprey have occurred along the Nelson River, but also in inland areas that will not be affected by the Project (*e.g.*, inland lakes, creeks and rivers). If it is assumed that osprey only consume fish from either the Keeyask reservoir or Stephens Lake, and fish consumption is the only pathway for methylmercury exposure, then the HQ for osprey in the Keeyask reservoir and Stephens Lake would be under one (Table 8-6). These HQ values are under one, suggesting that adverse effects are not expected in osprey inhabiting the Regional Study Area. This risk characterization approach only accounts for mercury osprey ingest over the six months they are in the Keeyask region Values may be higher if osprey arrive on the breeding grounds with mercury burdens from overwintering areas.

Table 8-6: Hazard Quotient Scores for Bald Eagle and Osprey in the Keeyask Reservoir and Stephens Lake

Species	Keeyask Reservoir	Stephens Lake
Bald Eagle	0.23	0.17
Osprey	0.72	0.39

Measureable effects on local bald eagle and osprey populations are not expected. Published studies examining the effects of mercury on bald eagle and osprey indicate that these species are fairly tolerant to high levels of methylmercury contamination (DesGranges *et al.* 1999; Bechard *et al.* 2009).

8.3.4.2.2 Waterfowl

For waterfowl (*e.g.*, mallard, Canada goose), an increase in the level of mercury in the food chain is not anticipated to have notable or measurable effects at the population level. Estimated levels of mercury in muscle tissue of waterfowl are anticipated to be approximately 0.19 ppm (Table 8-5). These levels are below those shown to cause a decline in reproductive success in mallards (*e.g.*, 0.67 ppm in muscle; Heinz 1976b) and the 1.0 ppm threshold associated with potential adverse health effects in waterfowl (Braune *et al.* 1999). For geese, levels are not anticipated to vary from current baseline estimates of 0.03 ppm in muscle tissues.

8.3.4.2.3 Other Species

Gulls and tens are piscivorous birds. However, an increase in mercury levels in the food chain is not thought to have measurable consequences. Terns predominantly feed on lower trophic level fish, thereby reducing the threat of bioaccumulation. As opportunists, gull diets are varied with fish consisting of only a small proportion of food consumed, thus significantly lessening the likelihood of adverse effects from mercury.

8.3.4.3 Conclusion about Residual Effects of Mercury in Birds

During operation, adverse ecological effects resulting from increased mercury in birds are anticipated to be minimal in the Keeyask reservoir. Though peak mercury levels will decline after 6-7 years, effects are predicted to persist for 20-30 years.

Monitoring plans will not be developed for continuous assessment of mercury in birds as changes in bird populations resulting from increased mercury are not expected to be measurable. However, mercury levels in fish will be monitored annually until maximum levels are reached, and periodically thereafter, until mercury levels return to baseline conditions.

While it is agreed that the Project may have negligible adverse effects on local bird populations, past experience with hydroelectric development by the Keeyask Cree Nations (KCNs) indicates that the effects may be of greater magnitude than predicted by technical science. The KCNs are also sceptical that mitigation measures can lessen these effects to the extent proposed. As such, programs will be initiated to monitor Project effects on birds (see TE SV Section 6).

The adverse residual effects of the Project will not overlap or interact spatially and temporally with effects from future Projects. The cumulative effects assessment step that deals with future projects and activities focuses on VECs that are adversely affected by the Project and are vulnerable to the effects of future projects and activities. As mercury in wildlife is not a VEC, it is not covered in the cumulative effects assessment (CEA) step that deals with future projects.

8.3.4.4 Environmental Monitoring and Follow-up

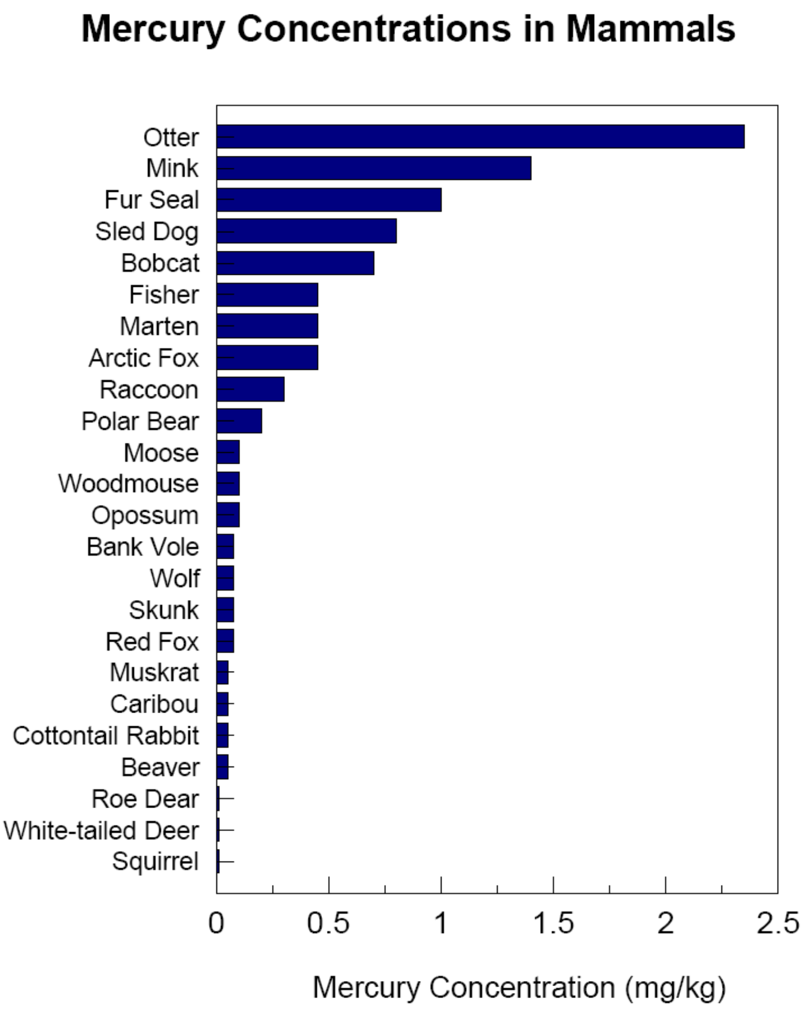
No monitoring of mercury levels in birds is proposed as mercury effects are expected to be negligible and not measurable at the population level.

8.4 MAMMALS AND MERCURY ASSESSMENT

8.4.1 Introduction

Mercury is a heavy metal that occurs naturally in plants, animals, air, water, sediments, bedrock, and soil (Environment Canada 2000). Natural sources of atmospheric mercury emissions in Canada are mainly vegetation, forest fires, fresh and marine water, and rock and soil (Environment Canada 2000). Mercury is converted to methylmercury (MeHg), an organic form taken up by plants and animals, by microorganisms in the environment (Morel *et al.* 1998). Human-caused flooding of large tracts of land increases methylmercury concentration in the reservoir created, as bacterial decomposition of inundated vegetation enhances the conversion of mercury to its more toxic, methylated form (Kelly *et al.* 1997).

Methylmercury is passed up the food chain in the diet of mammals via a process called bioaccumulation, where predators assimilate mercury from the prey they consume; the concentration of methylmercury is greater in **omnivores** than in **herbivores**, and is greater in **carnivores** than in omnivores (Wren 1986). Methylmercury is taken up by fish primarily in their food, and to a lesser extent in water passing over their gills (Hall *et al.* 1997). Mammals that consume these fish then incorporate the mercury they contain into their own tissues, where it accumulates. Although a wide range of mercury concentrations can be found in different mammal species (Figure 8-1), fish-eating mammals or **piscivores** are at the highest risk of accumulating mercury in their systems. Environmental mercury levels can be, and are most often, assessed for mammals in Manitoba and elsewhere by monitoring the concentration of mercury in aquatic carnivores, primarily because they consume fish (Kucera 1982). Mercury (Hg) is a persistent contaminant, and at high enough levels, can cause neurological damage to wildlife (Wren 1986).



From Wren, 1986 (as quoted in Facemire, 1995)

Figure 8-1: Mercury Concentration in Mammals (note mg/kg = μg/g)

Environment Canada (2010) states

> It is thought that elevated mercury levels in otters may cause early mortality due to toxicity and behavioural changes. While the reproduction and behaviour of bird species is generally affected by exposure to methylmercury, mammals most often suffer neurological effects. The severity of the toxic effects will depend on the degree of exposure, and may range from a slight impairment to reproductive failure or death.

Impaired growth and reproduction, kidney damage, and weight loss may also result at relatively low mercury concentrations (Environment Canada 2010). Due to the wide distribution of mercury in the Canadian environment, the risk is real and immediate, but there is currently no framework, guidelines or methylmercury criterion for protection of piscivorous or other mammalian wildlife to understanding the effects on mammals (Environment Canada 2010).

In higher vertebrates, mercury primarily exists as organic methylmercury, the form that can bioaccumulate. Due to the detrimental **neurotoxicological** effects of relatively small amounts of mercury, the frequent consumption of fish with moderate to high mercury levels may pose a risk to the health of wildlife such as mammals (Scheuhammer *et al.* 2007). In higher trophic level predators that consume fish for example, approximately 57% of all mercury in river otter (*Lontra canadensis*) kidney, and 62% in liver tissue is in its organic, methylated form, while approximately 91% of mercury in mink (*Mustela vison*) kidney and 80% in liver tissue is methylmercury. The variation is somewhat puzzling when viewed in the context of dietary differences between the two species where river otter are strongly piscivorous and mink are much more general carnivores (Evans *et al.* 2000). Evans *et al.* (2000) speculate that as most demethylation (conversion of mercury to its inorganic form) in mammals seems to occur in the liver with subsequent accumulation of inorganic mercury in the kidneys, the variability of observed in inorganic mercury concentrations in liver and kidney of river otter could be related to differences in the ability of individuals to demethylate mercury.

Approximately 95% of ingested methylmercury is transferred to the bloodstream from the gastrointestinal tract (Canadian Council of Ministers of the Environment 2000). Methylmercury is then transported throughout the body to tissues such as fur, muscle, liver, kidney, or brain (Sheffy and St. Amant 1982). Methylmercury accumulates in greater quantities in the brains of mammals than of fish (Canadian Council of Ministers of the Environment 2000). In Manitoba-wide studies, mercury concentration in three types of mink and river otter tissue was greater in livers than kidneys, and was lowest in brains (Kucera 1982). The greatest concentration of mercury in mink and river otters trapped in Wisconsin was in fur (Sheffy and St. Amant 1982). A large portion (65%) of methylmercury ingested by animals is excreted via the feces; while much less (4%) is excreted via urine (Farris *et al.* 1993). Methylmercury can also be transferred from a pregnant mammal to the fetus via the placenta, and from lactating females to their offspring (Ilback *et al.* 1991). Studies have shown that less than 1% of methylmercury ingested by mammals is secreted into milk (*e.g.*, Sell and Davison 1973; Neathery *et al.* 1974).

As with other wildlife such as fish or birds, predicting how elevated levels of methylmercury in the aquatic food chain will affect mammal populations is a complex process that requires consideration of a number of variables. The degree in which mammals are exposed to elevated levels of mercury is dependent upon diet, home range overlapping the source, and frequency and type of consumption (plants, animals or a combination) which may contain various levels of mercury. The build-up of mercury in mammals is also related to species longevity, as longer-lived species have a greater potential to bioaccumulate higher levels of mercury than shorter-lived species. The sex of a species and the ability to produce offspring can also change total exposure. After exposure, toxicological effects of methylmercury (to be referred to as mercury unless otherwise indicated) may range in mammals from loss of appetite accompanied by loss of weight, death of brain tissue leading to impairment of sensory and motor skills (*i.e.*, lethargy, inability to control limbs or limb paralysis, tremors, and convulsions). In acute cases, death may occur (Wren *et al.* 1986; Scheuhammer *et al.* 2007). Other effects not resulting in death may occur on reproduction, growth and behaviour (Dansereau *et al.* 1999).

For top-level predators, a wide range of mercury values has been reported from studies in North America. Mercury levels in Canadian river otter muscle ranged from 0.89 to 36.0 µg/g wet weight and from 0.02 to 96.0 µg/g wet weight in liver (Wren *et al.* 1980). Mink have similar ranges, from 0.71 to 15.2 µg/g wet weight in muscle tissue and from 0.04 to 58.2 µg/g wet weight in liver tissue. Sources of mercury reported from these studies included natural atmospheric, vegetation, soil and water mercury emissions, man-made reservoirs, and industrial point-sources of pollution, the latter of which were associated with some of the highest levels reported.

Environmental mercury levels can be assessed by monitoring the concentration of mercury in aquatic carnivores (Kucera 1982). As mink and river otter consume fish and other aquatic species, some individuals are most likely to be affected by environmental mercury. Traditionally, herbivorous species such as beaver (*Castor canadensis*), or more omnivorous species such as muskrat (*Ondatra zibethicus*) are not monitored near reservoirs or by point-sources of industrial pollution, because they do not accumulate mercury in their tissue to the same extent as an **indicator species** (in this case a top-level predator), and especially if animal health risks or human health risks have not been identified at levels reported for herbivores (Wren 1986). Animals that are omnivorous, or in the case of muskrat which are primarily herbivorous but having omnivorous elements in their diets, are used occasionally for mercury monitoring purposes (Driver and Derkson 1979). Large herbivores such as moose (*Alces alces*) have not been used to monitor mercury because exposure rates are generally lower than found in omnivores, samples are difficult to obtain, and sample size can be problematic. The linkages to reservoir development and potential exposure rates for moose have not been examined in the literature, nor does it appear to be of concern in other reservoir-related Environmental Impact Statements found in Canada (Hydro-Québec 2007; NALCOR 2009b).

More recently, mercury and other heavy metals have been monitored in caribou (*Rangifer tarandus*) tissue, especially as it relates to the atmospheric contribution of mercury and uptake by lichens, a primary food source for caribou (Gamberg *et al.* 2005). As with moose, the linkages to reservoir development for caribou have not been examined in the literature, nor does it appear to be of concern in other reservoir-related Environmental Impact Statements found in Canada. Given the dietary requirements of caribou, potential exposure rates to mercury that may be obtained from a reservoir are expected generally to be less than exposure rates for moose.

8.4.2 Approach and Methodology

8.4.2.1 Overview to Approach

The approach taken for the assessment of mammal mercury concentrations was similar to the approach applied for other terrestrial components. The mammals mercury assessment comprised two major components: a description of the existing conditions in the Project area to provide the foundation for assessing the potential effects of the Project on mammal mercury concentrations; and an effects assessment in which potential effects of the Project on mammal mercury concentrations were described.

The assessment focused on aquatic and riparian mammals of domestic importance for resource users. Mink and river otter are at the top of the aquatic food chain and represent the worst-case scenario in terms of mammal mercury concentrations. Beaver and muskrat were also included in the analyses to obtain information on mercury concentrations at lower trophic levels for herbivores, and in part, omnivores. In response to the Keeyask Cree Nations (KCNs) requests, an overview for mercury was provided to gain a better understanding of the main sources of mercury for domestic consumption of moose and caribou, which are also primary herbivores. The KCNs were instrumental in providing samples, in particular, for furbearers.

The environmental setting included a description of historical information where available to provide an overview of how wildlife mercury concentrations have changed over time and background data against which future changes can be evaluated. One primary data source was available to establish a point-in-time surrogate reference, namely the Churchill River Diversion (CRD) of Southern Indian Lake in northern Manitoba (Environment Canada 1987). In 1976, the level of Southern Indian Lake was raised approximately three metres (m) above its long-term mean by placing a dam at its natural outlet (Environment Canada 1987). A diversion channel redirected the flow of water from the Churchill River to the Nelson River, via the Rat and Burntwood rivers, the same year (Environment Canada 1987). Routine testing for mercury in affected lakes revealed elevated levels in fish, prompting an investigation into the causes. A comparison was made between mercury levels in fish and mammals in lakes affected by the CRD, and those in nearby waterbodies unaffected by the project. Documentation of mercury levels in river otter and mink were included from the Split Lake—Stephens Lake—Nelson River area.

Sampling was conducted as part of Keeyask environmental impact assessment studies to establish baseline mercury concentrations in aquatic mammal tissues, in order to follow any discernible trends if possible, discern any recent patterns in mercury levels, and provide baseline data against which future changes can be evaluated. The existing conditions for mammal species including beaver, muskrat, mink and river otter were defined over a period of six years (2003-2008). Other species of domestic interest included moose and caribou, where a limited number of samples were collected in 2010 and 2011. In addition, mercury concentrations were determined for mammals from several off-system areas to provide context, and that will serve as controls to monitor natural (*i.e.*, not Project-related) fluctuations or trends in mammal mercury levels against which potential corresponding changes related to the Project can be compared. Several areas were selected for study based in part on the request of the KCNs, who actively participated in the collections program. Target locations were also selected based on gaps in local sample areas, both on and off the Nelson River system (see Section 8.4.2.3).

Potential effects of the Project on mercury concentrations in muskrat, beaver, mink and river otter were assessed by modeling expected concentrations by:

- Using a predictive model from the scientific literature; and
- Using historic and recent data from nearby reservoirs (*i.e.*, Southern Indian Lake and Stephens Lake) as proxies for the future Keeyask reservoir.

The duration of elevated mercury concentrations in mammals was estimated based on model estimates from fish in the Keeyask region (Aquatic Environment Supporting Volume (AE SV)). Fish information sources for the assessment were linked to information obtained from the EIS studies, predictions generated for the Physical Environment Supporting Volume (PE SV), and scientific literature pertaining to hydroelectric development in Manitoba and elsewhere.

Potential Project effects on mercury levels in mammals were assessed using descriptions, empirical data (where available) and scientific judgement. Predictions that applied to herbivores and omnivores were literature-based. Surrogate models for top-level piscivorous predators such as mink and river otter were developed from historic data from Southern Indian Lake and Stephens Lake, and current data collected in the Local and Regional Study Areas. In some cases, context is provided by exploring known food sources in the Nelson River, to other waterbodies and watercourses in adjacent habitats, or by providing comparable information from the literature.

Potential Project effects on mercury levels in river otter and mink were assessed using a risk characterization approach. This approach uses exposure and toxicity assessments to link a chemical of potential concern, in this case mercury, with adverse ecological effects (NALCOR 2009a). The **hazard quotient** (HQ) was calculated in order to predict whether mercury would have adverse effects to top-level mammal predators in the Local Study Area, specifically Keeyask reservoir and Stephens Lake. Refer to Appendix 8A and 8B for more details on the risk characterization approach for mercury. Potential wildlife health effects were assessed further using benchmarks in the scientific literature.

8.4.2.2 Federal and Provincial Objectives and Guidelines

Environment Canada began a new study in 2008 in the framework of a national program, in order to improve knowledge of the effects of mercury in wildlife. However, Canada and Manitoba do not currently have a methylmercury criterion for protection of piscivorous or for other wildlife species. The framework currently does not address mercury exposure in any detail through food or bioaccumulation to higher trophic levels. As such, aquatic life that is exposed to methylmercury primarily through food (*e.g.*, piscivorous fish) may not be adequately protected. Moreover, these Water Quality Guidelines (WQGs) for mercury may not prevent the accumulation of methylmercury in aquatic life; therefore, through this process the tissue residue guideline (TRG; 33 µg MeHg·kg-1 wet weight) for the protection of wildlife that consume aquatic life may be exceeded (Canadian Council of Ministers of the Environment 2000). Thus, if the ultimate management objective for mercury is to protect high trophic level aquatic life and/or those wildlife that prey on aquatic life, more stringent site-specific application of these water quality guidelines may be necessary.

In the United States, the Environmental Protection Agency (USEPA 1997) found that "the adverse effect level (population impacts on piscivorous wildlife) for methylmercury in fish that occupy trophic level 3 lies between 0.077 and 0.346 µg/g wet weight (trophic level 4). A comparison of this range of values with published residue levels in fish suggests that it is probable that individuals of some highly exposed wildlife subpopulations are experiencing adverse toxic effects due to airborne mercury emissions."

Scheuhammer *et al.* (2007) stated it is probable that the current level of methylmercury exposure of free-living mink and other piscivorous mammals in a number of mercury-sensitive environments is sufficiently high to have subtle neurotoxic and other consequences, and that aqueous methylmercury concentrations likely exceed the USEPA derived mammalian wildlife criteria for mink (57 pg MeHg L^{-1}) in many aquatic ecosystems. However, it is currently unclear whether documented environmental concentrations and toxic effects on individual animals have population-level impacts in mink or other mammalian species.

8.4.2.3 Study Area

Samples of muscle and liver tissue of beaver, muskrat, mink, and river otter were collected from Split Lake Resource Management Area (SLRMA) Traplines 1, 3, 15, 60, 61, 62, and 65, from York Landing Trapline 13, and from Fox Lake Resource Management Area (FLRMA) Traplines 3, 4, and 5 (Map 8-1) by volunteer collections and under Scientific Permit issued by Manitoba Conservation.

Traplines were categorized as "**on-system**", "**off-system**" and "comparison areas." A trapline was classified as "on-system" if it overlapped with the Nelson River and was also located in the Regional Study Area (Table 8-7). The home ranges or sub-populations of animals such as muskrat, beaver, river otter, or mink collected on-system are hypothesized to overlap with regulated water. Most individuals were assumed to obtain a substantial portion of their diet from the Nelson River, or from aquatic environments that came into immediate or frequent contact with the Nelson River. Off-system traplines were considered comparison areas for unregulated water systems, which included many creeks, rivers, ponds, or lakes that were not in immediate contact with the Nelson River, but were also located within or near the Regional Study Area. Animals collected off-system are assumed to obtain a substantial portion of their diet from aquatic environments that did not have immediate contact with the Nelson River. Other comparison areas included those traplines downstream and outside the Regional Study Area, and that may or may not have direct contact with the Nelson River.

Table 8-7: Traplines Included in the Aquatic Furbearers Mercury Analysis

Trapline	System	Study Area
Split Lake RMA Trapline 15	On	Local
Fox Lake RMA Trapline 4	On	Comparison area[1]
Fox Lake RMA Trapline 5	On	Comparison area
Split Lake RMA Community Trapline 65	On	Regional
York Community Trapline 13	On	Regional
Fox Lake RMA Trapline 3	Off	Comparison area
Split Lake RMA Trapline 1	Off	Regional
Split Lake RMA Trapline 2	Off	Regional
Split Lake RMA Trapline 3	Off	Regional
Split Lake RMA Trapline 4	Off	Regional
Split Lake RMA Trapline 59	Off	Regional
Split Lake RMA Trapline 60	Off	Regional
Split Lake RMA Trapline 61	Off	Regional
Split Lake RMA Trapline 62	Off	Regional
Split Lake RMA Trapline 9	Off	Regional

1. Comparison areas were treated as part of the Regional Study Area

8.4.2.4 Data and Information Sources

8.4.2.4.1 Historic Studies

The oldest record documenting mercury in mammals found for Manitoba was from 1971-72 (Driver and Derksen 1979). From 1983 to 1989 and 1992 to 2005 the federal government, the province of Manitoba, and Manitoba Hydro studied mercury levels in fish as part of the "Canada-Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion" and its successor programs (AE SV). Routine testing for mercury in affected lakes revealed elevated levels in fish, prompting an investigation into the causes. Mercury levels in mammals such as mink and river otter were monitored along with fish (Environment Canada 1987). Mercury studies in mammals for this research were reported for the period between 1982 and 1985. Most mercury data for northern Manitoba lakes was compiled by Kucera (1983), and Canada-Manitoba Agreement (1987). In relation to the consumption of fish by mink and river otter, long-term records for mercury in fish have included, but are not limited to, studies in Split Lake, Stephens Lake, Gull Lake, the Aiken River, Assean Lake, Recluse Lake, Kiask Lake, Wasakaiowaka Lake, and the Limestone and Long Spruce areas of the Nelson River (AE SV).

Although other sources of data and information were compiled from the literature, it should be recognized that these studies were from outside of Manitoba, and conducted in potentially different environments. These sources are used to add context to potential effects discussions.

8.4.2.4.2 EIS Studies

Mercury in Mammals Studies

In addition to the data collected as part of the "Canada-Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion" (Environment Canada 1987), samples of muscle and liver tissue of beaver, muskrat, mink, and river otter were used to describe current conditions in the Regional Study Area. Samples were collected from local trappers from the SLRMA, from York Landing Trapline 13, and from the FLRMA (Map 8-2). Muscle and liver tissue samples were analyzed for mercury content if both were supplied by local trappers. Samples were also collected under a Scientific Permit issued by Manitoba Conservation to supplement Regional Study Area gaps.

Although the general extent of the Study Area for the collection of samples extended beyond the largest Study Area identified (*i.e.*, Zone 6) for approximately one-half of the samples processed, at least one trapline area sampled covered a large proportion of the Local Study Area, and about seven trapline areas sampled were related in close geographic context to the Local and Regional Study Areas.

Samples collected from December 2006 to April 2008 were analyzed using Environmental Protection Agency (EPA) Method 7473 for DMA-80 Total Mercury Analyzer (Environmental Protection Agency 2007). Briefly, a single sample from each animal was dried, then thermally and chemically decomposed in a decomposition furnace. Decomposition products were carried to a device that selectively traps mercury, where the concentration of mercury vapour was measured. The detection level of this method is 0.01 nanograms (ng), or 0.0001micrograms (µg), total mercury.

For the purpose of mercury content analysis, three sub-samples, each weighing approximately 0.2 grams (g), were removed from each tissue sample after slicing away a thin outside layer to ensure that the sample analyzed represented the actual moisture content of the animal's muscle (*i.e.*, wet weight). Total mercury concentrations were determined using a modification of the hot block method (EPA Method 200.3) described in Hendzel and Jamieson (1976) for samples collected prior to December 2006 and after April 2008. The limit of detection provided by this method is 0.01 micrograms per gram (μg/g), or 10 nanograms per gram (ng/g). The mean of the three replicates (subsample of the tissue of a particular animal) of each sample was calculated to determine the concentration of mercury in each tissue sample. This method was employed for samples collected from February 2003 to December 2006.

Where more than one replicate was measured, the average mercury concentration and variance of the sample was calculated. These averages were pooled with the single values produced by the EPA Method, and an overall average and standard error of the average mercury concentration were calculated for each species. Anomalous replicates were not included in the analysis.

Moose and caribou samples were analysed for mercury using the same methods as aquatic furbearers. Additional tests for heavy metals using the MET-WET-200.3-MS method. These samples were voluntarily provided by local resource users. To date, sample size is small (n=3) with no caribou kidney tissue being collected for caribou.

Dietary Studies for River Otter, Mink, Beaver and Muskrat

In the Regional Study Area, and in areas along the lower Nelson River, river otter and mink fecal samples were collected primarily in summer from latrines, and opportunistically along tracking transects (refer to Section 7 of the TE SV). Materials were dried, weighed and expressed as percent composition by dry weight. Summer plant clippings from muskrat, and occasionally from beaver, were collected from ponds, small lakes, and rivers, and identified to species where possible.

Predictive Increases in Mercury

Modeling was used to estimate mammal mercury concentrations in muskrat, beaver, moose, caribou, mink and river otter from the Local Study Area that might be expected as a result of the Project. The first approach involved deriving assumptions for the models based on scientific literature. To determine maximum concentrations and variability for the model, historic and recent data from a nearby reservoir (*i.e.*, Southern Indian Lake and Stephens Lake) were used as surrogates for the future Keeyask reservoir. In some cases, context is provided by exploring known food sources in the Nelson River, to other waterbodies and watercourses in adjacent habitats, or by providing comparable information from the literature. Other data were used from environments overlapping with, or similar to the Regional Study Area to establish baselines for herbivores such as moose and caribou. Refer to Appendix 8B for a list of assumptions used in the surrogate model for predicting mercury increases.

The second approach used model estimates from fish in the Local Study Area (AE SV) to derive estimates for Hazard Quotient assessments for top-level predators. A description of this modeling approach and method is provided in Table 8B-1.

Other Studies

Literature and data reviewed for establishing mercury baselines and predictions included the following:

- Results from other studies including Fish Quality – Mercury in Fish (See AE SEV and SE SV;
- Canada-Manitoba Mercury Agreement Studies (1982–1985);
- Information gained from other existing hydroelectric reservoirs, such as reservoirs in Québec;
- Mink and River Otter as Indicators of Mercury in Manitoba Watersheds (1979–1981);
- Mercury Levels in Wildlife within the Nelson River Basin of Manitoba (1971–1972);
- Trace Elements in Northwestern Minnesota Moose (1998–1999);
- Levels of Cadmium, Lead, Mercury and Cesium in Caribou Tissues from Northern Québec (1994–1996);
- Spatial and temporal trends of contaminants in terrestrial biota from the Canadian Arctic;
- Aboriginal traditional knowledge (ATK); and
- Other scientific literature pertaining to Project linkage pathways.

8.4.3 Environmental Setting

A total of 170 mammals (26 river otter, 50 mink, 57 beaver and 37 muskrat) were sampled from the Regional Study Area and from other comparison areas near the Limestone GS from 2003 to 2008 for analysis of mercury in tissues. Muscle and liver tissues were not always included in all samples provided by trappers. For most, species and sex of the animal, and the location of the animal collected were provided on maps.

In all years and areas sampled, mean mercury concentrations were substantially higher in the piscivores, as represented by liver content in river otter (0.08–3.97 µg/g wet weight) and mink (0.37–3.16 µg/g wet weight), than in the herbivorous beaver (<0.01–0.05 µg/g wet weight) and muskrat (<0.01– 0.06 µg/g wet weight). For areas adjacent to the Nelson River, mean mercury concentrations tended to be higher than in areas away from the river. River otter from the Nelson River tended to have the highest concentrations, although animals collected near Moose Nose Lake tended to be as high and occasionally higher.

Mercury levels in mink from Split Lake and Stephens Lake areas have remained about the same as compared with the observed historical record, from an average of 1.87 (range 0.15–2.55) µg/g wet weight in the liver of mink between 1982 and 1985 to 1.87[1] (range 0.37–3.16) µg/g wet weight from 2003 to 2008. Mercury concentrations in river otter liver have declined from 2.0 (range 0.82–17.63) µg/g wet weight from 1982 to 1985 to 1.01 (range 0.08–3.97) µg/g wet weight from 2003 to 2008. The decline in river otter mercury concentrations coincide with a similar decline in fish (AE SV). Details by species and collection locations are provided below.

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[1] Average of on-system and off-system samples.

8.4.3.1 Indicator Species (River Otter and Mink)

8.4.3.1.1 Historical Conditions

Historic records for mercury concentrations in indicator species such as river otter and mink near the Regional Study Area are located in the Split Lake – Stephens Lake areas, the Nelson River towards Limestone GS, adjacent to the Regional Study Area near Pikwitonei, and other reference areas from northern Manitoba. These two species were monitored as part of the Canada-Manitoba Mercury Agreement. Collections from the Southern Indian Lake area occurred approximately six to eight years after CRD. Collections from the Nelson House–Burntwood River area occurred approximately two to eight years after CRD. Collections from the Split Lake–Stephens Lake–Upper Nelson River areas occurred approximately 12 to 15 years after Kettle GS was built and Stephens Lake was flooded.

Unlike long–term records for fish, trends cannot be plotted for these species as data were collected over short periods from the Keeyask region in the early to mid-1980s.

Mercury levels in mink and river otter livers were monitored along the CRD route from 1979 to 1981[1] and from 1982 to 1985[2] (Environment Canada 1987). Liver tissue samples collected from Southern Indian Lake and the Burntwood River/Nelson House areas had greater mercury concentrations than those collected in other parts of Manitoba, such as Wekusko Lake, which was unaffected by the CRD. Split Lake–Nelson River and Pikwitonei had a wide range of values over the same time period, but the average concentration of mercury in the livers of mink and river otter were more similar to values reported at Wekusko Lake (Table 8-8 and Table 8-9).

Table 8-8: Mercury Concentration (µg/g wet weight) in Mink Liver Tissue Collected in Northern Manitoba, 1979 to 1985 (adapted from Kucera 1983 and Environment Canada 1987)

Area	1979/1981		1982–1985		
	Mean	Range	Median	Range	N
Wekusko	1.44	0.02–4.15	--	--	19
Southern Indian Lake	--	--	4.07	0.86–30.60	*
Nelson House/Burntwood River	2.34	0.42–9.78	3.53	0.21–25.46	*
Split Lake/Upper Nelson River	--	--	1.87	0.15–2.55	*
Pikwitonei	--	--	1.07	0.12–8.90	77

*From 1982 to 1985, 147 mink samples from Southern Indian Lake, Nelson House and Split–Stephens Lake were analyzed
From 1979 to 1981, 21 mink samples from Burntwood River were analyzed

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[1] Nelson House/Burntwood River plus unaffected areas such as Wekusko Lake.

[2] Nelson House/Burntwood River, Southern Indian Lake, approximately 7 to 10 years after the Churchill River Diversion; Split Lake/Upper Nelson River and Pikwitonei, approximately 21 to30 years after the development Kelsey and Kettle).

Table 8-9: Mercury Concentration (µg/g wet weight) in River Otter Liver Tissue Collected in Northern Manitoba, 1979 to 1985 (adapted from Kucera 1983 and Environment Canada 1987)

Area	1979/1981		1982–1985		
	Mean	Range	Median	Range	N
Wekusko	1.74	0.52–3.49	--	--	17
Southern Indian Lake	--	--	5.88	0.21–7.09	*
Nelson House/Burntwood River	--	--	4.78	3.41–6.15	*
Split Lake/Upper Nelson River	--	--	2.00	0.82–17.63	*
Pikwitonei	--	--	1.44	0.52–5.95	19

*From 1982 to 1985, 34 river otter samples from Southern Indian Lake, Nelson House and Split Lake were analyzed

Southern Indian Lake and Nelson House were areas affected by the creation of a reservoir for the CRD. Approximately six years after the inundation of Southern Indian Lake, mercury concentration in the livers of mink and river otters was greater in animals trapped in affected areas than those from unaffected areas such as Wekusko (Table 8-8 and Table 8-9). Mean mercury concentration in mink liver tissue ranged from 1.44 to 1.87 µg/g wet weight in unaffected areas (Wekusko, Split Lake, and off-system and comparison area traplines in the Regional Study Area), with individual values ranging from 0.02 to 4.15 µg/g wet weight, suggesting a relatively narrow average range. These values are similar to mercury levels in mink from James Bay territory, Québec, where mean concentration in liver tissue was 3.71 µg/g wet weight (Fortin *et al.* 2001) and in the Northwest Territories, where mean mercury in mink liver tissue ranged from 0.91 to 3.30 µg/g wet weight, considered a moderate concentration (Poole *et al.* 1998).

For river otters, mean mercury concentration in liver tissue from the Split Lake—Stephens Lake—Nelson River areas approximately 8 to 11 years after Stephens Lake was flooded ranged from 0.03 to 17.63 µg/g wet weight, suggesting a wider average range than mink. Mean mercury concentration in river otter liver was 4.05 µg/g wet weight in specimens collected from James Bay territory, Québec (Fortin *et al.* 2001).

8.4.3.1.2 Current Conditions

General Life History

River otter and mink are predators that feed primarily on aquatic organisms such as fish and shellfish. Consequently, higher concentrations of mercury are expected to accumulate in their tissues than all other mammal species in the Regional Study Area.

Fish are the main component of the river otter diet, and birds, amphibians, insects, and aquatic invertebrates are opportunistically consumed, particularly in summer (Reid *et al.* 1994). In the Regional Study Area, river otter fecal samples (n = 37) collected primarily in summer and expressed as percent composition by weight, were composed mainly of fish (>90%). In the lower Nelson River area, composition was more varied, and tended to include less fish. In descending order of composition, the diet included invertebrates (46%) fish (40%), vegetation (7%), mammals (5%), birds (1%) and unknown material (1%), which is very similar to the dietary composition of river otter found elsewhere in North America. Overall, unknown fish species (36%) constituted the largest proportion of samples in river otter diets. Where species of fish was identified from the Regional Study Area and the lower Nelson River, northern pike (28%) was most frequently found in scat, followed by freshwater drum (13%), sucker spp. (9%), perch (4%), cisco (2%), lake whitefish (2%), yellow perch (2%), burbot (1%), white sucker (1%) and minnow spp. (1%). Scales from relatively small fish (67%) were more often observed in the fecal samples than scales of large fish (33%).

Mammals are of primary importance in the mink diet year round, with muskrats, small mammals, hares, and rabbits commonly taken (Eagle and Whitman 1998). In summer, waterfowl, marsh–nesting birds, and aquatic invertebrates are consumed while in winter, fish are a more frequent source of food (Eagle and Whitman 1998). In the Regional Study Area and along the lower Nelson River, mink fecal samples collected in summer and fall were composed mainly of small mammals (92%), which is very similar to the dietary composition of mink found elsewhere in North America. The composition of mink scat also included unknown materials (3%), fish (2%), invertebrates (1%), vegetation (1%), and birds (1%). By proportion (n=7), small mammal species included meadow vole (43%), heather vole (29%), red–backed vole (14%) and northern bog lemming (14%). Overall, unknown fish species (2%) constituted a very small proportion of samples in the mink's diet.

North America

Previous studies in North America have recorded mercury levels in Canadian river otter muscle ranging from 0.89 to 36.0 µg/g wet weight and 0.02 to 96.0 µg/g wet weight in liver (Wren 1986). Similar values were reported for mink, ranging from 0.71 to 15.2 µg/g wet weight in muscle tissue and 0.04 to 58.2 µg/g wet weight in liver tissue (Wren 1986).

On-system and Off-system

Mean mercury concentration in mink and river otter muscle and liver tissue was greater in animals trapped on-system than off-system (Table 8-10, Table 8-11, and Table 8C-1 to Table 8C-4). As expected, mercury concentrations in the liver of river otter and mink were higher than in muscle. High levels of variation are likely attributed to two primary factors, including feeding rates and mercury content in prey within or adjacent to various waterbodies throughout the home ranges of the animals, and age of the animal. As the age of individuals could not be accurately assessed when they were trapped, and dentition and other internal structures were not collected, further analyses could not be performed.

Table 8-10: Mercury Concentration (µg/g wet weight) in Mink Tissue Collected in the Regional Study Area, 2003 to 2008

Area	Muscle Mean	Range	N	Liver Median	Range	N
On-system	1.15	0.55–2.24	18	2.31	1.36–3.04	9
Off-system	0.59	0.20–1.15	19	1.55	0.37–3.16	12
Comparison area	--	--	0	--	--	0

Table 8-11: Mercury Concentration (µg/g wet weight) in River Otter Tissue Collected in the Regional Study Area, 2003 to 2008

Area	Muscle Mean	Range	N	Liver Median	Range	N
On-system	0.59	0.13–1.52	14	1.66	0.30–3.81	12
Off-system	0.29	0.13–0.73	28	0.78	0.08–3.97	22
Comparison area	0.38	0.11–0.99	8	1.02	0.28–2.90	8

The average mercury concentrations in river otter muscle from animals collected on-system was 0.55 µg/g wet weight with a variance (var.) of ±0.15. The average off-system river otter muscle mercury concentration was 0.28 µg/g (var. ± 0.02) wet weight. The average mercury concentrations in mink muscle from animals collected on-system was 1.15 µg/g (var. ± 0.19) wet weight. The average off-system mink muscle mercury concentration was 0.59 µg/g (var. ± 0.08) wet weight.

Relatively high variations in mean mercury concentration in male and female river otter or mink tissues on- and off-system were apparent, but no pattern was observed (Table 8C-5 to Table 8C-8). As the age of individuals could not be accurately assessed when they were trapped, and indicators of age such as teeth or the reproductive systems were not submitted, age–dependent analyses were not performed.

Local and Regional Study Area

Mean mercury concentrations in mink and river otter muscle and liver tissue were greater in the Local Study Area than the Regional Study Area, although the variation was relatively high and the sample size from the Local Study Area was limited (Table 8C-9 to Table 8C-12). Mean mercury concentration in samples from the Local Study Area was also within the range of on-system values for these species. As expected, mercury concentrations in the liver of river otter and mink were higher than in muscle.

The average mercury concentrations in river otter muscle from animals collected in the Local Study Area was 0.67 µg/g (var. ± 0.20) wet weight. The average Regional Study Area otter muscle mercury concentration was 0.32 µg/g (var. ± 0.04) wet weight. The average mercury concentrations in mink muscle from animals collected in the Local Study Area was 1.12 µg/g (var. ± 0.12) wet weight. The average Regional Study Area mink muscle mercury concentration was 0.83 µg/g (var. ± 0.21) wet weight.

Variations in mean mercury concentration in male and female river otter or mink tissues in the Regional and Local Study Areas were apparent, but no pattern was observed (Table 8C-13 to Table 8C-16). As the age of individuals could not be accurately assessed when they were trapped, and indicators of age such as teeth or the reproductive systems were not submitted, age dependent analyses were not performed.

8.4.3.2 Herbivores (Beaver and Muskrat)

8.4.3.2.1 Historical Conditions

Historic records for mercury concentrations in beaver are not available for the Regional Study Area, or elsewhere in Manitoba. Other records predating 1976 collected from outside of Manitoba are reported in Table 8-12. Although sample size was low (n=14), very low concentrations are present in the muscle of beaver where means ranged from less than 0.01 to 0.02 µg/g wet weight, and the highest value reported was 0.04 µg/g wet weight. Liver values were not reported for beaver.

Historic records for mercury concentrations in muskrat are not available for the Regional Study Area. Limited records are reported for muskrat in the Saskatchewan River (*i.e.*, Nelson River Basin) from 1971 to 1972 with a sample size of 30. Muscle and liver total mercury expressed as µg/g wet weight are reported in Table 8-12), with very low concentrations in muscle where means ranged from less than 0.01 to 0.03 parts per million (ppm, the equivalent of µg/g), and the highest value reported was 0.06 µg/g. Mean liver values ranged from 0.01 to 0.13 µg/g (n=87), and the highest value reported in liver was 0.28 µg/g. Values were reported for Manitoba and Québec.

Table 8-12: Mercury Residue Levels (ppm or µg/g[1]) in Beaver and Muskrat Tissues in Canada

		Muscle			Liver			
Species	**Area**	**Mean**	**Number**	**Range**	**Mean**	**Number**	**Range**	**Reference**
Beaver	Bell River upstream, Québec	<0.01	1	--				Desai-Greenway and Price, 1976
	Lac Quevillon, Québec	0.01	5	<0.01–0.01				Desai-Greenway and Price, 1976
	Lac Pusticamica, Québec	<0.01	2	<0.01–<0.01				Desai-Greenway and Price, 1976
	Lac Waswanipi, Québec	0.01	3	<0.01–0.01				Desai-Greenway and Price, 1976
	Lac Matagami, Québec	0.02	3	<0.01–0.04				Desai-Greenway and Price, 1976
Muskrat	Manitoba	0.01	30	--	0.01	30	-	Radvanyi and Shaw, 1980
	Saskatchewan River, Nelson River Basin, Manitoba				0.13	47	0.04–0.28	Driver and Derksen, 1979
	Rupert River System, Québec	<0.01	3	<0.01–<0.01				Desai-Greenway and Price, 1976
	Broadback River System, Québec	<0.01	1	--				Desai-Greenway and Price, 1976
	Bell-Nottaway River System, Québec	0.02	3	<0.01–0.03				Desai-Greenway and Price, 1976
	Bell River upstream, Québec	<0.01	1	--				Desai-Greenway and Price, 1976
	Bell River downstream, Québec	0.03	3	0.01–0.06				Desai-Greenway and Price, 1976
	Nottaway River, Québec	0.03	3	0.01–0.06				Desai-Greenway and Price, 1976
	Lac Pusticamica, Québec	<0.01	2	<0.01–<0.01				Desai-Greenway and Price, 1976
	Lac Waswanipi, Québec	<0.01	3	<0.01–<0.01				Desai-Greenway and Price, 1976
	Lac au Goeland, Québec	<0.01	3	<0.01	<0.01			Desai-Greenway and Price, 1976
	Lac Matagami, Québec	0.01	2	<0.01–0.01				Desai-Greenway and Price, 1976

1. Parts per million and micrograms per gram are equal proportions

8.4.3.2.2 Current Conditions

General Life History

Because of their diet, beaver and muskrat are not expected to have high concentrations of mercury in their tissues. The beaver diet is vegetarian, consisting of leaves, twigs, and bark (Banfield 1987), with a preference for aspen (Jenkins and Busher 1979). Diet shifts from woody vegetation in winter to herbaceous material in spring and summer (Jenkins and Busher 1979; Clements 1991). Aspen trees are rare in the Regional Study Area (TE SV*)*. Herbaceous materials consumed by beaver in the Regional Study Area that were noted opportunistically included pond lily and some emergent vegetation.

Muskrat diets consist primarily of aquatic vegetation, including shoots, roots, bulbs and leaves (Boutin and Birkenholz 1998). Typical vegetation includes cattail, rushes, sedges, iris, water lily, and pondweed (Pattie and Hoffmann 1990). Muskrats typically forage for food by digging for vegetation on the bottom of ponds and lakes (Banfield 1987). Some animal matter, such as shellfish, frogs, turtles, and salamanders may also be consumed on occasion (Pattie and Hoffmann 1990). In summer, food samples from 12 ponds, lakes and rivers in the Regional Study Area indicated that muskrats primarily consumed submergent aquatic plants including pondweeds, water lilies, water arums and milfoil, and emergent plants such as swamp horsetail and sedges. These were very similar to the food preferences of muskrat found elsewhere in North America. A few snails and crayfish remains that were noted along shorelines near platforms and scat were suspected to have been consumed by muskrat. See Section 7 of the TE SV for additional information on muskrat sample locations and forage details.

North America

A review of the literature for beaver in North America finds mercury concentrations ranging from 0.01 to 0.03 µg/g wet weight in muscle and 0.02 to 0.04 µg/g wet weight in liver (Wren 1986). North American studies of muskrat find mercury concentrations ranging from less than 0.01 to 0.42 µg/g wet weight in muscle tissue and 0.05 to 0.11 µg/g wet weight in liver tissue from samples collected in Canada (Wren 1986). In one study from Ontario, Desai-Greenaway and Price (1976) reported that mercury concentrations in muskrats from the St. Clair River in Ontario dropped from 0.42 (range 0.04 – 0.69) µg/g wet weight to 0.08 µg/g in 1970 and to 0.01 µg/g in 1976. These decreases coincided with curtailed discharge of mercury into the St. Clair River in 1970.

On-system and Off-system

Mean mercury concentration in beaver and muskrat tissue was relatively low, and was very similar on-system and off-system (Table 8-13, Table 8-14, and Table 8C-1 to Table 8C-4). Average values of mercury concentrations in beaver and muskrat muscle and liver were either at or near the lower detection limit of 0.01 µg/g wet weight in most cases. Three muskrat liver tissue samples collected on-system averaged 0.03 µg/g wet weight.

Small variations in mean mercury concentration in male and female beaver or muskrat tissues on- and off-system were apparent, but no pattern was observed (Table 8C-5 to Table 8C-8). As the age of individuals could not be accurately assessed when they were trapped, and indicators of age such as teeth or the reproductive systems were not submitted, age dependent analyses were not performed.

Table 8-13: Mercury Concentration (µg/g wet weight) in Beaver Liver Tissue Collected in the Regional Study Area, 2003 to 2008

Area	Muscle			Liver		
	Mean	Range	N	Median	Range	N
On-system	<0.01	<0.01–0.01	34	<0.01	<0.01–<0.01	16
Off-system	<0.01	<0.01–0.03	16	0.01	<0.01–0.04	12
Comparison area	<0.01	<0.01–<0.01	6	<0.01	<0.01–0.01	6

Table 8-14: Mercury Concentration (µg/g wet weight) in Muskrat Tissue Collected in the Regional Study Area, 2003 to 2008

Area	Muscle			Liver		
	Mean	Range	N	Median	Range	N
On-system	0.01	<0.01–0.03	6	0.03	0.01–0.06	3
Off-system	<0.01	<0.01–0.01	16	<0.01	<0.01–0.03	14
Comparison area	<0.01	<0.01–<0.01	3	<0.01	<0.01–<0.01	3

Local and Regional Study Area

Mean mercury concentration in beaver tissue was relatively low, and was very similar in the Local and Regional Study Areas (Table 8C-9 to Table 8C-12). Average values of mercury concentrations in beaver muscle and liver were either at or near the lower detection limit of 0.01 µg/g wet weight. Although muskrat tissue samples were not available from the Local Study Area, Regional Study Area mercury concentrations in muskrat muscle and liver tissue were either at or near the lower detection limit of 0.01 µg/g wet weight.

Small variations in mean mercury concentration in male and female beaver or muskrat tissues from the Local and Regional Study Areas were apparent, but no pattern was observed (Table 8C-13 to Table 8C-16**Error! Reference source not found.**).

8.4.3.3 Other Mammals of Concern (Moose and Caribou)

Historic records for mercury concentrations in caribou are not available for the Keeyask region, or elsewhere in Manitoba. Other records predating 1996 collected from outside of Manitoba are reported in Table 8-15. Total mercury was assessed in samples of muscle, kidney, and liver from caribou (n = 317) harvested in two regions of northern Québec between 1994 and 1996. Mean total mercury concentration in muscle was 0.03 µg/g wet weight, 1.26 µg/g wet weight in kidneys and 0.67 µg/g wet weight in liver.

Concentrations were very low in muscle samples, but concentrations exceeded frequent consumption thresholds in most kidney samples and nearly half of the liver samples (see SE SV). Only one sample was reported from B.C. Total mercury concentrations in kidneys reported in the Yukon (Gamberg 1998) for the Porcupine caribou herd (n = 50) averaged 0.92 µg/g wet weight[1]. Mercury levels found in this study should be considered natural background levels, and are not of concern to the animals themselves.

Historic records for mercury concentrations in moose are not available for the Regional Study Area. Limited records are reported for moose in the Saskatchewan River (*i.e.*, Nelson River Basin) from 1971to 1972, but the sample size was very low (n = 2). Muscle and liver total mercury levels are reported in Table 8-15, with very low concentrations in muscle, where means ranged from less than 0.01 to 0.07 µg/g wet weight , and low concentrations in liver samples where means ranged from 0.05 to 0.06 µg/g wet weight (n = 5). The highest values reported for muscle and liver were 0.17 and 0.10 µg/g wet weight respectively. Values were reported for Manitoba, Québec and B.C. Total mercury concentration in kidneys reported in the Yukon (Gamberg 1998) for moose (n = 47) averaged 0.04 µg/g wet weight[2]. Mercury levels measured in this study are considered natural background levels (Gamberg 1998).

In response to general concerns from resource users (Keeyask Mercury and Human Health Technical Working Group March 23, 2010), liver, kidney and muscle samples from two caribou and one moose were analysed for heavy metal content, the results of which can be found in Table 8C-17.

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[1] Reported as 2.16 µg/g dry weight (standard deviation = 0.60), converted to wet weight using 0.43 kidney conversion factor (Kucera 1982).

[2] Reported as 0.09 µg/g dry weight (standard deviation = 0.11), converted to wet weight using 0.43 kidney conversion factor (Kucera 1982).

Table 8-15: Mercury Residue Levels (ppm or μg/g[1]) in Moose and Caribou Tissues in Canada

			Muscle			Liver		
Species	**Area**	**Mean**	**Number**	**Range**	**Mean**	**Number**	**Range**	**Reference**
Moose	Fraser River System, British Columbia	0.07	5	0.04–0.17	0.06	3	0.04–0.10	Desai-Greenway and Price, 1976
	Skeena River System, British Columbia				0.05	2	0.04–0.05	Desai-Greenway and Price, 1976
	Saskatchewan River, Nelson River Basin, Manitoba	0.05	2	0.04–0.06				Driver and Derksen, 1979
	Bell River downstream, Québec	0.01	2	<0.01–0.01				Desai-Greenway and Price, 1976
	Lac Pusticamica, Québec	<0.01	1	--				Desai-Greenway and Price, 1976
Caribou	Skeena River System, British Columbia	0.07	1	--				Desai-Greenway and Price, 1976
	Leaf River Québec (Immature)	0.03	57	0.033[2]	0.7	84	0.46[2]	Robillard *et al.* 2001.
	Leaf River Québec (Adult)	0.027	104	0.012[2]	0.7	176	0.41[2]	Robillard *et al.* 2001.
	George River-Torngat Mountains Québec (Immature)	0.021	19	0.008[2]	0.45	19	0.23[2]	Robillard *et al.* 2001.
	George River-Torngat Mountains Québec (Immature)	0.019	28	0.008[2]	0.38	28	0.15[2]	Robillard *et al.* 2001.
	Skeena River System, British Columbia	0.07	1	--				Desai-Greenway and Price, 1976
	Leaf River Québec (Immature)	0.03	57	0.033[2]	0.7	84	0.46[2]	Robillard *et al.* 2001.
	Leaf River Québec (Adult)	0.027	104	0.012[2]	0.7	176	0.41[2]	Robillard *et al.* 2001.
	George River-Torngat Mountains Québec (Immature)	0.021	19	0.008[2]	0.45	19	0.23[2]	Robillard *et al.* 2001.

1. Parts per million and micrograms per gram are equal proportions
2. Standard deviation

General Life History

Moose and caribou are not expected to have high concentrations of mercury in their tissues because of their diets. The moose diet is vegetarian, consisting of mainly of browse from preferred trees and shrubs. In winter, moose have restricted habitat ranges, primarily due to browse availability. Moose inhabit seral and mature habitat types, riparian and forested areas, and the periphery of burns (Irwin 1975; Coady 1982). In summer, moose home ranges expand (Crête and Courtois 1997) as new growth becomes available. Lowland and upland mature stands, shrubs, and aquatic areas are commonly inhabited (Irwin 1975; Coady 1982). Burned areas are also used in the summer; deciduous burn stands are preferred but conifer burn stands may also be used (Irwin 1975). In the Local Study Area, moose were rarely observed feeding on plants in the Nelson River, but they frequented the shorelines of rivers, lakes, and ponds in the Regional Study Area.

Caribou select habitat for a variety of reasons, particularly food availability and predator avoidance (Hirai 1998; Rettie and Messier 2000; Dyke 2008). In winter, caribou are highly selective regarding habitat, preferring areas with abundant arboreal and terrestrial lichens (Hirai 1998; Rettie and Messier 2000). As these lichens are found in older successional stages of forest, mature forests constitute important caribou habitat (Rettie and Messier 2000). Green forage such as horsetails, graminoids, and forbs are commonly consumed by woodland caribou in spring (Rettie *et al.* 1997; Rettie and Messier 2000). Summer and autumn forage consists of horsetails, graminoids, forbs, sedges, deciduous shrubs, and fungi (Rettie *et al.* 1997). Beginning in autumn, the diet shifts to arboreal and terrestrial lichens, which are important food sources in winter (Rettie and Messier 2000; Thomas and Gray 2002). It is suggested that as snow depth increases, arboreal lichens become the main source of food, as terrestrial lichens become increasingly difficult to detect and access (Thomas and Gray 2002).

North America

As described by Wren (1986), Desai-Greenway and Price (1976), and Driver and Derksen (1979), in North America, the levels of mercury in the muscle of moose were low and averaged 0.07 (range <0.01–0.17) µg/g wet weight. Liver values were similar, averaging 0.06 (range 0.04–0.10) µg/g wet weight. From a large sample size of moose from the Yukon (Gamberg *et al.* 2005), most mercury concentrations in the kidneys were measured near or below the level of detectability (average 0.02 µg/g wet weight, standard deviation (S.D) = 0.02).

Liver, muscle, and kidney samples supplied by resource users were analysed for mercury concentrations from one moose calf. Both the liver and muscle samples had total mercury concentrations less than the detectable level of 0.01 µg/g wet weight while the kidney had a concentration of 0.019 µg/g wet weight.

As described by Wren (1986), Desai-Greenway and Price (1976), and Robillard *et al.* (2002), in North America, the levels of mercury in the muscle of barren-ground caribou were low and averaged 0.03 µg/g wet weight (S.D. = 0.03). Liver values were higher than muscle, and ranged from 0.70 µg/g wet weight (S.D. = 0.46) to 2.04 (range 1.12–3.73) µg/g wet weight. From a large sample of barren-ground caribou in the Arctic, most mercury concentrations in the kidneys were measured between 1.20 µg/g wet weight (S.D. = 0.43) to 12.80 (range 8.71–18.7) µg/g wet weight. Overall, the Dolphin and Union, Porcupine and Qamanirjuaq caribou herds have relatively low levels of contaminants. The toxic elements measured by Gamberg (2008), including mercury, were found in measurable amounts in the kidney, but never higher than is considered 'normal to high' for domestic cattle. None of these elements currently approaches levels that would be expected to cause toxic effects in caribou. However, mercury concentrations in kidney have increased over time in at least one herd, and given the global concern about potentially increasing levels of mercury in the arctic environment, and declining caribou populations, it is considered essential to monitor this important northern species on an ongoing basis so that we are aware of changes in contaminant burdens as they occur.

Liver and muscle samples supplied by resource users were analysed for mercury concentrations from one caribou while another caribou just had muscle tissue analysed. Both the liver and muscle samples in the one caribou had total mercury concentrations of 0.014 µg/g wet weight while the muscle of the other caribou had a concentration of 0.019 µg/g wet weight.

8.4.4 Project Effects, Mitigation, and Monitoring

8.4.4.1 Construction Effects and Mitigation

During construction, it is unlikely that the amounts of mercury entering on-system locations will measurably affect the rates of mercury bioaccumulation in fishes (AE SV). As a result, a measurable accumulation of methylmercury in mammals is not anticipated during construction.

8.4.4.1.1 Residual Effects of Construction

Using the criteria established to determine the significance of Project effects for regulatory purposes there are no likely residual effects of Project construction on mercury in mammals during construction.

8.4.4.2 Operation Effects and Mitigation

Flooding will increase mercury levels in the reservoir. Potential effects on wildlife are linked to increases in fish mercury concentrations (AE SV) in the Keeyask reservoir and Stephens Lake.

Based on scientific literature, a surrogate model, and scientific judgement, estimated post-Project mercury levels in mammals are predicted to increase over baseline conditions (Table 8-16) and peak about three to seven years after the reservoir is impounded (following the peak maximum mean concentrations in fish). Mercury levels are expected to decline after about seven years and reach pre-Project levels approximately 20 to 30 years post-Project, following the rate of mercury decline in fish (AE SV).

A limited sample of historic river otter data was available for the surrogate model, with the maximum mercury concentration recorded in a single river otter sample trapped in the Stephens Lake area in 1983/1984, nine years after the construction of the Kettle GS. A larger sample size was available for the mink surrogate model, with the maximum mercury concentration recorded in a mink trapped in the Southern Indian Lake area in 1983/1984, seven years after the construction of the Missi Falls control center. The limited sample size of otter may explain why the maximum mercury concentration in mink were greater than that of river otter, as the likelihood of capturing animals with higher mercury concentrations increases with more samples. The minimum total mercury concentrations in mink were also considerably lower than in river otter.

Table 8-16: Model Estimates of Median and Most-likely Range of Total Mercury Concentrations (µg/g)[1] in the Liver of Mammals that Forage Within the Keeyask Reservoir and/or Stephens Lake

	Peak		Long-term
Species	**Day 1[2]**	**Year 3 to 7**	**Years 20-30**
Beaver	0.01 (<0.01–0.05)	0.01 (<0.01–0.05)	0.01 (<0.01–0.05)
Muskrat	0.02 (<0.01–0.06)	0.04 (<0.01–0.12)	0.02 (<0.01–0.06)
Mink	1.52 (0.56–3.16)	4.00 (0.56–30.60)	1.52 (0.56–3.16)
River otter	0.55 (0.28–3.97)	6.00 (0.28–17.63)	0.55 (0.28–3.97)

[1] µg/g = parts per million (ppm)
[2] Represents the existing environment and uses the first time the initial fill level is in effect

Mercury concentrations in herbivores (*e.g.*, beaver, muskrat) are not expected to change as a result of the Project due to the minute quantities of mercury taken up by plants. Small increases in total mercury concentrations will likely occur in some wildlife that forage on lower trophic level foods (*e.g.*, aquatic invertebrates, molluscs) found in the reservoir and Stephens Lake. These increases are not expected to have any measureable effects on local populations. Larger increases in total mercury concentrations are expected for some fish-eating wildlife (*e.g.*, mink, river otter) that forage within the Keeyask reservoir and/or Stephens Lake.

The potential effects of the Project on mercury levels in wildlife were screened using a HQ risk characterization approach, which uses exposure and toxicity assessments to link mercury with potential adverse ecological effects on wildlife (NALCOR 2009a). A hazard quotient is the ratio of "the average concentration of mercury being ingested" to a "known concentration where adverse effects may occur." A value less than one indicates that there is a low probability that adverse effects might occur. Hazard quotients were calculated for river otter, and mink, using modelled daily intake of fish from the Keeyask reservoir or Stephens Lake.

This risk characterization approach only assessed one pathway, the ingestion of fish, for methylmercury to accumulate in river otter. River otter are known to have a varied diet, with fish as the primary food source, plus shellfish, small mammals, and birds. It is therefore likely that multiple pathways for mercury accumulation exist for river otter. Consequently, it is possible that these other pathways would have a HQ greater than 0.10, pushing the overall HQ for mercury in river otter in the Keeyask region to be greater than one, likely affecting reproduction, growth, and/or survival. The HQ for river otter in the Stephens Lake area is not expected to exceed 0.50, even if additional pathways are considered, and it is unlikely that river otter will experience adverse effects from mercury in this area (Table 8-17).

Table 8-17: Hazard Quotient Scores for River Otter and Mink, on Fish in the Keeyask Reservoir and Stephens Lake

Species	Keeyask Reservoir	Stephens Lake
River otter	0.93	0.50
Mink	0.63	0.34

River otter are common in the Furbearers Regional Study Area and throughout Manitoba. Otter populations are generally resilient (*i.e.*, with high reproductive capacity), and dispersal behaviours of individuals allow for re-occupation of vacant habitat. Reduced reproduction or survival in the Keeyask reservoir will likely result in a negligible to small decline in the number of otter found in the Furbearers Local Study Area. Adaptive management will be considered to mitigate potential effects of reduced abundance if a large, unexpected decline in the local otter population is detected.

8.4.4.2.1 Residual Effects of Operation

The residual effect of mercury in mammals that is expected and likely is an increase in mercury concentrations in mammals that consume fish from the Keeyask reservoir. Maximum concentrations will decline in the long-term, but levels may remain higher than pre-Project concentrations for up to 30 years. Reduced reproduction and survivorship in the Keeyask reservoir may result in a small decrease in the abundance of river otter found in the Furbearers Local Study Area.

8.4.4.3 Conclusion about Residual Effects of Mercury in Mammals

During operation, adverse ecological effects resulting from increased mercury in wildlife are anticipated for river otter in the Keeyask reservoir. A small decline in the abundance of river otter found in the Furbearers Local Study Area is expected. Although peak mercury levels will decline after a few years, effects will persist for 20 to 30 years.

The adverse residual effects of the Project will not overlap or interact spatially and temporally with effects from future Projects. The cumulative effects assessment step that deals with future projects and activities focuses on VECs that are adversely affected by the Project and are vulnerable to the effects of future projects and activities. As mercury in wildlife is not a VEC, it is not covered in the cumulative effects assessment (CEA) step that deals with future projects.

Monitoring plans are developed to address uncertainty regarding the small decline in abundance predicted for river otter. Mercury levels in country foods will also be monitored until mercury levels return to baseline conditions to address concerns related to the consumption habits of affected species by local resource users (SE SV).

8.4.4.4 Environmental Monitoring and Follow-up

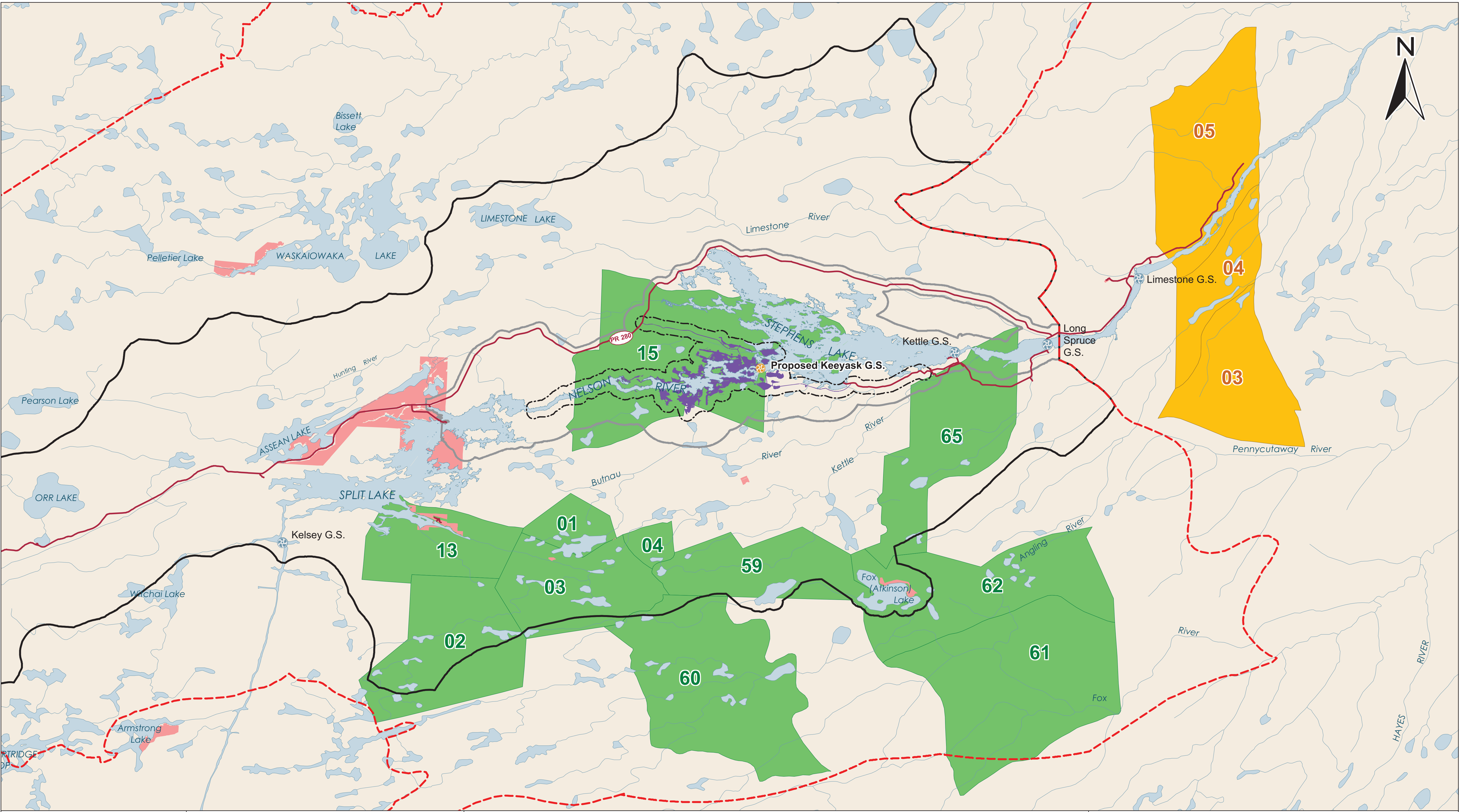
Monitoring plans are being developed to address uncertainty regarding the small decline in abundance predicted for otter (Table 8-18). If populations appear to be in decline and are larger than anticipated because of mercury effects, adaptive management practices could be implemented, such as limiting trapping in the Aquatic Furbearers Local Study Area. Limiting local trapping for otter and mink populations would only be recommended until local populations recover.

Mercury levels in country foods should be monitored annually until maximum levels are reached and periodically thereafter until mercury levels return to baseline conditions. Country foods monitoring is required to address concerns related to the consumption habits of affected species by local resource users (also refer to SE SV).

Table 8-18: Monitoring and Follow-Up Program for Mercury in Mammals

Supporting Topic/ VEC	Issue/Rationale	Monitoring	Timelines
Mercury in Wildlife (Supporting Topic)	• To verify predicted increases and address uncertainties regarding duration of mercury levels in country foods and top-level predators during operation.	• Monitor mercury levels in beaver, muskrat, river otter and mink, and in other wild game samples voluntarily supplied in the Keeyask and Stephens Lake areas, and in nearby off-system areas where no increase in mercury levels is predicted.	Annually during operation, until maximum levels are reached and then every three years until concentrations reach pre-impoundment levels (up to 30 years).

B Size BTB Landscape - Dec 2011



Keeyask Hydropower Limited Partnership

DATA SOURCE:
Study Areas and Nelson River shoreline - ECOSTEM Ltd.; Registered Trap Lines, First Nation reserves and roads - Manitoba Conservation; Water - NTS.

CREATED BY:
ECOSTEM Ltd.

COORDINATE SYSTEM: UTM NAD 1983 Z15N

DATE CREATED: 07-MAY-12

REVISION DATE: 07-MAY-12

0 10 20 Kilometre
0 5 10 Miles

VERSION NO: 1.0

QA/QC: APPROVED

Legend

Split Lake Registered Trap Lines

🟩 Trap Line Numbered by Section

Fox Lake Registered Trap Lines

🟨 Trap Line Numbered by Section

Study Areas

- ■ Project Footprint
- ⬚ Study Zone 3
- ☐ Study Zone 4
- ☐ Study Zone 5
- ⬚ Study Zone 6

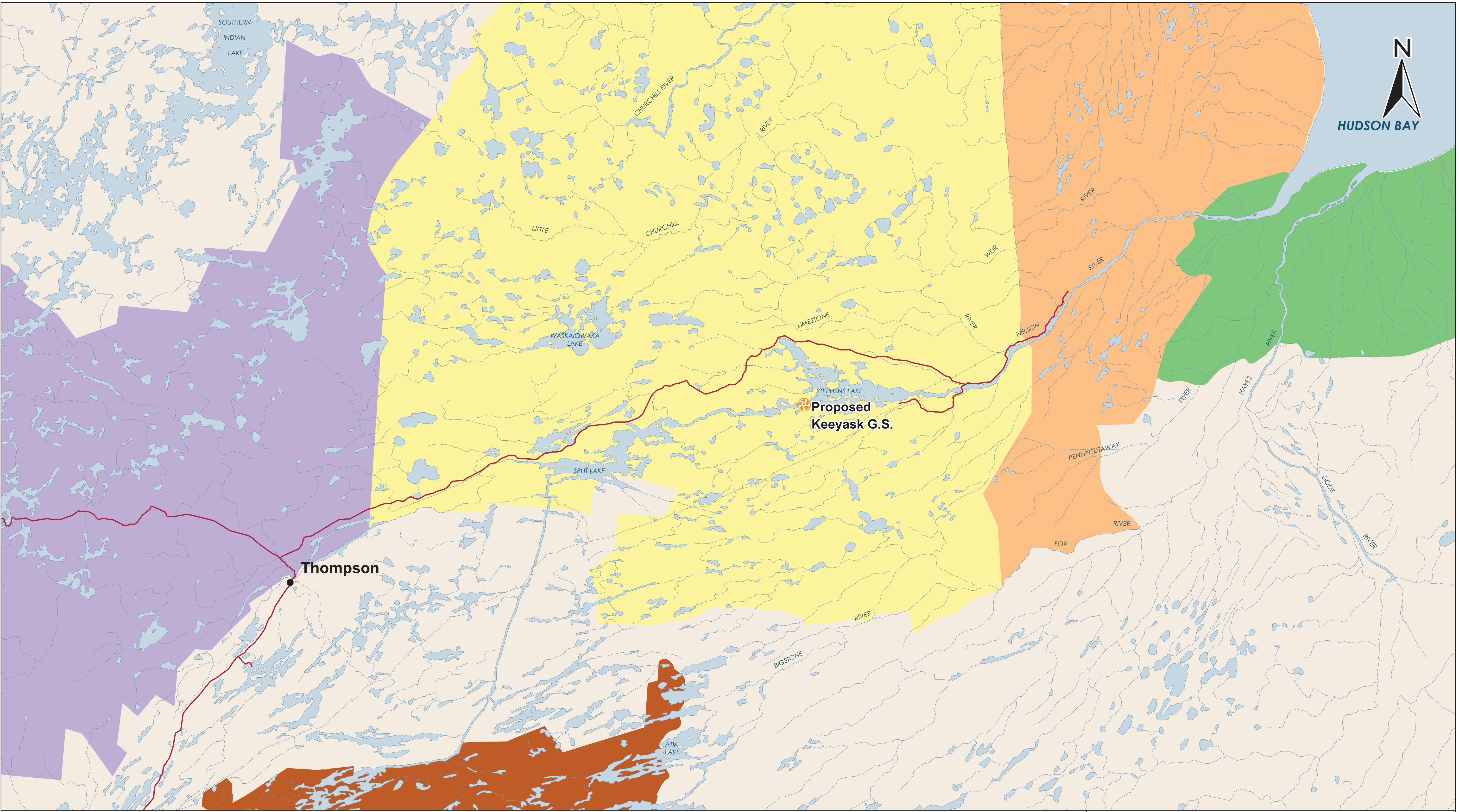
■ First Nation Reserve

Trapline Locations for Mercury Sampling

Map 8-1

File Location: Z:\Workspaces\Keeyask GS\Support\Mammal\EIS\Map 8.3-1. Trapline locations for mercury sampling.wor

B Size BTB Landscape - Dec 2011



File Location: Z:\Workspaces\Keeyask GS\Support\Mammal\EIS\Map ~ RMA's.wor

KEEYASK
Hydropower Limited Partnership

DATA SOURCE:
Resource Management Areas, roads and rail - Manitoba Conservation;
Water - NTS.

CREATED BY:
ECOSTEM Ltd.

COORDINATE SYSTEM:	DATE CREATED:	REVISION DATE:
UTM NAD 1983 Z15N	03-MAY-12	03-MAY-12
0 14 28 Kilometres 0 8 16 Miles	VERSION NO: 1.0	QA/QC: APPROVED

Legend
Resource Management Areas

- 🟫 Cross Lake
- 🟧 Limestone
- 🟪 Nelson House
- 🟨 Split Lake
- 🟩 York Factory

Resource Management Areas

Map 8-2

APPENDIX 8A

Effects of Mercury on Birds – A Review

8.5 APPENDIX 8A – EFFECTS OF MERCURY ON BIRDS – A REVIEW

The predicted levels of mercury in birds utilizing the Local Study Area (*e.g.*, Gull Lake, Nelson River) post-impoundment are based on modeled predictions for mercury levels in fish species (*i.e.*, lake whitefish, northern pike, walleye). As discussed in Section 2.0, concentrations of mercury in fish and bird species having similar feeding habits have been demonstrated to be comparable (Schetagne *et al.* 1999; Gerrard and St. Louis 2001). Because of this relationship, estimated existing levels of mercury in birds utilizing the potentially affected reaches of the Local Study Area (*e.g.*, Gull Lake) were based on existing methylmercury levels measured in fish species with similar feeding habits and diets (Table 8-1). Likewise, predicted levels of methylmercury in birds using the Local Study Area post impoundment are based on peak levels predicted for comparable fish species inhabiting the Keeyask reservoir (Table 8-3).

Levels of methylmercury in most fish and bird species are anticipated to peak five to seven years post-impoundment, and decline gradually to pre-impoundment levels over two to three decades. This pattern of methylmercury exposure is consistent with other hydroelectric impoundments including the Robert-Bourassa reservoir and La Grande complex reservoirs located in Quebec (Schetagne and Verdon 1999).

Studies have shown that initial toxic effects of methylmercury in birds are generally associated with reduced reproductive success, including decreased egg-laying, impaired hatchability, embryonic mortality and increased territorial fidelity (Heinz 1979; Barr 1986). At relatively high and continued levels of exposure, as often is the case in controlled laboratory testing, behavioural, neurological and physiological effects are also known to occur (Heinz 1979; Evers *et al.* 2005). Evidence of mercury-induced neurological and physiological effects in wild bird populations consuming prey species with elevated levels of methylmercury are quite rare. However, neurological effects have been observed in laboratory birds fed a diet containing 5.0 ppm methylmercury (Evers *et al.* 2005). Results from experimental testing involving mercury and birds are not always applicable to wild bird populations as species differ in their sensitivity to methylmercury (Koster *et al.* 1996). Furthermore, laboratory experiments usually involve feeding birds a synthetic form of mercury (*e.g.*, methylmercury chloride) at unnaturally high doses (Heinz 1974a; Heinz 1974b; Heinz and Hoffman 2004).

Increased levels of mercury within the aquatic environment following impoundment may lower the reproductive success of some waterbirds that breed along and forage within the Nelson River, Keeyask Forebay and Stephens Lake areas. As a result, fewer eggs per clutch and reduced survival of chicks may occur. Since species-specific thresholds for mercury exposure have not yet been established for most bird species, there is uncertainty as to how each individual or bird groups may respond to elevated mercury levels following impoundment. As species-specific thresholds are often determined based on laboratory experiments, applicability of test results (where available) to wild populations may not be appropriate.

The effect of increased methylmercury levels on birds is expected to be limited to areas of the Keeyask forebay, downstream to the Kettle GS. This is due to the presence of large water bodies downstream of the proposed Keeyask GS. Settling of sediments in Stephens Lake and the Kettle forebay will help limit the downstream effects of increased mercury in the aquatic environment.

8.5.1 Waterbirds

8.5.1.1 Non-piscivorous Waterbirds

For non-piscivorous waterbirds (*e.g.*, mallard, goldeneye, goose), an increase in the level of mercury in the food chain is not anticipated to have notable or measurable effects at the population level. Estimated levels of mercury in muscle tissue of non-piscivorous waterbirds are anticipated to be approximately 0.19 ppm (Table 8-5). These levels are below those shown to cause a decline in reproductive success in mallards (*e.g.*, 0.67 ppm in muscle; Heinz 1976b) and the 1.0 ppm threshold associated with potential adverse health effects in waterfowl (Braune *et al.* 1999). For geese, levels are not anticipated to vary from current baseline estimates of 0.03 ppm in muscle tissues (Table 8-5).

There is no evidence to suggest that the effect of methylmercury becomes progressively more severe through generations of mallard ducks (Heinz 1979a; Heinz 1979b). As such, mallards and/or other ducks that continue to breed within the Keeyask reservoir will be susceptible to methylmercury but will not experience an increase in the severity of effects over time.

8.5.1.2 Piscivorous Waterbirds

Piscivorous waterbirds include those species that consume a diet predominantly of fish (*e.g.*, mergansers, loons, gulls and terns). Piscivorous birds are considered higher trophic level feeders, and, therefore, are at a greater risk of accumulating higher levels of methylmercury than birds at lower trophic levels (*e.g.*, mallards, geese; Scheuhammer 1995; Scheuhammer *et al.* 2007). Within the group of piscivorous birds, the degree of methylmercury exposure in the diet varies with prey body size and type of prey species consumed. Generally, methylmercury concentrations in fish muscle tissue increase with fish size.

Common loons are a top predator that feed primarily on larger-bodied fish (*e.g.*, yellow perch, white sucker up to 25 cm long) and can live 25-30 years (Evers *et al.* 1997). Due to their diet and longevity, common loons are at a greater risk of accumulating toxic levels of methylmercury than most other fish-eating waterbirds (*e.g.*, mergansers, terns; USGS 2007). Methylmercury is biomagnified in longer-lived species, potentially causing toxic effects to the reproductive health and success of birds such as loons.

The potential effects of mercury biomagnification in loons include reproductive impairment, aberrant behaviour, and only rarely, death. Studies indicate that fish-eating birds such as loons can contain mercury levels sufficient to cause reproductive impairment and aberrant behaviour (Barr 1986). Barr (1986) suggests that mercury levels of 0.35-0.5 ppm in fish that loons prey upon may be adequate to interfere with reproductive behaviour such as establishing territories, egg laying and raising young. His studies indicated that, at levels between 0.3-0.4 in prey foods, loons laid fewer eggs and at levels above 0.4 ppm, no offspring were produced (Barr 1986). In 2004, average levels of mercury in both yellow perch and white sucker (*i.e.*, main prey for loons) sampled from Gull Lake's mainstem and backwaters were <0.04 ppm and <0.02 ppm respectively. Mercury levels for whitefish, a species with a similar diet to that of young perch, are anticipated to peak at 0.19 ppm five to seven years post impoundment (Aquatic Environment Supporting Volume). At these levels, methylmercury concentrations in loon diets (not loon muscle) would remain well below the 0.35-0.5 ppm threshold known to cause reproductive effects in loons (Barr 1986).

Common loons were infrequently observed along the Nelson River, Gull Lake and Stephens Lake areas (TE SV Section 6). This is likely a result of water-level fluctuation and turbidity associated with the generating stations currently operating along the Nelson River. Manipulation of water levels can disrupt the natural rhythm of annual water-level changes and can exaggerate the range of water-level fluctuation, causing a decrease in the number of loon territories and/or flooding of nests (Barr 1986).

Parts of the Nelson River and Gull Lake support small breeding populations of common merganser. Existing levels of methylmercury in common mergansers breeding within the Regional Study Area are anticipated to be similar to that of pike and walleye, ~0.22-0.4 ppm (Table 8-3). Although slightly lower, this estimate is consistent with the Canada-wide average of 0.6 ppm for mercury in common merganser muscle tissue (Braune and Malone 2006). Following impoundment, concentrations of mercury in merganser are anticipated to increase to ~1.0 ppm in muscle tissue (Table 8-5). Changes to foraging habitat (*e.g.*, increased turbidity) within the Keeyask Local Study Area may have a more notable effect on breeding success of mergansers using areas along the river system than increased levels of mercury in their diets. It is predicted that, for mergansers and other fish-eating birds, effects of increased mercury levels in forage fish as a result of GS operations will be small and not measurable at the population level.

8.5.1.3 Herons

The diet of great blue heron consists mainly of fish (20-25 cm long), but also amphibians, birds and invertebrates. Herons are opportunistic feeders, usually observed standing along the edges of wetlands or other shallow areas of water. Within the Project Footprint area, herons have infrequently been observed using shallow bays, inlets and creek mouths along the Nelson River and Gull Lake.

A variable diet consisting of lower trophic level organisms may reduce the intensity of potential health and/or behavioural problems associated with increased levels of methylmercury in their prey. Halbrook *et al.* (1999) found no effect on the reproductive success of herons foraging in a river reservoir despite methly-mercury concentrations of 0.09-0.69 ppm in forage fish tissue consumed by herons.

Although it is anticipated that impoundment will decrease suitable foraging habitat for herons in the Keeyask forebay, birds that continue to forage within this area will, for a period of time, be exposed to elevated levels of methylmercury through consumption of aquatic organisms. For example, existing levels of methylmercury in forage fish using Gull Lake range from 0.02 – 0.18 ppm. These levels are expected to increase slightly, following forebay impoundment (AE SV). Based on their variable diet, expected concentrations of methylmercury in forage fish post-impoundment and results from the Halbrook *et al.* (1999) study, effects of mercury on herons using the Project Footprint area are anticipated to be negligible.

8.5.1.3.1 Kingfisher

Belted kingfisher is a short-lived species (average lifespan four to five years) that consumes a varied diet consisting of small fish (*e.g.*, small perch 4-14 cm long), crayfish and small insects. Kingfishers forage in a variety of habitats located within a home breeding range of approximately 0.4-2.2 km (Lane *et al.* 2004). Habitats used for foraging generally include wetlands, creeks, rivers and lakes where clear water is available. Belted kingfishers will forage up to 1.6 km from a nest if calm, clear water for foraging is not readily available near the nest site (US EPA 2002).

Although there is a small degree of uncertainty, it is expected that belted kingfisher breeding along the Nelson River (including Gull Lake and parts of Stephens Lake) currently forage in alternate areas (*e.g.*, creeks, inland lakes, wetlands) due to the turbidity of the Nelson River. Following impoundment, forage conditions for belted kingfisher in the Keeyask forebay are anticipated to be even less adequate than pre-impoundment due to increased water turbidity.

Background (*i.e.*, 2003 and 2004) levels of mercury in potential kingfisher prey such as yellow perch inhabiting Gull Lake and Stephens Lake range from 0.02-0.05 ppm. Although not modelled, mercury levels in these fish are anticipated to increase only slightly following Project construction.

8.5.1.4 Piscivorous Raptors

Piscivorous raptors are those species that consume a diet largely if not exclusively of fish. Osprey is the only raptor found within the Keeyask Regional Study Area to feed exclusively on fish. Bald eagles consume fish but also other foods, including carrion.

Although osprey have been observed using the Regional Study Area, they are not common. Bald eagles however, are more common and have been observed nesting and foraging within the Local Study Area. Since osprey and bald eagles are top predator species and feed primarily on fish in the Local Study Area, they have the potential to accumulate high levels of methylmercury following Project construction.

A study conducted in Quebec compared the breeding success of osprey nesting near hydroelectric reservoirs (*e.g.*, La Grande) to osprey breeding and foraging along natural lakes and rivers (DesGranges *et al.* 1999). Results indicated that total mercury levels increased in osprey breeding near reservoirs and decreased in osprey breeding in areas away from reservoirs (DesGranges *et al.* 1999). Despite higher total mercury exposure for osprey foraging in reservoirs, number of young fledged was not statistically different between nests located near reservoirs and nests located near natural lakes and rivers.

A study of mercury levels in bald eagles breeding in Idaho reported high levels (>0.5 mg/kg [ppm] dry weight) of mercury in the feather tissue of most birds sampled (Bechard *et al.* 2009). Sampling occurred at various locations throughout the state, including areas in the southwestern portion of the state where reservoirs have been constructed. Throughout Idaho, average mercury levels in bald eagle feathers ranged between 9.8-36 ppm, well above the levels reported to cause reduced reproductive success and sterility in birds (>5.0 ppm in feathers; Bechard *et al.* 2009). Despite these high levels, all bald eagles sampled in Idaho bred successfully and their populations continue to increase (Bechard *et al.* 2009). Levels measured in bald eagles breeding in Idaho were consistent with levels measured in eagles breeding in other areas across the United States (Bechard *et al.* 2009). Adult feathers from eagles in the Great Lakes region contained an average of 19.4 mg/kg (ppm) dry weight methylmercury and 45.9 in South Carolina (Bechard *et al.* 2009).

Results from studies examining the effects of mercury on bald eagle and osprey reproduction indicate that these species are somewhat tolerant to high levels of methylmercury contamination. That is not to say that bald eagles aren't affected by heavy mercury burdens, as it is entirely possible for bald eagles to experience some form of sub-lethal effect (lower bone density, increased time spent preening) that isn't easily measured and/or has a notable effect on reproductive success. Based on studies conducted in other reservoirs, concentrations of methylmercury following reservoir impoundment are not anticipated to have a measurable effect on local bald eagle and osprey populations.

8.5.1.5 Bird Eggs

Eggs provide an important pathway for removing methylmercury burdens from blood and body tissues (*e.g.*, muscle) of female birds (Evers *et al.* 2005). Depending upon the species, depuration of methylmercury through eggs is replaced through dietary uptake of methylmercury within weeks or days of egg laying (Evers *et al.* 2005).

Concentrations of methylmercury in bird eggs vary with species. This variability is linked to diet, as birds that consume foods higher on the food chain (*e.g.*, fish) generally transfer higher levels of methylmercury into eggs than species that consume foods lower on the food chain. This relationship was evident when Evers *et al.* (2005) measured mercury levels in various species of waterbird eggs in northeastern United States (Table 8A-1). Higher mercury levels were observed in eggs from fish-eating birds than from birds that consume invertebrates (*e.g.*, common goldeneye) or a mixed diet of fish and other organisms (*e.g.*, herring gull; Table 8A-1).

Table 8A-1: Concentrations of Methylmercury in Eggs from Wild Waterbird Populations:

Species	**Methylmercury concentration in eggs (ppm)**	**Literature Source**
Common goldeneye	0.25	Evers *et al.* 2005 (NE United States)
Herring gull	0.55	Evers *et al.* 2005 (NE United States)
	0.18-0.24 (Lake Erie) 0.28-0.73 (Lake Ontario)	Koster *et al.* 1996 (Great Lakes)
	2-16	Vermeer *et al.* 1973 (Clay Lake, Ontario)
Common merganser	0.95	Evers *et al.* 2005 (NE United States)-
Common loon	1.05	Evers *et al.* 2005 (NE United States)
	0.35-1.34	Barr 1986 (north western Ontario)
Common tern	0.95-4.25 (Clay Lake) 0.59-0.93 (Wabigoon Lake)	Fimreite 1974 (Clay Lake, Ontario)
	0.11	Mierzykowski *et al.* 2005 (coastal Maine, USA)

Methylmercury levels ranging between 0.5 to 5.5 ppm in eggs have been shown to cause reproductive effects of reduced hatchability, low chick survival, decreased egg volume and compromised embryonic development in various bird species (Evers 2005). This large range in threshold concentrations is due to the high variability between species (Fimreite 1974). In some instances, thresholds determined through laboratory testing do not apply to wild populations. For example, Vermeer *et al.* (1973) found no adverse effects on reproduction in herring gulls despite methylmercury concentrations of 15.8 ppm in eggs.

For wild populations of common terns, the threshold for reproductive effects appears to be between 0.82 – 2.4 ppm of methylmercury in eggs (Fimreite 1974). Firmeite (1974) measured mercury levels in tern eggs from colonies upstream and downstream of a chlorine plant (source of mercury contamination) located near Dryden, Ontario. He found no effect on common tern reproduction when mean methylmercury concentrations were 0.82 ppm in eggs (measured in tern eggs upstream of the plant, at Wabigoon Lake). Reproductive success of terns however, was influenced when mean methylmercury concentrations were 2.4 ppm in eggs. These levels were measured in eggs from colonies downstream of the chlorine plant in Clay Lake. Only 10% of the tern colony nesting downstream of the plant fledged (Fimreite 1974). Thus, the threshold for a measurable decline in reproductive success for terns appears to be somewhere between 0.82-2.4 ppm of methylmercury in eggs.

Common loon thresholds for reproductive impairment appear when methylmercury in eggs reaches 2-3 ppm (Barr 1986). For wild populations of mallards and other duck species consuming similar diets low on the food chain, eggs generally have less than 1.0 ppm of methylmercury (Heinz 1976a). Reproductive impairment in mallards is associated with methylmercury concentrations over one ppm in egg tissue (Heinz 1976b; Heinz and Hoffman 2003).

Fortunately for young birds hatching with heavy body burdens of methylmercury, depuration of methylmercury from the body begins immediately. Body concentrations decrease with growth, through dilution, excretion and development of down and feathers (Becker *et al.* 1993). A study on tern eggs in Germany found that growth of down decreased body burden of methylmercury by 40% (Becker *et al.* 1993).

8.5.1.6 Waterfowl and Human Consumption

While consumption of fish tends to be the primary source for mercury bioaccumulation in humans, questions arise as to whether or not the consumption of waterfowl may also put human health at risk. Currently there are no human health guidelines for the consumption of game birds in Canada (Health Canada 2007).

Due to concern for contaminants in waterfowl harvested for consumption, a Canada-wide study was launched between 1987 and 1995 to better understand whether or not the consumption of game birds harvested in Canada posed a risk to human health (Braune *et al.* 1999; Braune and Malone 2006). During this period, various contaminants including mercury, were measured in muscle tissue taken from 32 species of waterfowl harvested at over 123 sites located nation-wide. Seven of these sites were located in Manitoba, ranging from the southeast and southwest corners of the province to Churchill in the north (Braune and Malone 2006). Study results indicated that for geese and swans, mercury levels in breast tissue were so low that they were almost always below detectable limits (Braune *et al.* 1999). For most other waterfowl species, levels were well below 0.1 ppm in muscle tissue. In conclusion of this study, Health Canada stated that contaminant levels found in the muscle tissue of the birds sampled (*e.g.*, geese, mallard, teal, scoter, goldeneye, scaup) did not pose a health hazard to human consumers and therefore waterfowl were safe to eat (Braune *et al.* 1999; Braune and Malone 2006.

APPENDIX 8B

Approaches to Surrogate Models and Risk Characterization

8.6 APPENDIX 8B – APPROACHES TO SURROGATE MODELS AND RISK CHARACTERIZATION

Surrogate Model Approach

The global assumptions and limitations of the mercury models used in this report are:

- The reservoir is flooded and mercury baseline is measured as Day 1 of operation;
- Herbivores and omnivores accumulate less total mercury in tissue than piscivores;
- Mercury in fish is expected to peak in 3 to 7 years; and,
- Because total mercury in piscivores are highly correlated with the ingestion rates of fish, total mercury bioaccumulation will approximate the rate of increase and decline in fish.

The parameters, assumptions and limitations of specific models for beaver, muskrat, mink and river otter are as follows:

Beaver

- Few to no beaver will live in the reservoir because of fluctuating water levels;
- Because beaver are herbivores, no change in mercury accumulations in tissue is expected; and,
- The range of variation is expected to remain similar to the existing environment.

Muskrat

- Few to no muskrat currently live in the Nelson River, and no change in abundance is expected for the future reservoir;
- Because muskrats are omnivores, limited increases in mercury accumulations in tissue is expected;
- The median value doubles following approximations of trophic level 2 descriptions (US EPA 1997);
- The lower range of variation is expected to remain similar to the existing environment, while the upper range value doubles following approximations of trophic level 2 descriptions (US EPA 1997); and,
- Mercury levels are expected to return to baseline levels at a rate that approximates declines in fish.

Mink

- The diet of mink consists primarily of small mammals supplemented with fish and other wildlife;
- Assumes the data from Southern Indian Lake and Stephens Lake are comparable to the future Keeyask reservoir;

- Assumes that peaking values from Southern Indian Lake and Stephens Lake following fish are comparable to the future peaking values for the future Keeyask reservoir;
- The median peaking value for mink is derived from the approximated median peaking value from Southern Indian Lake;
- The lower range is based on current values measured during field studies in the existing environment and the upper range is derived from the highest observed value from the surrogate studies in Manitoba; and
- Mercury levels are expected to return to baseline levels at a rate that approximates declines in fish.

River Otter

- The diet of river otter consists primarily of fish supplemented with other wildlife;
- Assumes the data from Southern Indian Lake and Stephens Lake are comparable to the future Keeyask reservoir;
- Assumes that peaking values from Southern Indian Lake and Stephens Lake following fish are comparable to the future peaking values for the future Keeyask reservoir;
- The median peaking value for river otter is derived from the approximated median peaking value from Southern Indian Lake;
- The lower range is based on current values measured during field studies in the existing environment and the upper range is derived from the highest observed value from the surrogate studies in Manitoba; and
- Mercury levels are expected to return to baseline levels at a rate that approximates declines in fish.

Risk Characterization Approach

In order for the predicted exposure to be compared against the toxicity reference value (TRV), the average daily dose (ADD) was calculated. ADD is defined as the amount of chemical an organism is exposed to on a mg/kg body weight/day basis and is normalized for body mass. The formula for calculating ADD is as follows:

$$\mathrm{ADD} = \mathrm{IF} \times \mathrm{AF} \times \mathrm{EPC}$$

Where:

- IF is the Intake Factor (kg fish/kg body weight • day)
- AF is the Absorption Factor (unitless)
- EPC is the Exposure Point Concentration (mg MeHg/kg fish)

The IF is calculated using the ingestion rate (IR) of fish (kg/day), the fraction of total ingestion from the site

(F_{site}), and the average body mass (BW) for the species in question. The following equation was used:

$$IF = (IR \times F_{site})/BW$$

For this study, the modelled methylmercury (mercury) concentrations for lake whitefish and northern pike were used to calculate the EPC (refer to AE SV). These two fish represent different groups of fish bald eagle, osprey, river otter or mink are likely to hunt, namely bottom feeders and piscivorous fish. Lake whitefish is a bottom feeder that typically feeds on crustaceans, molluscs, insects, and other small aquatic organisms and is not expected to accumulate large amounts of mercury. In contrast, northern pike are piscivores, feeding on other fish such as lake whitefish, and consequently are expected to accumulate greater amounts of mercury. The EPC is the geometric mean fish mercury concentrations, and was calculated for baseline levels, Project-only levels, and baseline + Project levels. Geometric is calculated by multiplying a set of numbers and finding the n^{th} route, where n is the count of the numbers used.

TRV values for mercury incorporated a chronic lowest-observed adverse effects level threshold for adverse effects to reproduction, growth, and/or survival. As there are limited studies available for these values in river otter, the TRV was determined for mink and then scaled by body weight for river otter. Refer to NALCOR 2009a for the calculation of TRV for mercury.

As previously stated, the HQ is the ratio of predicted exposure (ADD) to TRV; or HQ = ADD / TRV. Typically, a HQ greater than one indicates that the exposure concentration has surpassed the threshold and adverse effects are likely to occur. A HQ less than one means the exposure concentration has not surpassed the threshold and consequently adverse effects are unlikely to occur.

Values for all calculations can be found in Table 8B-1.

Table 8B-1: Parameters used in Risk Characterization Approach for Mammals and Birds

Location	Receptor	IF kg/kg-day	AF	EPC µg/g			IR kg/day	f_{site}	BW kg	ADD mg/kg-day			TRV mg/kg-day	HQ		
				Baseline	Project	Baseline + Project				Baseline	Project	Baseline + Project		Baseline	Project	Baseline + Project
Keeyask Reservoir	River Otter	0.13	1	0.12	0.36	0.50	1.02	1	8	0.02	0.05	0.07	0.07	0.23	0.68	0.93
	Mink	0.10	1				0.10	1	1	0.01	0.04	0.05	0.08	0.16	0.46	0.63
	Osprey	0.10	1				0.30	0.50	1.50	0.01	0.04	0.05	0.07	0.18	0.53	0.72
	Bald Eagle	0.05	1				0.40	0.6	5	0.00	0.02	0.01	0.09	0.06	0.23	0.17
Stephen's Lake	River Otter	0.13	1	0.15	0.25	0.09	1.02	1	8	0.02	0.03	0.01	0.07	0.28	0.22	0.50
	Mink	0.10	1				0.10	1	1	0.02	0.03	0.01	0.08	0.19	0.15	0.34
	Osprey	0.10	1				0.30	0.50	1.50	0.02	0.03	0.01	0.07	0.22	0.13	0.36
	Bald Eagle	0.10	1				0.40	0.6	5	0.01	0.01	<0.01	0.09	0.07	0.05	0.12

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APPENDIX 8C

Additional Tables

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8.7 APPENDIX 8C – ADDITIONAL TABLES

Table 8C-1: Mean Mercury Concentration (µg/g wet weight) in Aquatic Furbearer Muscle Tissue Collected On-system

Species	Number	Mean	Animal to Animal Variance	Standard Error
Beaver	38	0.01	<0.01	<0.01
Muskrat	6	0.01	<0.01	<0.01
Mink	18	1.15	0.19	0.10
River otter	20	0.55	0.15	0.09

Table 8C-2: Mean Mercury Concentration (µg/g wet weight) in Aquatic Furbearer Muscle Tissue Collected Off-system

Species	Number	Mean	Animal to Animal Variance	Standard Error
Beaver	18	0.01[1]	<0.01	<0.01
Muskrat	19	0.01	<0.01	<0.01
Mink	19	0.59	0.08	0.01
River otter	30	0.28	0.02	0.02

1. One replicate of 54 was removed from the analysis

Table 8C-3: Mean Mercury Concentration (µg/g wet weight) in Aquatic Furbearer Liver Tissue Collected On-system

Species	Number	Mean	Animal to Animal Variance	Standard Error
Beaver	20	0.01	<0.01	<0.01
Muskrat	3	0.03	<0.01	<0.01
Mink	9	2.31	0.41	0.21
River otter	18	1.72	1.24	0.26

Table 8C-4: Mean Mercury Concentration (µg/g wet weight) in Aquatic Furbearer Liver Tissue Collected Off-system:

Species	Number	Mean	Animal to Animal Variance	Standard Error
Beaver	11	0.01[1]	<0.01	<0.01
Muskrat	16	0.01	<0.01	<0.01
Mink	12	1.55	0.61	0.28
River otter	24	0.74	0.57	0.15

1. One replicate of 42 was removed from the analysis

Table 8C-5: Mean Mercury Concentration (µg/g wet weight) in Male and Female Aquatic Furbearer Muscle Tissue Collected On-system

	Species	Number	Mean	Animal to Animal Variance	Standard Error
Female	Beaver	3	0.01	<0.01	<0.01
	Muskrat	0	-	-	-
	Mink	2	1.09	0.11	0.23
	River otter	3	0.46	0.03	0.10
Male	Beaver	6	<0.01	<0.01	<0.01
	Muskrat	2	0.02	<0.01	0.01
	Mink	7	1.11	0.17	0.16
	River otter	11	0.76	0.16	0.12

Table 8C-6: Mean Mercury Concentration (µg/g wet weight) in Male and Female Aquatic Furbearer Muscle Tissue Collected Off-system

	Species	Number	Mean	Animal to Animal/ *Total* Variance	Standard Error
Female	Beaver	3	0.01	<0.01	<0.01
	Muskrat	2	0.00	*<0.01*	-
	Mink	5	0.65	0.14	0.17
	River otter	11	0.30	0.01	0.03
Male	Beaver	9	0.01[1]	<0.01	<0.01
	Muskrat	12	0.01	<0.01	<0.01
	Mink	14	0.58	0.06	0.07
	River otter	17	0.29	0.02	0.03

1. One replicate of 27 was removed from the analysis

Table 8C-7: Mean Mercury Concentration (µg/g wet weight) in Male and Female Aquatic Furbearer Liver Tissue Collected On-system

	Species	Number	Mean	Animal to Animal/ *Total* Variance	Standard Error
Female	Beaver	3	0.01[1]	*<0.01*	-
	Muskrat	0	-	-	-
	Mink	2	1.98	0.13	0.26
	River otter	3	0.95	0.05	0.13
Male	Beaver	6	<0.01	<0.01	0.00
	Muskrat	2	0.04	<0.01	0.02
	Mink	7	2.09	0.67	0.27
	River otter	11	2.06	1.23	0.33

1. One replicate of 9 was removed from the analysis

Table 8C-8: Mean Mercury Concentration (µg/g wet weight) in Male and Female Aquatic Furbearer Liver Tissue Collected Off-system

	Species	Number	Mean	Animal to Animal / *Total* Variance	Standard Error
Female	Beaver	3	0.01[1]	*<0.01*	-
	Muskrat	2	<0.01	*<0.01*	
	Mink	2	2.73	0.34	0.41
	River otter	7	0.60	0.10	0.12
Male	Beaver	9	0.02	<0.01	0.01
	Muskrat	12	0.01	<0.01	<0.01
	Mink	10	1.31	0.34	0.18
	River otter	15	0.86	0.85	0.24

[1] One replicate of 9 was removed from the analysis

Table 8C-9: Mean Mercury Concentration (µg/g wet weight) in Aquatic Furbearer Muscle Tissue Collected in the Local Study Area

Species	Number	Mean	Animal to Animal / *Total* Variance	Standard Error
Beaver	4	<0.01	*<0.01*	<0.01
Muskrat	0	-	-	-
Mink	5	1.12	*0.12*	0.16
River otter	10	0.67	0.20	0.14

Table 8C-10: Mean Mercury Concentration (µg/g wet weight) in Aquatic Furbearer Muscle Tissue Collected in the Regional Study Area

Species	Number	Mean	Animal to Animal Variance	Standard Error
Beaver	52	0.01	<0.01	<0.01
Muskrat	25	0.01	<0.01	<0.01
Mink	32	0.83	0.21	0.08
River otter	40	0.32[1]	0.04	0.03

[1] One replicate of 82 was removed from the analysis

Table 8C-11: Mean Mercury Concentration (µg/g wet weight) in Aquatic Furbearer Liver Tissue Collected in the Local Study Area

Species	Number	Mean	Animal to Animal / *Total* Variance	Standard Error
Beaver	4	<0.01	*<0.01*	<0.01
Muskrat	0	-	-	-
Mink	5	2.44	*0.41*	0.29
River otter	10	1.66	1.38	0.37

Table 8C-12: Mean Mercury Concentration (µg/g wet weight) in Aquatic Furbearer Liver Tissue Collected in the Regional Study Area

Species	Number	Mean	Animal to Animal Variance	Standard Error
Beaver	30	0.01[1]	<0.01	<0.01
Muskrat	19	0.01	<0.01	<0.01
Mink	16	1.70	0.63	0.20
River otter	32	0.89	0.76	0.15

1. Three replicates of 89, from two individuals were removed from the analysis

Table 8C-13: Mean Mercury Concentration (µg/g wet weight) in Male and Female Aquatic Furbearer Muscle Tissue Collected in the Local Study Area

	Species	Number	Mean	Animal to Animal/ *Total* Variance	Standard Error
Female	Beaver	0	-	-	-
	Muskrat	0	-	-	-
	Mink	1	1.33	-	-
	River otter	3	0.46	0.03	0.10
Male	Beaver	4	<0.01	*<0.01*	-
	Muskrat	0	-	-	-
	Mink	4	1.07	*0.14*	
	River otter	7	0.75	0.26	0.19

Table 8C-14: Mean Mercury Concentration (µg/g wet weight) in Male and Female Aquatic Furbearer Muscle Tissue Collected in the Regional Study Area

	Species	Number	Mean	Animal to Animal/ *Total* Variance	Standard Error
Female	Beaver	6	0.01	<0.01	<0.01
	Muskrat	2	0.00	*<0.01*	-
	Mink	6	0.68	0.12	0.14
	River otter	11	0.30	0.01	0.03
Male	Beaver	11	0.01[1]	<0.01	<0.01
	Muskrat	14	0.01	<0.01	<0.01
	Mink	17	0.68	0.14	0.09
	River otter	21	0.38	0.05	0.05

1. One replicate of 33 was removed from the analysis

Table 8C-15: Mean Mercury Concentration (µg/g wet weight) in Male and Female Aquatic Furbearer Liver Tissue Collected in the Local Study Area

	Species	Number	Mean	Animal to Animal/ *Total* Variance	Standard Error
Female	Beaver	0	-	-	-
	Muskrat	0	-	-	-
	Mink	1	2.25	-	-
	River otter	3	0.95	0.05	0.13
Male	Beaver	3	<0.01	*<0.01*	-
	Muskrat	0	-	-	-
	Mink	4	2.49	*0.53*	
	River otter	7	1.97	1.69	0.49

Table 8C-16: Mean Mercury Concentration (µg/g wet weight) in Male and Female Aquatic Furbearer Liver Tissue Collected in the Regional Study Area

	Species	Number	Mean	Animal to Animal/ *Total* Variance	Standard Error
Female	Beaver	6	0.01	*<0.01*	<0.01
	Muskrat	2	<0.01	*<0.01*	
	Mink	2	2.39	*0.53*	-
	River otter	6	0.52	0.07	0.12
Male	Beaver	11	0.01[1]	<0.01	<0.01
	Muskrat	14	0.01	<0.0	<0.01
	Mink	13	1.54	0.56	0.21
	River otter	19	1.14	1.09	0.24

1. One replicate of 33 was removed from the analysis

Table 8C-17: Heavy Metal Concentrations (µg/g wet weight) in Moose and Caribou Tissue Collected in the Regional Study Area

Heavy Metal	Detectable Limit	Moose			Caribou		
		CRM1			GK1		KL1
		Liver	Muscle	Kidney	Liver	Muscle	Muscle
Aluminum	0.6	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60
Antimony	0.01	<0.010	<0.010	<0.010	0.102	<0.010	<0.010
Arsenic	0.01	0.03	<0.010	0.043	0.028	0.032	0.058
Barium	0.04	0.063	1.26	0.129	0.096	0.34	0.117
Beryllium	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Bismuth	0.004	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
Boron	0.2	0.58	0.51	0.55	0.21	<0.20	<0.20
Cadmium	0.004	0.304	<0.0040	1.13	<0.0040	<0.0040	<0.0040
Calcium	10	54	259	109	54	74	76
Cesium	0.004	0.0472	0.104	0.108	0.316	0.351	0.427
Chromium	0.1	0.13	0.14	0.12	0.21	0.2	0.18
Cobalt	0.02	0.136	<0.020	0.047	<0.020	<0.020	<0.020
Copper	0.02	7.13	1.66	4.6	2.03	1.7	2.51
Iron	4	135	25.6	103	46.4	42.2	43.3
Lead	0.04	<0.040	<0.040	<0.040	6.7	<0.040	<0.040
Lithium	0.2	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Magnesium	2	181	274	188	302	289	281
Manganese	0.04	4.41	0.266	3.54	0.229	0.207	0.321
Molybdenum	0.01	0.827	<0.010	0.22	<0.010	<0.010	<0.010
Nickel	0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Phosphorus	4	4070	2320	2840	2410	2400	2300
Potassium	4	3180	3610	3670	4350	4620	3830
Selenium	0.1	0.13	<0.10	0.7	0.22	0.2	0.27
Silver	0.02	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Sodium	2	741	380	1420	619	802	706
Strontium	0.01	0.015	0.172	0.037	0.016	0.025	0.032
Tellurium	0.04	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040
Thallium	0.006	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060
Thorium	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Tin	0.04	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040
Titanium	0.02	0.022	0.117	0.039	0.034	<0.020	<0.020
Uranium	0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Vanadium	0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc	0.2	24.4	27	27	75.3	90.2	78.5
Zirconium	0.6	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60