KEEYASK GENERATION PROJECT

August 2013

Report # 11-05

Responses of Terrestrial Habitats to Reservoir Flooding and Water Regulation in Northern Manitoba

ENVIRONMENTAL STUDIES PROGRAM

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Responses of Terrestrial Habitats to Reservoir Flooding and Water Regulation in Northern Manitoba

Draft Report Prepared For:

Manitoba Hydro

By:

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EXECUTIVE SUMMARY

Reservoir creation and water regulation are expected to be major contributors to direct and indirect effects on terrestrial habitat and ecosystems. Reservoir-related flooding would remove some terrestrial areas. Over time, the reservoir would expand due to peatland disintegration and mineral bank erosion, leading to further terrestrial habitat loss. Flooding and water regulation would alter nearby terrestrial areas through groundwater and edge effects, creating substantial changes to terrestrial ecosystems in some locations.

This report presents results from Keeyask Generation Project studies conducted to improve our understanding and predictive capability regarding the potential effects of reservoir flooding and water regulation on terrestrial habitat and ecosystems. Three general types of potential flooding and/or water regulation effects were examined. First, inland effects, which were those effects only transmitted from the Nelson River to an inland area through a deep groundwater layer. Second, shore zone effects related to wetland losses in the Nelson River shallow water and beach water depth duration zones due to hydroelectric development. Third, shore zone effects transmitted through a surface groundwater layer, surface water regime and/or ice processes, thereby affecting terrestrial ecosystems extending from shallow water to areas inland from the shoreline. This report also reports on historical losses of shoreline wetlands in the Gull Lake and Kettle reservoir reaches of the Nelson River.

Since it was not possible to conduct large scale experiments to determine likely Project effects, existing reservoirs and/or regulated rivers in northern Manitoba, referred to as proxy areas, were studied as examples for how key Keeyask terrestrial ecosystem components were expected to respond to flooding and water regulation. Data were developed for four Nelson River reaches previously exposed to hydroelectric development (the proxy areas) from historical air photos, recent air photos and/or aerial surveys, depending on the particular study. Other results from these same proxy areas, as well as two proxy areas on the Burntwood River provided additional evidence or corroboration for observed patterns.

Inland Effects

The inland groundwater effects study found no conclusive evidence of inland groundwater effects in the Kelsey or Kettle proxy areas. Although potential signs of groundwater-related effects on inland terrestrial habitat were mapped for less than 1% of the area searched in both of the proxy areas, conditions such as land surface height above the reservoir and other information indicated that most of these potential effects were actually due to causes unrelated to flooding and/or water regulation (e.g., natural vegetation succession, age-related tree mortality, naturally occurring ground ice permafrost melting). After eliminating these situations, no more than 0.1% of the terrestrial habitat area in each proxy area was classified as having at least a limited possibility of being a groundwater effect. Even these remaining situations could have been the result of unrelated causes.

Shore Zone Effects

The extent and nature of shore zone effects, as well as the pathways and drivers for change, were documented using a time series of historical air photos for several existing reservoirs in northern Manitoba. Since historical air photos are often the only means for documenting the effects of impacts that occurred decades ago, recent low level photos acquired from a helicopter were used to verify the documented patterns to the extent feasible, as well as to provide higher resolution data and an oblique perspective for effects.

Shore zone studies addressed the following questions:

- How much wetland area in the beach and shallow water zones was lost to hydroelectric development in the Gull, Kettle and Long Spruce proxy areas?
- What proportion of the shoreline exhibited inland edge habitat effects due to flooding and/or water regulation?
- What was the typical width of flooding and/or water regulation effects on terrestrial habitat located on the inland side of the shoreline?
- What were the key factors interacting with flooding and/or water regulation to drive inland edge zone habitat change?
- What were the pathways of inland edge habitat change and how rapid was the response to elevated water levels?

Historical Wetland Loss in the Shallow Water and Beach Water Depth Zones

Analysis of historical air photos indicated that, prior to flooding and water regime changes related to Lake Winnipeg Regulation and the Churchill River Diversion, unvegetated shallow water comprised 78% and 95% of Gull and Kettle shoreline length, respectively. All of the vegetated wetland types were more prevalent in Gull than in Kettle.

Fen was the most common wetland type confirmed to have vegetation, comprising 6.5% and 0.2% of the pre-development Gull and Kettle reach shorelines, respectively. Tall shrub meadow was the next most common wetland type overall, accounting for 1.8% of the mapped shorelines.

The extent to which the herb/low shrub meadow zone was vegetated could not be mapped due to the air photo scale. Based on the photo-interpreted extent of the upper beach zone, the potential extent of herb/low shrub meadow wider than 10 m was less than 11% of shoreline length.

Marsh was rare on the Nelson River in the Gull and Kettle proxy areas (less than 2% of shoreline length). Historical data were not available to explain why such a low proportion of the shallow water area available for marsh was actually vegetated, especially in the Kettle reach. Possible causes included high river flows, ice scouring and/or several successive high water years.

Measured as a percentage of shoreline length, Kettle flooding removed more vegetated beach and shallow water wetlands in off-system waterbodies than on the Nelson River.

Inland Edge Habitat Effects

The inland edge habitat effects study searched for terrestrial habitat effects on the inland side of the shoreline (i.e., the inland edge zone) that extended more than 10 m inland of the initial flooding shoreline. Portions of the proxy area shoreline lacking suitable historical air photos were excluded from the analysis, as were segments that had burned, were cleared or were peat plateau bogs at initial flooding (peat plateau bogs typically do not experience groundwater effects because their surface is usually elevated above reservoir water).

Observed changes included tree mortality and changes to vegetation structure, vegetation composition and ecosite type. After approximately 31 years of project operation, inland edge habitat effects were detected on approximately 4% of the Kelsey shoreline and 41% of the Kettle shoreline for the portions of the proxy area shorelines analyzed. Less than 1% of the Long Spruce shoreline had inland edge effects.

Where present, shore zone effects such as tree mortality or vegetation composition change that were not attributable to natural changes typically extended less than 25 meters inland from the initial flooding shoreline in the Kelsey, Kettle and Long Spruce proxy areas, with the vast majority extending less than 50 meters. There were localized areas where confirmed effects extended more than 75 m, but these locations comprised less than 1.5% and 0.6% of the Kelsey and Kettle shorelines, respectively. The effects width at approximately 31 years after flooding was wider than 10 m for 35% of the searched shoreline in Kettle, and no more than 3% of the Kelsey and Long Spruce mapped shorelines.

The overall mean width of potential effects over the entire searched shoreline length was approximately 6 m and 14 m for Kelsey and Kettle, respectively, assuming an average 5 m effect even where none were observed. While inland edge effects width was not measured for Long Spruce, overall mean width would be very low since only 1% of the shoreline had observable effects.

The analysis examined factors controlling the extent and nature of reservoir-related groundwater, surface water and edge effects on terrestrial habitat along the inland side of the shoreline. The following provides broad generalizations regarding the factors controlling the extent of inland edge habitat effects, both in terms of proportion of shoreline affected and the width of the edge effects. Due to the number of potential controlling factors, there will be localized exceptions to these generalizations.

Local relief (i.e., amount of elevation change) on the inland side of the shoreline was a key factor contributing to differences in inland edge effects observed between and within the proxy areas. Inland edge effects extending more than 10 m inland generally were not observed in shore segments with moderate to high slopes at the inland edge. The importance of local relief was attributed to two factors. First, most boreal plant species have a shallow rooting system. For this reason, elevated groundwater must come relatively close to the land surface before it can affect vegetation. Second, there are physical limitations to how much raised water levels on the Nelson River can elevate the shore zone groundwater table.

Ecosite type and local inland relief were also important factors influencing the width of inland edge habitat effects (note that there is a strong correspondence between local relief at the shoreline and ecosite type because most of the peatland ecosite types have a level rather than a sloping surface). In the Kelsey and Kettle proxy areas, the widest inland edge effects tended to be in shore segments with deep wet peatlands (i.e., horizontal fen, basin bog, flat bog) on the inland edge, while the narrower width classes were associated with mineral, thin peatland and shallow peatland ecosite types. Level ecosite types were expected to demonstrate inland edge habitat effects further inland than a sloped ecosite type for the reasons described above. Deep wet peatlands typically had level surfaces whereas the underlying mineral/bedrock layer in thin or shallow peatlands, or the substrate surface in mineral ecosites, typically rose gradually to rapidly from the shoreline. Raising the water table in deep wet peatlands would move the groundwater into the plant rooting zone if it wasn’t already there prior to reservoir flooding. Although the narrower effects width classes were associated with mineral and thin to shallow peatlands, Kettle showed that even these ecosites can experience relatively wide edge effects if their surfaces have a low slope.

Kelsey demonstrated that ice scouring was an additional factor influencing the proportion of shoreline with inland effects, even in shoreline segments where local relief was too high for groundwater effects to occur.

The predominant pathway of inland edge vegetation change was characterized based on Kettle since this was the proxy area most similar to the Keeyask area and had the best air photo time series. This pathway of change was as follows: tree mortality within the first five years; vegetation structure change due to removal of deceased tree canopy in most of the affected shoreline by 15 years after flooding; and then further changes to vegetation composition and change due to colonization and development of tall shrubs after 32 years.

Most of the tree mortality present at age 32 had already occurred prior to age 15. Almost all of the shore zone effects wider than 10 m observed after age 15 occurred along shorelines that were already affected at age 15. By age 15, tree mortality and the associated vegetation structure change were the dominant shore zone effect, and by age 32, the dominant shore zone effect along these shorelines was vegetation composition and further structure change as a tall shrub band developed in the shore zone. It appeared that most of the long-term inland edge habitat change was complete by year 32.

As noted above, peat plateau bog shore segments were not included in most of the studies included in this report. This was because their dynamics are quite different from the remaining shoreline ecosite types, and those dynamics are the subject of other project reports. To summarize results from this and other project reports, groundwater effects on peat plateau bog habitat were not observed. Under natural conditions, peat plateau bogs are elevated above the surrounding areas and their banks undergo recession due to ground ice melting. Consequently, the inland edge habitat simply collapsed or subsided into the reservoir before groundwater-related habitat effects could occur.

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1 BACKGROUND

1.1 INTRODUCTION

The Keeyask Hydropower Limited Partnership is proposing to develop the Keeyask Generation Project (the Project), a 695 megawatt (MW) hydroelectric generating station and associated facilities, at Gull (Keeyask) Rapids on the lower Nelson River upstream of Stephens Lake in northern Manitoba. The Project includes permanent infrastructure, access roads, temporary borrow, camp and work areas, and approximately 45 km^2 of terrestrial flooding.

The Project would have a variety of direct and indirect effects on terrestrial ecosystems. Studies to develop a better understanding of local terrestrial ecosystems and to help predict potential Project effects were undertaken from 2001 to 2012. As part of the regulatory review process, an environmental impact statement for the Project was submitted on July 6, 2012. If licensed, the current schedule has Project construction occurring from 2014 to 2022.

Reservoir creation and water regulation are expected to be major contributors to direct and indirect Project effects on terrestrial habitat and ecosystems. Reservoir-related flooding would remove some terrestrial areas. Over time, the reservoir would expand due to peatland disintegration and mineral bank erosion, leading to further terrestrial habitat loss. Flooding and water regulation would alter nearby terrestrial areas through groundwater and edge effects, creating substantial changes to terrestrial ecosystems in some locations.

This report presents results from Project studies conducted to improve our understanding of the potential effects of Project flooding and water regulation on key components of terrestrial ecosystems. Since it was not possible to conduct large scale experiments to determine likely Project effects, existing reservoirs and/or regulated rivers in northern Manitoba (i.e., proxy areas) were studied as examples for how key Keeyask terrestrial ecosystem components were expected to respond to flooding and water regulation. This report supplements results previously reported from other proxy area studies (ECOSTEM 2012a, b).

1.2 REPORT ORGANIZATION

This report is organized into seven sections as follows. This background section provides a brief overview of terrestrial habitat in the region, potential project effects, an explanation of how terrestrial ecosystems were classified for the studies (including differences between classifications based on uplands and wetlands versus inland and shore zone), and a discussion of important factors controlling inland and shore zone wetlands. The next major section (Section 2) describes the study areas used in this report, including the proxy areas used to provide a local basis for predicting Project effects and to confirm information in the literature. Section 3 provides an overview of the study approaches taken to understand the effects of flooding and water regulation on wetlands and shore zones for the Keeyask reservoir area. Sections 4 to 8 present the four studies outlined in Section 3, including the study design and analytical methods for the particular study, followed by the study results which are organized by each of the proxy areas relevant to that study. Section 9 concludes the report concludes with a discussion of study results. Definitions for key terms are provided in the Glossary (Section 10).

1.3 REGIONAL CONTEXT

In terms of the broad regional context, the Project lies within a transitional area. The region overlaps three Ecozones (Boreal Shield, Taiga Shield and Hudson Plains), four Ecoregions (Churchill River Upland, Hayes River Upland, Hudson Bay Lowland, Selwyn Lake Upland), and six Ecodistricts (Smith et al. 1998).

Geologically, the Project is within the Canadian Shield. This Precambrian bedrock is dominated by greywache gneisses, granite gneisses and granites (Betcher et al. 1995). Multiple glaciations have deposited four till layer types containing cobbles and boulders, which are overlain with sands and gravels (JDMA 2012). After the last glaciation, thin layers of silts and clays were deposited on the bottom of glacial Lake Agassiz, forming varved clay and silt deposits, which can be quite thick in low-lying areas and thin or locally absent on ridges and knolls (JDMA 2012). Peat veneer and peat blanket deposits have developed on the poorly drained flatlands and depressions left after Lake Agassiz drained into the Hudson Bay and the Beaufort Sea (JDMA 2012).

While overall the terrain is gently sloping, steep sloping drumlins and glaciofluvial ridges occur throughout the area. Lakes of various sizes are common across the landscape. Drainage is generally towards the north and east into the Hudson Bay through the Nelson and Hayes Rivers (Smith et al. 1998).

Peats of varying thicknesses overlay the fine-grained glaciolacustrine clay and silt which is found on the gently sloping terrain. Veneer bogs, peat plateau bogs, and fens generally overlay clayey glaciolacustrine sediments (ECOSTEM 2012b). Veneer bogs are common on gentle slopes, while shallow to deep peat plateau bogs and fens are common in depressions and potholes (ECOSTEM 2012b).

Discontinuous permafrost is typical of the study area. Melting permafrost in peat plateaus has created thermokarst features called collapse scars, which are visible across the landscape (Smith et al. 1998).

Organic soil material derived from woody forest and sedge peat dominates the study area (ECOSTEM 2012b). The Crysolic soil order is the most common followed by the Organic and Brunisolic orders. The remaining soil orders are uncommon. Fibrisols and Mesisols, which are the dominant great groups in the area, are generally associated with very poorly drained fens and Sphagnum bogs (ECOSTEM 2012b). Mineral and organic soils in the study area frequently contain permafrost extending to varying depths. Cryosolic soils are mostly found in Sphagnum bogs, and to a lesser extent feathermoss bogs, and are generally very poorly drained (ECOSTEM 2012b). Permafrost activity contributes to surface topography and deeper soil layer processes.

Mineral soils tend to occur on drumlins, glaciofluvial ridges and along the Nelson River. Brunisols tend to be found on gently to strongly rolling topography and are associated with deep dry sites. Brunisols are most commonly associated with glacio-lacustrine and till deposition modes, and moderately well drained soils (ECOSTEM 2012b). Luvisolic soils are also present within the study area, especially on nearly level terrain. The Luvisols are most commonly found on rapid to moderately well drained soils developed on till or glacio-fluvial deposits (ECOSTEM 2012b).

The region lies within a cold, subhumid to humid, Cryoboreal climate and experiences short, cool summers and long, very cold winters. The mean annual temperature for this region is approximately –4.1°C and the mean annual precipitation is approximately 500 mm, with one third of the precipitation falling as snow (Smith et al. 1998). The average growing season is 131 days, with approximately 880 growing degree-days (Smith et al. 1998).

Historical climate trends using climate normals from the Gillam weather station indicate a warming of the local climate. Statistically significant upward temperature trends were identified for Gillam airport minimum, mean and maximum temperatures, though not for every month, season or annual data series (Manitoba Hydro 2012). The number of growing degree days above 0 °C and 5 °C had an upward trend in conjunction with the upward temperature trend.

Looking ahead, climate change scenarios, on average, project increasing temperatures and precipitation for the Keeyask Regional Study Area (Water Resources Engineering Department 2012). Winter is projected to experience the greatest change, with annual temperature and precipitation changes increasing between the 2020s and the 2080s. A smaller subset of climate change scenarios also project increasing evapotranspiration for the same time periods, although climate modeling uncertainty is not well captured in the limited subset of scenarios.

ECOSTEM (2012b) provides a more detailed description of the regional context.

1.4 POTENTIAL PROJECT EFFECTS

Reservoir creation and water regulation associated with the Project will have a variety of direct and indirect effects on terrestrial ecosystems. Figure 1-1 illustrates many of the potential pathways for terrestrial ecosystem effects from reservoir creation and water regulation.

Reservoir creation will flood terrestrial ecosystems, converting them to aquatic ecosystems in deeper water, and creating wetland areas in the shallow water. The larger opening created by flooding may induce additional edge effects in the surrounding terrestrial areas. Over time, reservoir expansion will lead to further terrestrial habitat loss and alteration.

In addition to altering water and ice regimes, reservoir creation and water regulation will raise groundwater levels along the new shoreline, which eventually alters soils, vegetation and other environmental attributes. Inland terrestrial ecosystems may also be affected if they are connected to the reservoir through buried mineral layers that are water permeable, or through openings in a relatively impermeable layer overlying a buried permeable layer (see Section 1.5.2 for details).

Since peatlands cover approximately 90% of the proposed reservoir and surrounding area, understanding the pathways for reservoir and water regime effects on peatlands will be especially important for predicting Project effects. Water percolates readily through peatlands. Reservoir creation will rapidly decrease the depth to groundwater in most peatlands along the reservoir shoreline (ECOSTEM 2012a). Effects will be substantially delayed in some peatland types, such as peat plateau bogs where ground ice acts as a barrier to water movement and subsurface temperature changes. For peatlands separated from the reservoir by peat plateau bogs, groundwater depth may not change until the ground ice in the intervening peat plateau bog melts.

Project related decreases in depth to groundwater could have substantial effects on terrestrial ecosystems. It is widely recognized that depth to groundwater table is the dominant factor structuring peatlands (Rydin and Jeglum 2006) and that differences as small as 20 cm can produce dramatic differences in boreal peatland vegetation structure. Many other ecosystem attributes and functions such as carbon storage and wildlife habitat quality could also be affected by groundwater depth changes.

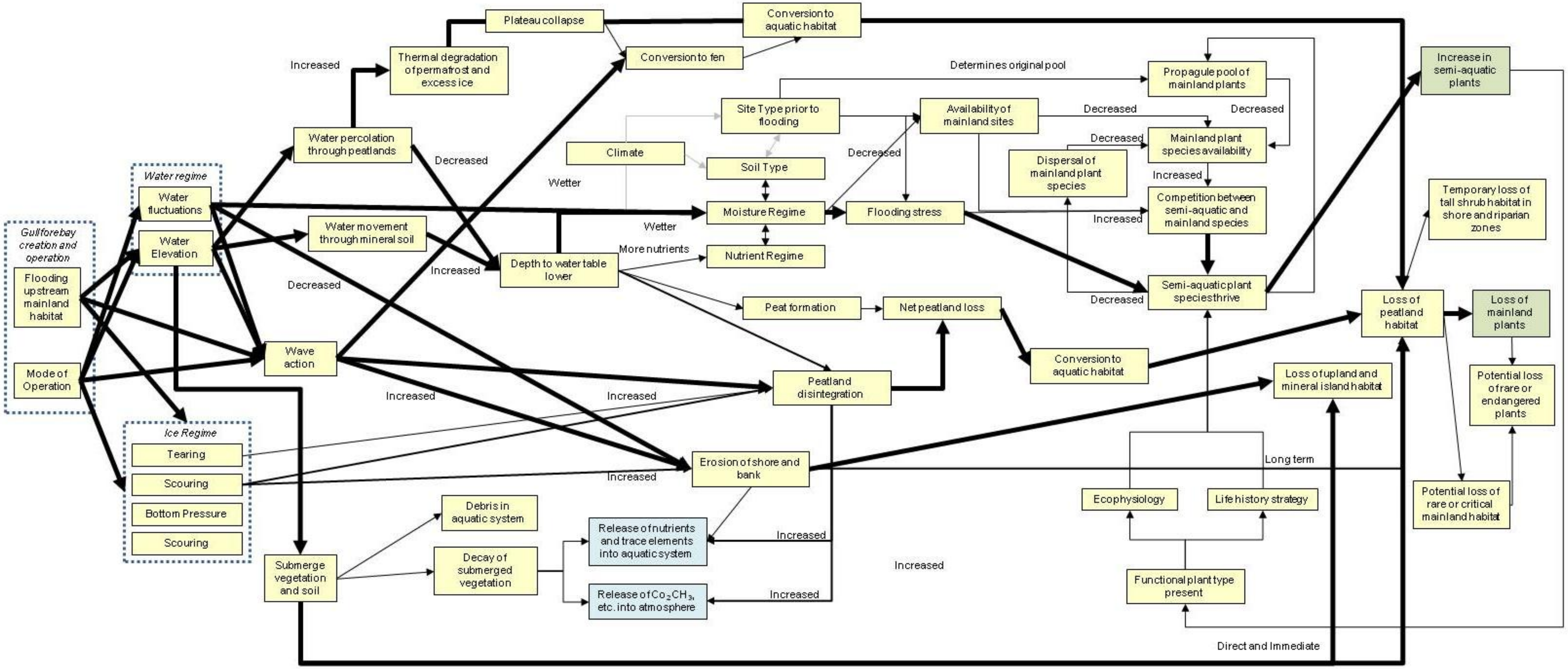

Figure 1-1: **Network linkage diagram for Keeyask reservoir creation and potential upstream water regime and environmental changes**

1.5 OVERVIEW OF TERRESTRIAL HABITAT AND ECOSYSTEM RESPONSES TO FLOODING AND WATER REGULATION

1.5.1 Major Ecological Zones

An ecosystem is a functional unit[1] comprised of the living and non-living things in a geographic area, as well as the relationships between all of these things (Aber and Melillo 1991). An ecosystem has patterns (*e.g.*, a vegetation mosaic), structures (*e.g.*, food web, trophic structure), dynamics (*e.g.*, cycling of energy, nutrients and matter) and performs functions (*e.g.*, converts carbon dioxide into plant material, creates soil, provides wildlife habitat). Ecosystems occur in different sizes, with the size being determined by the organism or process of interest. For example, the ecosystem for a bacterium may be a decaying log, whereas the ecosystem for a squirrel may be portions of two adjacent forest stands.

Habitat is the place where an organism or a population lives. Because all natural areas are habitat for something, “terrestrial habitat” in this report is a collective term for all land habitats for all species. Habitat for a particular species is identified with a species prefix such as moose habitat or jack pine habitat.

Wetlands and uplands are the two major types of terrestrial habitat and ecosystems (Figure 1-2). Wetlands are land areas where periodic or prolonged water saturation at or near the soil surface shapes ecosystem patterns and processes (National Wetlands Working Group 1997). Uplands are all land areas that are not wetlands. As is the case throughout Manitoba’s boreal forest, large fires were the dominant natural driver (i.e., controlling factor) in study area uplands (ECOSTEM 2012b). Groundwater, surface water and water nutrient regimes are the key drivers in most wetlands, and among the driving factors in the remaining ones (Keddy 2010). Figure 1-3 from Tiner (1991) illustrates how uplands and wetlands are organized along the surface water/groundwater gradient.

According to hydrological connections criteria (National Wetlands Working Group 1997), the two major types of wetlands in the Project area were shore zone and inland wetlands (Figure 1-2). Shore zone wetlands were located along the shorelines of a waterbody, while inland wetlands were all remaining wetlands. The dominant drivers for shore zone wetlands were water level fluctuations, water flows, and waves. Ice scouring was also important for Nelson River shoreline wetlands. The dominant drivers for inland wetlands were depth to groundwater and wildfire.

An alternative way to classify terrestrial ecosystems is to initially sub-divide them into inlands and shore zone (compare Figure 1-4 with Figure 1-2). This classification was used for these

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[1] Following Allen and Starr (1982), any ecosystem object or hierarchy described herein is an epistemological construct that facilitates analysis, prediction and land-use management and may have no independent ontological basis.

studies because their dominant drivers, or controlling factors, were dramatically different (ECOSTEM 2012b), and because the linkages between Project effects and ecosystems was clearer. Differences in dominant drivers strongly influenced the types of contextual information assembled for the studies, how field studies were designed, and how field data were analyzed.

“Shore zone” is the term used in this report to capture all of the ecological zones that are directly and indirectly affected by natural and regulated flooding, water level fluctuations, surface water flows, and ice processes (which also includes upland areas; Figure 1-2). The shore zone includes shallow water areas created by flooding, areas that are periodically inundated, areas that are rarely inundated but are influenced by elevated groundwater, habitat edge effects created by the presence of a waterbody (which affects wetlands and uplands), and all areas affected by ice processes.

Dominant drivers were critical to understanding ecosystem dynamics and predicting potential Project effects. Using dominant driving factors, the two major sub-divisions of the shore zone are the shallow water (shallow water is a type of wetland in the Canadian Wetland Classification System (National Wetlands Working Group 1997)) and the inland edge zones (Figure 1-4). The inland edge includes ice-scoured uplands, and areas where reservoir-related edge effects and elevated groundwater influence vegetation and soils. “Riparian” is not used in this context since it has a number of different definitions in everyday, policy and scientific usage. For example, some riparian definitions include the entire shore zone, while others only include the adjacent inland transition zone. The riparian term is reserved to name wetland forms as defined by the Canadian Wetland Classification System[2].

Inlands were further subdivided into uplands and inland wetlands (Figure 1-4) based on dominant drivers.

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[2] In the Canadian Wetland Classification System, wetland form is the primary subdivision of the five wetland “classes”: bog, fen, swamp, marsh, shallow water.

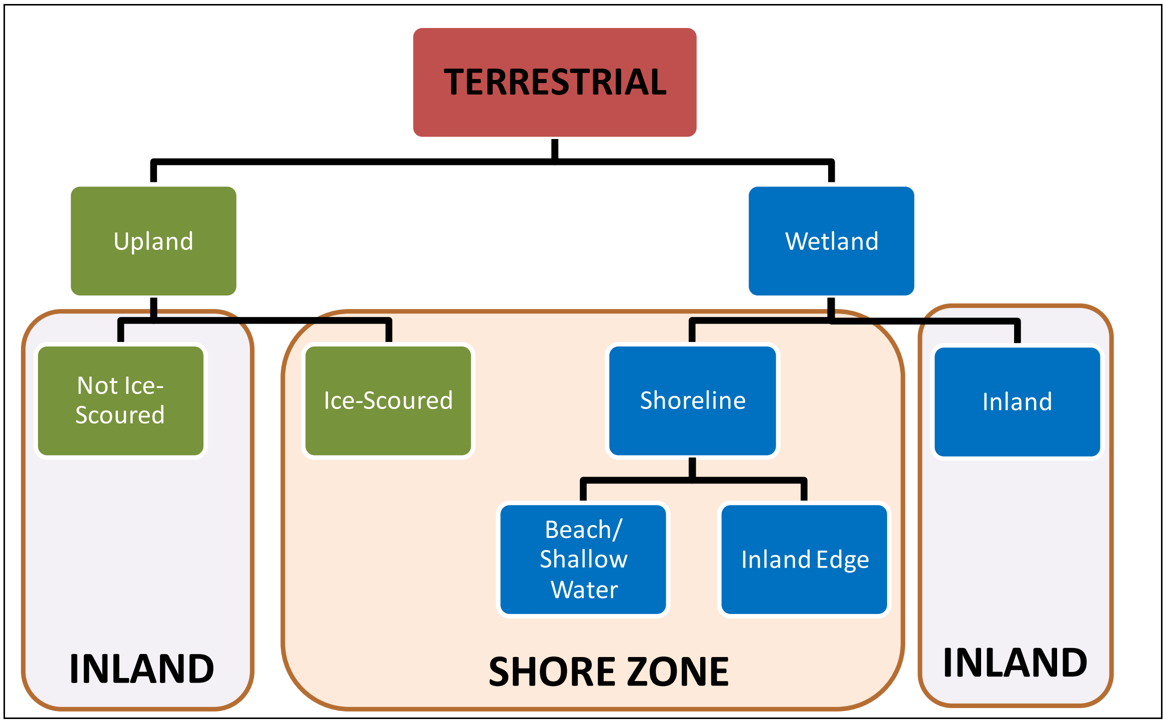


Figure 1-2: **Hierarchical relationships of upland and wetland ecological zones**

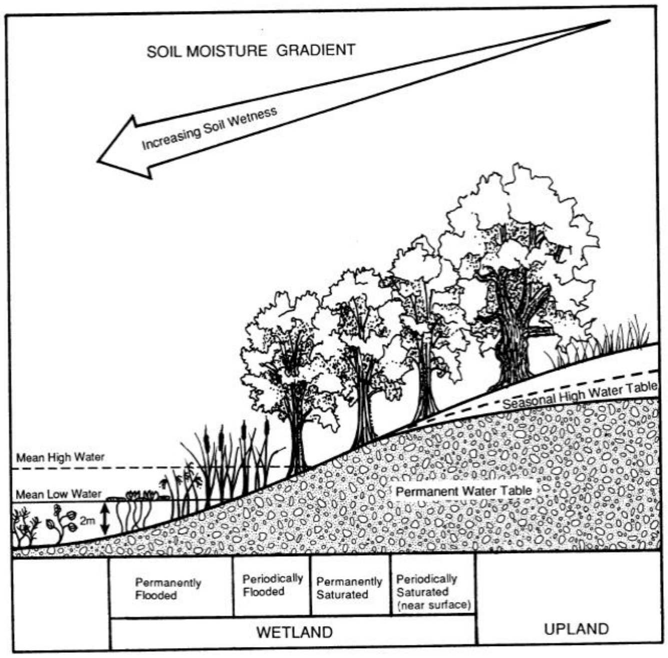


Figure 1-3: **The general location of wetlands along the soil moisture gradient**

The seasonal high water table represents the average height of the water table for a significant period during the wet part of the growing season in most years. (source: Tiner 1991).

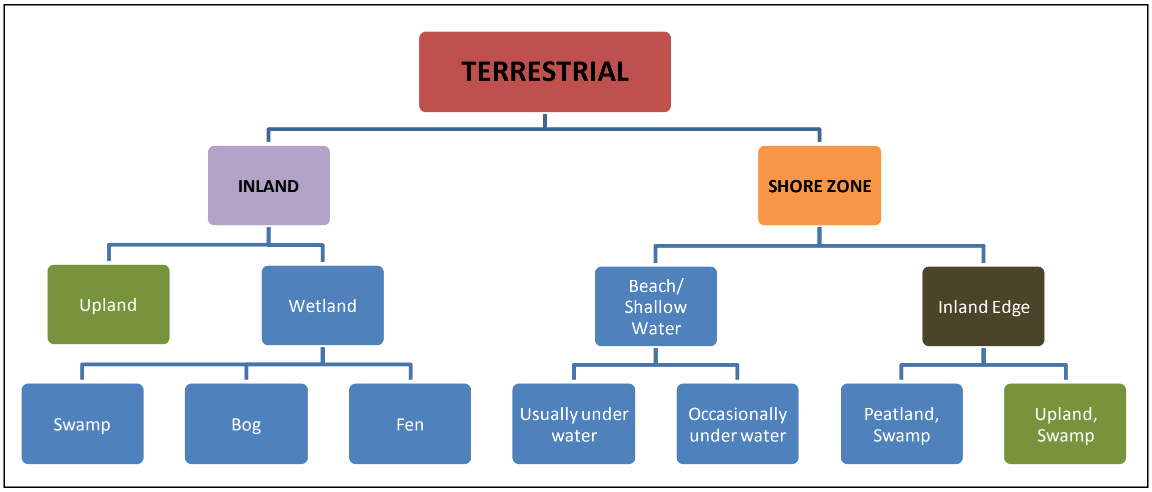


Figure 1-4: Hierarchical relationships of inland and shore zone ecological zones

Box shading corresponds with Figure 1-2.

1.5.2 Shore Zone Processes and Drivers

At any given shoreline location, different plant species are typically arranged into bands that reflect a transition in typical growing season water depths (Figure 1-3 shows the concept while Photo 1-1 to Photo 1-3 show examples from the Project area). Differential plant tolerances to flooding duration are the dominant mechanism creating shore zone vegetation bands (Hellsten 2000; Keddy 2010). Species that can only survive with their roots under water for a relatively short period (*e.g.*, tall shrubs) grow in the higher elevations of the shore zone because this area is rarely under water. Species that cannot survive out of the water for very long grow in the lower elevations of the shore zone (*e.g.*, pondweeds (*Potamogeton* spp.)). In other words, a sequence of vegetation bands forms because although daily, monthly and annual water level fluctuations constantly change water depths and the amount of the shore zone area that is inundated/exposed, some areas are typically under water for longer periods relative to other areas. The different vegetation bands occur in different “water depth duration zones”. Labeled photos show shore zone vegetation bands produced by water fluctuations at a location on the Nelson River shoreline (Photo 1-1) and a location in an off-system lake (Photo 1-3) in the Project area.

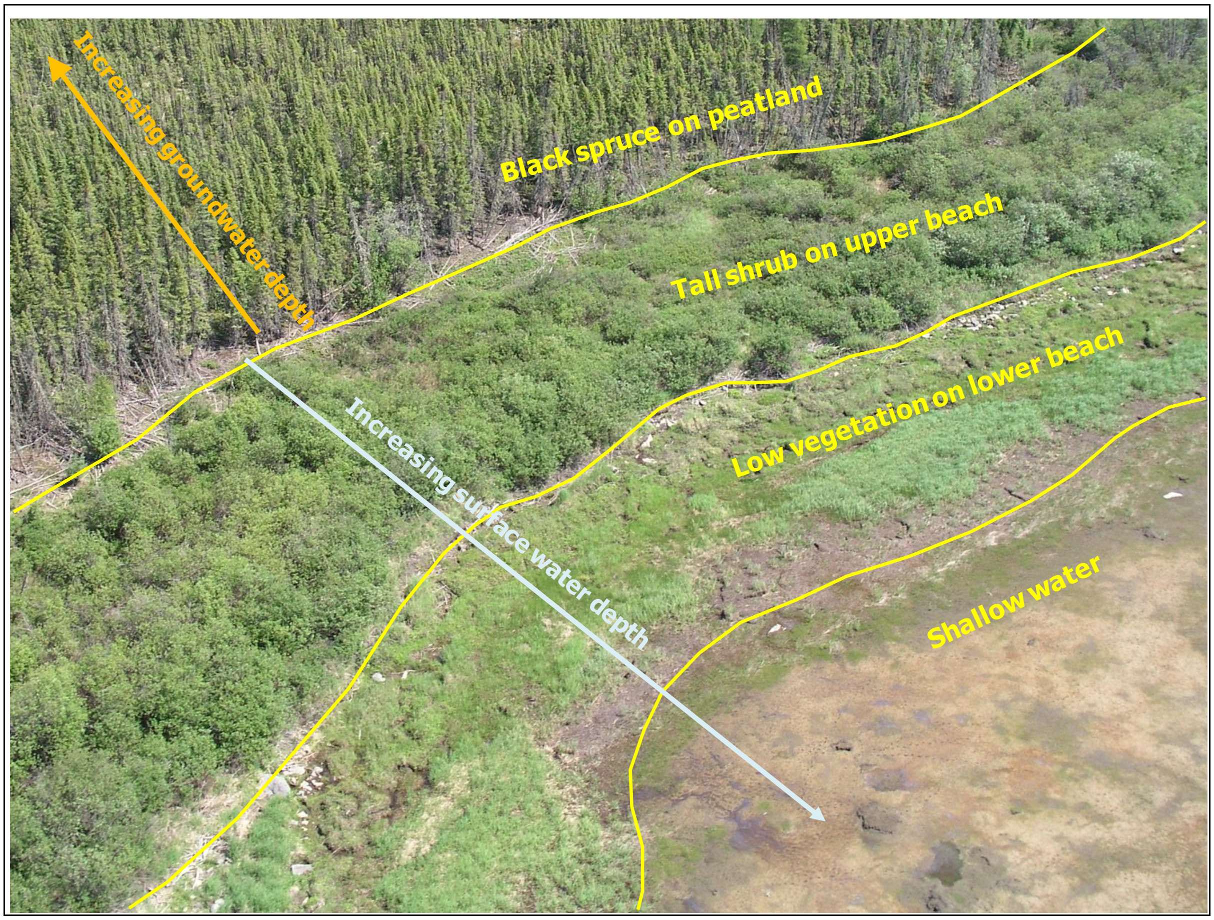


Photo 1-1: Photo illustrating shoreline water depth duration zones, vegetation bands and wetland classes in a back bay on the Nelson River when the water level is very low

Note: All of the shallow water zone appearing in this photo is exposed because the Nelson River water level is very low.

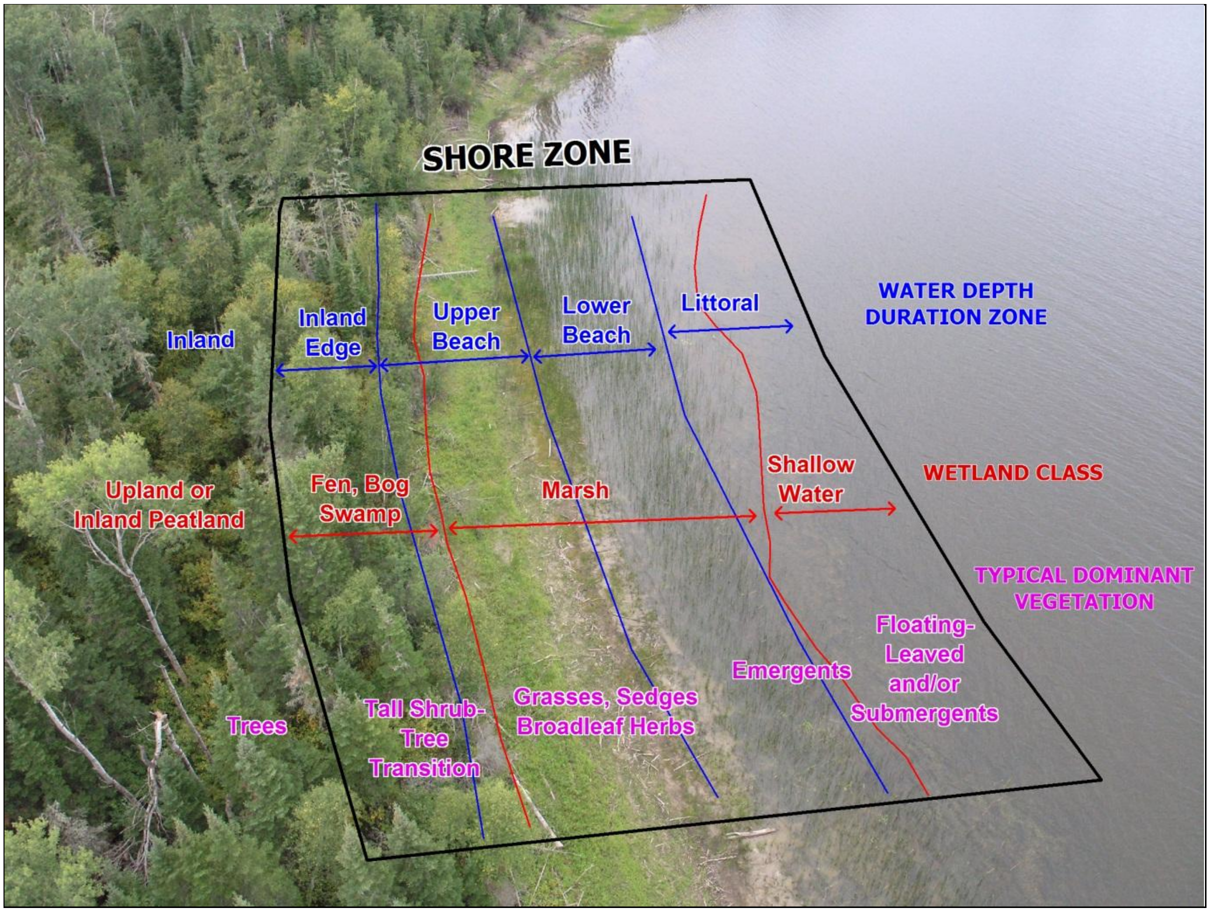


Photo 1-2: **Photo illustrating shoreline wetland water depth duration zones, vegetation bands and wetland classes in an off-system waterbody**

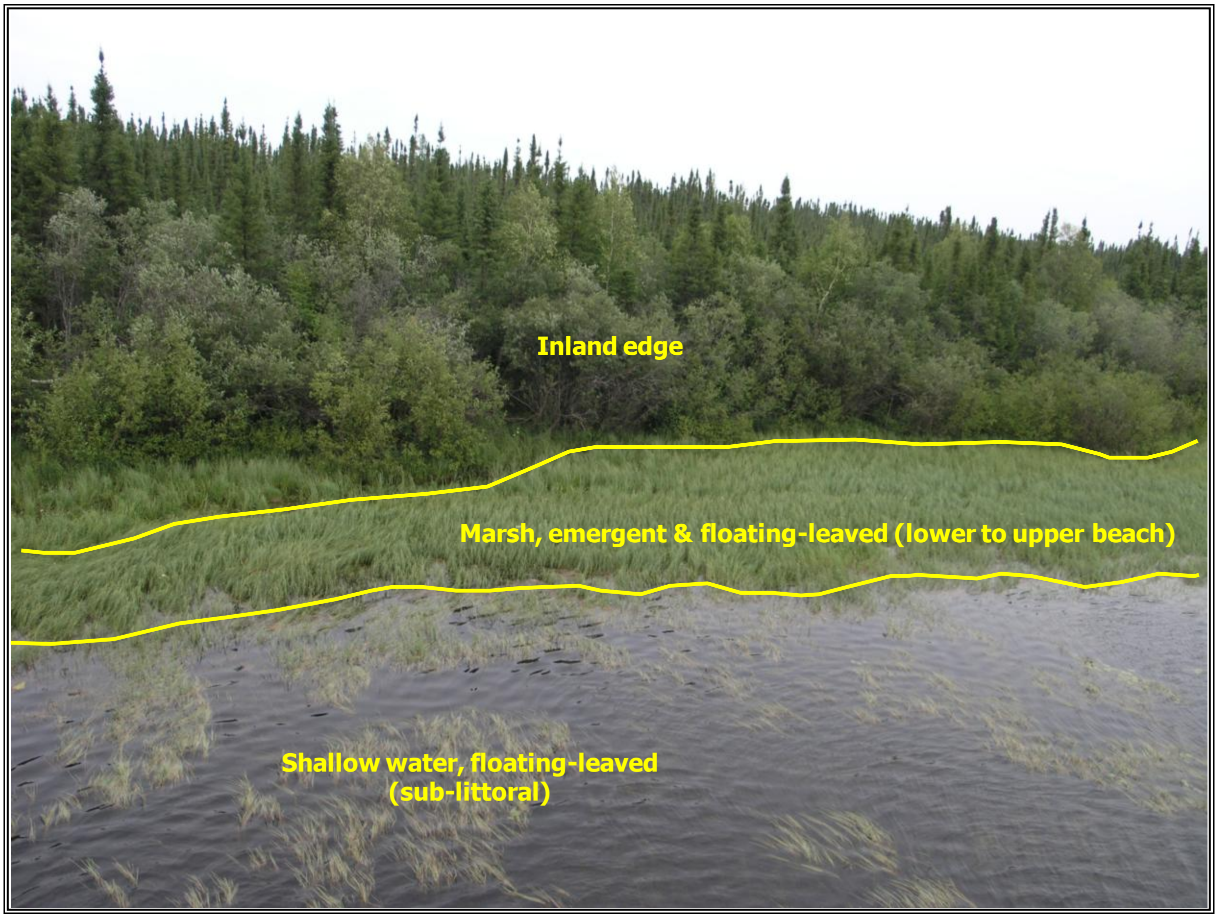


Photo 1-3: **Typical off-system marsh growing on the lake bottom**

On a daily basis, the width of the beach (*i.e.*, the exposed organic or mineral substrate that is the lake bottom on some days) varies with water levels. The beach is at its widest when water levels are at their lowest elevation. Also, at any given moment, low slope shoreline locations have a wider beach than high slope shoreline locations.

Plant species distributions along the shore zone water depth gradient are best understood when a plant's location within the shore zone is related to standardized growing season water depths rather than water depths on the day of sampling (Rorslett 1984; Wilcox and Meeker 1991; Hellsten 2000; Keddy 2010). A standardized water depth is the water elevation on a given day minus the median growing season water elevation calculated over the three to five years prior to the date of interest (Hellsten 2000). The frequency of standardized daily water depths is a key water regime parameter for shore zone plants and soils.

Standardized growing season water depths can be usefully grouped into standardized water depth duration zones (U.S. Army Corps of Engineers 1987; Hellsten 2000). Using Hellsten (2000), because this study was specifically developed to address the effects of water regulation from hydroelectric development, the water depth duration zones going from driest to wettest are inland edge, supra-littoral, upper eu-littoral, middle eu-littoral, lower eu-littoral, upper sub-littoral and lower sub-littoral. In this report, everyday names used for this sequence are inland edge, upper beach/inland edge transition (supra-littoral), upper beach (upper eu-littoral), middle beach (middle eu-littoral), lower beach (lower eu-littoral), shallow water (upper and lower sub-littoral) and deep water/aquatic (Figure 1-5). Table 1-1 describes the water duration zones and the types of species that typically grow in each zone.

Other components of water regime that are important drivers for shore zone ecosystems include the timing and duration of high or low water levels. A key effect typical of northern hydroelectric developments is the seasonal reversal of flows and water levels. Water levels in natural rivers are typically highest during the spring, whereas water levels are often highest during late fall and early winter in regulated systems to store water for the annual peak heating demand that occurs during the winter.

Different water regimes in different waterbodies or river reaches produce different water depth duration zones. Consequently, water regime can lead to shore zone vegetation zonation at two spatial levels: the site and the waterbody (or river reach). Site level zonation refers to the shore zone vegetation bands occurring at a particular location (see above). Waterbody level zonation refers to reaches of a river or large segments of a lake having different water regimes. Even in a natural river, the elevation ranges of the duration zones will vary in reaches where the flow passes through more constricted areas. A given flow passing through a more constricted reach will have more variable water levels than the same flows passing through a less constricted reach. Consequently, different river reaches can have different water depth duration regimes.

While water regime is generally the primary influence on shore zone ecosystems, other factors are important drivers for shore zone ecosystems. These other important factors include water chemistry, light regime, wave energy, erosion, sediment deposition, substrate freezing during winter drawdowns, ice scouring, ice-related substrate compression, substrate slope, substrate shape and substrate type (Hellsten 2000; Keddy 2010).

The preceding generalizations regarding shore zone patterns and drivers have been confirmed for areas subjected to hydroelectric water regulation (Keddy and Fraser 2000; Keddy 2010).

ECOSTEM (2012b) characterizes shore zone dynamics and habitats in the Keeyask area.

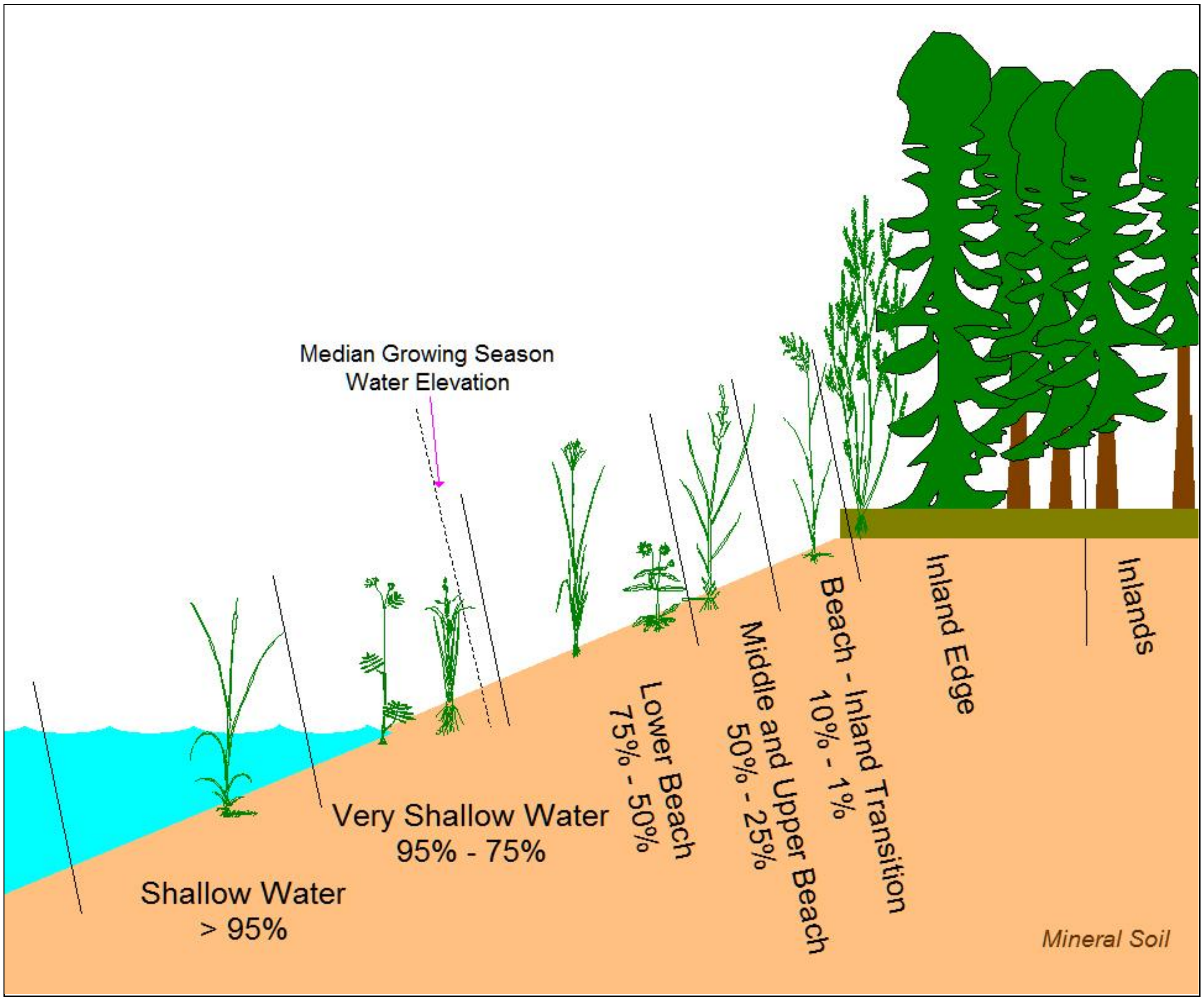


Figure 1-5: **Water depth duration zones and the types of plants found in each zone**

Table 1-1: Water duration zones, associated water conditions and types of species found in each zone

Water Duration Zone	Water Conditions[1]	Typical Species[2]
Inland Edge- Peatland Ecosite	Under water less than 1% of the time & surface organic layer >= 20 cm deep.	Fen or bog plants. Substrate edge may be a floating or expandable mat that moves up and down with moderate water level fluctuations thereby keeping plant roots from being submerged. Most woody plants, ericaceous plants, many herbs.
Inland Edge- Mineral Ecosite	Under water less than 1% of the time & surface organic layer < 20 cm deep.	Plants which will die if their roots are under water for extended periods during the growing season. Most woody plants, many herbs.
Beach - Inland Transition	Under water more than 1% but less than 10% of the time.	Plants which grow poorly in wet soil but can survive periodic short-term flooding. Graminoids, ruderal herbs, shrubs.
Middle & Upper Beach	Under water more than 10% but less than 50% of the time.	Plants which can tolerate alternating periods of inundation and desiccation during a season between years where the condition may persist for more than about 30 days. Tall to short emergents. Most are graminoids and ruderal herbs.
Lower Beach	Under water more than 50% but less than 75% of the time.	Plants which can tolerate alternating periods of inundation and desiccation during a season between years where the condition may persist for more than about 45 days. Tall emergents. Most are monocots. These species also expand their distribution into the higher portion of the Very Shallow Water when water levels drop for a prolonged period.
Shallow Water	Under water more than 75% but less than 99% of the time. Bottom freezing occurs in most or all of this zone.	Plants which cannot tolerate desiccation but which can tolerate bottom freezing and ice pressure. Hydrophytes ("true" aquatic plants according to some authors)
Deep Water	Under water at least 99% of the time.	Not part of the terrestrial ecosystem.

Notes: [1] Number of growing season days over past three to five years.

[2] Sources include Rorslett 1984, Mark and Johnson 1985, Wilcox and Meeker 1991, Hellsten 2000 and Keddy 2010

1.5.3 Inland Processes and Drivers

The processes and drivers for reservoir-related effects are different for inlands and the shore zone. Based on the manner in which these major ecological zones have been defined, a buried hydrological connection between the reservoir and an inland area is a prerequisite for flooding and water regulation to have an inland effect.

Figure 1-6 illustrates overburden stratigraphy and the separation of surface and deep groundwater layers in a hypothetical location where the deep and surface groundwater layers are isolated from each other. In this figure, water moves through the intertill layer at a high rate relative to the clay and till (but not as high as through peat). However, water movement through the clay and till layers is greatly restricted, which has the effect of isolating the deep groundwater layer from the surface groundwater layer.

Figure 1-7 shows an alternative stratigraphy in which a highly water permeable intertill layer is connected to the lake. In contrast with Figure 1-6, Figure 1-7 shows a hypothetical situation where three holes in the clay and till layers provide connections between the surface and deep groundwater layers.

Figure 1-8 illustrates the potential effects of higher water levels from reservoir flooding or water regulation on shore zone and inland zones by superimposing flooding and water regulation on the conditions in Figure 1-7. The peatlands bordering the lake in this series of figures may represent various terrestrial habitat types such as marsh, bog, and fen, all of which could be affected by flooding or water level regulation on the river. Section 1.5.2 elaborates on shore zone processes, drivers, and terrestrial ecosystem responses.

Figure 1-8 also illustrates how higher water levels from reservoir flooding can affect inland areas, that is, areas that have no direct physical connection to reservoir water. In this figure, flooding raises river water levels within the range of lake water levels. Under these conditions it is possible for the river to influence lake water levels and hydrology, which would affect shore zone habitat on this lake.

The surficial material stratigraphy of the Project area generally creates two groundwater layers, consisting of an upper (surface) groundwater layer and a lower (deep) groundwater layer such as those shown in Figs 1-6 to 1-8 (Stantec 2012). Throughout most of the Project area, the organic soils are underlain by mineral soils consisting of postglacial deposits of coarse alluvium materials, and highly impermeable lacustrine clays that overlay a till layer, which has relatively low permeability to vertical water movement. The surface groundwater layer is located on top of these relatively impermeable surface deposits. These surface deposits are generally underlain by a relatively permeable intertill layer, which contains the deep groundwater layer.

The clay cap and/or till layer may be absent at certain types of locations (e.g., crests of hills or ridges) due to glacial or post-glacial processes such as Lake Agassiz wave-washing, or because the deposits are high relief glaciofluvial materials. On this basis, it is theoretically possible that there may be locations in the Project area where the surface and deep groundwater layers are connected such as shown in Figure 1-7 and 1-8. Nevertheless, there are physical limitations on the degree to which flooding and water regulation can affect groundwater, which constrains the geographic extent of terrestrial habitat effects (see Section 4).

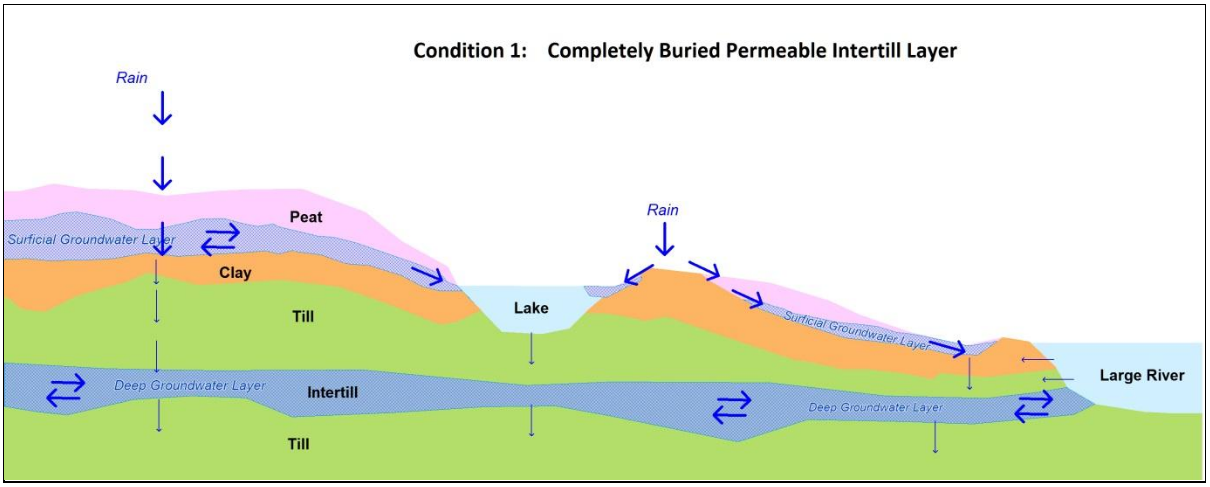


Figure 1-6: Illustration of overburden stratigraphy and the separation of surface and deep groundwater layers in a hypothetical location

Arrow thickness signifies relative rate of water flow.

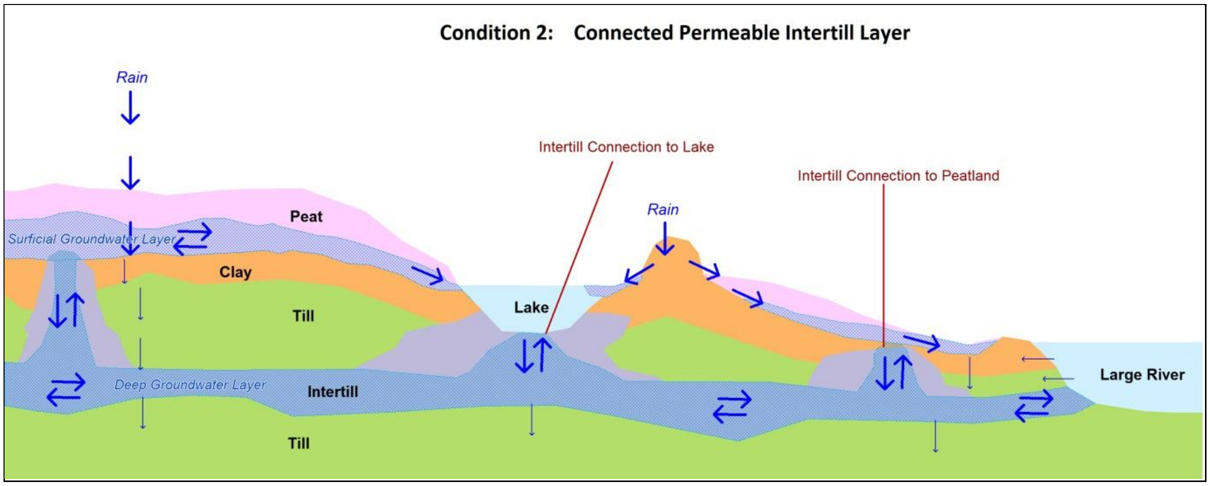


Figure 1-7: Illustration of overburden stratigraphy and connected surface and deep groundwater layers in a hypothetical location

Arrow thickness signifies relative rate of water flow.

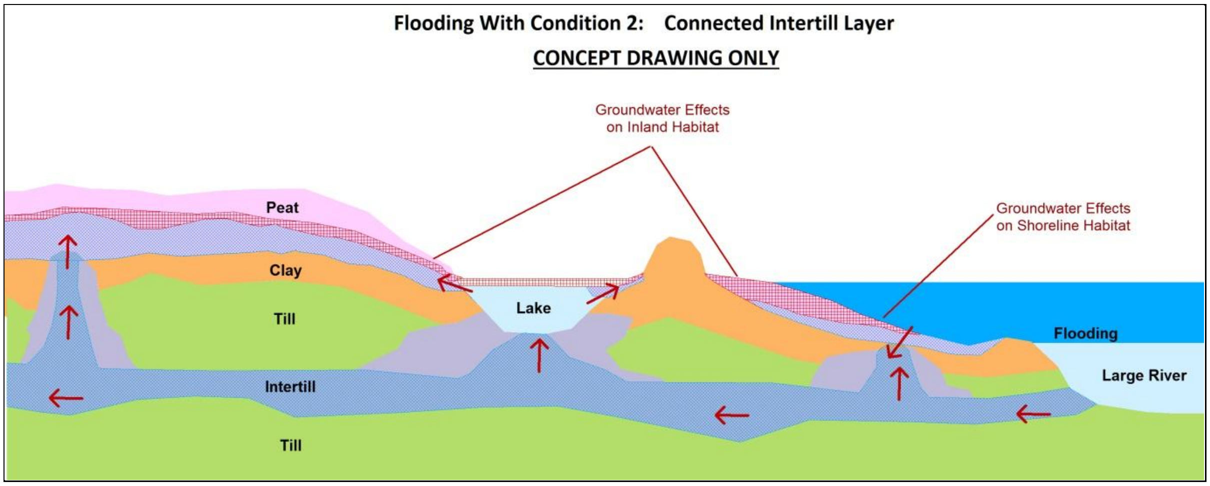


Figure 1-8: **Illustration of changes to surface (red cross-hatching) and deep groundwater layers (red arrows and blue cross-hatching) after raising water levels on the river in a hypothetical location where the layers are connected**

2 STUDY AREAS

Project effects assessment areas and proxy areas were the two types of study areas used for the responses to flooding and water regulation studies. Project effects assessment areas were used to identify and evaluate potential Project effects while proxy areas were river reaches previously affected by hydroelectric development flooding and/or water regulation that provided examples of how the Project could potentially affect shore zone ecosystems.

2.1 PROJECT STUDY AREAS

The Project effects assessment areas for terrestrial habitat and wetland function are referred to as the Local and Regional Study Areas. The Local Study Area was the area where the Project could potentially alter terrestrial habitat while the Regional Study Area was the ecological region relevant for evaluating the magnitude of local effects. ECOSTEM (2012b) describes the methods used to delineate the boundaries of the Local and Regional Study Areas. Map 2-1 shows the Local and Regional Study Area as well as the predicted Project Footprint and flooding.

As described in Section 1.5.2, the primary sub-division of a waterbody into zones is often based on water regime, since this is generally the most important influence on shore zone composition in a study area. This was the primary reason why Nelson River and off-system shoreline wetlands were addressed separately, as well as why the Kelsey, Split Lake, Gull Lake, Stephens Lake and Long Spruce reaches of the Nelson River were separate shore zone study areas (Map 2-2). A secondary sub-zonation of each of these Nelson River reaches was based on broad differences in other influential factors such as wave energy, current, sedimentation or surface materials, to the extent relevant information was available to create these sub-zones. These latter factors were considered for the stratification component of field studies and when analyzing field data, where relevant.

2.2 PROXY AREAS

The proxy areas had three broad purposes for the responses to flooding and water regulation studies. First, to confirm that the generalizations about shore zone patterns and dynamics reported in the scientific literature applied to local conditions. Second, to improve understanding of local relationships to the extent needed to complete the environmental assessment (few literature studies included directly comparable areas). Finally, to provide data to develop qualitative and quantitative effects prediction models. More than one proxy area was used because no single one represents ecological conditions identical to Keeyask and to provide replication for any findings.

2.2.1 Potential Proxy Areas

Proxy areas were selected to be ecologically comparable to the proposed Project reservoir area in terms of pre-flood soil composition, climate, topography, water temperature, water chemistry, water regime and reservoir morphology. Some variance in ecological conditions relative to Keeyask can strengthen the generality of the results because they provide data for a range of conditions that may influence the outcomes of interest.

Potential proxy areas in northern Manitoba included reaches along the Nelson and Burntwood Rivers. The potential Nelson River proxy areas were the Kelsey, Kettle, Long Spruce, and Limestone reservoirs (Map 2-3; referred to as Kettle, Kelsey, Long Spruce, and Limestone respectively). The Kettle reservoir is also known as Stephens Lake.

Nelson River reaches upstream of Kelsey were not considered because the reach immediately upstream is bedrock outcrop terrain; areas further upstream represented a substantially warmer climate. Split Lake, located immediately downstream of the Kelsey dam on the Nelson River, was not considered for use as a proxy area because the Churchill River Diversion and Lake Winnipeg Regulation (CRD/LWR) did not substantially alter water levels on the lake, but instead changed the water level timing pattern, which also occurred in the Gull reach (Split Lake Cree - Manitoba Hydro Joint Study Group 1996b).

The potential Burntwood River proxy areas were created by the Churchill River Diversion. These included South Indian Lake, Notigi reservoir, and Wuskwatim Lake (Map 2-3; referred to as South Indian, Notigi and Wuskwatim, respectively).

2.2.2 Ecological Comparability

Surface deposits (Map 2-4) were comparable for all potential proxy areas except for Long Spruce and Limestone. Long Spruce was partially, and Limestone was entirely, in a marine deposition area (Nielsen et al. 1981).

Parent material data (Agriculture and Agri-Food Canada 1996), which was mapped at a larger scale than surface deposits, indicated that peatlands were the most abundant parent material around Keeyask, Kettle, Long Spruce, Limestone and Wuskwatim (Map 2-5). Lacustrine material was the most abundant type at Kelsey and South Indian, as well as most of Notigi. Bedrock outcrop was interspersed with the lacustrine material in the west portion of Notigi. Despite the prevalence of non-organic materials in the small scale surface materials mapping, the Notigi flooded area was predominantly peatlands.

Permafrost distribution is a synthetic indicator of the interaction of climate and surface materials. Permafrost distribution, as indicated by Soil Landscapes of Canada (SLC; Ecological Stratification Working Group 1996), was the same for all of the potential proxy areas except for Long Spruce and Limestone (Map 2-6). Since Long Spruce fell on the edge of an Ecozone boundary, it is important to note that SLC polygon boundaries often represent a location within a broad transition zone rather than a distinct edge between types (Mills et al. 1976a). Exceptions occur where attributes do have abrupt changes (e.g., surface materials). Given that the climate does not have abrupt boundaries and surface permafrost mapping (ECOSTEM 2012b) demonstrates a broad transition in permafrost, the polygon boundary was probably placed in that location based on a combination of minimum mappable polygon size and abrupt changes in surface deposits. On this basis, Long Spruce permafrost distribution was considered to be sufficiently similar to Keeyask. This was less likely for Limestone given its distance from the mapped polygon boundary.

The number of growing degree days above 0° C was similar for Keeyask and Kettle (Freemark et al. 1999; Map 2-7). The apparent difference for Long Spruce was likely an artifact of the polygon boundary being determined by factors other than climate. These three locations were too close together to have substantial differences in climate given the low relief and elevation change. Again, this was less likely for Limestone given its distance from the polygon boundary. Keeyask had substantially fewer effective growing days than Notigi, South Indian, Wuskwatim and Kelsey (1,643 versus 1,743, 1,742, 1,779 and 1,727, respectively) and considerably fewer than Limestone (1,822).

Kettle reservoir was the only potential proxy area that had the same mapped values as Keeyask for all of the ecological comparison attributes. Overall, values for the other proxy areas except for Limestone were sufficiently similar to be relevant for proxy area analysis. Limestone was dropped from further consideration as a potential proxy area based on insufficient ecological comparability.

2.2.3 Historical Information Availability

Regardless of how comparable potential proxy areas were, the availability of suitable historical information limited which ones could be included in studies. A time series of large scale historical stereo aerial photography was the key data source for historical change analysis. For this purpose, the time series should ideally include at least one year shortly before flooding, a number of closely spaced years in the early years after flooding, and more widely spaced years with increasing time since flooding extending for at least 20 years post-flooding.

Table 2-1 lists the available photography for the Nelson River proxy areas. Kettle had the best time series of historical photos at a scale of 1:20,000 or larger. Kettle photography was available for the following post-flooding ages (i.e., number of years since flooding): -9, 0.2, 4, 15, 22, 28, 32 and 35 (i.e., 1962, 1971, 1975, 1986, 1993, 1999, 2003 and 2006). The date of the pre-flood photography was deemed to be sufficiently close to the date of flooding given the slow rate of change for inland peatlands under natural conditions.

Table 2-1: Stereo-photography available for the Kelsey, Kettle and Long Spruce proxy areas

Proxy Area	Period	Years Since Flooding	Year[1]	Photo Scale (1:xx,xxx)	Geographic Coverage
Kelsey	Pre-flood		1927	Oblique	North portion of reservoir
			1927-34	Various	North portion of reservoir
		-14 to -10	1946-50	39 000	Entire reservoir
		-10 to -8	1950-52	36 000	Entire reservoir
		-9 to -4	1951-56	58 000	Entire reservoir
	Post-flood	3	1963	12 000	Kelsey dam
		5	**1965**	16 000	Entire reservoir
		11	1971	12 000	Northwest portion of reservoir
		15 to 19	1975-79	56 000	Entire reservoir
		26	1986	20 000	North portion of reservoir
		26	1987	20 000	Northeast portion of reservoir
		31	1991	20 000	Northeast portion of reservoir
		31	**1991**	15 840	Entire reservoir
Kettle and Long Spruce	Pre-flood	-16	1954	62 000	Kettle, Long Spruce
		-9	**1962**	12 900	Kettle, Long Spruce
	Post-flood	0.2	**1971**	24 800	Kettle
		4	1975	57 000	North 2/3 of Kettle
		12	1982	40 000	Kettle
		13	1984	23 000	North of Long Spruce
		15	**1986**	20 000	West 2/3 of Kettle
		20	1991	16 500	South side of Kettle
		22	1993	10 200	Portions of Kettle
		28	1999	20 000	Kettle
		32	**2003**	15 000	West side of Kettle, Long Spruce reservoir
		32	2003	20 000	South side of Kettle
		32	2003	60 000	East side of Kettle, Long Spruce
		35	**2006**	15 000	Kettle and Long Spruce

Notes: [1] Bolded years were the years primarily used for air photo time series analysis.

For the Kelsey proxy area, stereo-photography of sufficient coverage and scale (>1:20 000) was available for only two years post-flood, and with only smaller scale (1:36 000) photography available for pre-flooding conditions. Pre-flood vegetation and ecosites were represented for Kelsey by photography acquired in 1950 and 1952, while 1962 photography was used for Kettle. In both cases, this was the year that was closest to the time of reservoir flooding, and had the largest scale stereo photography for the highest proportion of the proxy area. Long Spruce reservoir had good historical large-scale photo coverage, although with less years available than Kettle.

Pre-CRD/LWR photography for Wuskwatim was available from 1972, and post-CRD/LWR photography was available from 1978 and 1985. 1981 photography was also available for a portion of the proxy area. Digital orthophotos were available for 1998 (1:60,000 scale), and low altitude helicopter photos were available for 2001.

South Indian was dropped from further consideration as a potential proxy area because it did not have suitable historical air photo coverage.

Three historical air photo years were available for Notigi (Table 2-2). While the photography scale was adequate for some purposes such as mapping reservoir-related peatland disintegration patterns and pathways, it was too small for mapping shore zone and inland terrestrial habitat effects.

Table 2-2: Stereo-photography available for the Notigi proxy area

Period	Years Since Flooding	Year	Photo Scale (1:xx,xxx)
Pre-flood	-7	1969	32,000
Post-flood	0.8, 0.9	1978	50,000
Post-flood	22	1998	60,000

2.2.4 Generally Suitable Proxy Areas

Based on ecological comparability and suitable historical information, the following five generally suitable proxy areas for creating historical change datasets were identified: Kelsey, Kettle, Long Spruce, Notigi and Wuskwatim. The latter two of these were used to create historical change data for peatland disintegration studies but not for the shore zone and inland effects studies due to photography scale. The total number of proxy areas was increased to six by using the Gull reach of the Nelson River (referred to as Gull) as a proxy area for recent flooding effects; prolonged very high water levels from 2005 to 2010 provided an opportunity to study short-term responses to flooding. To distinguish between existing and post-Project situations, Gull reach refers to the pre-Project conditions while Keeyask reach refers to the post-Project hydraulic zone of influence (which has slightly different geographic extents than the Gull reach).

Table 2-3 provides the proxy area names, locations and some comments. The identity and number of proxy areas used for a study depended on the study questions. Overall, generalizations relied most heavily on Kettle because it was immediately downstream of the proposed Keeyask reservoir, was the most ecologically comparable proxy area, and had the best historical time series of large scale aerial photography. The remaining proxy areas provided replication and valuable additional information for components of model development or verification. Previously reported results for Notigi (ECOSTEM 2012a) and Wuskwatim (ECOSTEM and Calyx 2003) provided some additional and/or corroborating information for proxy area findings.

Each study included in this report (see Section 3 for an overview of the studies) used a subset of the generally suitable proxy areas, depending on the data needs created by the questions being addressed.

Table 2-3: Generally suitable proxy areas for Keeyask

Proxy Area	Proxy Area Location	Comment
Kelsey Reservoir	Nelson River ~80 km upstream of Gull Lake.	Flows from Lake Winnipeg Regulation. Water levels regulated by Kelsey dam.
Gull Lake	Nelson River between Split Lake and Kettle.	Flows from Lake Winnipeg Regulation and Churchill River Diversion. Water flow regulated by Kelsey dam and Notigi control structure.
Kettle Reservoir	Nelson River immediately downstream of Gull and upstream of Long Spruce.	Flows from Lake Winnipeg Regulation and Churchill River Diversion. Water levels regulated by Kettle dam.
Long Spruce Reservoir	Nelson River immediately downstream of Kettle and upstream of Limestone.	Flows from Lake Winnipeg Regulation and Churchill River Diversion. Flows regulated by Kettle Dam and water levels by Long Spruce dam.
Notigi Reservoir[1]	Burntwood River immediately downstream of South Indian.	Flows from Churchill River Diversion. Water levels regulated by Notigi control structure.
Wuskwatim Lake[1]	Burntwood River ~80 km downstream of Notigi dam.	Flows from Churchill River Diversion. Water flow regulated by Notigi control structure.

Notes:[1] Directly used for peatland disintegration and indirectly used for shore zone and inland effects studies.

2.2.5 Proxy Area Water Regimes

As described in Section 1.5.2, water regime is a key driver for shore zone patterns and processes. This section describes initial flooding, where applicable, and the water regime of each of the proxy areas used for the shore zone and inland effects studies.

The Kelsey reservoir, which was created in 1960, raised water levels by 9.5 m at the dam (Table 2-4). At Kettle, the first inundation occurred in 1970, raising water levels by 30 m at the dam. Kettle water levels were lowered for a period during 1971 to facilitate dyke remediation. Long Spruce inundation raised water levels by approximately 26 m at the dam (Split Lake Cree - Manitoba Hydro Joint Study Group 1996b). In 1976, the Churchill River Diversion (CRD) project raised water levels at the Notigi control structure by approximately 8 m, and by approximately 3 m at Wuskwatim Lake to increase the generating capacity of Nelson River hydroelectric projects.

Table 2-4: Year of water level change, amount of water elevation change and area flooded for the different proxy areas, and year of hydroelectric developments affecting the Nelson River system.

Proxy Area/ Hydroelectric Development	Year When Water Levels Changed[1]	Water Elevation Change at Structures (m)	Area Flooded (km^2)
Kelsey	1960	9.5	165
Kettle	1970	30	221
Lake Winnipeg Regulation	1975	n/a	n/a
Churchill River Diversion	1976	n/a	n/a
Notigi	1976	8	35[2]
Wuskwatim	1976	3	18[2]
Gull water regime changed	1976	n/a	n/a
Long Spruce	1977	26	14

Notes:[1] Corresponds to in-service year for hydroelectric developments and/or year when median water levels changed due to hydroelectric developments for regulated areas. [2] For the proxy area portion of the reservoir. Area is a draft estimate that requires confirmation.
Source: Split Lake Cree - Manitoba Hydro Joint Study Group (1996b)

Daily water elevation data for the growing season were used to characterize the growing season water elevation regime of each proxy area. The growing season was defined as the period from June 1 to September 30 each year, which could include river ice in some years.

Table 2-5 provides percentile values for growing season water elevations during the 1996 to 2005 period. Since shore zone locations were sampled for these studies over several years and some species respond more slowly than others to annual median water level changes, the water depth duration zones were calculated over a ten year period to provide a general comparison of water depth duration zones among the proxy areas. The 1996 to 2005 ten year period is also the period prior to and including when most of the shore zone field studies were completed.

To standardize the Table 2-5 percentiles for comparison across proxy areas, Table 2-6 converts the water elevations from the upper and lower ends of each water depth duration zone into water depth duration zone elevation ranges. Gull had the highest range of elevations for all zones combined and for the beach zones for the 1996 to 2005 period.

Water elevation percentiles vary somewhat depending on the period included. This can be illustrated by presenting the normal range of growing season water elevations for various periods. The normal range is the difference between the 95th and 5th percentile values. As described above, water depth duration rather than the water fluctuation range is generally the primary influence on shoreline wetland habitat composition. One day or one week of extremely high levels that floods vegetation located in areas that rarely flood will not kill that vegetation. Some shrub and trees species are known to survive more than one year of inundation. The normal range of growing season water elevations is an indicator for the potential width of the beach and shallow water zones for a given constant substrate slope when water depths are considered in isolation.

Table 2-5: Growing season (June 1 to September 30) water elevation percentiles for proxy areas during the 1996 to 2005 period

Water Depth Duration Zone[1]	Percent-age of Days[2]	Elevation (m ASL) at Top of Depth Duration Zone[3]			
		Kelsey	Gull	Kettle	Long Spruce
Beach-Inland Transition	0.1	184.43	154.94	141.13	110.26
Upper Beach	10	184.39	154.30	141.08	109.94
Middle Beach	25	184.38	153.86	140.67	109.90
Lower Beach	50	184.35	153.04	140.36	109.85
Very Shallow Water	90	184.29	152.67	140.09	109.78
Shallow Water	95	183.94	151.99	139.70	109.70
Deep Water	99.9	183.02	151.51	139.00	108.64

Notes:[1] Vegetation bands defined by percentage of growing season inundated by water. [2] Percentage of days water levels are above the elevation shown in the columns to the right. [3] Standardized water elevation at top of water depth duration zone.
Source: Manitoba Hydro- WRE (2009).

Table 2-6: Depth (m) of the water depth duration zones[1] for proxy areas during the 1996 to 2005 period

Water Depth Duration Zone	Kelsey	Gull	Kettle	Long Spruce
Beach-Inland Transition	0.04	0.64	0.05	0.32
Upper Beach	0.01	0.44	0.41	0.04
Middle Beach	0.03	0.82	0.31	0.05
Lower Beach	-0.41	-1.05	-0.66	-0.15
Very Shallow Water	-0.42	-0.09	-0.28	-0.05
Shallow Water	-0.50	-0.39	-0.42	-1.02
All Zones[2]	1.41	3.43	2.13	1.63
All Beach zones[3]	0.45	2.31	1.38	0.24

Notes: [1] Calculated by subtracting daily water elevations from the median elevation over the ten year period. Depths with positive values indicate how much the top of the duration zone is typically out of the water while negative depth values indicate the typical submergence depth for the bottom of the duration zone. [2] Sum of absolute values of depths. Corresponds with the difference in elevations ASL for the beach-inland transition and deep water duration zones in Table 2-5. [3] Includes the upper, middle and lower beach water depth duration zones.

Table 2-7 illustrates how the normal ranges of growing season water elevations varied with time in the proxy areas by providing values for three periods of increasing length. Gull and Kettle had normal ranges of growing season water elevations that were approximately 2.4 m and 2.0 m, respectively, for the 1978 to 2005 period (Table 2-7). The corresponding normal ranges for Kelsey and Long Spruce are just less than 1 m, which is similar to that proposed for the Keeyask reservoir. The normal ranges are slightly different for the longer open water season as follows: 0.8 m for Kelsey, 2.3 m for Gull, 2.0 m for Kettle and 0.8 m for Long Spruce.

Although the Keeyask reservoir maximum range is 1 m, the expected actual range is less due to a combination of peaking and based loaded operation (Keeyask GS EIS Physical Environment Supporting Volume (PE SV) Section 4.4.2.2). Seven-day peaking mode water fluctuations will range up to 1.0 m, while base loaded operation water levels will remain relatively constant.

When compared with the 1978 to 2005 period, the normal ranges of growing season water elevations at Kelsey and Gull increase for the 1996 to 2005, and the 2001 to 2005, periods; Kettle decreases for these periods; while Long Spruce is lower for the first period and higher for the second.

The shortest period (2001 to 2005), which is also the most recent, has the largest normal range for Kelsey and Gull. Although all periods examined include years of extremely high and extremely low water levels, the shortest period emphasizes them because both extremes occurred during this period and the period length is relatively low.

Table 2-7: Normal range[1] of growing season (June 1 to September 30) water elevations (m) for proxy area locations during various periods

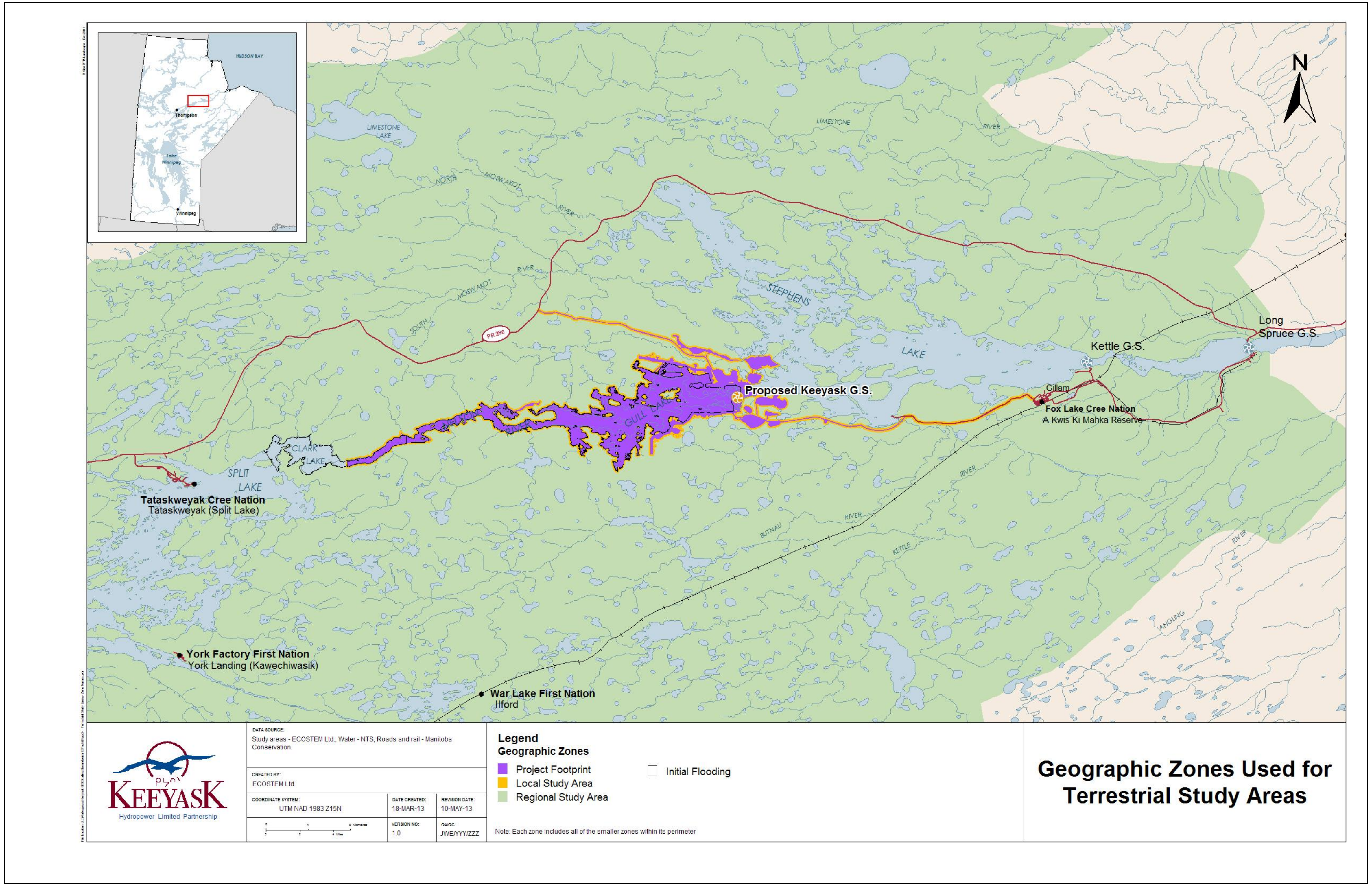
Period	Kelsey	Gull	Kettle	Long Spruce
1978 to 2005	0.82	2.41	2.01	0.91
1996 to 2005	0.88	2.85	1.68	0.31
2001 to 2005	1.14	3.14	1.42	0.33

Notes:[1] Normal range is the difference between the 95th and 5th percentile values. See text for explanation.

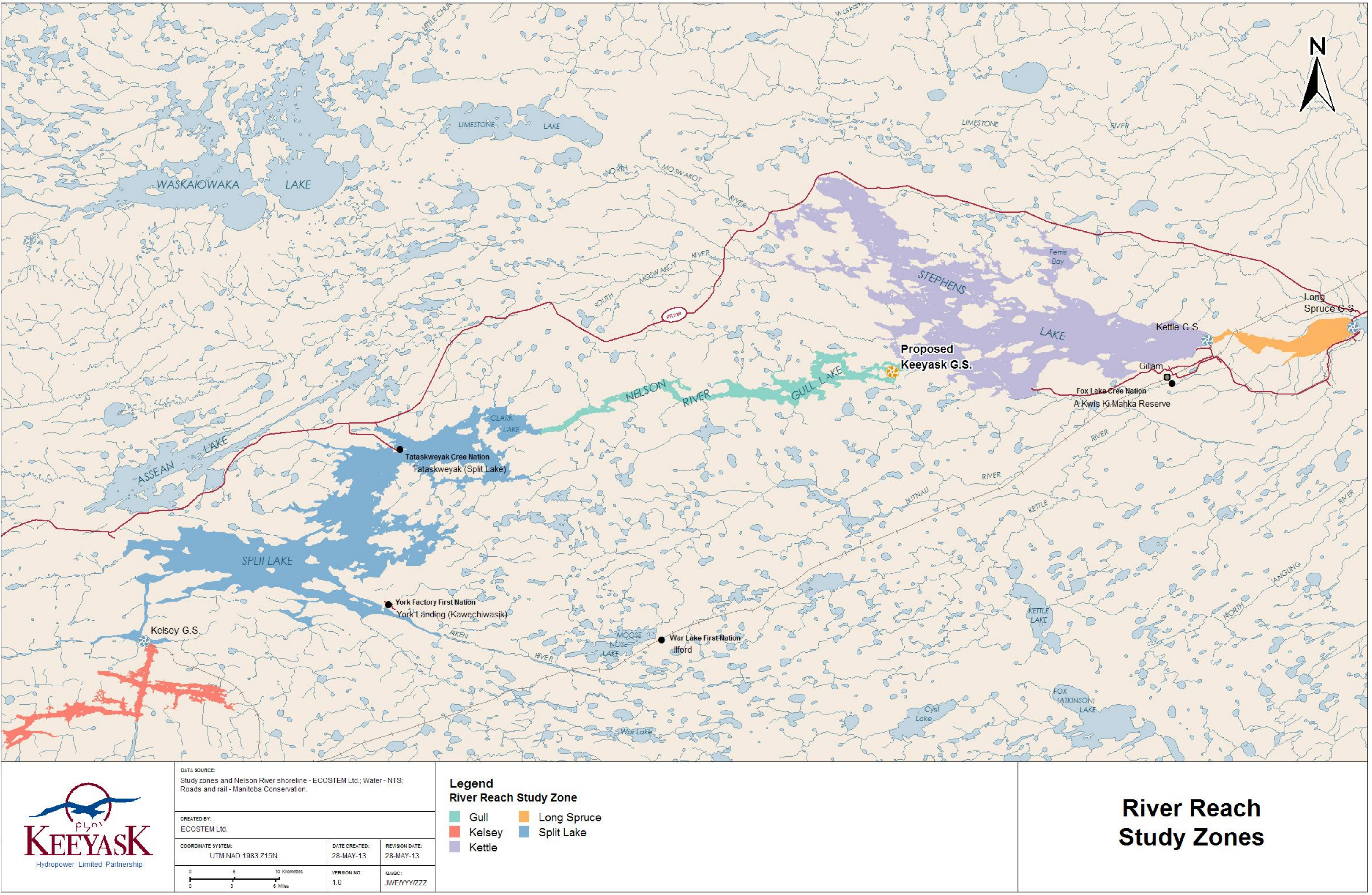
The larger the elevation range, the wider the corresponding zone will be for a constant substrate slope. All other things being equal, Gull had the widest beach zones during the 1996 to 2005 water elevation regime while Kelsey and Long Spruce had the narrowest.

The timing and duration of water levels is also important for shore zone ecosystems. If daily water levels constantly fluctuate over the entire range rather than following alternating declining and increasing trends, then plants will have difficulty establishing and flourishing. That is, even though Gull has a larger water depth range for the beach zone than Kettle (Table 2-6), which implies wider beaches all other things being equal, this may not translate into wider marsh areas if monthly or weekly water levels continually fluctuate over a wide range (Wilcox and Meeker 1991).

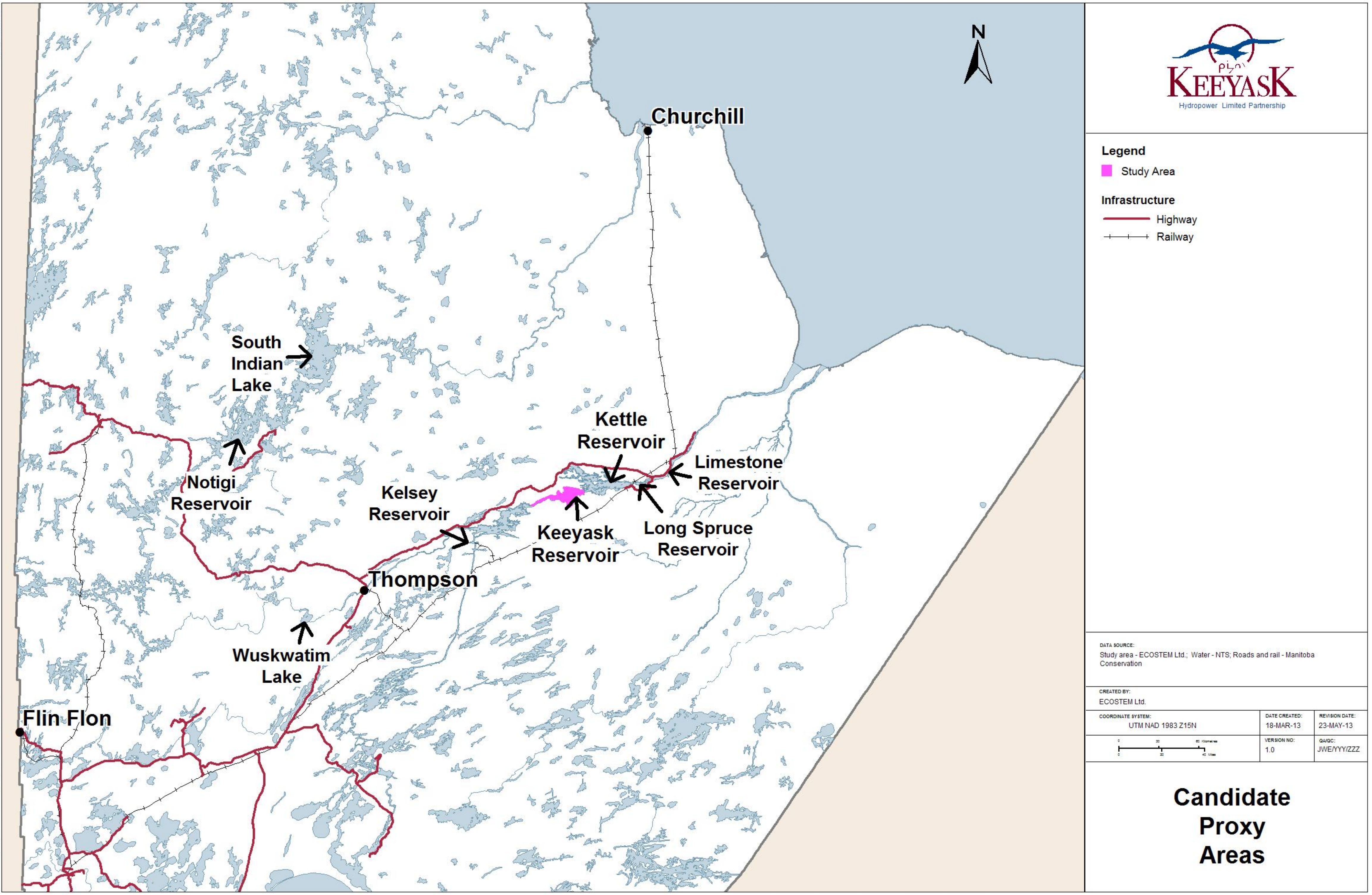
2.3 MAPS



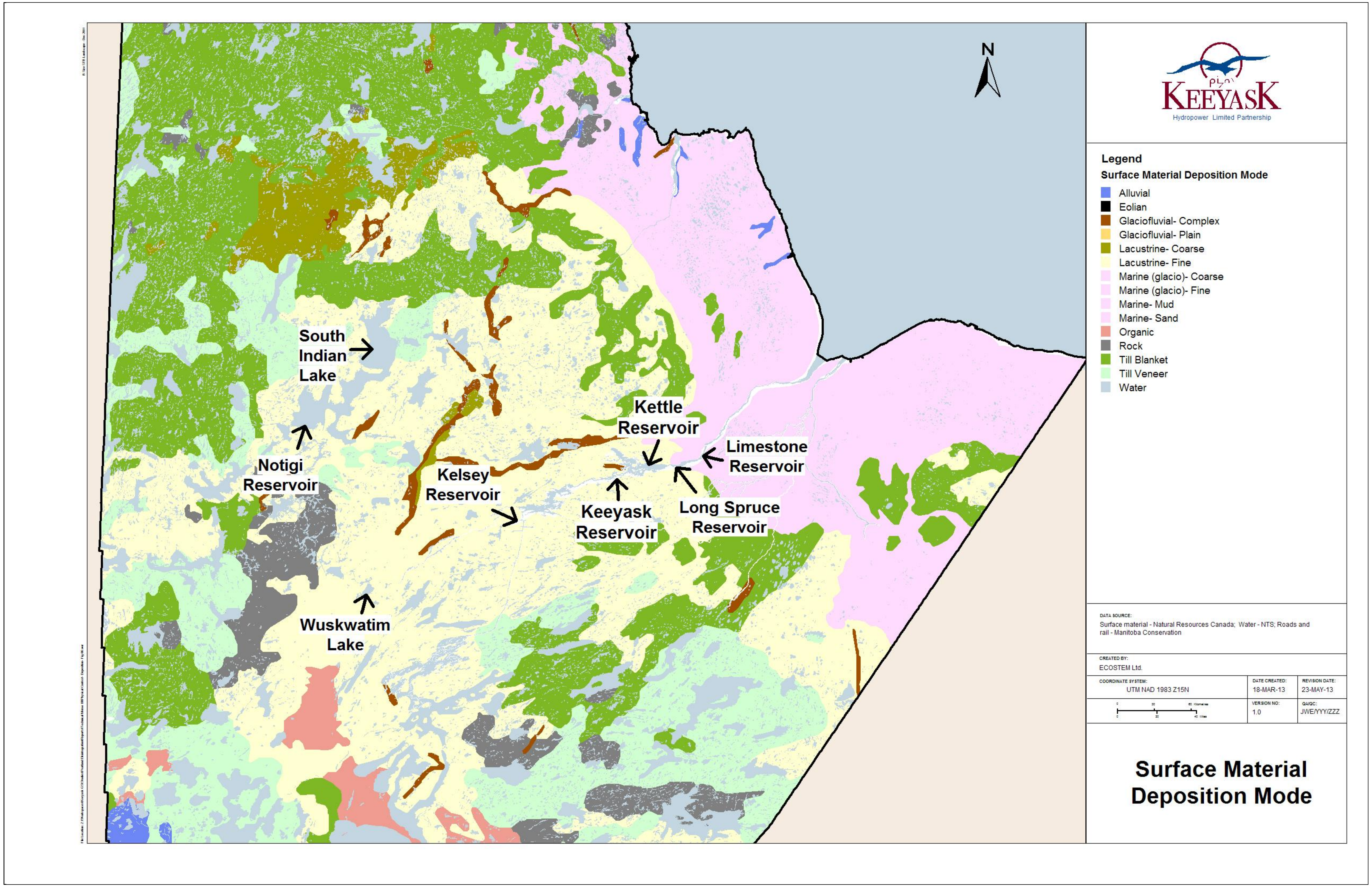
Map 2-1: **Keeyask Local and Regional Study Areas**



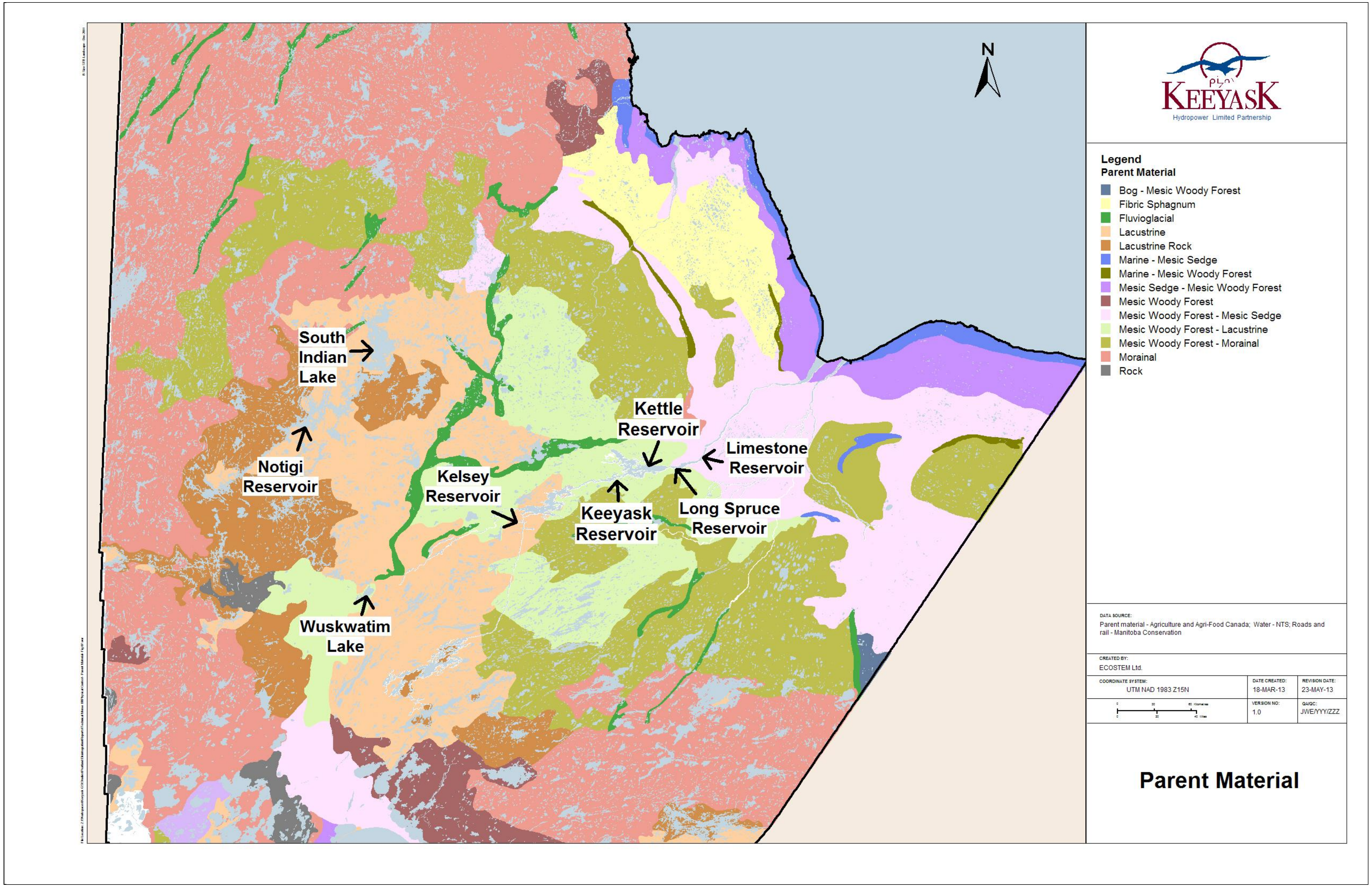
Map 2-2: **River reach study zones**



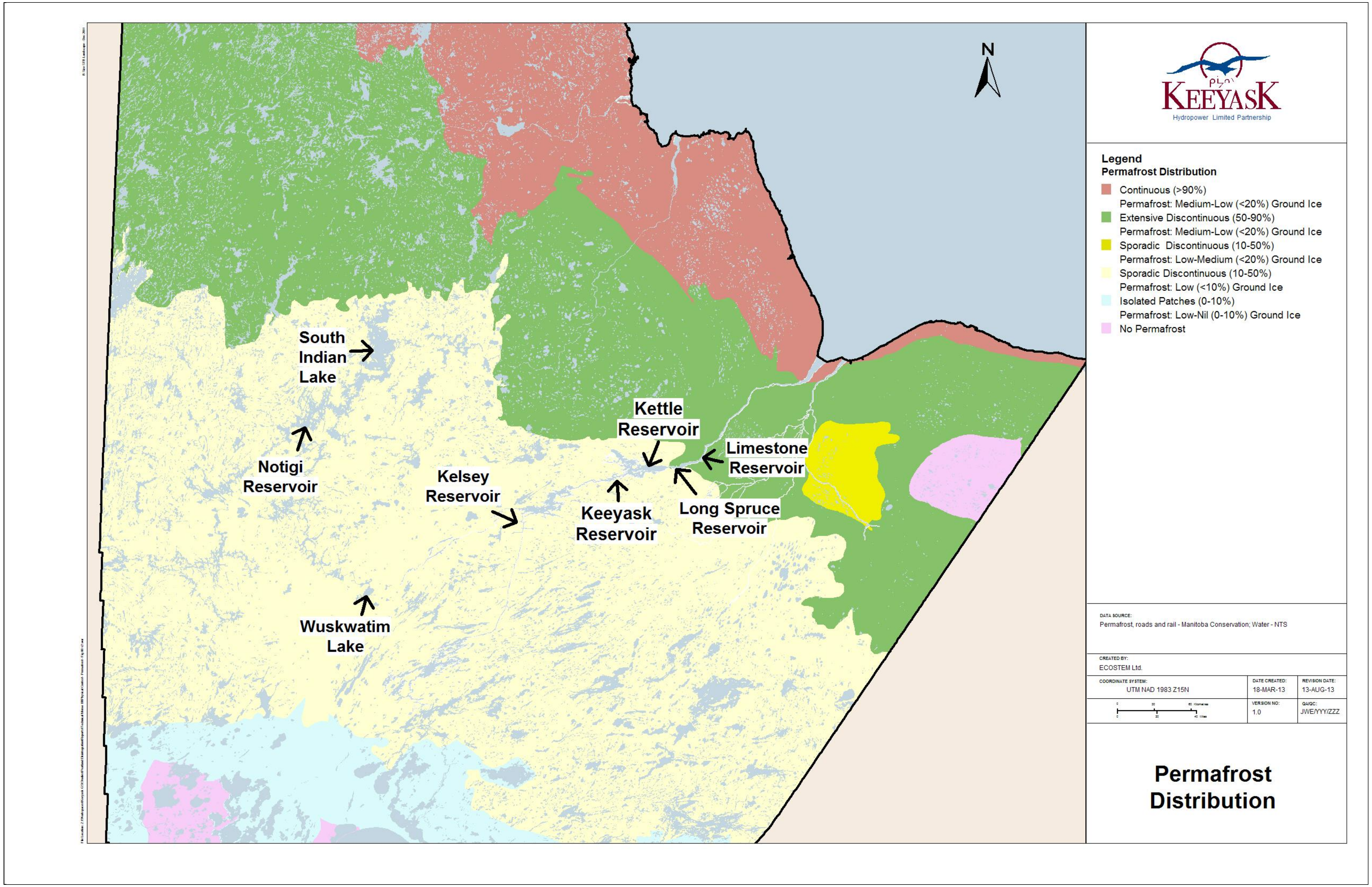
Map 2-3: **Locations of potential proxy areas in northern Manitoba**



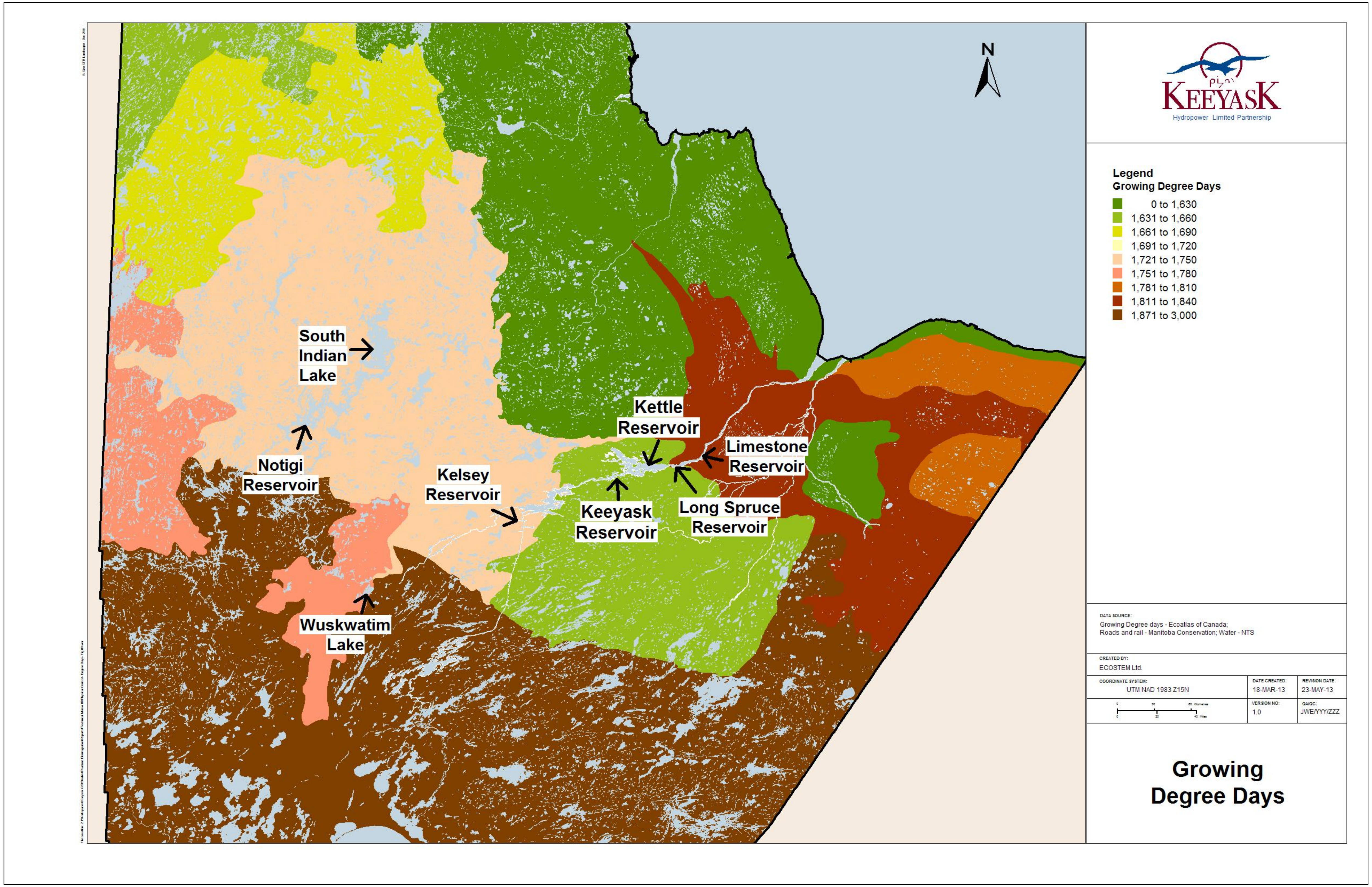
Map 2-4: **Surface deposits in northern Manitoba (Nielsen et al. 1981)**



Map 2-5: Soil parent material in northern Manitoba (Agriculture and Agri-Food Canada 1996)



Map 2-6: **Permafrost continuity distribution in northern Manitoba**



Map 2-7: **Growing degree days in northern Manitoba**

3 OVERVIEW OF STUDIES

3.1 APPROACHES TO UNDERSTANDING FLOODING AND WATER REGULATION EFFECTS

The main pathways for direct and indirect Project effects on shore zone habitat and ecosystems are flooding, reservoir expansion, and water regulation. Peatland disintegration, which is the primary mode of reservoir expansion after initial flooding, was expected to be the largest contributor to reservoir expansion during the first 15 years of Project operation, with its subsequent contribution declining with time (ECOSTEM 2012a). Reservoir expansion is a key pathway for effects because it removes shore zone habitat. The development and application of a peatland disintegration prediction model is described in a separate report (ECOSTEM 2012a), which also includes results from historical air photo time series analysis and soil chronosequence analysis conducted to characterize and model peatland disintegration processes such as shoreline peat breakdown.

This report addresses potential effects that flooding and water regulation can have on shore zone habitat and ecosystems. Given the potential degree of Project effects and the lack of existing long-term monitoring data for the effects of reservoir creation and water regulation on terrestrial habitat and ecosystems in northern Manitoba, considerable effort was expended on developing observational datasets from proxy areas (Section 2.2) to support this endeavor.

The two general approaches used to develop habitat effects datasets from proxy areas were:

- Historical air photo time series analysis extending as far back as 1950 to as recently as 2006, depending on the proxy area; and,
- Recent air photos analysis extending from 2003 to 2011, which represented a period of very low water levels followed by very high water levels.

Historical air photo time series analysis was primarily used to identify the total spatial extent of effects as well as pathways and stages of change. Recent air photo analysis was used to corroborate historical air photo time series analysis results, to detect potential effects that may not visible in historical air photos, and to provide estimates of how rapidly shore zone attributes change in response to flooding. Both approaches improved the understanding of the local drivers and mechanisms for change.

Historical air photo time series analysis involved mapping changes observed in a temporal sequence of historical air photos taken at a specific location, with the first photo date being prior to hydroelectric development. The changes mapped from the air photo temporal sequence documented actual responses to flooding and/or water regulation over time. These responses were analyzed concurrently with changes in other potential shore zone drivers, such as surface material type, bank slope, local relief or water regime, to the extent these could also be determined from available information. The main limitation of the historical time series air photo approach was that documented changes were constrained to those that could be observed from above, given the scale and quality of the photos.

Recent air photo analysis documented shore zone effects using low altitude photos taken from a helicopter over multiple summers from 2003 to 2011. Recent air photo analysis was also used to document short-term shore zone responses to prolonged very high water levels and flows on the Gull reach of the Nelson River from 2005 to 2010.

Other Project studies also contributed useful information. Labwork was conducted to better understand the physical properties of peat, peat buoyancy, flooded peat resurfacing potential, and organic sediment settling rates. These parameters were measured and characterized using peat samples collected in the Keeyask reservoir area (ECOSTEM 2011a, b). Soil chronosequence transect studies conducted for peatland disintegration model development (ECOSTEM 2012a) complemented historical air photo time series analysis by providing data from the vegetation canopy to the subsurface, and by providing higher resolution data. Soil chronosequence transect analysis used changes in space to provide an analogue for changes in time (Walker et al. 2010). A chronosequence transect was a field sampled transect that passed through locations representing different times since flooding. Each transect originated in a currently unaffected location, proceeded through one or more response to flooding stages, and ended in the open reservoir water. Soil and water stratigraphy were sampled at strategic locations along transects.

The two study approaches were used in combination with previously reported results from labwork, soil chronosequence studies, and other publications (e.g., ECOSTEM and Calyx 2003) to cross-corroborate results and to improve the understanding of terrestrial ecosystem responses to reservoir flooding and water regulation. These results and relevant literature were collectively used to provide inferences on the processes and drivers that produced the observed responses to flooding and water regulation.

3.2 STUDIES

Table 3-1summarizes the studies included in this report.

Inland studies focused on areas too distant from the river to be directly affected by changes to the surface groundwater layer and the Nelson River water regime (Section 1.5.2). That is, areas where groundwater depth may be changed by buried hydrological connections between Nelson River water and the inland surface groundwater layer. Shore zone studies focused on the size and nature of the flooding and/or water regulation zone of influence on adjacent terrestrial habitat, as transmitted through surface water and the surface groundwater layer.

Section 4 presents the study conducted to document extent and nature of flooding and water regulation effects on inland terrestrial habitat and ecosystems in the proxy areas using historical and recent air photos, as well as aerial surveys conducted in 2011.

The following four studies were conducted to provide information regarding the extent and nature of flooding and water regulation effects on shore zone terrestrial habitat and ecosystems:

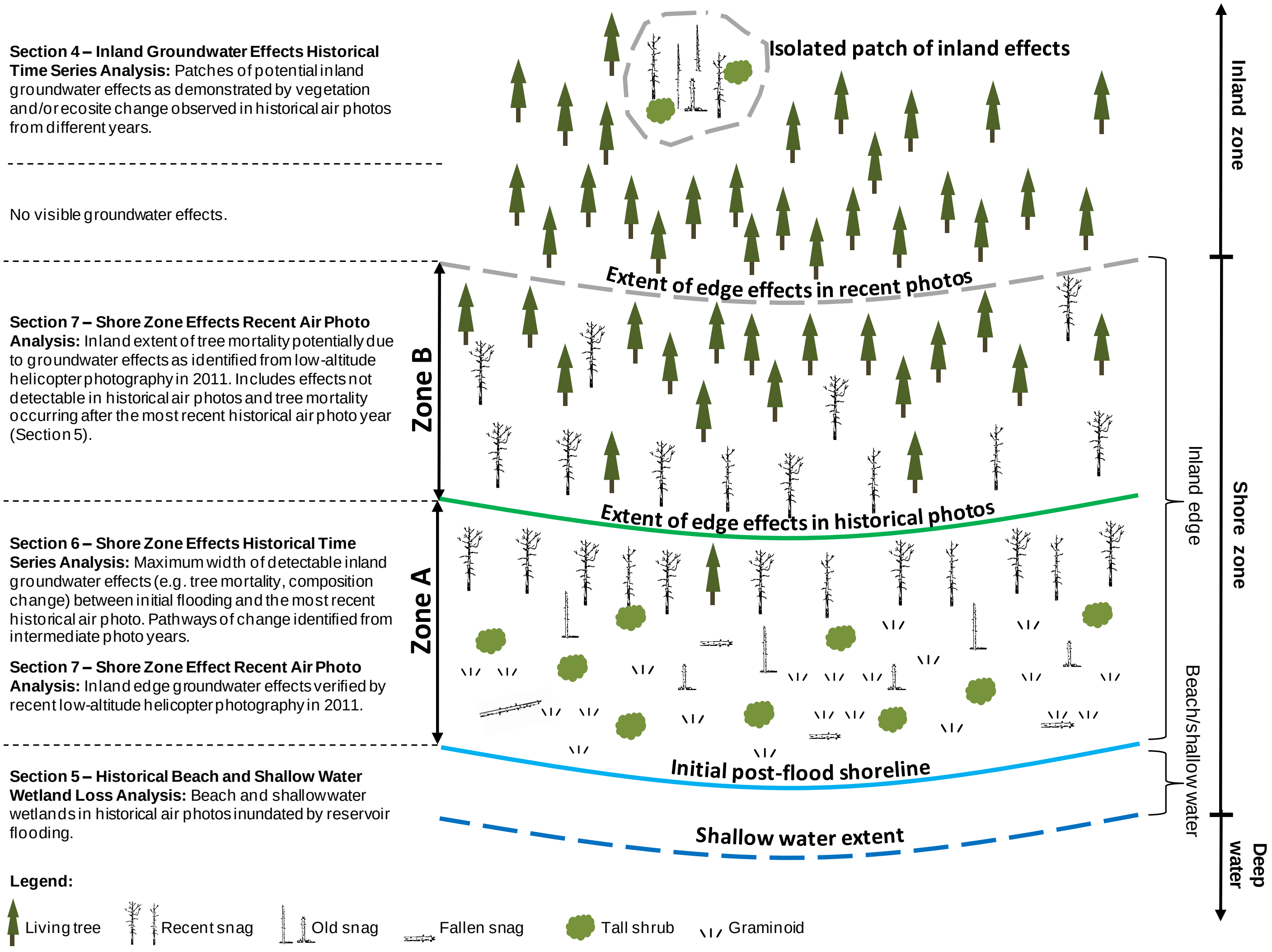
- Historical beach and shallow water zone wetland loss (Section 5):
    - Uses historical air photos to map the pre-flood extend of marsh and other shallow water wetland types in the Gull and Kettle proxy areas.
- Extent and nature of effects on shore zone habitat attributes using historical air photo time series analysis (Section 6):
    - Evaluates short and long-term effects by analyzing changes during each period in the time series, as well as total changes between the beginning and the end of the time series;
- Extent and nature of effects on shore zone habitat attributes using recent air photo analysis (Section 7):
    - Evaluates long-term effects;
    - Documents short-term effects in locations subjected to extremely high water levels from 2005 to 2010; and,
- Short-term responses of shore zone trees to flooding (Section 8).

Figure 3-1 illustrates the different ways that the studies in Sections 4, 5, and 7 document flooding and water regulation effects on the shore zone and on inland areas at a hypothetical shoreline location. Table 3-1 summarizes each study in terms of the ecological zones included, types of effects that were included and the types of data used.

For the practical implementation of theoretical methodology, habitat types and habitat mapping are often used as proxies for ecosystem types and ecosystem mapping (*e.g.*, Leitão *et al.* 2006; Noss *et al*. 2009). Mapping and describing the visible ecosystem attributes that were not mobile (*e.g.*, vegetation, site conditions, surface water, topography, most recent disturbance type), and the disturbance regime associated with a location, corresponded with the definition for mapped terrestrial habitat used for Project studies (ECOSTEM 2012b). Mapped habitat was used as a proxy for stand level ecosystems because habitat includes most of the major ecosystem components (*e.g.*, vegetation, soils), biomass and controlling factors. Mapped habitat was also the basis for measuring plant and wildlife habitat availability. For these reasons, statements about terrestrial habitat in the remainder of this report are often also proxy statements about many terrestrial ecosystem components.

Table 3-1. Studies included in this report, ecological zone studied and types of data used

Study	**Ecological Zone**	**Effects Included**	**Primary Data Source**
Inland Effects (Section 4)	**Inland** – Areas too distant from the reservoir to be affected by flooding and surface groundwater changes.	Tree mortality. Vegetation structure change. Ecosite change.	Large scale historical air photos
Historical Beach and Shallow Water Zone Wetland Loss (Section 5)	**Shore Zone** – Areas on the water side of the pre-development shoreline.	Flooding and water regulation	Large scale historical air photos
Inland Edge Effects from Historical Photos (Section 6)	**Inland Edge** – Areas on the inland side of the initial post-flooding shoreline.	Tree mortality. Vegetation composition and structure change. Ecosite change.	Large scale historical air photos
Inland Edge Effects from Recent Photos (Section 7)	**Inland Edge** – Areas on the inland side of the initial post-flooding shoreline.	Tree mortality. Vegetation composition and structure change. Ecosite change.	Low-altitude photography from a helicopter
Short-Term Tree Responses to Flooding (Section 8)	**Shore Zone** – Areas on the water and inland side of the current shoreline where tree mortality is present.	Recent tree mortality (past 5 years)	Low-altitude photography from a helicopter



Section 4 – Inland Groundwater Effects Historical Time Series Analysis: Patches of potential inland groundwater effects as demonstrated by vegetation and/or ecosite change observed in historical air photos from different years.

No visible groundwater effects.

Section 7 – Shore Zone Effects Recent Air Photo Analysis: Inland extent of tree mortality potentially due to groundwater effects as identified from low-altitude helicopter photography in 2011. Includes effects not detectable in historical air photos and tree mortality occurring after the most recent historical air photo year (Section 5).

Section 6 – Shore Zone Effects Historical Time Series Analysis: Maximum width of detectable inland groundwater effects (e.g. tree mortality, composition change) between initial flooding and the most recent historical air photo. Pathways of change identified from intermediate photo years.

Section 7 – Shore Zone Effect Recent Air Photo Analysis: Inland edge groundwater effects verified by recent low-altitude helicopter photography in 2011.

Section 5 – Historical Beach and Shallow Water Wetland Loss Analysis: Beach and shallow water wetlands in historical air photos inundated by reservoir flooding.

Figure 3-1: **Overview of Sections 4 to 7 flooding and water regulation effects studies along a hypothetical post-flood shoreline whose position remained static since initial flooding**

4 INLAND GROUNDWATER EFFECTS

4.1 STUDY DESIGN AND DATA COLLECTION

Observational datasets for reservoir-related groundwater effects on inland terrestrial habitat were created through historical air photo time series analysis. Of the generally suitable proxy areas selected in Section 2.2, Kettle and Kelsey were used to study inland effects. Post-LWR/CRD water level changes in the Gull proxy area were too low for inland habitat effects to be attributed to groundwater changes by this type of observational study.

Potential inland areas experiencing groundwater effects due to reservoir flooding were identified using a combination of historical air photo time series analysis and aerial surveys conducted in 2011. Photo-interpreted conditions in pre- and post-flood photos of the same areas were compared to identify locations with possible groundwater effects. Changes in vegetation and soils that may have resulted from elevating the surface groundwater table (*i.e.*, top of surface groundwater layer) through connections between Nelson River flooding and/or water regulation with the surface groundwater through the deep groundwater (e.g., Figure 1-8) were mapped. Evidence of such effects were dramatic changes in vegetation structure or ecosite type (e.g. tree mortality, wetland type change) that were unrelated to beaver dams, fire or melting of ground ice permafrost, and were spatially separated from the Nelson River by unaffected vegetation and ecosites (see Figure 3-1). Areas showing differences not attributable to succession or burn were identified as potential inland groundwater effects.

The extent of pre-flood photography determined the maximum extent of area searched for potential effects. Table 2-1 lists the available photography for the Kelsey and Kettle proxy areas. Pre-flood vegetation and ecosites were represented for Kelsey by photography acquired in 1950 and 1952 while 1962 photography was used for Kettle. In both cases, this was the year that was closest to the time of reservoir flooding (1960 and 1970, respectively) and had the largest scale stereo photography for the highest proportion of the proxy area. Given that inland vegetation and ecosites change slowly in the absence of disturbance, the number of years between the photos and flooding were few enough to consider that the photos represented conditions at initial flooding.

For Kelsey, pre-flood stereo photo coverage was limited and relatively small-scale (1:36,000). Post-flooding conditions for the maximum search area were interpreted using 1965 and 1991 photography (Table 2-1), which provided two post-flood time periods for potential effects, 1960 – 1965 and 1965 – 1991. The ability to detect potential effects for the initial flooding to 1965 period was somewhat limited by the small scale and lower quality of the 1952 photography.

The 1991 air photo interpretation completed for Kelsey was cross-checked with the 1991 Forest Resource Inventory mapping (Manitoba Conservation), which was developed from the same stereo photos that were used for this study. The cross-check involved comparing the photo-interpreted species composition and canopy closure in the stereo-photography as well as Forest Resource Inventory mapping, with the post-flood 1965 photos and selecting polygons where there were differences that were not clearly due to vegetation succession or a burn. Areas showing differences not attributable to succession or burn were identified as potential inland groundwater effects.

Post-flooding conditions for Kettle areas were interpreted using 1971, 1986, 2003 and 2006 photography (Table 2-1). Because the 2003 and 2006 photography covered different portions of the study area but were close together in time since last photography, they were combined as a single 2003/2006 time point. As a result, the two interpreted post-flood time periods were 1970 to 1986 and 1986 to 2003/2006.

The photo-interpreted habitat change maps were field validated by conducting aerial surveys by helicopter on July 12–14, August 2, and September 7–8, 2011. One purpose of the surveys was to verify potential inland groundwater effects identified through historical air photo time series analysis. Additional purposes of the surveys were to expand the data outside of the areas covered by the historical photos, and to identify other areas of potential groundwater effects resulting from reservoir creation in the inland areas adjacent to the Kelsey and Kettle reservoirs that might not be visible in the historical photos. The latter analysis was accomplished by comparing current vegetation and ecosite types in the helicopter photos with those present in the 1962 air photos. Helicopter-based photos were acquired during the aerial surveys to assist with mapping and documenting any potential groundwater effects.

It was possible that some potential changes observed in the air photos were simply surface water level changes resulting from between year precipitation differences and not to reservoir-related inland groundwater effects. Monthly historical weather data acquired from Environment Canada (2012) was obtained to identify precipitation differences between photography years. The nearest weather station to Kettle was at Gillam and at Thompson for Kelsey. For Kelsey, data from both of these stations were used for comparison, and to assess regional differences since that proxy area is approximately halfway between the two stations. For Kelsey, daily precipitation data from the Gillam weather station were available for all of the photography years (Table 4-1). Precipitation data from the Thompson weather station were available only for the 1991 photography year. The nearest alternate stations with daily precipitation data included Wabowden (1950 – 51) and Grand Rapids (1965). For Kettle, daily precipitation data were available from Gillam for the 1986, 2003 and 2006 photography years. For 1962, precipitation data were available from the nearby Bird weather station.

Comparison of precipitation data between stations indicated some within region variability. Most notably, in 1950 total annual precipitation at the Gillam station was 361 mm compared with 546 mm at Wabowden. However, the following year showed nearly identical annual precipitation amounts at these two stations. Other years with comparable precipitation data did not show large differences between stations. Weather data for 1991 showed little difference between Gillam and Thompson. Overall, 1962 was the wettest year in the Kettle area, while 1950 was the driest year.

Table 4-1: Climate data available for the Kelsey reservoir and Kettle reservoir groundwater effect proxy area photography years

Station	Location	Precipitation Data	Temperature Data
Gillam	56.92°N, -94.70°W	1950, 1951, 1986, 1991, 2003*, 2006*	1950*, 1951, 1986, 1991, 2003, 2006*
Thompson	55.80°N, -94.86°W	1991, 2003, 2006	1991, 2003, 2006
Bird	56.50°N, -94.20°W	1962	1962
Wabowden	54.92°N, -98.63°W	1950, 1951, 1965	1950, 1951, 1965
Norway House	53.98°N, -97.83°W	1965	-
Grand Rapids	53.18°N, -99.27°W	1965*	1965*

Notes:* Data not available for entire year.

4.2 ANALYSIS

The data sources used for GIS representations of inland habitat varied by proxy area. Inland habitat mapping, created for other Project studies (ECOSTEM 2012b), was used to represent the Kettle inland areas. New fields, incorporating data produced by the current study, were added to the previously generated dataset. For Kelsey new fields, incorporating data produced by the current study, were added to the 1991 Forest Resource Inventory (Manitoba Conservation) polygon dataset.

Table 4-2 describes the fields added to the inland habitat datasets for use in this study. Each of these fields was populated for polygons that displayed potential inland groundwater effects.

Table 4-2: Fields added to the inland habitat datasets for the inland groundwater effects analysis study

Field	Description	Values
Fine Ecosite 1965 (Kelsey) Fine Ecosite 1986 (Kettle)	Fine ecosite type of polygon in the indicated year of photo if different than most recent year[1]	Fine Ecosite Type
Fine Ecosite 1991[2]	Fine ecosite type in 1991 (Kelsey only)	Fine Ecosite Type
Species upper 1965 (Kelsey) Species upper 1986 (Kettle)	Upper layer species composition in that year if different than current year of habitat dataset	Species composition (e.g. "Low vegetation", "BS8TL2")
Closure upper 1965 (Kelsey) Closure upper 1986 (Kettle)	Canopy closure class of the upper vegetation layer in that year if different than current year	Percent composition code to nearest 10% (e.g. 5 = 50%, 10 = 100%)
Change Comment	Description of changes observed	Text
Change Type	Type of change(s) observed between periods	e.g. "Mortality", "Structure", "Mortality and structure"

Notes:[1] Most recent year in the time series: 1991 for Kelsey and 2003 or 2006 for Kettle.
[2] Fine Ecosite type in 2003 for Kettle was already part of the habitat mapping dataset and not added as a new field.

4.3 RESULTS

4.3.1 Kelsey Proxy Area

Using the historical air photo time series, inland areas along approximately 142 km, or 26%, of the 551 km Kelsey reservoir shoreline, were searched for inland groundwater effects. These represent areas not disturbed by factors other than reservoir creation between initial flooding and 1991. Based on available stereo-photo coverage, approximately 11,600 ha was searched in the 1965 series, and 4,600 ha in the 1991 series (Map 4-1). The reduction in searched area in the 1991 photos was due to fires occurring between 1965 and 1991.

No potential groundwater effects areas were identified for the 1960 to 1965 period. Although the quality of pre-flood photography was poor, no areas of tree mortality or blow-down were apparent in the 1965 series.

The analysis identified six potential areas of inland groundwater effects for the 1965 to 1991 period (Table 4-3) at the locations shown in Map 4-2. These included an area of tree mortality along a waterway not initially flooded by the reservoir, two areas that may have had tree mortality a few years prior to 1991 (possible recently formed snags), one area showing a large reduction in tree density, and one area with apparent ecosite change in the form of permafrost melting. The sixth area exhibited some vegetation change, but could possibly have been the result of natural vegetation succession. Five of these areas were deemed to be unlikely groundwater effects because they were either: too far up slope to be affected by groundwater from the reservoir, more likely to be a result of ongoing climate warming, or appeared to be the result of a different kind of disturbance. In one area, the presence of mortality could not be confirmed because subsequent fire had cleared the area.

Of the total area with potential effects, a single 6 ha location (tree mortality along a waterway), or 0.1% of the 4,612 ha searched, was retained as having a reasonable potential for being a groundwater effect. However, this waterway connects to and is near the Kelsey reservoir so there is good potential for this to be a shore zone rather than an inland effect.

Table 4-3: Potential inland groundwater effects areas in the Kelsey proxy area between 1965 and 1991

Effect Area	Type of Potential Effect	Area Affected (ha)	Reasonable Likelihood of Being a Reservoir Effect	Percentage of Searched Area
1	Mortality	6.0	Yes	0.13[1]
2	Mortality	24.0	No	
3	Mortality	7.1	No	
4	Mortality and structure change	5.1	No	
5	Ecosite change	3.7	No	
6	Succession	2.0	No	
	All possible reservoir effects	47.8		1.04
	Remaining area searched	4,564.2		98.96
	Total area searched	4,612		100

Notes:[1] Total for percentage of searched area with "likely" reservoir effects.

Helicopter surveys to verify whether or not these could be inland groundwater effects areas due to reservoir flooding were unsuccessful because all of these areas were burned by wildfires that occurred after the 1991 photos were taken.

Helicopter surveys of unburned areas did not identify any other potential inland groundwater effects areas.

4.3.2 Kettle Proxy Area

Inland areas along approximately 717 km, or 75%, of the 955 km of Kettle reservoir shoreline were searched for inland groundwater effects using the 1971, 1986 and 2003/2006 historical air photos. This corresponded with approximately 25,900 ha of searched inland area (Map 4-3). The searched inland area excludes ground-ice peatland areas (i.e., peat plateau bogs) that are still responding to past climate change, areas that were burned in the post-flood time period, or were influenced by human infrastructure (e.g. roads, dykes, settlements), all of which were identified through prior habitat mapping. These conditions could have confounding influences on potential groundwater effects due to reservoir creation. Much of the inland areas along the eastern portions of the reservoir were excluded for these reasons.

No potential groundwater effects were identified in the 1971 stereo photos. Groundwater effects were not expected for the 1971 photos since they were taken less than one year after reservoir flooding.

Air photo analysis identified two potential groundwater effects areas for the 1971 to 1986 period and four potential groundwater effects areas for the 1986 to 2003/2006 period (Table 4-4) at the locations shown in Map 4-4. By 1986, a total of 6.5 hectares, or 0.03% of the searched area were identified as having potential groundwater effects (Table 4-4). By 2003/2006, this area increased by approximately 0.01% to 9.8 hectares.

The two areas with potential effects during the 1971 to 1986 period exhibited tree mortality, along with a change in vegetation structure and ecosite type. Area 1 was a pre-flood riparian fen that expanded in size during that period, while Area 2 was a horizontal fen that converted to a riparian fen (Map 4-4).

During the 1986 to 2006 period, there was further tree mortality in Area 1, while tree cover completely disappeared in Area 2. During that period three additional areas showed changes. Area 3, which was adjacent to an inland lake connected to the reservoir (Map 4-4), showed tree mortality and structural change. Two areas (4 and 5) showed tree mortality, and composition, structure and ecosite change. Area 4 was adjacent to the reservoir, and a large portion of the change was likely due to hydrological connections between the reservoir and the surface rather than the deep groundwater layer.

Table 4-4: Potential inland groundwater effect areas in the Kettle proxy area for the 1971 – 1986, and 1986 – 2006 periods

Effect Area	Type of Effect 1971 - 1986	Area Affected 1971 - 1986 (ha)	Percentage of Searched Area by 1986	Type of Effect 1986 - 2006	Area Affected 1986 - 2006 (ha)	Percentage of Searched Area by 2006	Moderate Likelihood of Being a Reservoir Effect
1	Mortality, structure and ecosite	5.1	0.02	Mortality	5.1	0.02	Yes
2	Mortality, structure and ecosite	1.4	0.01	Mortality and structure	1.4	0.01	Yes
3	None	-	-	Mortality and structure	0.6	0.00	Yes
4	None	-	-	Mortality, composition, structure and ecosite	0.8	0.00	Yes
5	None	-	-	Mortality, composition, structure and ecosite	1.9	0.01	Yes
	All potential effects	6.5	0.03		9.8	0.04	
	Remaining area searched	25,913.5	99.97		25,910.2	99.96	
	Total area searched	25,920	100		25,920	100	

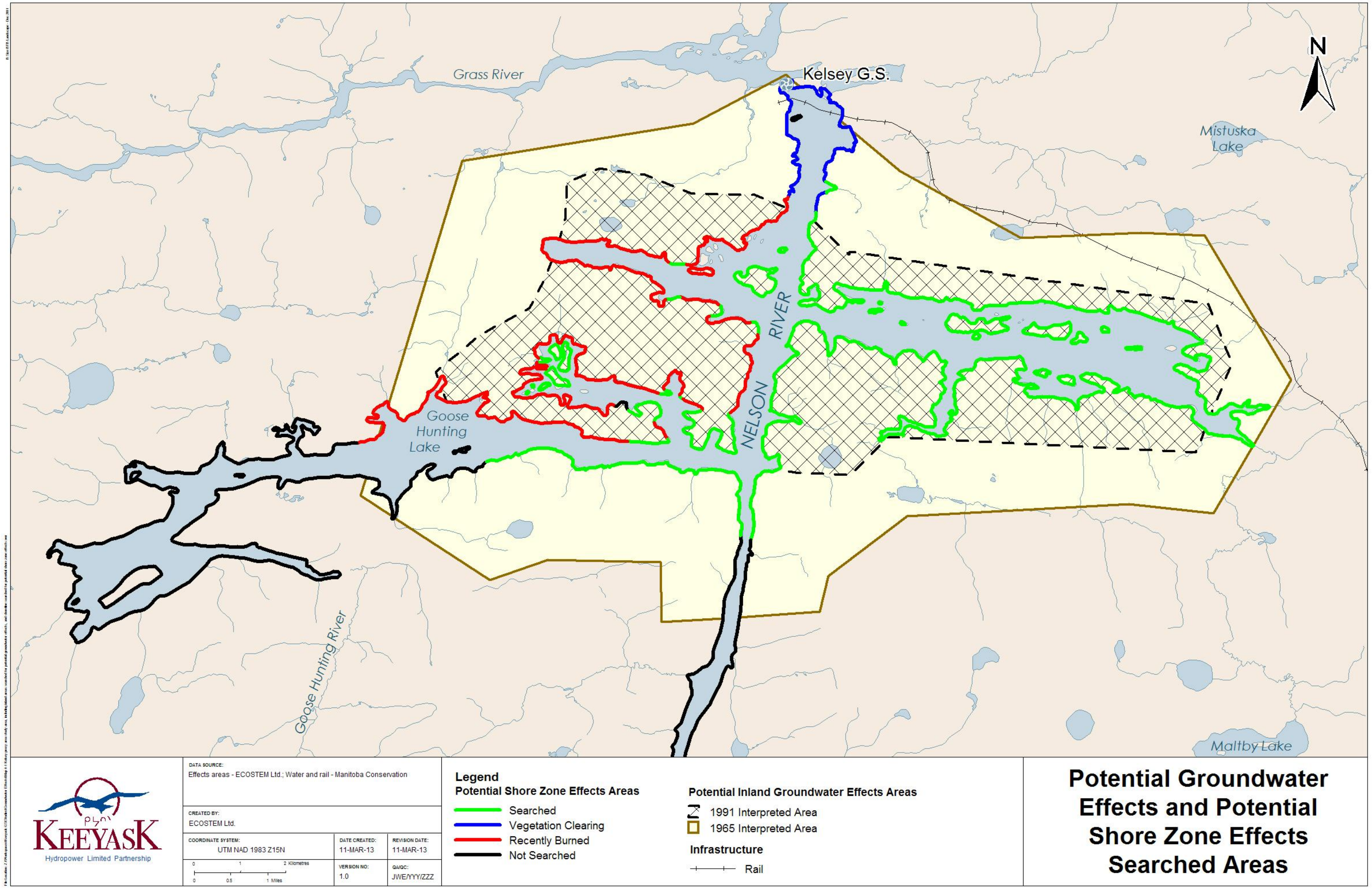
4.4 DISCUSSION

Based on historical photos, potential groundwater-related flooding effects on inland terrestrial habitat totaled less than 1% of the area searched in the Kelsey and Kettle proxy areas. The topographic position of the potential changes indicated that most of these potential effects were actually due to natural factors such as natural vegetation succession, age-related tree mortality or naturally occurring ground ice permafrost melting. After eliminating these unlikely locations, approximately 0.1% of the area in Kelsey and less than 0.1% (0.04%) of the area in Kettle was classified as having at least a reasonable likelihood of being a groundwater effect.

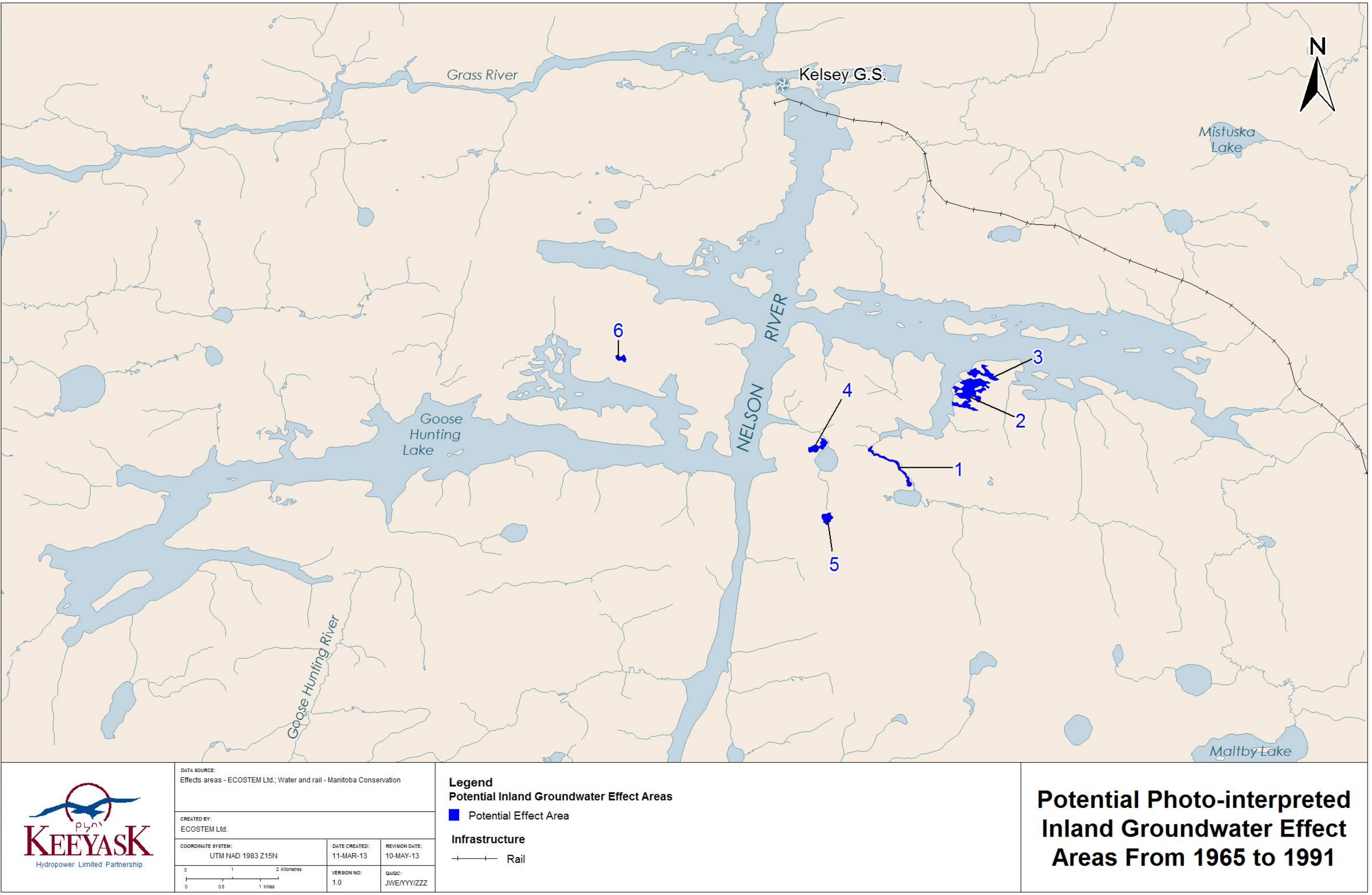
For these small remaining areas, likelihood of effects could not be confirmed for Kelsey due to an inadequate number of years in the historical photography and large fires burning the potential effects area after the last photo year. Helicopter surveys and recent mapping were able to confirm whether or not the Kettle effects were likely from deep groundwater layer changes. Most of these effects were likely to be from surface hydrological connection with the reservoir through peatlands because of the close proximity to the reservoir. Even if these were classified as likely deep groundwater connection effects, the total percentage of inland area affected was extremely low.

The total amounts of potential inland effects were so small that it was not possible to comment on differences between Kelsey and Kettle with respect to inland responses to reservoir flooding.

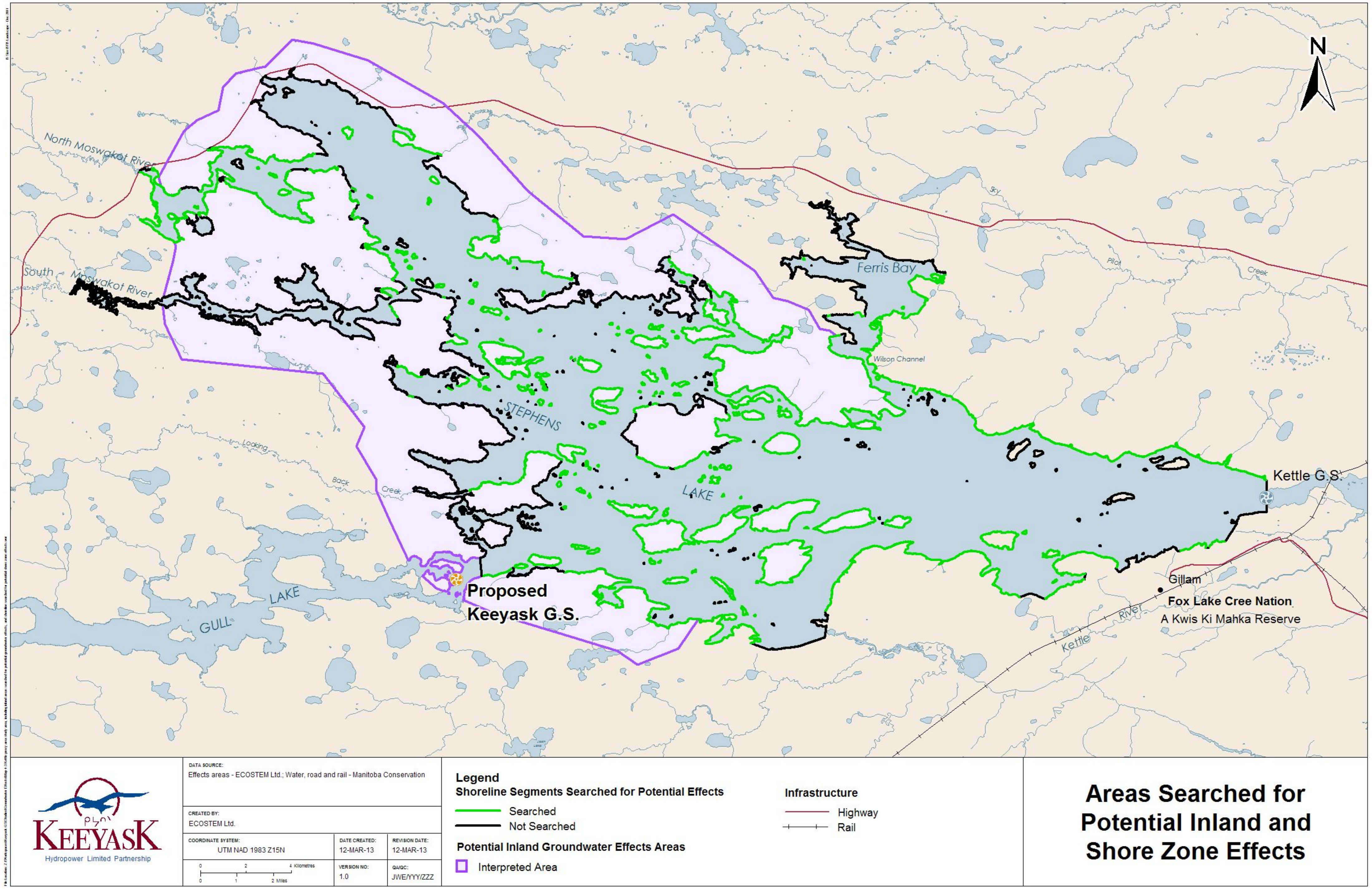
4.5 MAPS



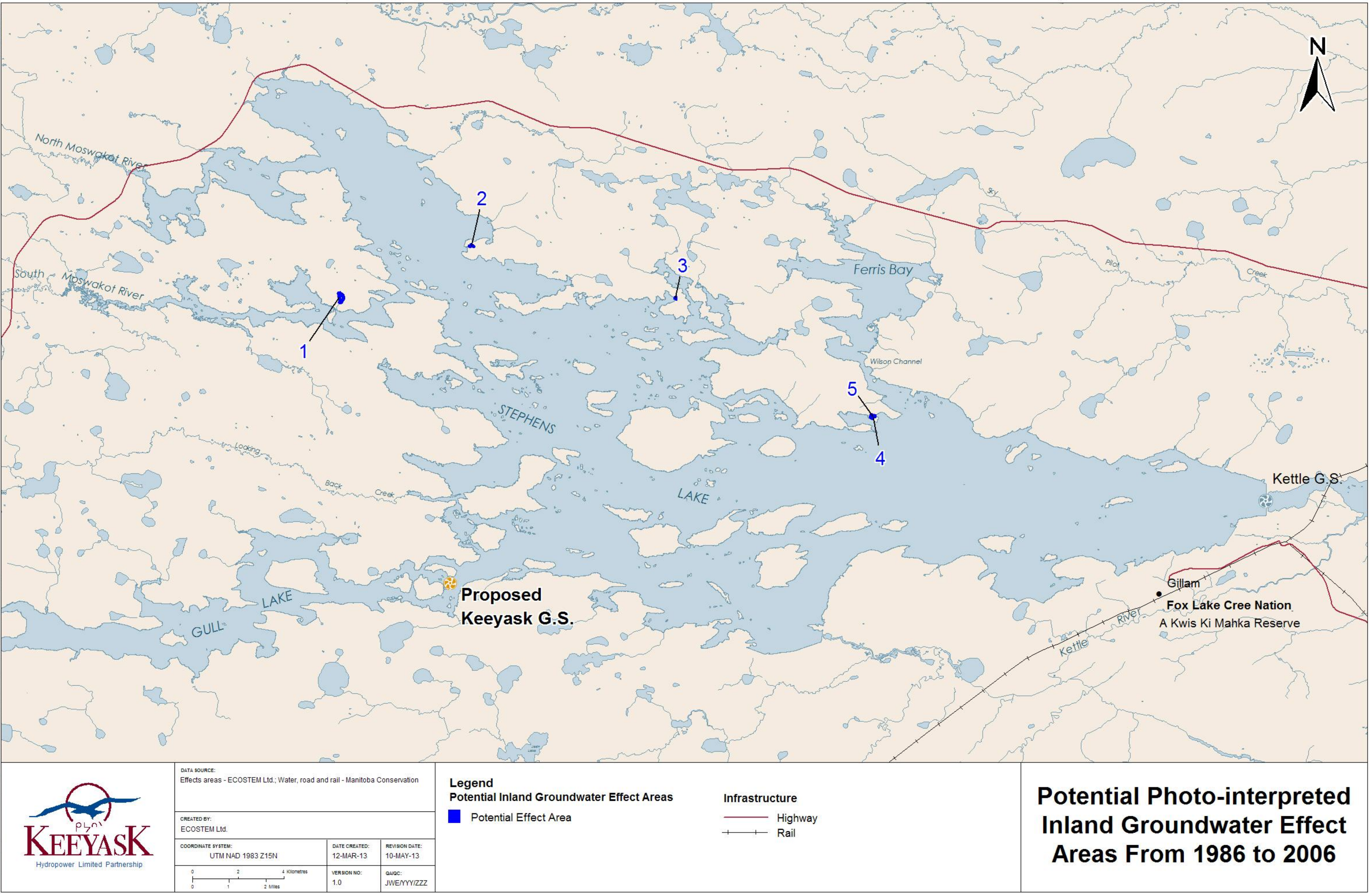
Map 4-1: Kelsey proxy area study area, including inland areas searched for potential groundwater effects, and shoreline searched for potential shore zone effects



Map 4-2: **Potential inland groundwater effect areas in the Kelsey reservoir area identified through photo-interpretation between 1965 and 1991**



Map 4-3: **Kettle proxy area study area, including inland areas searched for potential groundwater effects, and shoreline searched for potential shore zone effects**



Map 4-4: **Potential inland groundwater effect areas in the Kettle reservoir area identified through photo-interpretation between 1986 and 2006**

5 HISTORICAL BEACH AND SHALLOW WATER WETLAND LOSS

5.1 STUDY DESIGN AND DATA COLLECTION

The objective of this study was to document how much vegetated wetland was present in the beach and shallow water zones prior to flooding and LWR/CRD water regulation in the Gull and Kettle proxy areas. The scale of Kelsey pre-flood photography was too small for this purpose.

For both the Gull and Kettle proxy areas, photography acquired prior to flooding and water regulation (1:12,900 scale acquired in 1962) was interpreted for wetlands on the offshore side of the inland edge (Figure 1-5). Because the extent to which herb/low shrub meadow was vegetated could not be mapped due to the air photo scale, the potential extent of herb/low shrub meadow was mapped as the photo-interpreted extent of the upper beach zone wider than 10 m.

5.2 ANALYSIS

The approach used to create GIS representations for the historical shorelines varied by proxy area. Preliminary photo-interpretation showed that the locations of the historical and existing shoreline locations for the Gull proxy area were sufficiently similar (ECOSTEM 2012b) that the dataset for the existing shoreline could be used for this study. For the Kettle proxy area, the historical shoreline locations for Nelson River and off-system waterbodies were initially digitized from an early edition 1:250,000 NTS paper map, which was scanned and georeferenced. Portions of the shoreline position from the small-scale NTS map were refined using the larger-scale 1962 stereo-photography to more accurately represent complex portions of the shoreline, and reduce the potential for underestimating the length of shoreline segments.

The proxy area shorelines were segmented wherever there was a photo-interpreted change in wetland type in the beach/ shallow water portions of the shore zone (see Figure 1-5). For each segment, the wetland type adjacent to open water was identified as the dominant wetland type for that segment. In some cases, a second wetland type was present between the dominant wetland type and the inland side of the shoreline. These wetlands were identified in a sub-dominant wetland field. Table 5-1 describes the wetland types used in this study. Table 5-2 lists and describes the data fields created for the shoreline GIS datasets.

Given the scale of the photos, it typically was not possible to determine whether or not a herb/low shrub meadow area was vegetated with herbaceous plants. Consequently, the areas reported for herb/low shrub meadow represent potential rather than actual vegetated areas, and were determined as areas in the herb/low shrub meadow water depth duration zone that clearly were not exposed bedrock or barren mineral material. Another limitation related to photo scale is that the dominant species composition of meadow and marsh wetlands could not be determined.

Table 5-1: Wetland types and classification criteria used in the historical beach and shallow water wetland loss study.

Wetland Type	Criteria				Indicators	
	Peat-land	Open Water	Water Table	Other	Most Abundant Vegetation	Location
Bog	Yes	-	Usually > 15 cm below surface	-	Sphagnum	-
Fen	Yes	-	-	-	Sedges; Grasses; brown mosses; tamarack	At edge of flowing water for riparian type
Shrub Meadow	-	-	Infrequent to frequent flooding (intermittently wetted zone)	Tall shrub cover >= 25%	Tall shrubs	Sloping substrate in beach zone. Transition between open water and upland
Herb/low shrub meadow	-	-	Infrequent to frequent flooding (intermittently wetted zone)	Tall shrub/tree cover < 25%	Herbs; low shrubs	Sloping substrate in beach zone. Transition between open water and upland
Marsh	No	up to 2m deep	-	Non-woody emergent veg cover >= 25%	Emergents	-
Shallow Water	No	up to 2m deep	-	Emergent veg cover < 25%	Submergents; floating-leaved; sparse emergents	-

Notes : More than one of the above types may be seen in a sequence: e.g., shallow water - marsh - fen - bog. Sometimes the marsh zone (i.e., emergent sedge band) in this sequence will be too narrow to map.

Table 5-2: Data fields provided in the historical shoreline wetlands dataset for the historical loss of marsh study.

Field	Description	Values[1]
Wetland	The dominant wetland type adjacent to open water	Wetland Type (see Table 5-1)
Wetland_SubDomt	A subdominant wetland type on the inland side of the dominant wetland type	Wetland Type (see Table 5-1)
Waterbody_Type	Identifies if the waterbody is part of the Nelson River system or an off-system waterbody	Nelson River or Off-system
Reach	Reach of the Nelson River coinciding with the proxy area	Gull or Kettle

Notes:[1] Empty values indicate that no data was available or applicable for the segment.

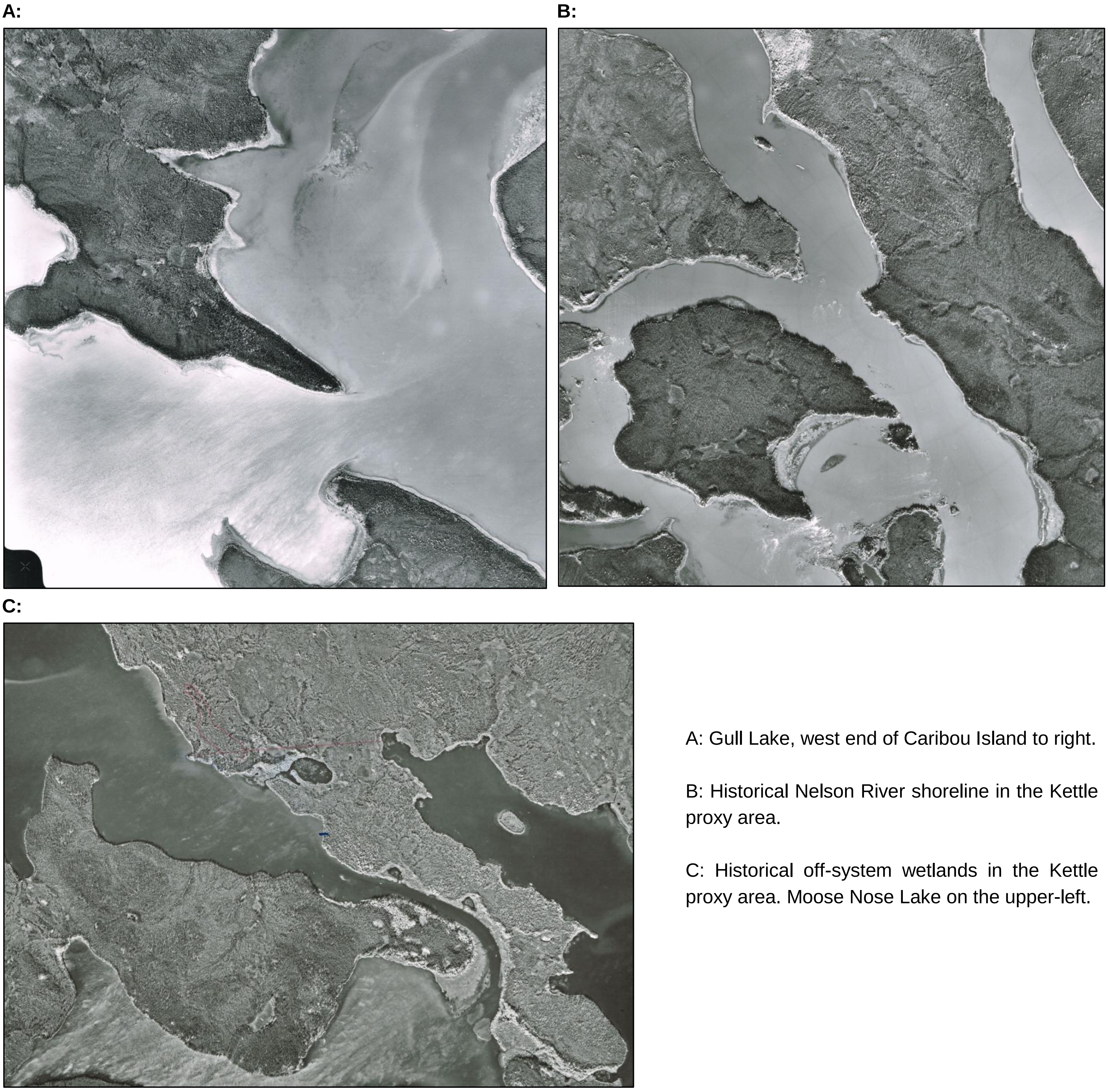
5.3 RESULTS

Approximately 198 km of pre-CRD/LWR Gull proxy area shorelines were searched for beach and shallow water zone wetlands, with the searches extending from Birthday Rapids to Gull Rapids (Map 5-1). Coincidentally, approximately 198 km of CRD/LWR and pre-flooding Kettle proxy area shorelines were also searched, with the searches extending from Gull Rapids to Kettle Rapids at the future site of the Kettle generating station (Map 5-2).

Shallow water was the predominant wetland type on the water side of the shoreline of the pre-development Nelson River for both proxy areas, occurring along 86% of the shoreline (Table 5-3). Herb/low shrub meadow was the second most abundant shoreline wetland, followed by fen. Marsh made up approximately one percent of the pre-development shoreline over both proxy areas. Examples of historical Nelson River and off-system shorelines are provided in Figure 5-1.

Open shallow water alone was found along 95% Kettle proxy area shoreline compared with 78% in Gull (Table 5-3).

Meadow, the most common wetland type in both proxy areas, occurred along only approximately 11% and 4%, respectively, of the Gull and Kettle shorelines. As indicated above, the areas reported for herb/low shrub meadow represented potential rather than actual vegetated areas. Herb/low shrub meadow and shrub meadow occurred in the beach zones of the shore zone (Figure 1-5), typically on sloping topography with mineral substrates where the organic layer is thin or absent.



A: Gull Lake, west end of Caribou Island to right.

B: Historical Nelson River shoreline in the Kettle proxy area.

C: Historical off-system wetlands in the Kettle proxy area. Moose Nose Lake on the upper-left.

Figure 5-1: Examples of historical wetlands (ca. 1962) in the Gull Lake and Kettle proxy areas.

Table 5-3: Percent composition of shallow water shoreline wetlands circa 1962 in the Gull and Kettle proxy areas, including off-system waterbodies that were subsequently inundated by the Kettle reservoir.

Dominant Wetland Type	Nelson River (percentage of shoreline length)			Off-system
	Gull Reach	Kettle Reach	Both	
Shallow Water	77.8	95.2	86.5	50.0
Marsh	1.8	0.5	1.1	3.8
Herb/low shrub meadow	10.7	3.7	7.2	0.3
Shrub Meadow	3.2	0.4	1.8	-
Fen	6.5	0.2	3.4	45.2
Bog	-	-	-	0.7
Total shoreline (km)	*197.8*	*198.1*	*395.8*	*366.8*

Marsh was rare even in the pre-development Nelson River condition, having been identified along only 1.8% and 0.5% of the shorelines in Gull and Kettle, respectively. This marsh was confined to sheltered bays along the Nelson River, and on the downstream side of one of the larger islands (Map 5-1 and Map 5-2).

Forty-seven hectares of pre-development off-shore emergent vegetation (emergent vegetation islands) were mapped in the Nelson River (Table 5-4). The vast majority of this area was located in the Gull reach of the Nelson River (98%), primarily in bays and in in Gull Lake north of Caribou Island (Map 5-2). This could not be attributed to shoreline length differences. On a lineal shoreline basis, Gull Reach had 2,326 m^2 of emergent vegetation islands per kilometer of shoreline, while the Kettle reach only had 56 m^2/km.

Table 5-4: Area of Nelson River emergent vegetation islands (off-shore marsh) circa 1962 in the Gull and Kettle proxy areas, including the total area per square kilometer of each reach.

Historical Nelson River Reach	Emergent Vegetation Island Area (ha)*	Island Area per km of Shoreline (m^2/km)
Gull Reach	46.0 (98%)	2,326
Kettle Reach	1.1 (2%)	56
Both	47.1 (100%)	1,190

Notes: Emergent vegetation island areas are calculated as mapped polygon area multiplied by the estimated proportion of emergent cover.

Pre-development shore zone wetlands were also mapped in off-system waterbodies that were inundated by the Kettle reservoir, which included approximately 367 km of shoreline. Shore zone wetland composition in these off-system waterbodies was substantially different from the Nelson River proxy areas. Shallow water made up only half of the shoreline length (Table 5-3). Fens made up approximately 45% of the remaining shoreline, while marsh was nearly 4%.

The historical and current proportions of beach and shallow water wetlands in Gull were very similar (compare second column in Table 5-3 and Table 5-5), likely due to the lack of flooding from past hydroelectric development in this reach.

Table 5-5: Percent composition of shallow water shoreline wetlands circa 2003 in the Gull and Kettle proxy areas.

Dominant Wetland Type	Gull Reach	Kettle Reach	Both
Shallow Water	79.7	57.2	72.4
Marsh	1.1	7.6	3.2
Herb/low shrub meadow	4.8	-	3.3
Shrub Meadow	4.4	7.9	5.6
Fen	10.0	27.2	15.5
Bog	-	0.1	0.0
Total shoreline (km)	*253.5*	*120.6*	*374.1*

Source: ECOSTEM (2012b)

In contrast with Gull, the current proportions of Kettle shoreline wetlands were more similar to historical conditions in the off-system waterbodies flooded by Kettle than to historical shoreline wetland conditions in Gull, at least in terms of percentage of shoreline length composed of the five wetland classes. The similarity of species composition could not be determined from historical air photos.

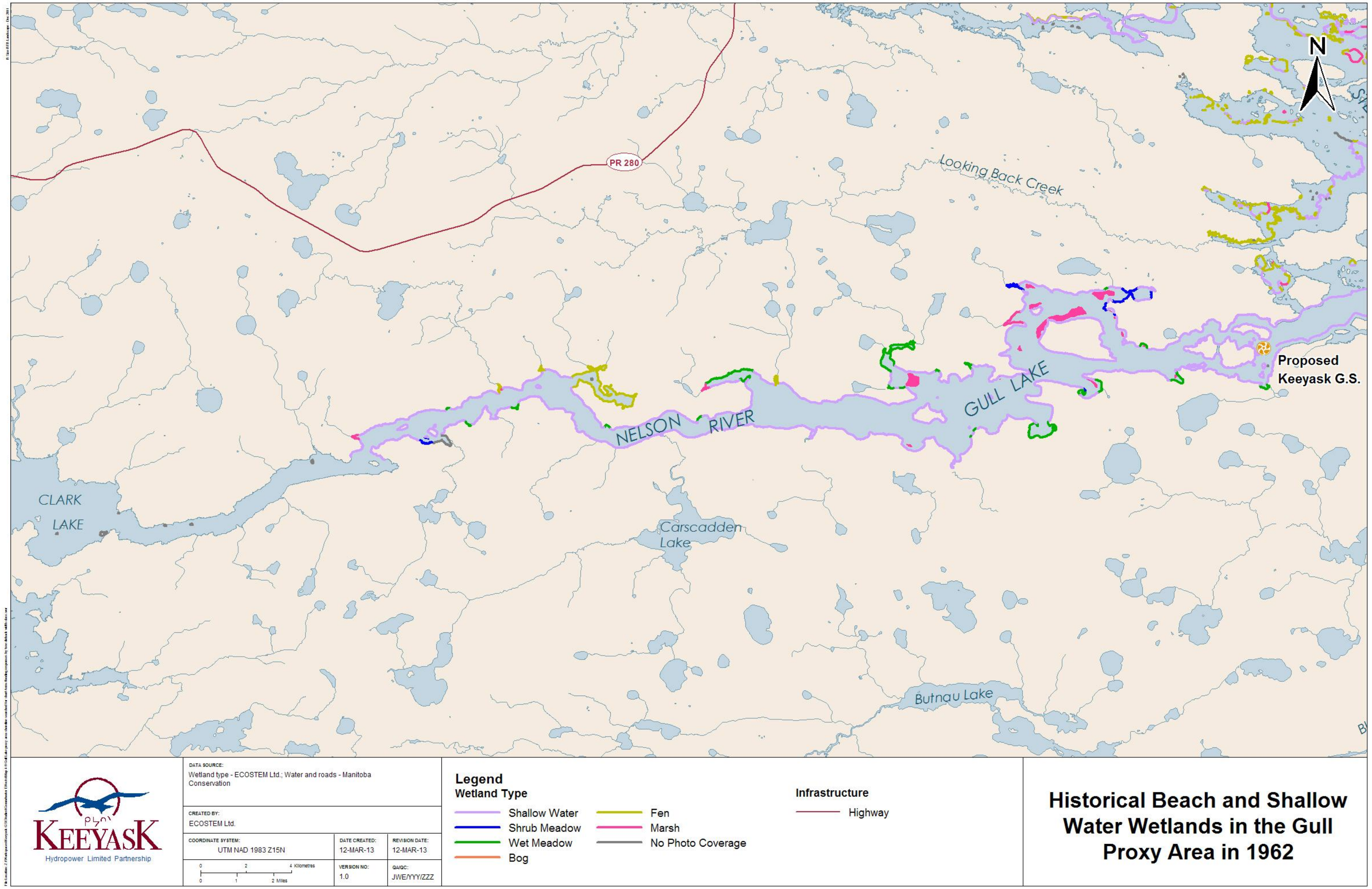
A qualitative evaluation of the historical photos for the 1962 Long Spruce proxy area shoreline provided information from a third proxy area. This evaluation indicated that the beach and shallow water wetlands were predominantly comprised of shallow water wetlands, and occasionally some herb/low shrub meadow. No marsh was identified along the Long Spruce shoreline.

5.4 DISCUSSION

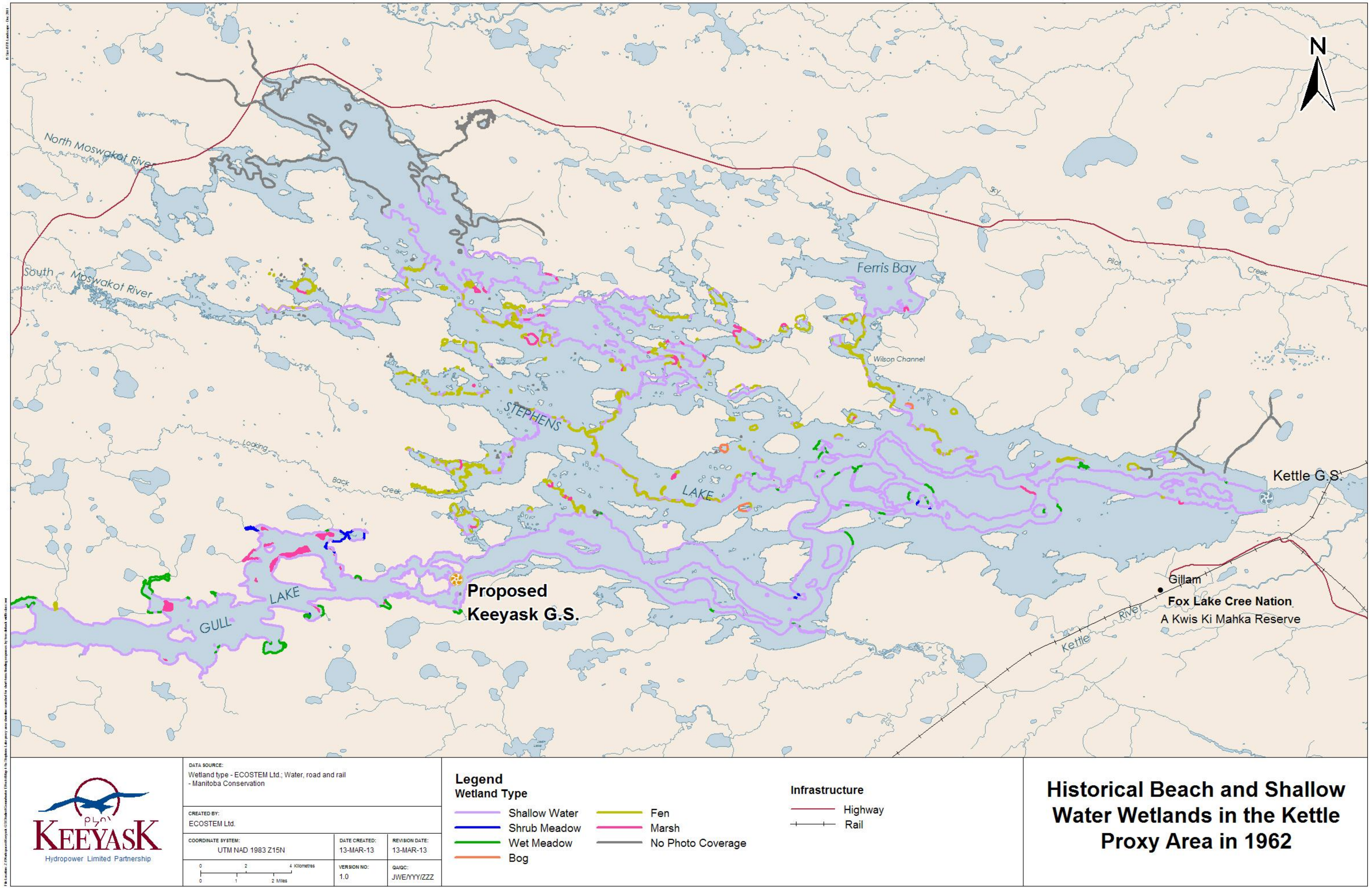
Analysis of historical air photos indicated that, prior to flooding and the CRD/LWR water regime changes, marsh was rare on the Nelson River in the Gull and Kettle proxy areas (less than 2% of shoreline length). Marsh was more abundant in the Gull than in the Kettle proxy area (1.8% versus 0.5%). While meadow and fen wetlands were more abundant in the Gull than in the Kettle proxy area, their maximum extent in either proxy area was approximately 12% of shoreline length. Additionally, in the case of herb/low shrub meadow, the reported areas represented potential areas because it could not be determined what proportion of this area was actually vegetated. Two additional factors influencing the mapped herb/low shrub meadow area are that: 1) vegetation cover varies from year to year in response to recent water levels (fen, bog and shrub meadow vegetation cover typically changes slowly) and; 2) the water level in the photo influences the interpretation of whether or not a herb/low shrub meadow wider than 10 m is recorded as being present. It is noted that the width of the herb/low shrub meadow at a particular location is heavily determined by the substrate slope, substrate type and water regime, so there is no straightforward way to convert shoreline length in herb/low shrub meadow area.

Most of the marsh that was lost to Kettle flooding and water regulation was in the off-system waterways and lakes that were inundated by the Kettle reservoir. Nearly 4% of the inundated shoreline had marsh along it.

5.5 MAPS



Map 5-1: **Pre-development (pre-CRD/LWR) beach and shallow water wetlands in the Gull proxy area in 1962.**



Map 5-2: Pre-development (pre-CRD/LWR) beach and shallow water wetlands in the Kettle proxy area in 1962.

6 EXTENT AND NATURE OF INLAND EDGE EFFECTS USING HISTORICAL AIR PHOTO TIME SERIES ANALYSIS

6.1 STUDY DESIGN AND DATA COLLECTION

The nature and width of surface water, groundwater and edge effects on shore zone terrestrial habitat were documented through historical air photo time series analysis. This provided data to monitor changes that occurred over a long period. Where the available photo years included a sufficient number of time steps in appropriate years, it was possible to also document the pathways of change. These changes were then associated with the potential drivers for the nature and rate of observed changes. This methodology was essentially the same as that used to develop the information needed to construct the peatland disintegration reservoir expansion predictive model (ECOSTEM 2012a).

Of the generally suitable proxy areas selected in Section 2.2, Kettle and Kelsey were the proxy areas used by this study. Previously published results for Notigi (ECOSTEM 2012a) and Wuskwatim (ECOSTEM and Calyx 2003) were relevant for verifying certain results.

This study used the same photo years and time periods as in Section 4. For each photo year, the inland edge zone (Figure 1-5) was searched for possible surface water, groundwater and/or edge effects on vegetation and/or ecosite type that had occurred since the previous photo year in the time series. This study measured the width of edge effects from the shoreline location at its initial flooding position (i.e., shoreline location in first post-flood photo year; see Figure 3-1).

The shoreline was searched for potential reservoir-related shore zone habitat effects that extended more than 10 m inland (10 m was used as the minimum width of detectable effects given the scale of the air photos), using the same stereo photos as were used for the inland groundwater effects study (Section 4.1). Evidence of reservoir-related shore zone habitat effects consisted of changes in vegetation structure or ecosite type that were unrelated to natural processes such as wildfires or background ground ice permafrost melting. Background ground ice permafrost melting refers to the ongoing ground ice permafrost melting occurring in the Regional Study Area (Map 2-1) as a lagged response to past climate change (ECOSTEM 2011c).

Any of the following conditions were recorded as potential reservoir-related shore zone habitat effects (corresponds to “Zone A” in Figure 3-1):

- Patches of tree blow-down;
- Tree mortality (recently killed trees, or snags, remain standing for at least five years);
- Changes in overstorey tree species composition that were unrelated to natural drivers (e.g., changing site conditions) or natural vegetation succession;

- Changes in the composition of the dominant shrub and tree species in the tall shrub and sub-dominant tree layers that were unrelated to natural drivers or natural vegetation succession. This type of change could not be assessed for inland edge segments where overstorey canopy closure was high; and,
- Changes in ecosite type that were not caused by natural processes.

Observations were made from the stereo photos by visually scanning a 50 m wide inland edge band for potential effects, and further if potential effects were detected (Figure 3-1). Potential relevant changes were based on a comparison of one photo year with the previous available photo year in the time series. Other factors that may have influenced the extent and nature of edge effects (e.g., inland edge ecosite type) were interpreted and mapped from the same stereo photos. When completing the photo-interpretation, portions of the shoreline that had burned or undergone recession due to natural ground ice melting (i.e., peat plateau bog disintegration) were skipped over. A characterization of shore segments undergoing peat plateau bog disintegration is provided by ECOSTEM (2012a), which is a detailed study of peatland disintegration in the Kettle and Notigi reservoir areas.

Where available, low altitude oblique helicopter-based photos taken of the shore zone while flying over the water were used to corroborate the photo-interpretations. Aerial surveys were completed on July 13, 2011 for Kelsey and on August 2 and September 8, 2011 for Kettle.

6.2 ANALYSIS

The approach used to create GIS representations for the reservoir shorelines varied by proxy area. Since an existing shoreline dataset existed for portions of the Kettle reservoir shoreline (ECOSTEM 2012b), new fields to incorporate the data produced by this study were added to the existing dataset. Where the study area extended beyond the existing mapped shoreline, additional shoreline within the study area was added to the dataset. Shoreline was added by converting the previously mapped Kettle reservoir polygon into polylines, and then using these polylines to fill in the missing shoreline segments. The shoreline was then segmented wherever there were potential groundwater effects, and where inland edge ecosite class or inland edge substrate slope class changed.

For Kelsey, digital shorelines were created by converting the reservoir polygon derived from NTS mapping into polylines and then erasing all portions of the polylines that were not captured by the stereo photo interpretation. The remaining polylines were then segmented wherever potential groundwater or shore zone-related effects were observed in the time series analysis. Since recent large scale stereo air photos were not available for Kelsey, the 1991 photos were used to interpret and further segment the polylines based on inland edge ecosite class.

Table 6-1 describes the fields added to the shoreline datasets for use in this study. Each of these fields were populated for each shore segment that was searched for potential effects.

Table 6-1: Fields added to the shoreline datasets for the air photo time series analysis study

Field	Description	Values[2]
Shore Effect[1]	A change in vegetation or ecosite potentially due to shore zone effects	Yes (Y); No (N)
Effect: Blowdown[1]	Tree blowdown potentially due to shore zone effects	Yes (Y) or blank
Effect: Mortality[1]	Vegetation mortality potentially due to shore zone effects	Yes (Y) or blank
Effect: Composition[1]	Vegetation composition change potentially due to shore zone effects	Yes (Y) or blank
Effect: Structure[1]	Vegetation structure change potentially due to shore zone effects	Yes (Y) or blank
Effect: Ecosite[1]	Ecosite change potentially due to shore zone effects	Yes (Y) or blank
Edge Ecosite (Kelsey) Edge Ecosite 1962 (Kettle)	Fine ecosite type at the inland edge of the reservoir shoreline prior to flooding	Ecosite Type
Edge Ecosite[1]	Fine ecosite type at the inland edge if different than previous years	Ecosite Type
Effect Width[1]	Width class of the effect for that year	<=10 m; 11-25 m; 26-50 m; 51-75 m; >75 m

Notes:[1] One field in the dataset for each period in the time series (e.g. "shore effect 1965").
[2] A value of -99 indicates that the segment was not included in this study.

For Kelsey, the first post-flooding photos for the entire proxy area were taken at reservoir age 5, followed by a 26-year period without complete proxy area coverage with large scale photos. A study limitation for Kelsey was that reservoir expansion due to shoreline erosion could have occurred before the first set of post-flooding stereo photos were taken (reservoir age 5), such that relatively immediate effects were no longer evident. Similar limitations applied for the subsequent periods between photo years in the time series for both Kelsey and Kettle. To identify segments of shoreline where these limitations applied, mapped shore segments experiencing shoreline erosion (including peatland disintegration) were identified using shoreline position changes demonstrated between air photo years.

Some potential small patches of shore zone groundwater effects may have been undetectable in the stereo-photos, particularly if they were manifested in the understorey layers. To account for this possibility, segments where no groundwater effects were detected were assigned an effect width class of "≤10 m" (see Table 6-1).

6.3 RESULTS

6.3.1 Kelsey Proxy Area

A time series of historical air photos (Section 3.1) was available for approximately 142 km, or 26%, of the 551 km of Kelsey reservoir shorelines (Map 6-1). Of this length, a total of 9.5 km (7%) was excluded from the 1965 evaluation due to generating station related vegetation clearing, and 20.4 km (14%) was excluded due to peat plateau bog disintegration. An additional 28.8 km (20%) was excluded in the 1991 series due to fire disturbance. This left 112.1 km of 1965 shoreline and 83.9 km of 1991 shoreline to search for potential inland edge effects (Table 6-2).

Table 6-2: Kelsey shoreline with available stereo-photo coverage in the 1965 and 1991 photo series

Shoreline with stereo-photo coverage	1965 Photo Series		1991 Photo Series	
	Length (km)	%	Length (km)	%
Analysed shoreline	112.1	79	83.9	59
Cleared shoreline	9.5	7	8.9	6
Peatland disintegration	20.4	14	20.4	14
Burned shoreline	0.0	0	28.8	20
*Total mapped shoreline (km)**	*141.5*		*141.5*	

Notes:* Total mapped shoreline represents total covered shoreline length in common for both 1991 and 1965 series.

Photo 6-1 to Photo 6-5 show conditions along searched shorelines as they existed in summer 2011. Photo 6-1 and Photo 6-2 illustrate the relatively high relief along large portions of the shoreline, particularly evident in the reservoir area nearer the horizon.

Photo 6-3 and Photo 6-4 show two bays where there was reservoir expansion due to disintegration of ground ice peatlands. These areas were disintegrating slowly due to the melting of ground ice in contact with the reservoir (ECOSTEM 2012a). The floating peat mats adjacent to the elevated portion of the islands were also elevated prior to disintegration.

As illustrated in Photo 6-5, a large 1992 wildfire burned much of the inland area surrounding the reservoir.

The following paragraphs provide an overview of shore zone habitat changes over time. See Figure 1-5 for the water depth duration zones (e.g., beach, inland edge) used in the descriptions.

By reservoir age five (1965 stereo-photo series), a high proportion of the inundated trees were still standing, protruding out of the water in the lower beach and shallow water zone. There was no apparent tree mortality, blowdown, or species composition changes within the inland edge, and no discernible evidence of inland edge vegetation or ecosite change.

By reservoir age 31 (1991 stereo-photo series), trees protruding out of the water had disappeared. Beach vegetation had appeared along portions of the shoreline. Peatland disintegration had occurred in some back-bay areas where reservoir flooding contacted previously isolated ground ice peatlands. Stereo-photos number 1 and 2 in Figure 6-1 provide examples of an inundated back-bay area at reservoir age five (1965) and age 31 (1991).

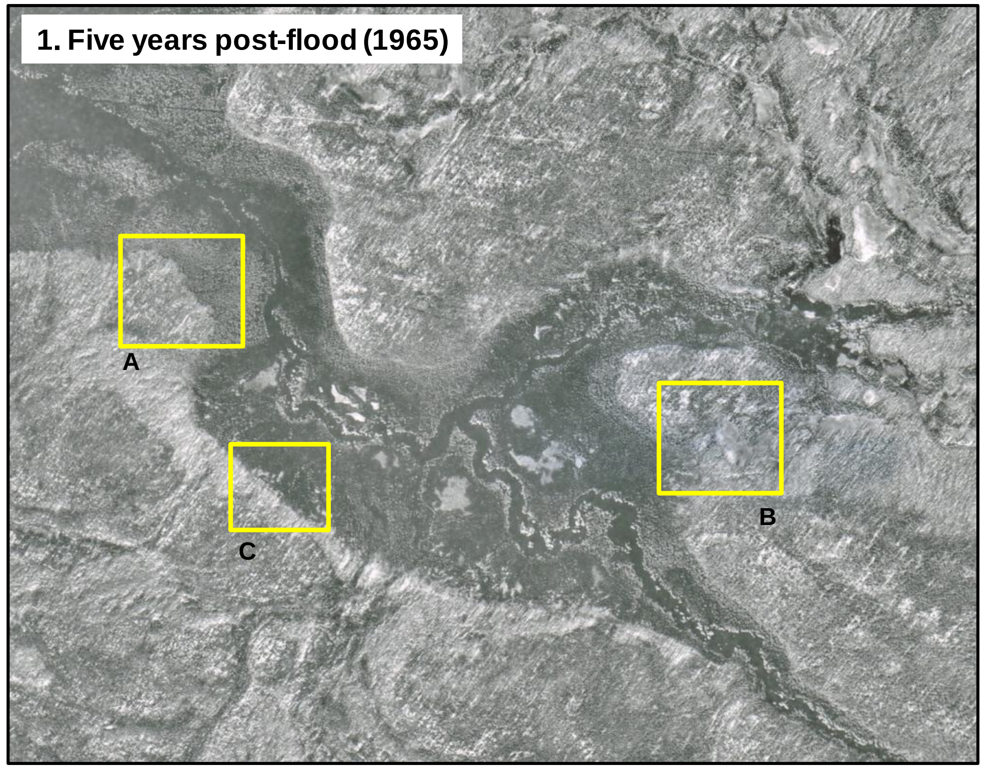
Photo 6-1: **Kelsey reservoir shoreline looking east along the north side of the eastern arm in 2011 (in Map 6-2 looking east toward area shown in Figure 6-1)**

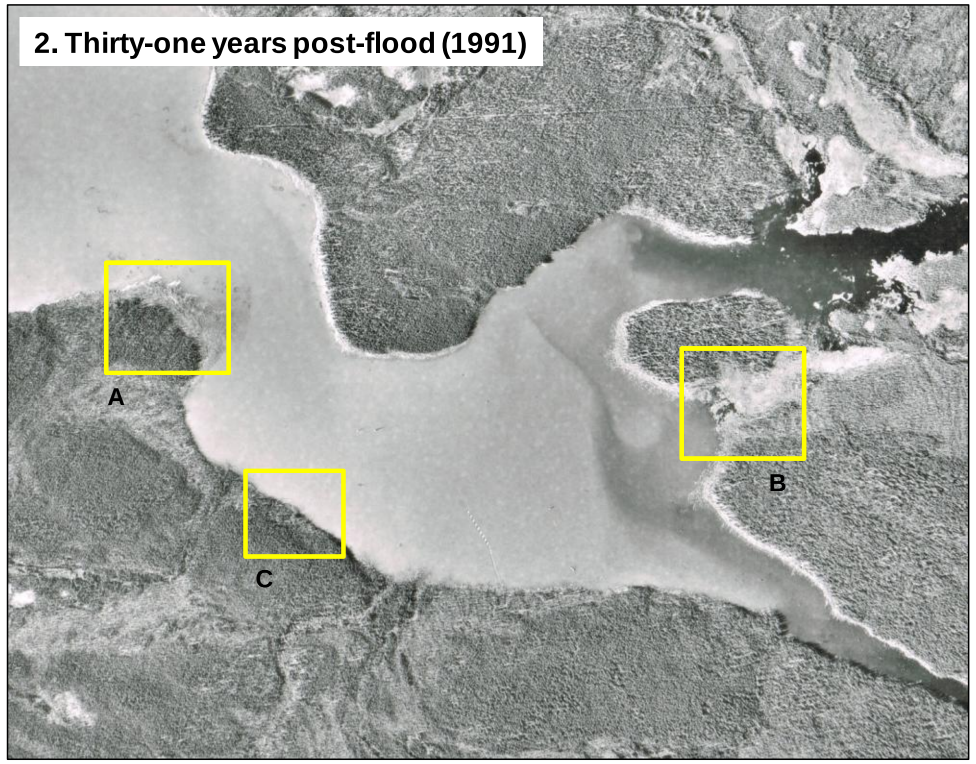
Photo 6-2: **Kelsey reservoir shoreline along the main Nelson River channel. Looking north from the south end of the photo coverage area (Map 6-2)**

Photo 6-3: **North Kelsey reservoir shoreline looking northeast toward the generating station (in background) across a disintegrating peatland (Map 6-2)**

Photo 6-4: **Remnants of a peat plateau bog that was initially above water in a flooded area and subsequently has mostly disintegrated, forming a bay off the southwest arm of the reservoir (Map 6-2)**

Photo 6-5: **Looking southwest across an inundated stream off the east arm of the Kelsey reservoir. Surrounding area is regenerating following a wildfire in 1992 (Map 6-2)**





A:

Shore zone vegetation change between 1965 and 1991 on veneer bog on slope. Tree mortality, with vegetation structure and composition change to shrub and graminoid dominated cover.

B:

Shore zone ecosite change and tree mortality between 1965 and 1991. Treed horizontal fen changed to graminoid riparian fen.

C:

No shore zone effects due to groundwater change. Blanket bog peatland at inland edge, with mineral crest in the background.

Figure 6-1: Comparison of a portion of the Kelsey reservoir five and thirty-one years post-flooding using 1965 and 1991 stereo-photos and 2011 helicopter photos: (A) and (B) Areas with shore zone vegetation and ecosite change; and (C) An area with no apparent shore zone effects. See Map 6-2 for comparison location.

6.3.1.1 Shore Zone Changes Between Reservoir Ages 5 and 31 Years

Potential reservoir-related shore zone effects extending more than 10 m inland of the initial post-flood shoreline were recorded for approximately 3% (2.7 km) of the 83.9 km of searched 1991 shoreline (Table 6-3). Potential causes for these effects included ice scouring and changes to soil moisture regime resulting from elevated groundwater. Ice scouring was generally deemed to be the cause for shore zone effects in the main Nelson River channel along higher relief mineral and thin peatland banks, where tree cover had been completely removed well above the water elevation (Map 6-1). Groundwater changes were assumed to be the cause for potential shore zone effects in the back-bay areas along shorelines with low relief. On this basis, nearly 53% of the potential inland edge effects were likely due to groundwater changes, while the remaining 47% were likely due to ice scouring.

Table 6-3: Potential shore zone effects between age 5 (1965) and age 31 (1991) in Kelsey, and their causes, measured as shoreline length and percentage of total searched shoreline.

Likely Cause of Potential Effect	Length (km)	Percentage of Total Length Searched
None	81.2	96.7
Groundwater change	1.4	1.7
Ice scour	1.3	1.5
Total searched shoreline (km)	*83.9*	*83.9*

In the approximately 3% of the shoreline with observed effects, the most common effects width classes were 11–25 m and 26–50 m at 45% and 32% of the shoreline with effects, respectively (Table 6-4). Over 87% of the widths of potential effects were less than 75 m.

After weighting for shoreline length, the overall mean width of potential inland edge effects was 49 m for the portion of the shoreline with potential effects. This value dropped to 6.4 m when averaged over the entire searched shoreline length (note this assumes an average 5 m effect even in shore segments where no effect was observed). Based on comparison of the treeline position in 1965 and in 1991 for shore segments not undergoing peat plateau bog disintegration, there was no apparent shoreline erosion in the searched shoreline including segments where potential shore zone effects were detected, so it was unlikely that erosion would have masked the width of effects throughout this period.

For the limited areas with inland edge effects, tree mortality was the most common effect occurring between 1965 and 1991 measured as percentage of shoreline length or area of change, followed by ecosite change and then by a combination of tree mortality and ecosite change (Table 6-5). Photo A in Figure 6-1 shows an example of a dead tree fringe in the Kelsey reservoir, visible as an area of standing and fallen snags near the living tree line.

Table 6-4: Width of potential shore zone effects between age 5 (1965) and age 31 (1991) in Kelsey by effects width class, measured as shoreline length and percentage of total affected shoreline

Width Class	Length (km)	Percentage of Affected Length	Percentage of Total Length Searched
0 to 10 m	81.2	n/a	96.7
11 to 25 m	1.2	44.8	1.5
26 to 50 m	0.9	32.2	1.0
51 to 75 m	0.3	10.2	0.3
>75 m	0.3	12.8	0.4
Total length (km)	*83.9*	*2.7*	*83.9*
Overall mean width of effects (m)*		48.7	6.4

Notes:* Class midpoint width average over total shoreline length. Midpoint value for >75m class is 175m.

Table 6-5: Shoreline length and area of potential shore zone effects between age 5 (1965) and age 31 (1991) in Kelsey proxy area by effect type

Type of Effect	Shoreline Length (km)	Percentage of Searched Shoreline	Area (ha)*	Percentage of Affected Area
None	81.2	96.74	n/a	n/a
Tree mortality	1.3	1.55	4.6	35
Tree mortality and ecosite change	0.4	0.49	3.7	28
Ecosite change	0.4	0.46	3.9	30
Tree mortality & vegetation structure change	0.4	0.43	0.6	5
Tree mortality, vegetation composition & structure change	0.3	0.33	0.5	4
All	83.9	100	13.3	100

Notes:* Area calculated as class midpoint width multiplied by total shoreline length in that effects width class. Midpoint value used for the >75m class was 175m.

Using pre-flood conditions at the initial flooding shoreline, the basin bog and horizontal fen pre-flood inland edge ecosite types (see Table 6-5 in ECOSTEM Ltd. 2012b for definitions of ecosite types) had the highest percentage of their shoreline with potential effects (100%), all showing potential groundwater effects (Table 6-6). Both of these ecosite types converted to riparian fen by age 31, and, in addition, tree mortality occurred in the horizontal fen (Table 6-7). Despite the magnitude of effects on these ecosites, they only accounted for approximately 0.35 km of the 83.9 km searched shoreline. These ecosites also had the furthest inland shore zone effects, extending more than 75 m for all cases. The extent of effects on these types was most likely due to the low relief and low topographical position of these ecosite types (both of which already have groundwater saturation close to the surface), allowing elevated groundwater from the reservoir to penetrate further inland.

Veneer bog and blanket bog were the next highest affected ecosite measured as proportion of shoreline (Table 6-6), both of which converted to riparian fen, including tree mortality in the former type (Table 6-7). While the percentage of veneer bog affected was relatively high, the percentage applied to only 0.7 km of shoreline. The width of potential groundwater effects in these types were lower than those discussed above. This was likely due to higher relief, and shallower peat depth to the mineral substrate, which potentially provided a barrier to inland penetration of surficial groundwater.

Table 6-6: Potential shore zone effects as a percentage of shore zone inland edge ecosite type between age 5 (1965) and age 31 (1991)

Pre-Flood Ecosite Type	**No Effect (%)**	**Potential Effect (%)**		***Total Length (km)***
		Groundwater	**Ice scour**	
Deep dry mineral	95.3	-	4.7	*27.5*
Veneer bog on slope	98.8	1.2	-	*52.6*
Veneer bog	71.1	28.9	-	*0.7*
Blanket bog	88.9	11.1	-	*2.2*
Slope bog	100.0	-	-	*0.1*
Peat plateau bog/ collapse scar mosaic	100.0	-	-	*0.4*
Basin bog	-	100.0	-	*0.2*
Horizontal fen	-	100.0	-	*0.2*

Table 6-7: Shore zone inland edge ecosite potential groundwater effects as a percentage of affected shoreline along the searched shoreline between age 5 (1965) and age 31 (1991)

Pre-flood Ecosite Type	Searched Shoreline (km)		Percentage of Affected Shoreline by Effect Type			
	Not Affected	Potentially Affected	Ecosite Change to Riparian Fen	Tree Mortality	Structure Change	Composition Change
Deep dry mineral	26.3	1.3	-	100	-	-
Veneer bog on slope	52.0	0.6	-	100	100	43
Veneer bog	0.5	0.2	100	100	-	-
Blanket bog	1.9	0.2	100	-	-	-
Slope bog	0.1	-	-	-	-	-
Peat plateau bog/ collapse scar mosaic	0.4	-	-	-	-	-
Basin bog	-	0.2	100	-	-	-
Horizontal fen	-	0.2	100	100	-	-
All types	81.2	2.7	29	85	23	10

Deep dry mineral comprised the highest overall proportion of potentially affected shoreline (47%), followed by veneer bog on slope and blanket bog (Table 6-8). Despite being less common along the shoreline than veneer bog on slope, mineral ecosites had a substantially higher proportion of potential shore zone effects, mostly in the form of tree mortality (Table 6-7). Most of that tree mortality, particularly that extending inland on higher-relief topography, was associated with ice scouring along the main river channel. Tree mortality further inland may also have been due to tree senescence, however this was difficult to verify due to the 1991 burn that disturbed vegetation along the affected shoreline.

Of the mapped ecosites along the shoreline, slope bog, peat plateau bog/ collapse scar mosaics and riparian fen did not have any potential shore zone effects detected. The approximately 100 meters of shoreline slope bog and 900 meters of riparian fen that had no apparent groundwater effects was presumably because that ecosite type generally already had groundwater close to the surface.

Shore zone recession and ecosite dynamics for initial flooding shorelines that are peat plateau bog are described in a peatland disintegration technical report (ECOSTEM 2012a).

Table 6-8: Ecosite composition along searched Kelsey shoreline with and without potential shore zone effects as a percentage of total searched shoreline between age 5 (1965) and age 31 (1991)

Pre-Flood Ecosite Type	No Effect	Potential Effect		
		Groundwater	Ice scour	Both
Deep dry mineral	32.3	-	100.0	47.4
Veneer bog on slope	64.1	44.3	-	23.3
Veneer bog	0.6	14.5	-	7.6
Blanket bog	2.4	16.8	-	8.8
Slope bog	0.1	-	-	-
Peat plateau bog/ collapse scar mosaic	0.5	-	-	-
Basin bog	-	11.8	-	6.2
Horizontal fen	-	12.5	-	6.6
Total Length (km)	*81.2*	*1.4*	*1.3*	*2.7*

All of the ecosite changes along the shoreline between 1965 and 1991 were confined to shallow peatlands (blanket bog and veneer bog) and deep peatlands (horizontal fen and basin bog), all of which converted to riparian fen (Table 6-7). While ice scour and groundwater effects were observed, no ecosite changes were identified for mineral and thin peatland (veneer bog on slope) shoreline ecosites, likely because the planting rooting zone becomes elevated above the reservoir groundwater influence within a few meters of the shoreline.

The reported ecosite changes to riparian peatland were largely definitional rather than representing a dramatic vegetation change. That is, because a peatland adjacent to water is by definition a riparian peatland so that reservoir flooding to an inland peatland by definition converts it to a riparian peatland. Pre-flooding vegetation structure of riparian peatlands was very similar to that of basin bog and horizontal fen because the groundwater is close to the surface in all three types (cite ECOSTEM 2012b). For the same reason, vegetation composition of riparian bog and basin bog are similar, as are riparian fen and horizontal fen (cite ECOSTEM 2012b). Depending on the overall change in groundwater levels, some tree mortality may occur after an inland deep wet peatland is converted to a riparian peatland, and some expansion of the peatland may occur, especially if adjacent to ground ice peatlands further inland. Generally, the width of these ecosite changes are measured to the furthest inland extent of the affected horizontal fen or basin bog regardless of whether or not there were any observable changes in the remainder of the peatland.

6.3.2 Kettle Proxy Area

Approximately 150 km, or 16%, of the 955 km of Kettle reservoir shoreline (Map 6-3) was searched for the inland edge effects analysis based on historical air photo time series (Section 3.1). The searched area represented a wide range of levels for influential factors in this proxy area by extending through the central portions of the Kettle reservoir, including the western bays, the central main body of the reservoir, several of the large central islands, and a portion of the northern shoreline and Ferris Bay (Map 6-3). Approximately 58 km (39%) of the searched shoreline was excluded due to peatland disintegration between 1971 and 2006 (Map 6-3), leaving a total of 92.3 km of shoreline for analysis.

Photo 6-6 to Photo 6-11 show conditions along searched shorelines as they existed in the summers of 2007 and 2011. Photo 6-6 and Photo 6-7 provide an overview of two major areas analyzed in Kettle reservoir for shore zone effects, including some of the large, central islands and the southern portions of Ferris Bay. Photo 6-8 to Photo 6-10 illustrate typical shoreline conditions in the searched areas, including areas with no apparent shore zone effects, and areas exhibiting vegetation change since 1971. Photo 6-11 provides an example of a reservoir expansion area where the shoreline has receded since 1971 due to the peatland disintegration.

The following paragraphs provide an overview of shore zone habitat changes over time. See Figure 1-5 for the water depth duration zones (e.g., beach, inland edge) used in the descriptions.

Less than a year after flooding (1971 stereo-photo series), most of the inundated trees were still standing and were visible, protruding out of the water (see example in Figure 6-2). There were no apparent tree mortality, blowdown or species composition changes inland of the waterline, and no discernible evidence of shore zone vegetation or ecosite change (Table 6-9).

By reservoir age 15 (1986 stereo-photo series), trees protruding out of the water in the beach zone had disappeared. Beach zone vegetation, primarily low, herbaceous vegetation, had appeared along portions of the shoreline. Peatland disintegration had occurred in some back-bay areas and around some newly-formed islands where reservoir flooding likely contacted previously isolated ground ice peatlands. Stereo-photo numbers 1 to 3 in Figure 6-2 provide examples of inundated peatlands, in the lower-centre of the photo, which disintegrated and formed some floating peat islands.

By reservoir age 32, further reservoir expansion had occurred in areas undergoing peatland disintegration. Beach zone vegetation continued to develop along much of the shoreline, with the establishment of a tall shrub zone.

Photo 6-6: **Overview of some of the central islands in Kettle reservoir that were analyzed for potential shore zone effects between 1971 and 2003/2006. The large foreground island is mineral while the islands immediately behind it are disintegrating peatlands. Photo taken in 2007 looking west (Map 6-4)**

Photo 6-7: **Overview of south portion of Ferris Bay in the Kettle reservoir that was analyzed for potential shore zone effects between 1971 and 2003/2006. Photo taken in 2007 looking west (Map 6-4)**

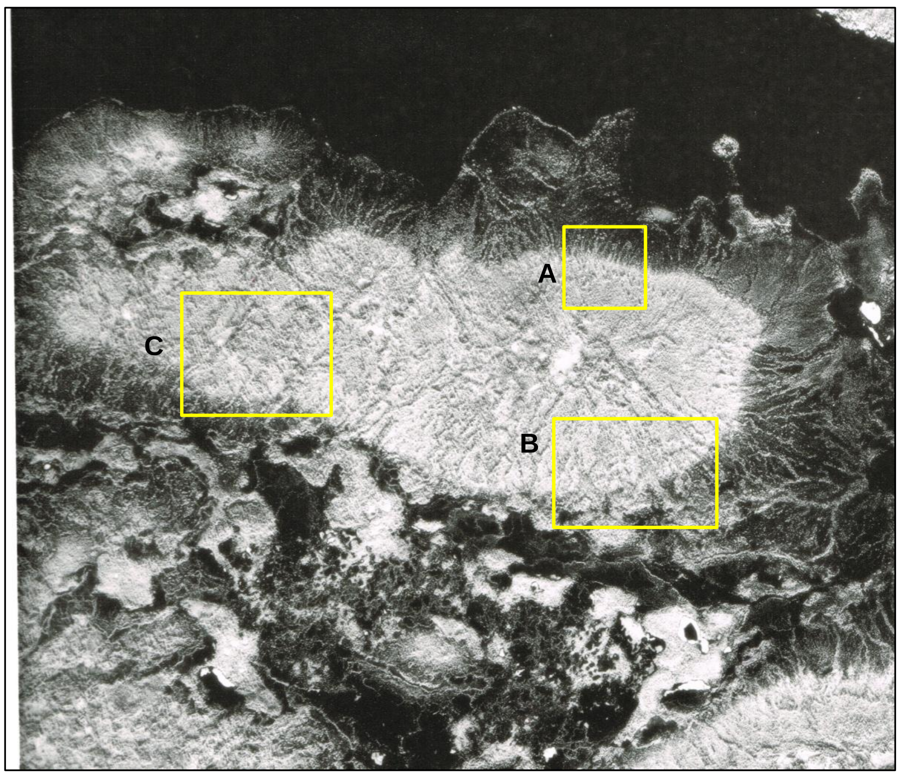
Photo 6-8: **High-slope mineral bank along a portion of the analyzed Kettle shoreline with no visible shore zone effects between 1971 and 2003/2006. Photo taken in 2011, looking northeast (Map 6-4)**

Photo 6-9: **Low-slope organic bank in the Kettle reservoir showing tree mortality and tall shrub development in the shore zone between 1971 and 2003/2006. Note scattered dead trees amongst the tall shrubs which are replacing what was a treed area immediately after flooding. Photo taken in 2011, looking north (Map 6-4)**

Photo 6-10: High-slope organic bank in the Kettle reservoir with no apparent shore zone effects between 1971 and 2003/2006. Dead trees in the background are jack pine that are located well above the reservoir water level. Photo taken in 2011, looking north (Map 6-4)

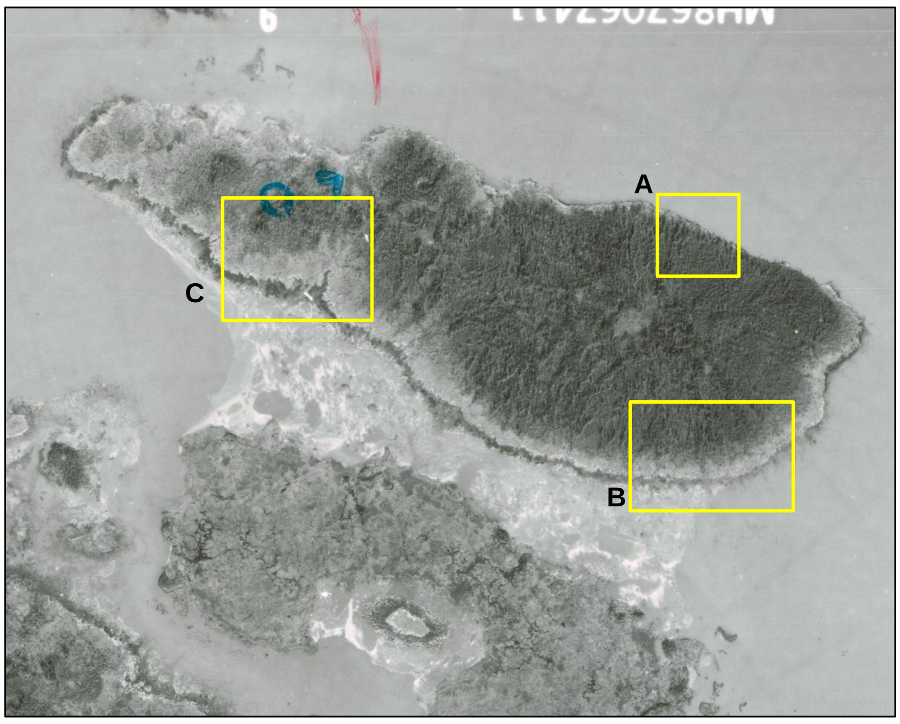
Photo 6-11: **Searched shoreline in the western portion of the Kettle reservoir showing shoreline recession due to peatland disintegration, tree mortality and composition change in the shore zone between 1971 and 2003/2006. Photo taken in 2011, looking northwest (Map 6-4)**

1. < 1 year post-flood (1971)



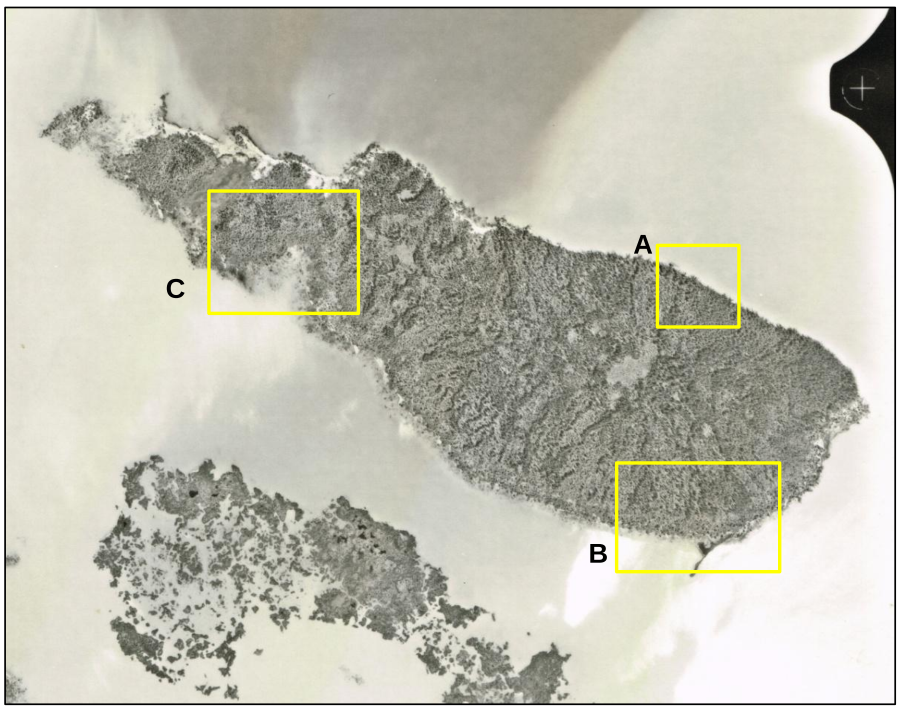
A:
No shore zone vegetation change between 1971 and 2003/2006. Veneer bog on gentle slope at inland edge with peat banks visible at shoreline.

2. 15 years post-flood (1986)



B:
Shore zone vegetation change between 1971 and 2003/2006 on veneer bog on slope. Tree mortality and structure change by 1986, and composition change to shrub and graminoid-dominated cover by 2003.

3. 32 years post-flood (2003)



C:
Shore zone vegetation change between 1971 and 2003/2006 on blanket bog. Shoreline recession, wide tree mortality and structure change by 1986, with further recession and mortality, and composition change to shrub-dominated cover by 2003.

Figure 6-2: **Comparison of a portion of the Kettle reservoir less than one, fifteen, and thirty-two years post-flooding using 1971, 1986 and 2003 stereo-photos and 2011 helicopter photos: (A) An area with no apparent shore zone effects; (B) an area with shore zone vegetation change; and (C) an area with receding shorelines and vegetation change. See Map 6-4 for comparison location.**

6.3.2.1 Shore Zone Changes Between Reservoir Ages 0.2 and 15 Years

Potential reservoir-related shore zone effects extending more than 10 m inland of the initial flooding shoreline were recorded for approximately 39% (36.5 km) of the age 15 (1986 air photos) searched shoreline (Table 6-9). The likely potential cause identified for these effects was changes to soil moisture regime resulting from elevated groundwater. Unlike Kelsey, there was no visible evidence that ice scouring was an important factor in the searched areas of Kettle.

Table 6-9: Length (km) and percentage of potential shore zone effects in the searched portions of the Kettle proxy area for each of the stereo-photo series

Time period	No Potential Effect (km (%))	Potential Effect (km (%))	All (km (%))
1971 Photo Series	91.9 (100%)	0.0 (0%)	91.9 (100%)
1986 Photo Series	55.7 (61%)	36.2 (39%)	91.9 (100%)
2003/2006 Photo Series	54.5 (59%)	37.4 (41%)	91.9 (100%)

Although a substantial percentage of the shoreline had potential inland edge effects, the average width of mapped effects was less than 15 m by the end of the first 15 years after flooding. The most common effects width classes were the 11 to 25 m and 26 to 50 m classes, occurring along 17% and 16% of the searched shoreline, respectively (Table 6-10). Ninety-six percent of the recorded widths of potential effects were less than 50 m. Shoreline recession due to erosion was not identified between 1971 and 1986 in the searched areas, so it was unlikely that any of the potential effects were erased during this period.

After weighting for shoreline length, the overall mean width of potential inland edge effects was 25.5 m for the portion of the shoreline with potential effects (Table 6-10). This value dropped to 13.1 m when averaged over the entire searched shoreline length (a width of 5 m was used even where no effects were observed).

Table 6-10: Potential shore zone effects width class, shoreline length and percentage of total affected shoreline between age 0.2 (1971) and age 15 (1986) in the searched Kettle proxy area

Width Class	Length	Percentage of Affected Length**	Percentage of Total Length Searched
0 to 10 m	60.5	13.1	65.8
11 to 25 m	15.6	43.2	17.0
26 to 50 m	14.5	40.0	15.7
51 to 75 m	1.3	3.7	1.5
Total length (km)	*91.9*	*36.2*	*91.9*
Overall mean width of effects*		25.5	13.1

Notes:* Class midpoint width average over total shoreline length. Midpoint value for >75m class is 100m.
** 4.7 km of the 0 - 10m width class had identifiable potential shore zone effects.

Tree mortality combined with vegetation structure change was the most common inland edge effect occurring between 1971 and 1986, followed by tree mortality alone. This was true for both shoreline length and area (Table 6-11). Tree mortality occurred along all of the potentially affected shoreline during this time period. Vegetation structure change was associated with most of the tree mortality along the affected shoreline. Vegetation structure change occurred during this period after tree mortality was extensive enough to change the canopy structure, usually after snags begin to decay and fall. Vegetation structure changed from a treed to a low vegetation type.

Table 6-11: Shoreline length and area of potential shore zone effects in the Kettle proxy area searched shoreline by effect type between age 0.2 (1971) and age 15 (1986)

Type of Effect	Shoreline Length (km)	Percentage of Searched Shoreline	Area (ha)	Percentage of Affected Area
None	55.7	60.6	n/a	n/a
Tree mortality and vegetation structure	31.2	34.0	78.3	85
Tree mortality	4.1	4.5	11.3	12
Ecosite change, tree mortality and vegetation structure	0.9	0.9	2.8	3
All	91.9	100	92.3	100

Notes: * Class midpoint width average over total shoreline length. Midpoint value for >75m class is 100m.

Calculated as a percentage of shoreline length for each ecosite type, the flat bog, blanket bog, veneer bog and riparian fen ecosite types had the highest proportion of their shoreline with potential effects (Table 6-12). Effects along blanket bog and riparian fen ecosite types extended furthest inland on average, 34 and 30 meters, respectively (Table 6-12), however the total affected length was very low for riparian fen. Shore zone effects in pre-flood riparian fen consisted of tree mortality along the fringes of the fen, likely due to increases in groundwater levels.

Ecosite change was primarily associated with horizontal fen, followed by blanket bog converting into riparian fen ecosites (Table 6-13). All of the affected inland edge horizontal fen converted to riparian fen as well as showing tree mortality and vegetation structure change. Approximately one third of the affected blanket bog converted to riparian fen, while all showed tree mortality and structure change. Effects on the remaining ecosite types were limited to tree mortality with vegetation structure changes.

Table 6-12: Potential shore zone effects as a percentage of pre-flood shoreline ecosite type between age 0.2 (1971) and age 15 (1986) for the searched Kettle proxy area shorelines**

Pre-Flood Ecosite Type	No Effect	Potential Effect	*Total Length (km)*	Mean Effect Width (m)*
Deep dry mineral	70.1	29.9	*37.9*	23
Veneer bog on slope	54.6	45.4	*47.5*	26
Veneer bog	38.5	61.5	*1.2*	25
Blanket bog	34.7	65.3	*2.7*	34
Slope bog	90.6	9.4	*0.7*	18
Slope fen	100.0	-	*0.3*	-
Peat plateau bog	100.0	-	*0.2*	-
Peat plateau bog/ collapse scar mosaic	100.0	-	*0.1*	-
Flat bog	-	100.0	*0.2*	18
Horizontal fen	56.6	43.4	*0.5*	18
Riparian fen	48.6	51.4	*0.6*	30

Notes:* Mean effect width calculated using the mid-point value of width class for each segment in the category. ** "0" values are values that round to zero. Absence is represented by "-".

Table 6-13: Potential shore zone effects as a percentage of affected shoreline by pre-flood ecosite type and effect type between age 0.2 (1971) and age 15 (1986) for the searched Kettle proxy area shorelines

Pre-flood Ecosite Type	Searched Shoreline (km)		Percentage of Affected Shoreline by Effect Type			
	Not Affected	Potentially Affected	Ecosite Change to Riparian Fen	Tree Mortality	Vegetation Structure Change	Vegetation Composition Change
Deep dry mineral	26.6	11.3	-	100	71	-
Veneer bog on slope	25.9	21.6	-	100	96	-
Veneer bog	0.5	0.7	-	100	100	-
Blanket bog	0.9	1.8	36	100	100	-
Slope bog	0.7	0.1	-	100	100	-
Slope fen	0.3	-	-	-	-	-
Peat plateau bog	0.2	-	-	-	-	-
Peat plateau bog/ collapse scar mosaic	0.1	-	-	-	-	-
Flat bog	-	0.2	-	100	100	-
Horizontal fen	0.3	0.2	100	100	100	-
Riparian fen	0.3	0.3	-	100	100	-
All types	55.7	36.2	2	100	89	-

Notes:* "0" values are values that round to zero. Absence is represented by "-".

Veneer bog on slope had by far the highest overall proportion of potentially affected shoreline (60%), followed by deep dry mineral (Table 6-14). The distribution of shore zone effects among the ecosite types closely reflected the overall proportions of ecosite in the searched areas. However, the proportion of veneer bog on slope was higher along the affected shoreline than the shoreline with no apparent effects. Veneer bog on slope also made up the highest proportion of shoreline for all shore zone effect width classes up to 50 meters (Table 6-15).

In terms of the nature of effects for veneer bog on slope, tree mortality was present in all of the affected shoreline while vegetation structure change was present in 96% of this affected shoreline (Table 6-13). The observed vegetation changes close to the shoreline were attributed to the elevation of saturated soil into the plant rooting zone. Deep dry mineral and veneer bog on slope with shore zone effects greater than 50 meters wide occurred in smaller segments along the shorelines of some of the smaller, lower-relief islands in

Stephens Lake. Wider effects may be a result of a combination of lower relief, and exposure to higher wave energy.

Of the ecosites occurring along the shoreline, only slope fen did not have any potential inland edge effects. The approximately 300 meters of shoreline slope fen that had no apparent groundwater effects was presumably because that ecosite type generally already had groundwater close to the surface, and/or the local relief (slope) was high enough to limit the inland extent of reservoir groundwater effects.

No potential inland edge effects were described for peat plateau bogs adjacent to the reservoir, likely because the plateau elevates the vegetation rooting zone above the water level.

Table 6-14: Ecosite composition along searched Kettle shoreline with and without potential shore zone effects as a percentage* of total searched shoreline between age 0.2 (1971) and age 15 (1986)

Pre-Flood Ecosite Type	No Effect	Potential Effect	Both
Deep dry mineral	47.7	31.3	41.2
Veneer bog on slope	46.5	59.6	51.6
Veneer bog	0.8	2.0	1.3
Blanket bog	1.7	4.9	2.9
Slope bog	1.2	0.2	0.8
Slope fen	0.5	-	0.3
Peat plateau bog	0.4	-	0.2
Peat plateau bog/ collapse scar mosaic	0.2	-	0.1
Flat bog	-	0.5	0.2
Horizontal fen	0.5	0.6	0.6
Riparian fen	0.5	0.8	0.6
Total Length (km)	*55.7*	*36.2*	*91.9*

Notes:* “0” values are values that round to zero. Absence is represented by “-“.

Table 6-15: Ecosite composition along searched Kettle shoreline with potential shore zone effects as a percentage* of total affected shoreline between age 0.2 (1971) and age 15 (1986) by width class

Pre-Flood Ecosite Type	Width of potential shore zone effects			
	0-10 m	**11-25 m**	**26-50 m**	**51-75 m**
Deep dry mineral	26.0	43.8	17.7	51.7
Veneer bog on slope	74.0	47.9	68.6	48.3
Veneer bog	-	2.8	2.0	-
Blanket bog	-	1.7	10.3	-
Slope bog	-	0.4	-	-
Flat bog	-	1.2	-	-
Horizontal fen	-	1.4	-	-
Riparian fen	-	0.8	1.3	-
Total length (km)	*4.7*	*15.6*	*14.5*	*1.3*

Notes:* "0" values are values that round to zero. Absence is represented by "-".

6.3.2.2 Shore Zone Changes Between Reservoir Ages 15 and 32/35 Years

By reservoir age 32 or 35 (2003 and 2006 stereo-photography), depending on which portion of the reservoir, potentially affected shoreline length increased by 1.3 km, from 36.2 km in 1986, to 37.4 km in 2003 (Table 6-9).

While the relative proportion of the different effect width classes along the searched shoreline did not change substantially, proportion increases were greatest for the 11–25 m and 51–75 m width classes, accompanied by a decrease in the 26–50 m width class (compare Table 6-10 and Table 6-16). The overall average effect width, as measured from the initial flooding shoreline position, increased slightly from 25.5 to 28.0 meters when averaged over the affected shoreline, and from 13.1 to 14.4 meters averaged over the entire searched shoreline (Table 6-16).

The most common inland edge effect occurring during the 1986–2003/2006 period was vegetation structure and composition change (22% of searched shoreline) followed by tree mortality combined with vegetation structure and composition change (Table 6-17). With respect to affected area, tree mortality with vegetation structure and composition change was greater than structure and composition change alone with 55% of the total affected area for the former, followed by 41% for the latter (Table 6-17).

Table 6-16: Width of potential shore zone effect in Kettle searched shoreline between ages 15 (1986) and 32/35 (2003/2006) by width class, measured as shoreline length and percentage of total affected shoreline in the searched Kettle proxy area

Width Class	Length	Percentage of Affected Length**	Percentage of Total Length Searched
0 to 10 m	59.5	13.6	64.8
11 to 25 m	14.0	37.5	15.3
26 to 50 m	15.6	41.6	17.0
51 to 75 m	2.2	5.8	2.3
>75 m	0.6	1.6	0.6
Total length (km)	*91.9*	*37.4*	*91.9*
Overall mean width of effects*		28.0	14.4

Notes:* Class midpoint width average over total shoreline length. Midpoint value for >75m class is 100m.
** 5.1 km of the 0 - 10m width class had identifiable potential shore zone effects.

Table 6-17: Potential shore zone effect type in Kettle searched shoreline between ages 15 (1986) and 32/35 (2003/2006) measured as shoreline length and area of potential shore zone effects

Type of Effect	Shoreline Length (km)	Percentage of Searched Shoreline	Area (ha)	Percentage of Affected Area
None	54.5	59.3	n/a	n/a
Structure and composition	20.2	22.0	42.8	40.8
Mortality, structure and composition	16.7	18.2	57.3	54.7
Ecosite, mortality, structure and composition	0.5	0.6	4.8	4.5
All	91.9	100	104.9	100

The distribution of inland edge effects among the different ecosite types during the 1986 to 2003/2006 period was very similar to that in the previous time period (Table 6-18 and Table 6-19). In the 26 to 50 m effect width class, which had the highest increase in proportion, most of the effects were associated with veneer bog on slope ecosite (65%), followed by deep dry mineral ecosite (Table 6-20). Riparian fen showed the largest increase in proportion of affected ecosites for this time period, however it should be noted that this increase generally represented continuing inland expansion and vegetation change on a peatland converted to riparian fen during the previous time period.

The percentage of shoreline with ecosite change during this period was the same as during the 1971 to 1986 period, with the remaining horizontal fen converting to riparian fen, and one area where a riparian fen increased in width (Table 6-21). All of the affected ecosite types exhibited vegetation structure and composition change going from low vegetation to tall shrub-dominated vegetation. Continuing tree mortality during the 1986–2003/2006 period was highest for the affected slope bog, horizontal peatland, and deep dry mineral, although for slope bog only about 100 meters of shoreline was affected. Continued tree mortality was lowest for riparian fen, occurring with only 19% of the affected shoreline.

Table 6-18: Potential shore zone effects as a percentage of shoreline ecosite type between ages 15 (1986) and 32/35 (2003/2006) in the searched Kettle proxy area**

Ecosite Type in 1986	No Effect	Potential Effect	*Total Length (km)*	Mean Effect Width (m)*
Deep dry mineral	69.0	31.0	*37.9*	26
Veneer bog on slope	53.4	46.6	*47.5*	27
Veneer bog	38.5	61.5	*1.2*	25
Blanket bog	45.4	54.6	*2.1*	33
Slope bog	90.6	9.4	*0.7*	18
Slope fen	100.0	-	*0.3*	-
Peat plateau bog	100.0	-	*0.2*	-
Peat plateau bog/ collapse scar mosaic	100.0	-	*0.1*	-
Flat bog	-	100.0	*0.2*	18
Horizontal fen	-	100.0	*0.3*	86
Riparian fen	19.7	80.3	*1.4*	47

Notes:* Mean effect width calculated using the mid-point value of width class for each segment in the category.
** "0" values are values that round to zero. Absence is represented by "-".

Table 6-19: Ecosite composition along searched Kettle shoreline with and without potential shore zone effects as a percentage* of total searched shoreline between ages 15 (1986) and 32/35 (2003/2006)

Ecosite Type in 1986	Effect Type on Searched Shoreline		
	No Effect	Potential Effect	All
Deep dry mineral	48.0	31.4	41.2
Veneer bog on slope	46.5	59.1	51.6
Veneer bog	0.8	2.0	1.3
Blanket bog	1.7	3.0	2.3
Slope bog	1.2	0.2	0.8
Slope fen	0.5	-	0.3
Peat plateau bog	0.4	-	0.2
Peat plateau bog/ collapse scar mosaic	0.2	-	0.1
Flat bog	-	0.5	0.2
Horizontal fen	-	0.8	0.3
Riparian fen	0.5	3.1	1.6
Total Length (km)	*54.5*	*37.4*	*91.9*

Notes:* "0" values are values that round to zero. Absence is represented by "-".

Table 6-20: Ecosite composition along searched Kettle shoreline with potential shore zone effects as a percentage* of total affected shoreline between ages 15 (1986) and 32/35 (2003/2006) by width class

Ecosite Type in 1986	Width of potential shore zone effects*				
	0 to 10 m	11 to 25 m	26 to 50 m	51 to 75 m	>75 m
Deep dry mineral	28.1	41.0	22.6	48.7	-
Veneer bog on slope	71.9	51.3	64.8	46.3	31.0
Veneer bog	-	3.2	1.9	-	-
Blanket bog	-	1.9	5.5	-	-
Slope bog	-	0.5	-	-	-
Flat bog	-	1.3	-	-	-
Horizontal fen	-	-	-	5.0	31.2
Riparian fen	-	0.9	5.2	-	37.8
Total length (km)	*5.1*	*14.0*	*15.6*	*2.2*	*0.6*

Notes:* "0" values are values that round to zero. Absence is represented by "-".

Table 6-21: Shore zone inland edge ecosite potential groundwater effects as a percentage* of affected shoreline along the searched shoreline between ages 15 (1986) and 32/35 (2003/2006)

	Searched Shoreline (km)		Percentage of Affected Shoreline by Effect Type			
Ecosite Type in 1986	Not Affected	Potentially Affected	Ecosite Change to Riparian Fen	Tree Mortality	Structure Change	Composition Change
Deep dry mineral	26.1	11.8	-	64	100	100
Veneer bog on slope	25.3	22.1	-	40	100	100
Veneer bog	0.5	0.7	-	40	100	100
Blanket bog	0.9	1.1	-	-	100	100
Slope bog	0.7	0.1	-	100	100	100
Slope fen	0.3	-	-	-	-	-
Peat plateau bog	0.2	-	-	-	-	-
Peat plateau bog/ collapse scar mosaic	0.1	-	-	-	-	-
Flat bog	-	0.2	-	-	100	100
Horizontal fen	-	0.3	100	100	100	100
Riparian fen	0.3	1.2	19**	19	100	100
All types	54.5	37.4	1	46	100	100

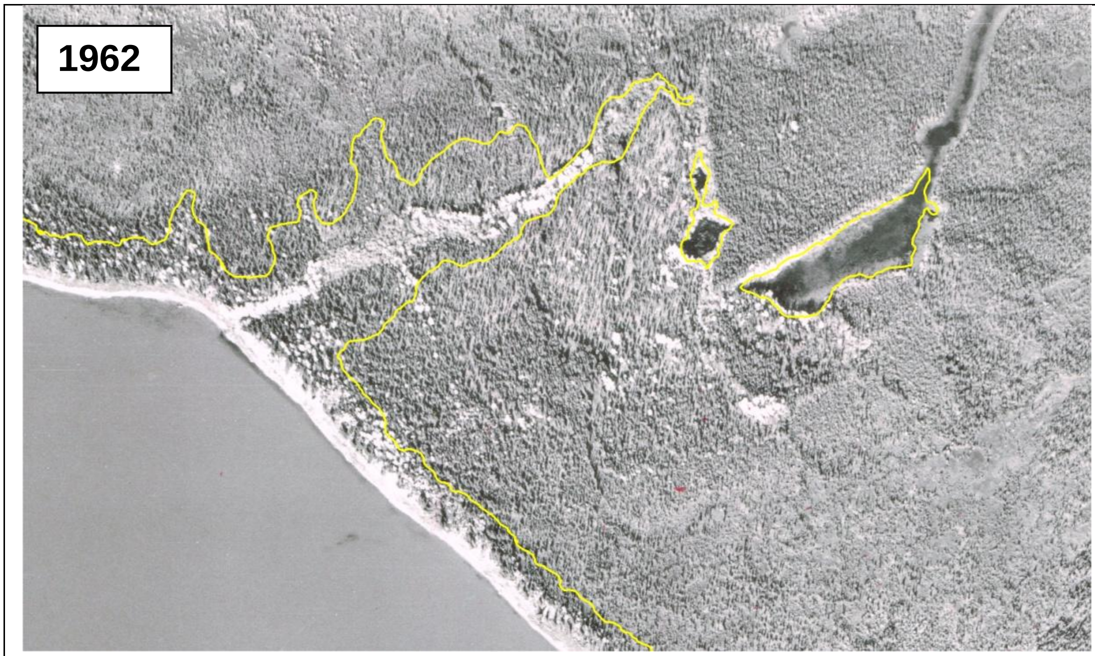
Notes:* “0” values are values that round to zero. Absence is represented by “-“. ** Inland expansion of riparian fen

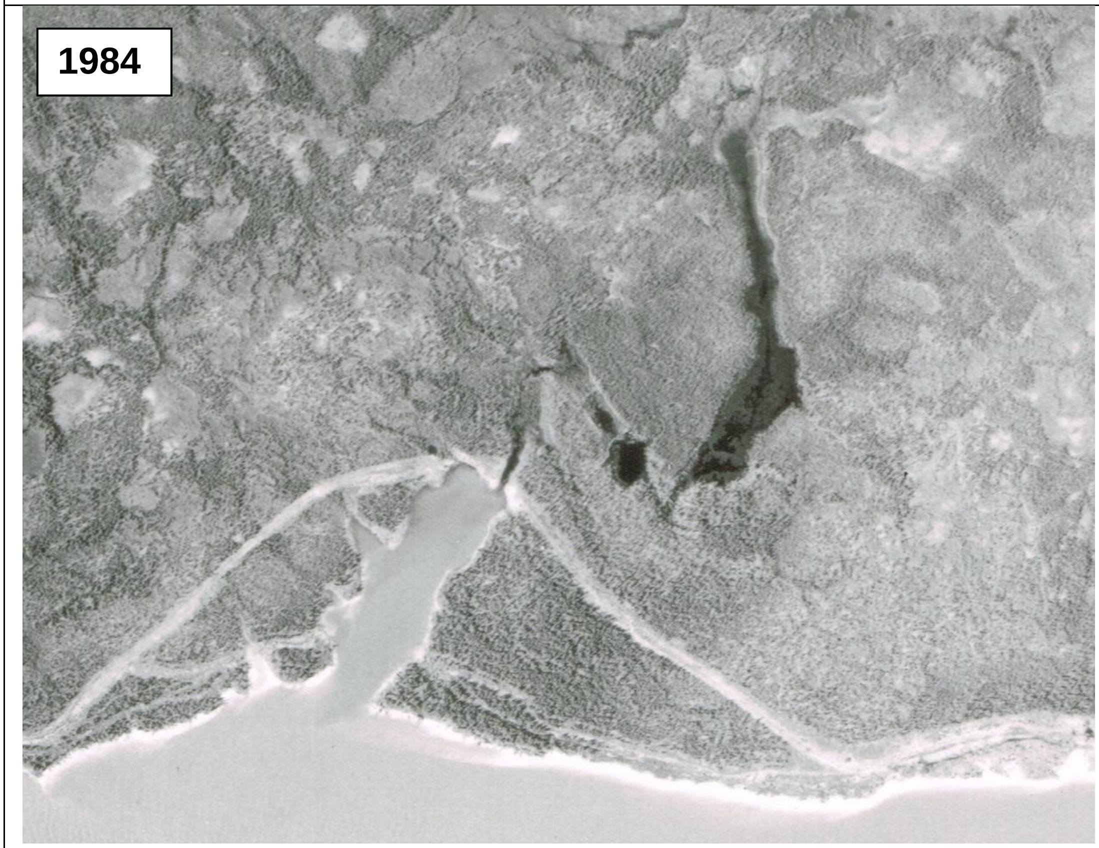
6.3.3 Long Spruce Proxy Area

Dykes formed most of the shoreline in the eastern portion of the Long Spruce proxy area. Larger peatland areas remained where the reservoir widened near the western ends of the dykes. Within these widened areas, ongoing peatland disintegration was occurring along most of the shoreline up to the 2003/2006 photography period. While the loss of peat plateau bog was a reservoir effect, there were no observed vegetation changes on the inland edge peat plateau bog, likely because the rooting zone was elevated well above the reservoir water level.

A review of the historical photography for the Long Spruce proxy area shore zone indicated that this proxy area was more similar to Kelsey than to Kettle with respect to physical conditions along the shorelines. As with Kelsey, the Long Spruce proxy area had higher relief along the shorelines, particularly the western half. In that portion, bank recession due to mineral bank erosion was the dominant shore zone effect, with no apparent groundwater effects in the inland edge.

Only two localized areas of potential inland edge habitat effects from reservoir-related groundwater changes were identified in the Long Spruce proxy area, totaling less than 1% of the total shoreline length. Both of these locations were areas where runnels were flooded, resulting in a surface groundwater hydrological connection between the reservoir and inland wet peatlands. The increased groundwater resulted in tree mortality and ecosite change along approximately 300 meters of shoreline in those locations. Figure 6-3 illustrates the location with the most extensive effects.


1962


1984

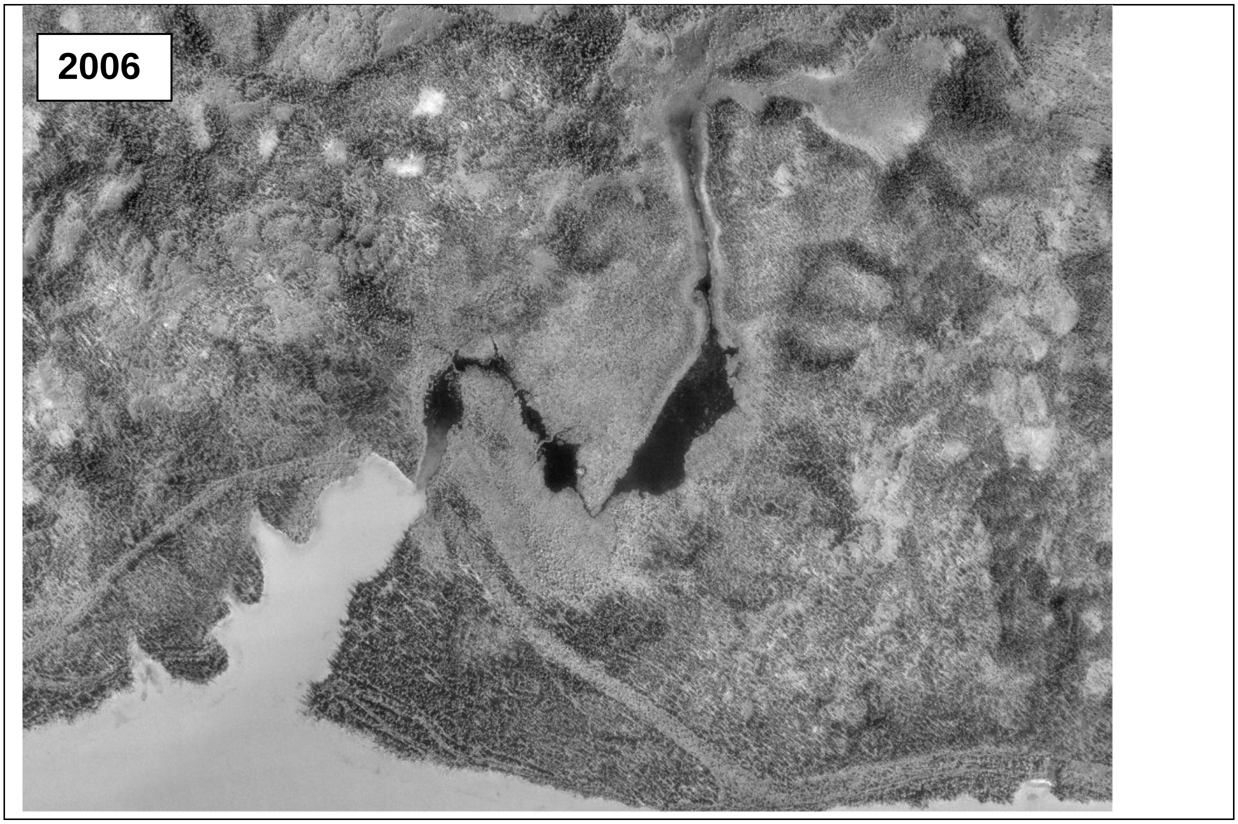


Figure 6-3: Example of shore zone vegetation change in the Long Spruce proxy area resulting from a hydrological connection between the reservoir and an inland wet peatland.

Note: Yellow polyline in 1962 photo represents the 2006 shoreline position.

6.4 DISCUSSION

The Kelsey, Kettle and Long Spruce proxy areas represented a range of conditions for terrain, shoreline ecosite composition and reservoir water dynamics. Much of the Long Spruce reservoir was a riverine environment while the Kettle reservoir was predominantly a lacustrine and terrestrial environment, and Kelsey was a mixture of riverine and lacustrine environments. Relief adjacent to the initial post-flooding shoreline was generally somewhat higher in the Kelsey and Long Spruce proxy areas compared with Kettle. This difference likely at least partially accounted for a much lower proportion of the Kelsey shoreline area exhibiting shore zone effects compared with Kettle (3% versus 41%; Table 6-3 and Table 6-17) during the first 30 years after flooding, as well as similar qualitative comparisons with Long Spruce. A large portion of this difference was attributed to physical limitations on how high groundwater can be elevated above the reservoir water level.

Part of the difference in proxy area affected shoreline proportions may also have been related to the higher quality of historical photography for Kettle proxy area compared with Kelsey, and to the fact that most of the available shoreline for analysis in Kelsey burned during the effects period. However, the effect on the overall proportion of mapped shoreline effects was expected to be low because the difference in photo quality was not highly limiting and because the same photo series were available for Kettle and Long Spruce.

Qualitative observations of changes in the Long Spruce proxy area reinforced the importance of local relief and a riverine versus lacustrine environment in determining the extent and nature of shore zone effects over time.

Due to the riverine component and higher relief of the Kelsey proxy area, approximately half of the observed shore zone effects were due to ice scour, whereas this was absent in the searched shoreline in Kettle. Ice scour affected Kelsey reservoir shoreline along the main river channel, where there was a high proportion of mineral shoreline. Ice scour was not observed in the Long Spruce reservoir.

The proportion of mineral ecosite along the potentially affected shoreline was higher in Kelsey than in Kettle, despite comprising similar proportions of searched shoreline in both areas. However, when ignoring ice scour effects in Kelsey and comparing groundwater effects only to those in Kettle, veneer bog on slope comprised the highest proportion of potentially affected shoreline in both proxy areas. No groundwater effects were detected along mineral ecosite in Kelsey, at least partially due to the prevalence of higher shoreline relief creating physical limitations on the extent of groundwater effects.

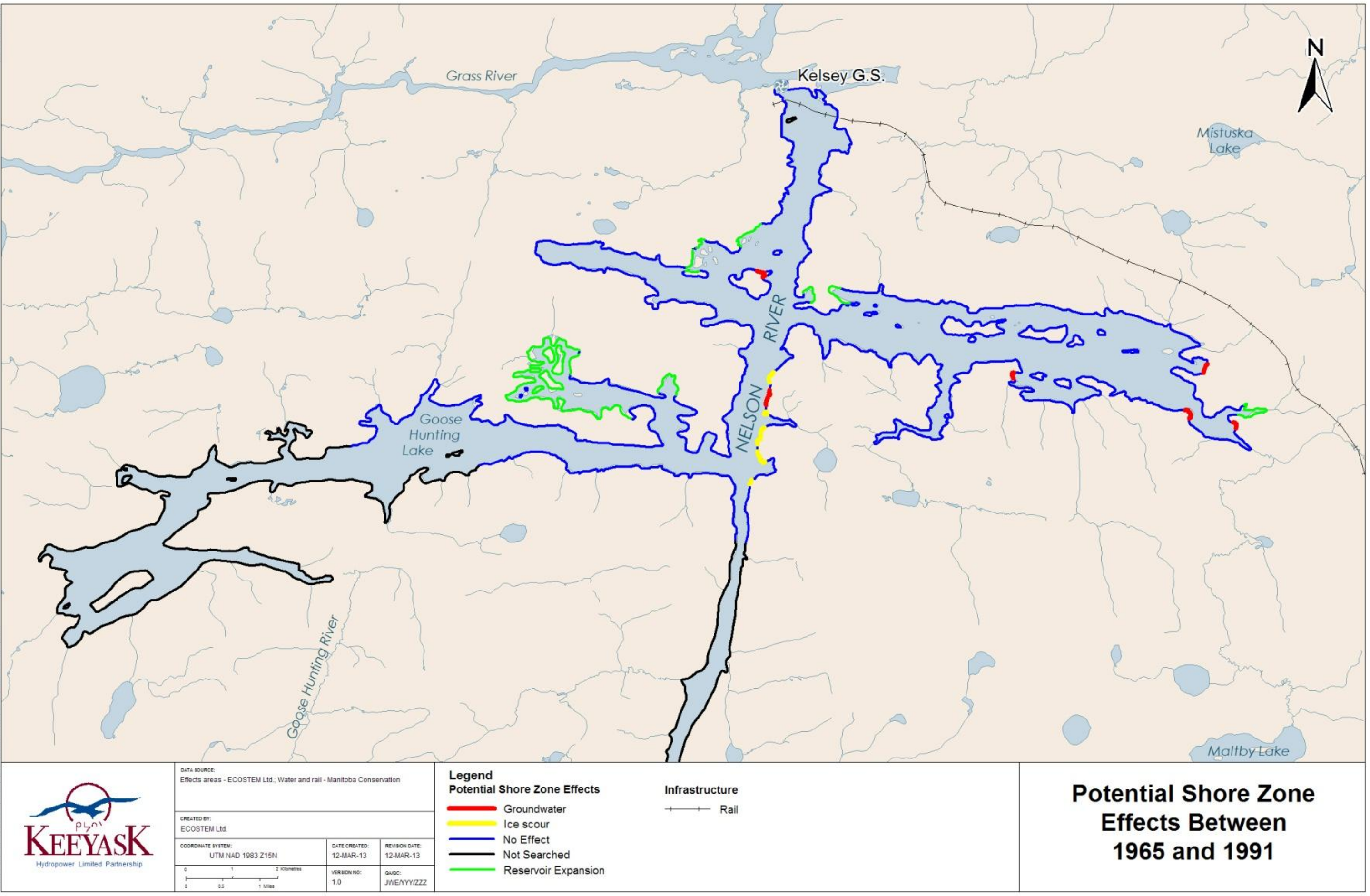
With respect to width of effects, potential shore zone effects in both proxy areas usually extended less than 25 meters inland and the vast majority less than 50 meters . In Kelsey, the widest shore zone effects tended to be associated with deep wet peatlands while the narrower width classes were associated with mineral and thin to shallow peatlands, Kettle differed in that most of the shoreline with effects greater than 50 meters were associated with mineral and veneer bog on slope (although, where deep wet peatlands were affected, the effects tended to be wide). In Kettle, low relief and position along the shorelines of smaller islands appeared to be associated with these wide effects. This suggests that shoreline relief may be one of the most important factors determining the width of shore zone effects in the years following flooding.

Based on the results from the Kettle proxy area, which was most similar to the Keeyask area and had the best air photo time series, the pathway of vegetation change in the shore zone over 30 years was predominantly tree mortality, followed by vegetation structure change, followed by vegetation composition change. Almost all of the shore zone effects during the 1986 to 2003/2006 time period occurred along shoreline that was already affected by 1986 (Map 6-5). By 1986, tree mortality and the associated vegetation structure change were the dominant shore zone effect, and by 2003/2006, the dominant subsequent shore zone effect along these shorelines was vegetation composition and further structure change as a tall shrub band developed in the shore zone (Figure 6-2). Further tree mortality occurred during the 1986–2003/2006 period, but most of the mortality had already occurred prior to 1986.

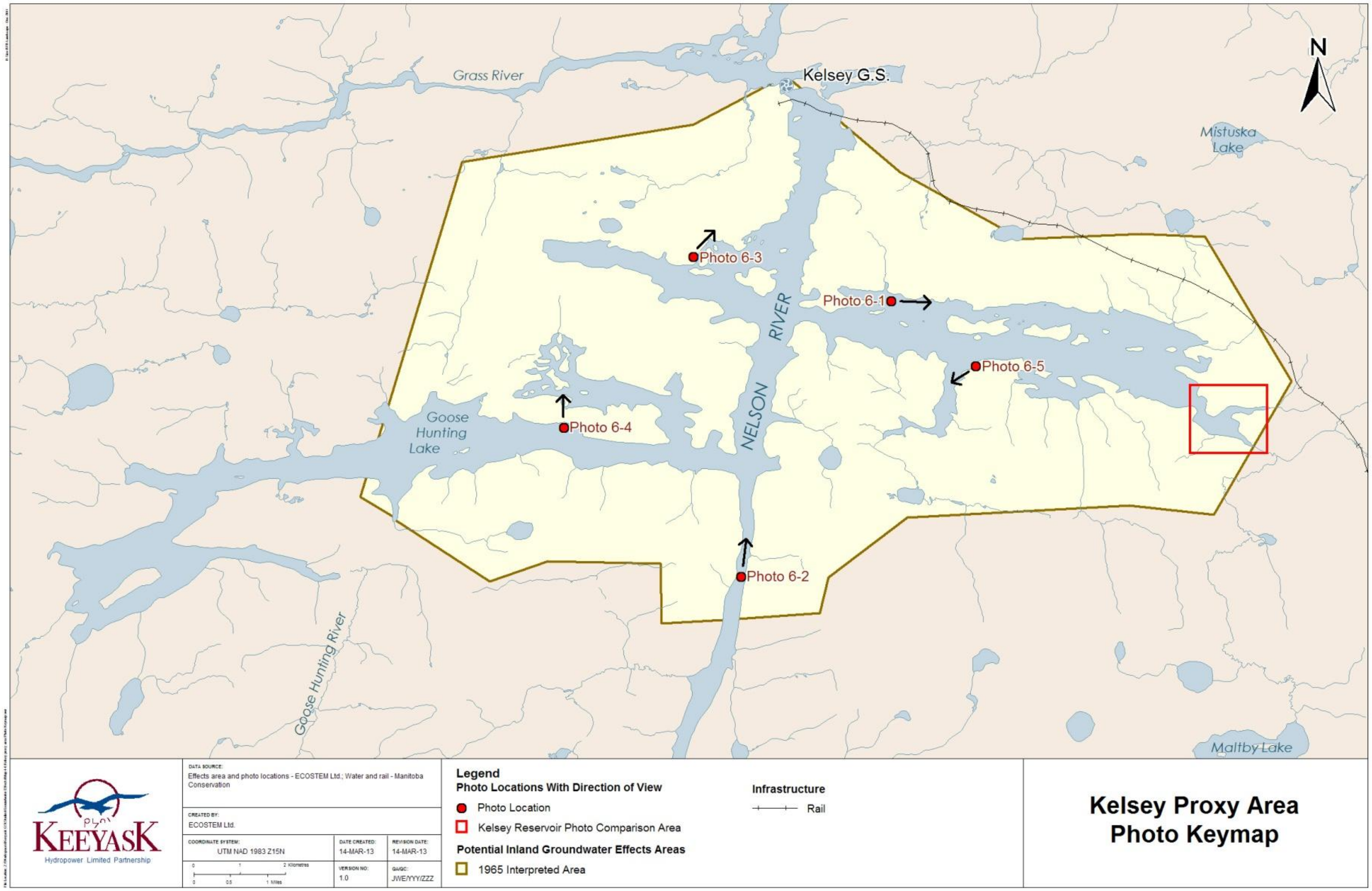
The pathways and stages of change were different for peat plateau bog shoreline segments. In general, there were no vegetation changes because the surface of peat plateau bog was elevated well above the reservoir water level. This conclusion was supported by evidence from other studies that found that ground ice changes typically extended less than 1 m inland from the peat plateau bog bank edge (ECOSTEM 2012a).

Shore zone studies from the Wuskwatim proxy area (ECOSTEM Ltd. and Calyx Consulting 2003) found that tree mortality due to groundwater changes was most frequent along shoreline characterized by organic and medium to low sloping clays. These are similar conditions to where shore zone effects were identified in the Kettle and Kelsey areas.

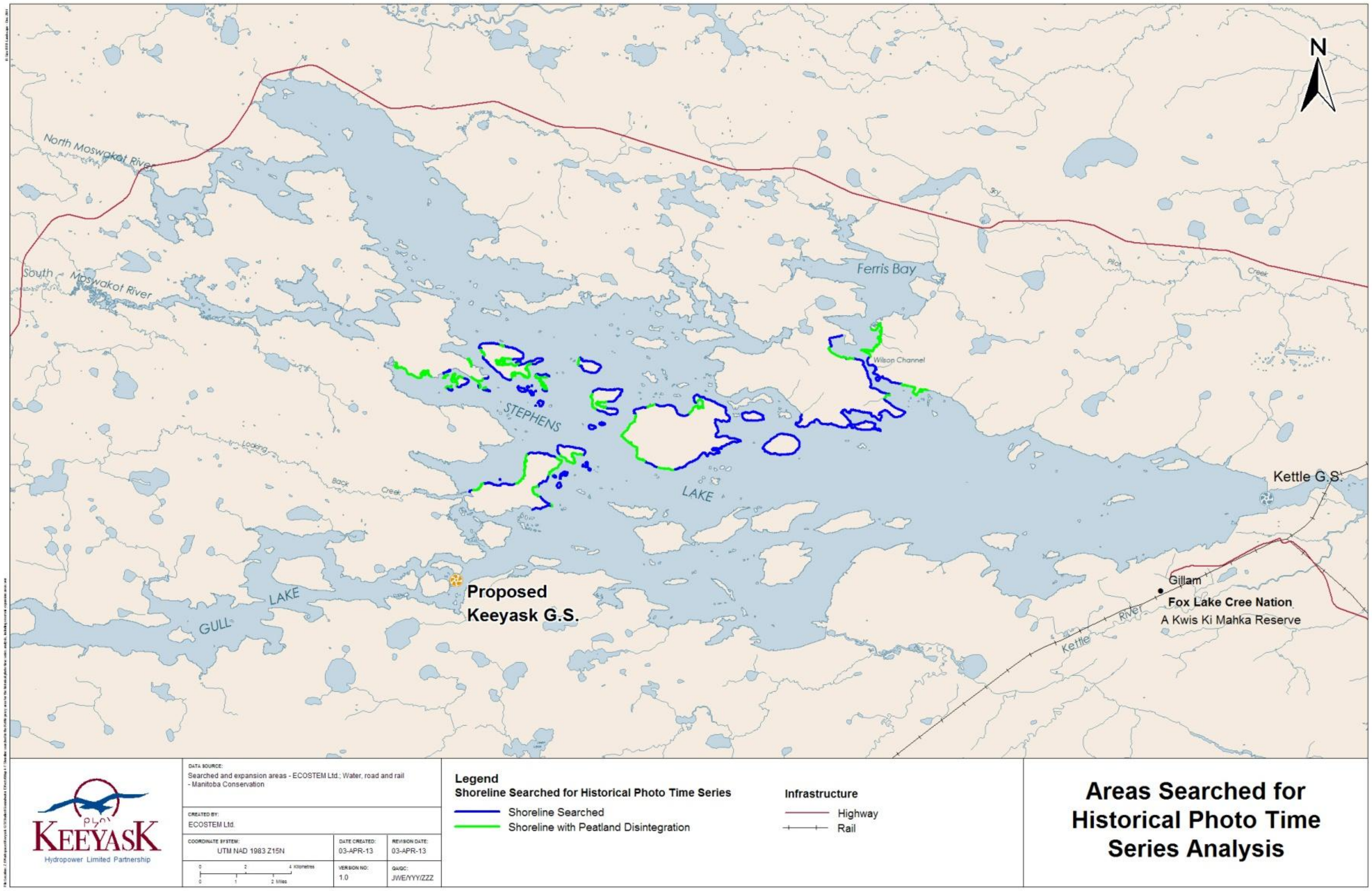
6.5 MAPS



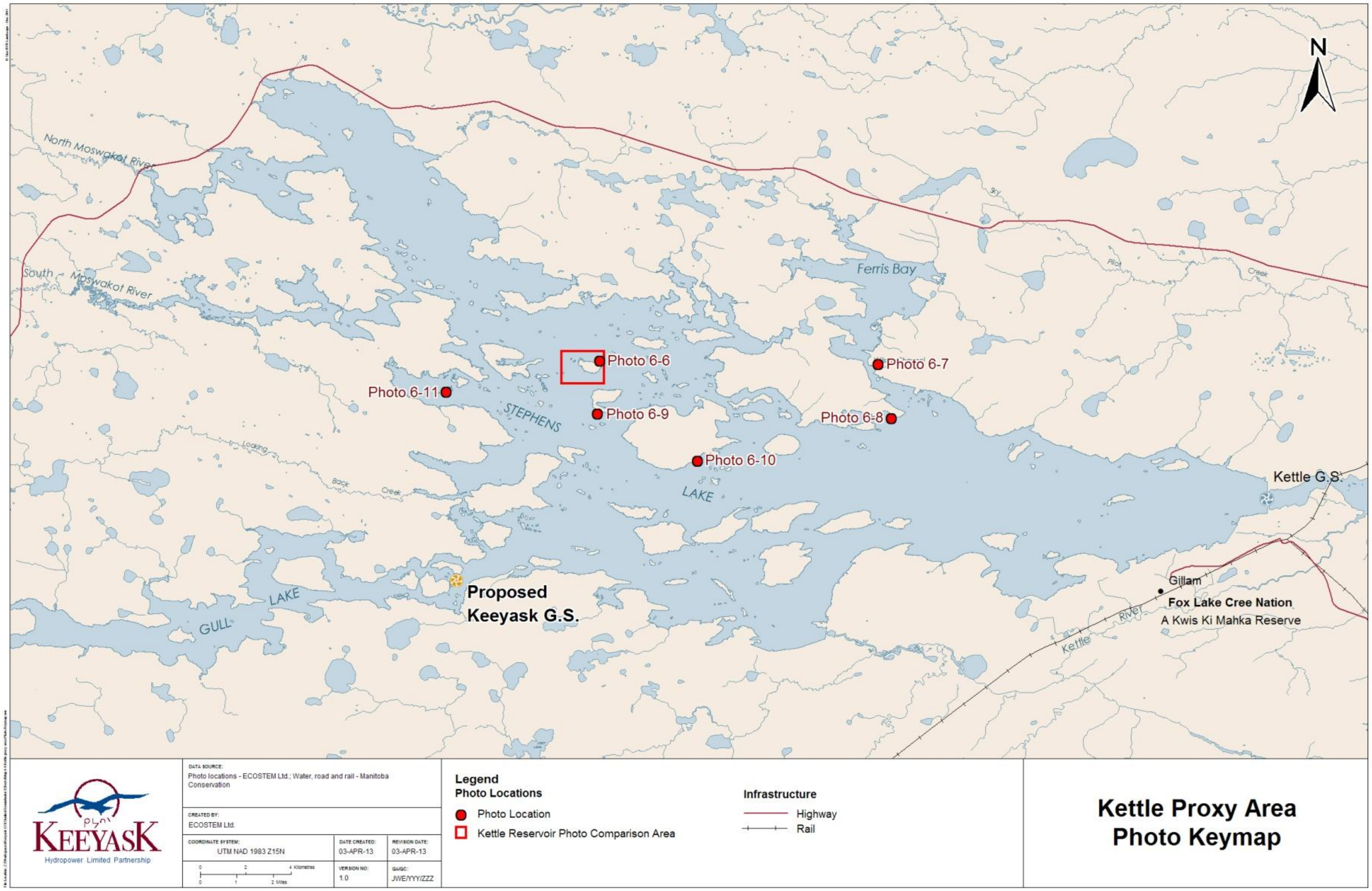
Map 6-1: **Potential shore zone effects along the Kelsey proxy area shoreline between 1965 and 1991**



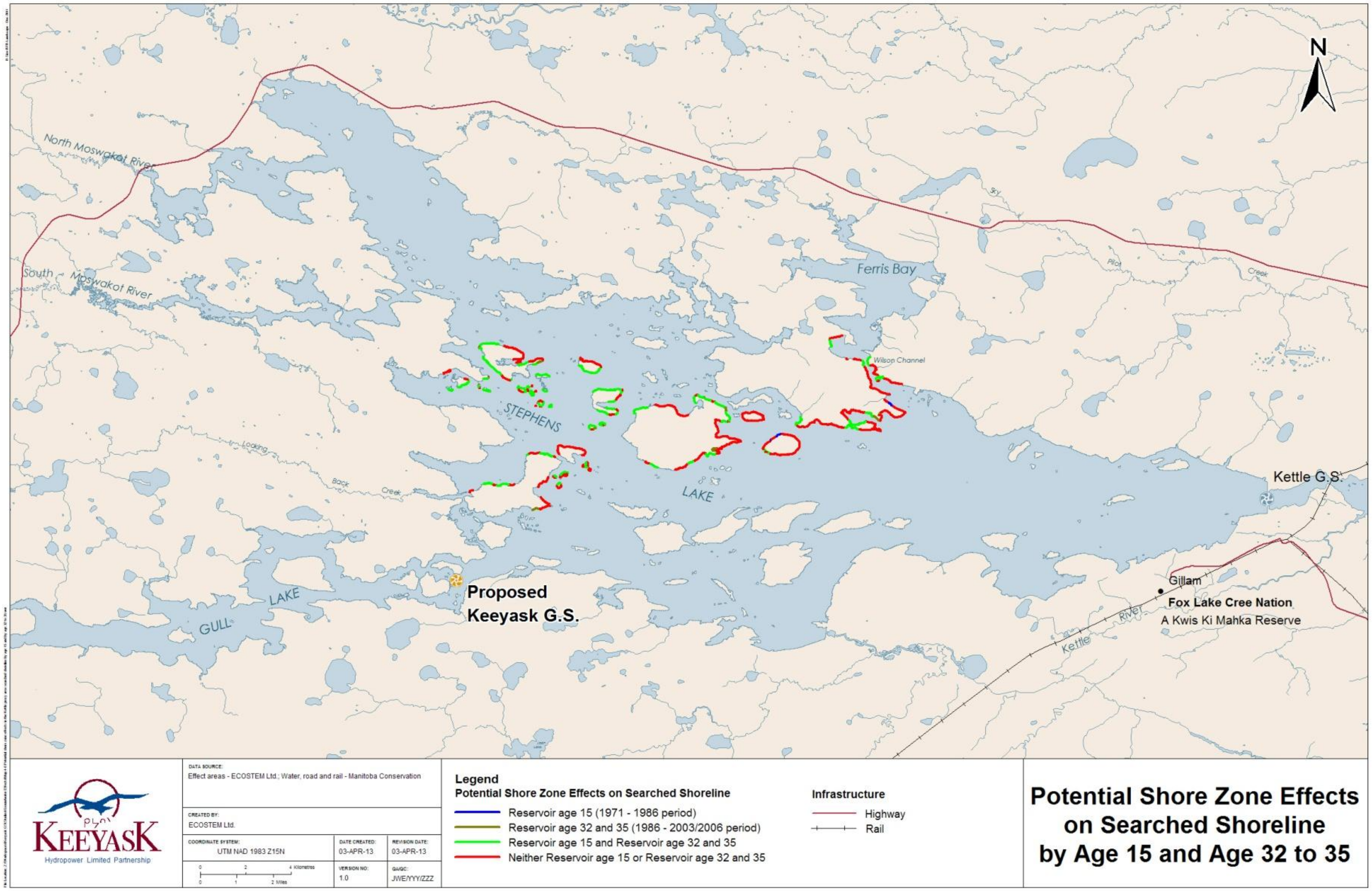
Map 6-2: **Key map for photo figure locations in the Kelsey proxy area**



Map 6-3: **Shoreline searched in the Kettle proxy area for the historical photo time series analysis, including areas not searched due to peatland disintegration**



Map 6-4: **Key map for photo figure locations in the Kettle proxy area**



Map 6-5: **Potential shore zone effects in the Kettle proxy area searched shoreline by age 15 and by age 32 to 35**

7 EXTENT AND NATURE OF INLAND EDGE EFFECTS USING RECENT AIR PHOTOS

7.1 STUDY DESIGN AND DATA COLLECTION

The second approach to documenting the nature and extent of flooding and/or water regulation effects on shore zone habitat used a combination of recent air photos, aerial surveys and ground surveys at the Kettle reservoir. Low altitude photos of the inland side (inland edge and inland zones in Figure 1-5) of the reservoir shoreline were the primary data source for this study. This approach documented substantial changes in potential indicators for long-term shore zone effects, which extended the results from the Section 5 study inland (see Zone "B" in Figure 3-1) because more detail is discernible in low altitude still photos than in the stereo photos. The extent and nature of these changes were then related to potential influential factors. These data were also used to verify the photo-interpreted effects from the time series analysis of shore zone effects in Section 5.

The low altitude photos of the inland side of the reservoir shoreline were taken from a helicopter on September 8, 2011 (see Figure 7-1B). The helicopter altitude was adjusted so that at least 50 m of terrestrial habitat on the land side of the shoreline was usually captured in the photo. Helicopter speed was set to create overlap in successive photos, but wind conditions and other factors precluded overlap between some successive photos. Shore segments that had burned or were cleared since initial flooding were not photographed. As the helicopter flew along the shoreline, a person sitting in the rear seat photographed the inland band. A second person in the front seat was visually searching for clusters of dead trees occurring more than 25 m inland and, at such locations, notes were taken and waypoints were recorded with a handheld GPS unit. The low altitude, oblique, inland facing photos were the primary data source used to identify potential inland effects for most of the islands in the Kettle reservoir.

Kettle was included as a proxy area because the primary purpose of this study was to verify methods and results from the historical air photo time series analysis. Kelsey was used to a very limited extent because large portions of the reservoir shoreline had burned since flooding, so that only a small proportion of shoreline mapped in Section 5 was available for analysis in 2011. Preliminary aerial surveys of the available shoreline did not detect any potential shore zone effects in Kelsey.

7.2 ANALYSIS

In the office, the helicopter-based inland edge photography acquired on September 8, 2011 was examined for potential groundwater effects using essentially the same method as the historical air photo time series study (Section 6.3). The photos were examined for effects that extended more than 10 m inland from the shoreline. For some shore segments, the 2011 shoreline position was virtually the same as that mapped in Section 5. In other segments where erosion had shifted the 2003/2006 shoreline position or where high water levels inundated the inland edge in 2011, hiding the shoreline, the digitized shore position from Section 5 was used as the reference location for estimating the width of flooding and/or water regulation effects.

For segments of shoreline where tree and/or tall shrub mortality extended beyond 50 m inland, low altitude, oblique inland facing photos taken from over the water on August 2, 2011 (e.g., photo A in Figure 7-1) were used to determine width if possible.

The shoreline was subdivided into segments subject to a minimum length of 50 meters. A new segment was created where there was a change in the:

- Presence or absence of tree mortality due to potential inland groundwater effects;
- Percentage of trees that were dead;
- Width of tree mortality band; or,
- Inland edge ecosite type.

Ecosite type at the inland edge was interpreted from stereo and helicopter photography to identify situations where the inland edge ecosite differed from the ecosite type from habitat mapping. These situations occurred where the ecosite patch along the shoreline was too small to meet the minimum mappable polygon size according to the ecosite mapping methods (ECOSTEM 2012b).

For the GIS representation of the data, fields were added to the shoreline dataset created by the air photo time series analysis study (Section 5). Table 7-1 describes the fields added to the shoreline dataset for this study.

After mapping was completed, the mid-point values of the potential effect width classes were added to the upper limit value of the effect width classes from the historical air photo time series mapping completed for Section 5. This provided a combined overall width of potential shore zone effects starting from the initial flooding shoreline location. The upper limit from the historical air photo analysis was used to provide a precautionary upper-limit range of potential effects.

Table 7-1: Fields added to the shoreline dataset for the shore zone effects using recent air photos study

Field	Description	Classes[1]
Potential Inland Effect	Presence of inland edge mortality potentially due to groundwater changes	Yes (Y); No (N); Not Applicable (NA)
Tree Mortality Width	Width of shoreline tree mortality measured as perpendicular distance from shoreline	<=10 m; 11-25 m; 26-50 m; 51-75 m; >75 m
Tree Mortality Percent	Percentage of trees within the tree mortality zone that are dead	Low: <10% Moderate: 10 – 50% High: >50%
Tree Mortality Gap	Identifies if there is a gap >10 m between the inland edge and the start of tree mortality	1 = Yes 0 = No
Blowdown	One or more patches of tree blow-down are present	Yes; no
Effect Width	Width of all shoreline effects measured as perpendicular distance from shoreline	Width in m
Ecosite Fine	Inland fine ecosite type from habitat mapping	Ecosite type
Edge Ecosite	Inland edge ecosite type. Only entered if different than fine ecosite type from habitat mapping	Ecosite type
Edge Mortality	Tree mortality from potential ground effects occurs on edge ecosite that is different from the ecosite type from habitat mapping	Yes (Y)

Notes:[1] A value of -99 in a field indicates that the segment was not included this study.

7.3 RESULTS

7.3.1 Kelsey Proxy Area

Aerial surveys and available helicopter photography were able to verify potential groundwater effects within the unburned portions of the shoreline identified in Section 5, but did not identify any further inland edge effects in the Kelsey proxy area. As discussed in Section 5, the riverine environment and higher local relief was thought to have limited the groundwater effects along much of the shoreline.

7.3.2 Kettle Proxy Area

Over 80 km (87%) of the shoreline that was searched for historical inland edge effects in the Kettle proxy area (Section 5) was also searched for inland edge effects using low altitude helicopter photography (Table 7-2).

All of the shoreline segments identified as having effects in Section 5 also had observed effects in this study. The total length of shoreline with potential inland edge effects identified by this study was the same as was mapped in Section 5. With regard to the nature of effects, this study identified some individual tree mortality that was not visible in the stereo photos (see Zone “B” in Figure 3-1). This consisted of scattered tree and/or tall shrub mortality. The trees usually had small crowns. Mortality was limited to a single tree species, such as jack pine (*Pinus banksiana*), in some locations. The scattered distribution and apparent age of the trees at these locations suggested the mortality was more likely due to natural causes rather than reservoir-related groundwater or edge effects.

Results in the remainder of this section focus on effects in addition to those captured in Section 5 because the shore segments with effects, and the predominant nature of those effects, were accurately mapped in Section 5.

Tree and/or tall shrub mortality, potentially due to groundwater effects extending inland from the shoreline, were identified for approximately 6% (10.0 km) of the searched shoreline (Table 7-2). An additional 16% of the shoreline was identified with potential but unlikely groundwater effects, because the vegetation mortality occurred far upslope of the potential influence of higher groundwater, or on raised mineral ecosites. In those areas, tree mortality may have been due to other factors such as disease or senescence. This effectively increased the potential width of shore zone effects for nearly 5% of the shoreline searched in the time series analysis. All of these inland extensions were in locations already documented in Section 5.

Table 7-2: Potential, and potential but unlikely shore zone groundwater effects as a percentage of the 151 km of shoreline searched in the historical time-series analysis for the Kettle proxy area, and percentage of the 121 km of shoreline searched using recent helicopter photos

Potential Recent Groundwater Effects	Length (km)	Percentage of time series shoreline	Percentage of searched shoreline with helicopter photos
Likely	4.9	5.3	6.1
Unlikely	12.8	13.9	15.9
None	62.8	68.0	78.0
Not searched*	11.8	12.8	n/a
Total searched shoreline for time series analysis	92.3	100.0	-
Total searched shoreline for recent helicopter photos	80.5	-	100.0

Notes:* Portions of the shoreline from the historical time series analysis were not searched because of inadequate helicopter photo coverage, or because some small islands had no remaining inland vegetation and were skipped.

Of the 80.5 km of searched shoreline, the width of additional potential effects ranged from 0 m to 50 m inland from the historical time series mapping (Table 7-3). Most of the additional effects extended more than 25 m inland, with 11 to 25 m and 26 to 50 m being the most common width classes at 6% of the searched shoreline combined.

In approximately 11.4 km of shoreline segments, apparent mortality often appeared to extend beyond 125 meters inland but actual width could not be determined due to truncated photo coverage and the tree mortality was too scattered and/or recent to detect in stereo-photos. This mortality usually consisted of scattered, older, dead jack pine trees that presumably died from natural causes rather than shore zone effects because they were located upslope on mineral or thin peatland ecosites, on islands that have not burned for a long period of time. If mortality had been from elevated groundwater then it was expected that aspen and black spruce mortality should have been present too.

The total estimated area for the additional potential effects detected in the recent helicopter-based photos was 15 ha (Table 7-3).

Table 7-3: Potential shore zone groundwater effect width class from recent photography analysis in the Kettle proxy area as a percentage of searched shoreline

Width Class	Length (km)	Percentage of Searched Length	Area (ha)	Percentage of Potentially Affected Area
0 m	75.6	94	n/a	n/a
1 to 10 m	0.3	0	0.1	1
11 to 25 m	1.3	2	2.2	15
26 to 50 m	3.4	4	12.6	84
All	80.5	100	15.0	100

Notes:* Class midpoint width average over total shoreline length. Midpoint value for >75m class is 100m.

After combining the potential groundwater effects determined from the recent air photo analysis with the upper-limit of existing inland edge effects from the time series analysis, the overall proportion of the lower width classes decreased slightly, while the upper width classes increased (Table 7-4). Of the shoreline segments that had potential effects in the time series analysis (Section 6.3), additional effects mostly occurred in the less than 25 m width classes, with a fairly even distribution among the other <75 m width classes (Table 7-4). No further effects width increases were identified for the >75 m width class from the time series analysis. Additional effects were all fairly recent, with a combination of widespread mortality in a band along the shoreline, and some more scattered mortality along the shoreline and at the base of sloping topography close to the shoreline.

Overall, after effects from both studies were combined, most of the potential effect widths remained under 50 meters, but there was a small decrease in the proportion of width classes up to 25 meters, and an increase in all width classes greater than 25 meters. Using the mid-point of the width class, the overall average width of inland edge effects was 31 meters for the affected shoreline, or 17 meters when averaged over the entire searched shoreline. Using the upper-limit of the width class to produce a precautionary estimate, the overall average width of inland edge effects was 40 meters for the affected shoreline, or 24 meters when averaged over the entire searched shoreline. Some of these averages may include areas of natural tree mortality, particularly in areas of scattered tree mortality near the base of sloping topography.

Table 7-4: Combined width of potential shore zone groundwater effects from historical time series and recent helicopter-based photos

Width Class	Potential effects from time series analysis		Combined potential effects from recent photo and time series analysis	
	Length from time series analysis in km and (%)	Percent of width class with further effects*	Overall effects using time series mid-point width and (%)	Overall effects using time series upper-limit width and (%)
0-10m	49.8 (62)	5.1	47.2 (59)	47.2 (59)
11-25m	14.0 (17)	11.4	13.1 (16)	12.4 (15)
26-50m	14.6 (18)	4.8	16.3 (20)	17.1 (21)
51-75m	1.6 (2)	6.1	3.1 (4)	2.8 (3)
>75m	0.6 (1)	0.0	0.7 (1)	1.0 (1)
All	80.5 (100)	6.1	80.5 (100)	80.5 (100)

Notes:* Percentage of shoreline length in width class from historical time series analysis that had additional potential effects.
** Combined width of effects using upper limit of historical time series width classes.

The overall combined area of potential inland edge groundwater effects was 112 ha. The overall combined area of potential inland edge groundwater effect would increase to nearly 190 ha if a very precautionary upper-limit area value is used for the affected area from the time series analysis.

Most of the likely potential inland edge effects from the recent air photo analysis were associated with deep dry mineral or veneer bog on slope ecosites, which comprised 92% of the affected shoreline combined (Table 7-5). Despite making up 42% of the searched shoreline, deep mineral was associated with most (76%) of the shoreline where potential groundwater effects were identified in the recent air photo analysis.

Potential inland edge groundwater effects extending inland were most common along the shorelines of the islands in the west-central part of the reservoir (Map 7-1). Effects also extended furthest inland in those areas. Some of the smaller islands had lower relief than shoreline on the mainland, and shore zone effects detected in the time-series analysis were similarly wide.

Tree and/or tall shrub mortality was the only potential inland edge groundwater effect identified along the shoreline in the Kettle proxy area. Figure 7-1 provides examples of tree mortality potentially due to groundwater effects. The tree mortality visible in these photos was too recent and scattered to detect in the stereo-photography used for the time series analysis. Most of the dead trees in these photos remain standing and most of their canopy branches remain intact.

Table 7-5: Shoreline ecosite type associations with potential shore zone groundwater effects as a percentage of total effect length

Ecosite Type	Likely groundwater effect from recent air photo analysis (%)		Overall potential groundwater effect (%)[1]		All (%)
	No Effect	Potential Effect	No Effect	Potential Effect	
Deep dry mineral	39.5	76.3	47.2	35.3	41.7
Veneer bog on slope	52.5	15.7	46.6	54.5	50.2
Veneer bog	1.6	-	1.1	2.0	1.5
Blanket bog	2.0	5.5	1.6	3.1	2.3
Slope bog	1.0	-	1.5	0.2	0.9
Slope fen	0.4	-	0.7	-	0.4
Peat plateau bog	0.3	-	0.5	-	0.3
Peat plateau bog/ collapse scar peatland mosaic	0.1	-	0.3	-	0.1
Flat bog	0.2	-	-	0.5	0.2
Horizontal fen	0.2	-	-	0.5	0.2
Riparian fen	2.2	2.5	0.7	4.0	2.2
Total shoreline (km)	*75.6*	*4.9*	*43.5*	*37.0*	*80.5*

[1] Recent air photo analysis effects combined with historic time series analysis effects from Section 5.

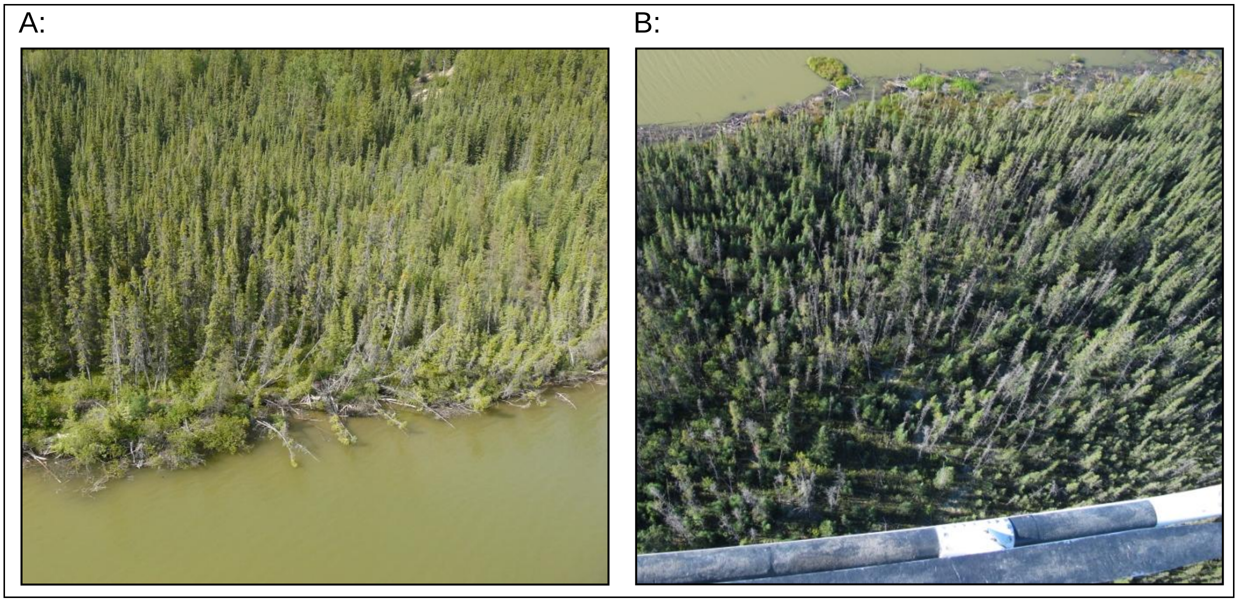


Figure 7-1: Examples of tree mortality potentially due to groundwater effects. A: Peatland at the base of a mineral slope. B: Overhead view of mortality on a thin peatland inland of recently disintegrated peatlands

7.3.3 Long Spruce Proxy Area

Helicopter photography qualitatively verified ongoing mineral bank erosion and peatland disintegration as the dominant processes driving shoreline change in the Long Spruce proxy area. No further shore zone effects in the inland edge were detected. As discussed in Section 5, the Long Spruce proxy area was more similar to the Kelsey proxy area than to Kettle.

7.4 DISCUSSION

The recent air photo analysis confirmed results from the historical time series analysis (Section 5). Both approaches recorded the same percentage of shoreline affected.

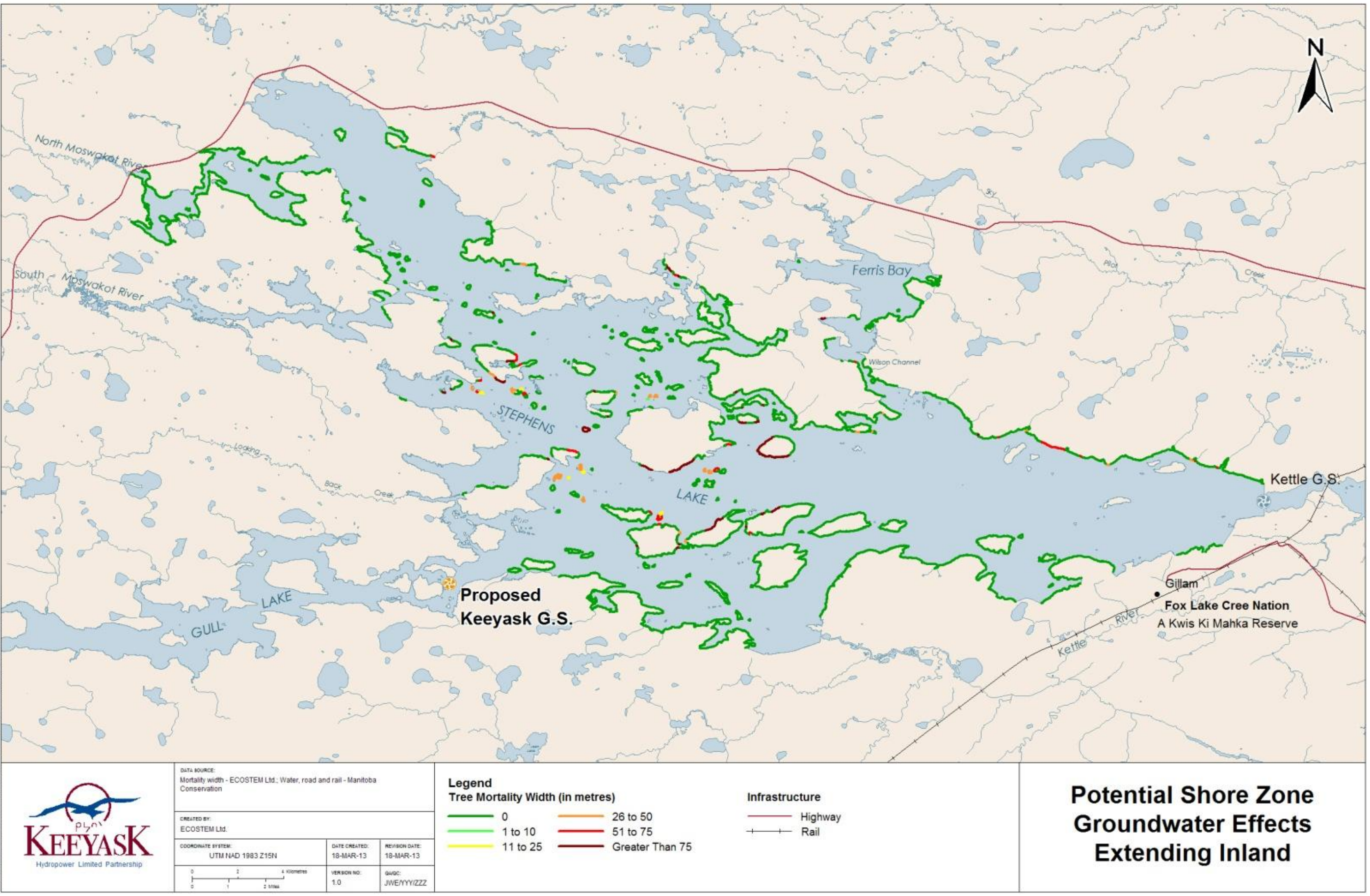
The recent air photo analysis also confirmed that the historical stereo air photos did not overestimate width of edge effects. Recent air photo analysis expanded the width of potential groundwater effects beyond the detection limits of the historical time series analysis in some locations. The proportion of shoreline with additional effects was small compared with the length identified in Section 5. Using the helicopter-based photos to detect more subtle effects increased the overall average width of effects over the searched shoreline from approximately 14 meters to 17 meters wide.

The advantage of the recent air photos was the ability to detect smaller scale changes than could be detected by stereo photos acquired at a scale smaller than 1:12,000. These changes included scattered individual tree mortality and a single tree mortality band along the shoreline.

Some of the scattered individual tree mortality observed in the recent photos was attributed to natural causes rather than reservoir-related effects. Specifically, scattered jack pine tree mortality on mineral or thin peatland sites that were elevated more than two meters above the reservoir water level and where the mortality was mixed with living trees from other species. Jack pine is an early successional species, which often begins to senesce after about 80 years of age (Burns and Honkala 1990). Most of scattered jack pine mortality occurred on larger islands within the reservoir, where fires were likely to be less frequent, allowing stands to reach greater ages than average for the Regional Study Area. Based on historic fire mapping, most of the islands in the Kettle reservoir have not burned in the past 80 years (see ECOSTEM Ltd. 2012b).

Most of the additional effects recorded from recent air photos were associated with mineral ecosites rather than veneer bog on slope. These were typically single tree bands along the shoreline that were too narrow to be detectable in the stereo photos. The remaining recorded effects usually were the inland areas where the thinning out of widespread tree mortality had transitioned to widely scattered individual trees.

7.5 MAPS



Map 7-1: Potential shore zone groundwater effects extending inland of the inland edge by width class in the Kettle proxy area

8 SHORT-TERM RESPONSES OF SHORE ZONE TREES TO FLOODING

8.1 STUDY DESIGN AND DATA COLLECTION

This study documented short term responses of trees to elevated water levels using the Kettle proxy area (Section 2.2) and the existing Gull reach as of 2011. Growing season water levels and flows were generally high to extremely high on the Gull reach of the Nelson River for most of the 2005 to 2010 period (Figure 8-1). These water level conditions provided an opportunity to document how quickly trees respond to higher water levels and relate these responses to environmental factors such as topography and ecosite. Conditions were similar at Kettle with the exception that the increases relative to historical levels were not as pronounced (Figure 7-1).

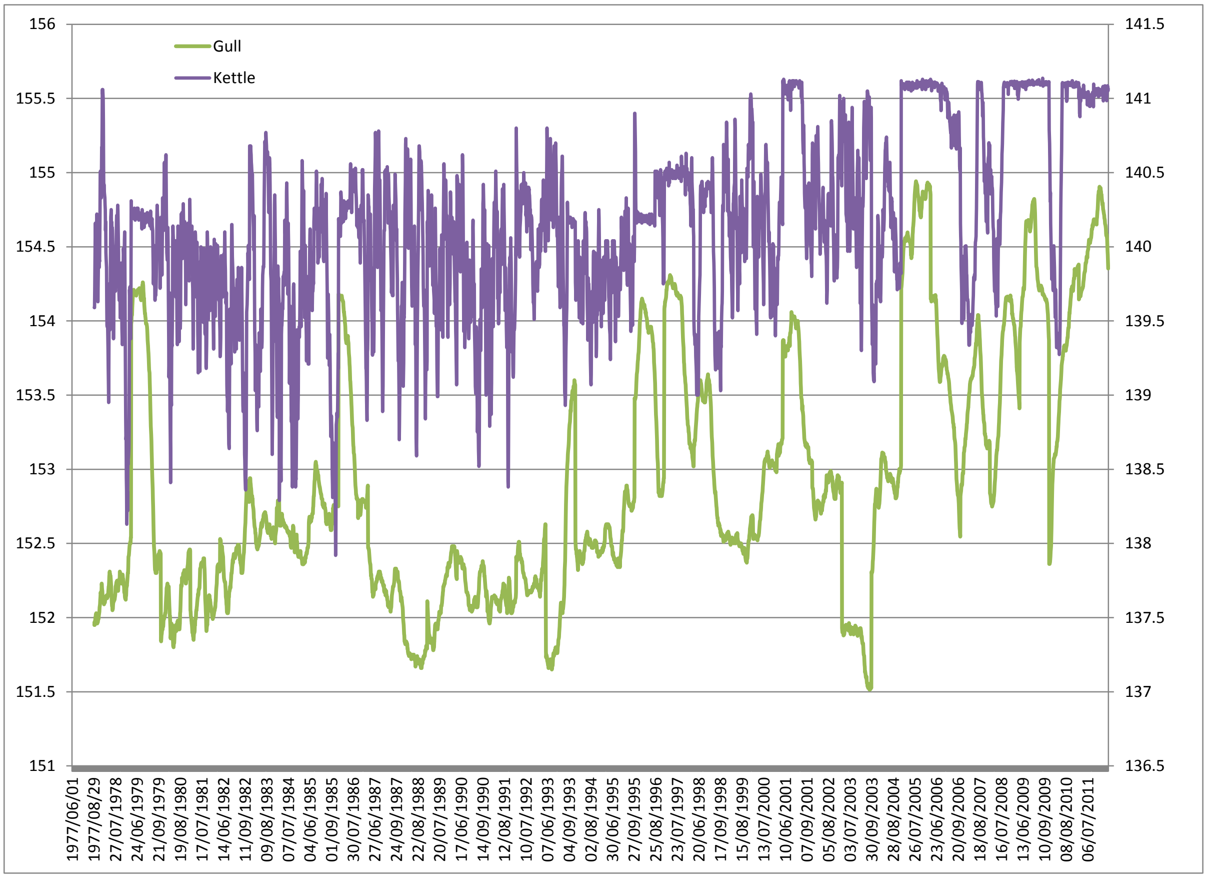


Figure 8-1: Daily water levels at Gull and Kettle during June to September for the 1977 to 2011 period

Proxy area shorelines were searched for recent tree mortality. Shoreline segments were skipped if trees had been cleared for debris management or if fires had burned to the shoreline in 1999, 2001 or 2005. Both of these disturbances masked flooding effects. Shore segments were also skipped if they had undergone too much erosion between 2005 and 2011 to reliably interpret flooding effects for this purpose.

The amount of shore zone tree mortality between 2005 and 2010 was determined from low altitude oblique photos of the shore zone, which were taken from a helicopter flying over the water. Helicopter-based photos taken in 2003 and 2005 established the amount of tree mortality present prior to higher water levels while analogous photos taken in 2011 established short-term tree mortality.

Surface water flooding during the period was thought to be an important influence on the extent of tree mortality. Degree of water inundation in the tree zone was classified based on the amount of surface water in the tree dieback zone that was visible in the 2011 photos but not present in the 2003 photos.

Low altitude oblique photos from other years, large scale (1:15,000) stereo photos taken in 2006, and digital orthography images created from 2003, 2006 and 2010 remote sensing were available to corroborate patterns and/or identify potential confounding factors. DOI's were used as an aid to determine the degree (not necessarily amount) of dieback as well as whether or not the shoreline erosion from 2003 to 2011 precluded determination of tree mortality. Shoreline features in the large scale stereo photos were also used to pinpoint the location of the helicopter-based photos, since there is some spatial error involved with using handheld GPS data collected in a moving helicopter.

8.2 ANALYSIS

An existing classified shoreline dataset was already available for the entire Gull shoreline (ECOSTEM 2011c). Shoreline dataset fields already available for 2003 conditions from the shoreline classification were beach material type, bank material type and bank height (Table 8-1 and Table 8-2).

Fields to incorporate the additional data produced from this study were added to the existing shoreline dataset that was used for Sections 5 and 7. Table 8-3 describes the fields added to the existing shoreline dataset and the classes used for each field. When populating the dead tree width and water inundation fields, segments that fell within burns were given a value of 999 while segments that fell in areas without adequate helicopter-based photo coverage were given a value of 888. The 888 value could also represent areas that were lacking helicopter-based photo coverage and burned. Segments that were unclassified because they were outside of the study area were given a value of -99. Segments that were too eroded to type were given a value of 777.

Table 8-1: Beach and bank material types

Material Type	
Bedrock	Fine textured with Boulders
Boulders	Fine textured with Cobbles
Cobbles	Fine textured with Gravel
Gravel	Fine textured with Heterogeneous material
Boulder till	Fine textured
Sand with Rock	Peat with Cobbles with Boulders
Sand with Cobbles	Peat with Cobbles
Sand	Peat with Rock
Sand with Heterogeneous material	Peat
Heterogeneous material	Unknown
Fine textured with Rock	

Table 8-2: Bank height classes

Class	Height Range
No bank	0 m
Low	< ~ 1 m
Mixture of low and medium	See low and medium
Medium	~1 to ~3 m
High	> ~ 3 m
Unknown	N/A

Table 8-3: Fields added to the shoreline dataset for the short-term responses of trees to flooding study

Field	Description	Classes and criteria (class code in dataset)
Dead Tree Width 04	Width of shoreline tree mortality in 2004 measured as perpendicular distance from shoreline	Width in 3 m increments; inadequate photo coverage (888); burned (999)
Dead Tree Width 11	Width of shoreline tree mortality in 2011 measured as perpendicular distance from shoreline	Width in 3 m increments; inadequate photo coverage (888); burned (999); too much erosion (777)
Dieback	Width of tree dieback in m	Dead Tree Width 11 minus Dead Tree Width 04
Water Inundation	Degree of water inundation into the treed zone between 2003 and 2011	None (surface water extending past the 2003 treeline not visible); Present (surface water visible and covering <75% of the total tree dieback width) High (surface water visible and covering >75% of the total tree dieback width) Inadequate photo coverage (888)

Tree mortality and water inundation values were added to the existing classified shoreline dataset. In situations where the observed tree mortality occurred over a substantially shorter or longer portion of the shoreline, the shoreline was further segmented subject to the constraint that the minimum shoreline segment length was 40 m.

The width of the tree dieback zone was estimated using the number of dead trees along an imaginary line running perpendicular to the shoreline. One dead tree was assumed to have a 3 m diameter based on field data collected along shore zone habitat transects. Therefore, one dead tree from the shore would equal 3 m of dieback, two dead trees in a row perpendicular to the shoreline would equal 6 m of dieback, and so on. When a line of dead trees was not clearly visible in the photo (e.g., where clumps of live trees obscured the view), adjacent shoreline was scanned until a clear transect was found.

The dead tree width recorded for each shore segment was the typical number of dead trees arranged in a perpendicular line from the shoreline multiplied by 3 m. The existing shoreline dataset was further segmented where typical dead tree width changed subject to the constraint that a shore segment must be at least 40 m long.

For each shore segment, the extent of water inundation in the dead tree zone was classified into one of four classes (Table 8-3).

8.3 RESULTS

8.3.1 Gull Proxy Area

While 172 km of Gull proxy area shoreline had suitable helicopter-based photo coverage (Table 8-4), approximately 30% of this total length was excluded due to recent disturbances or ongoing erosion, leaving 120 km of shoreline to search for tree dieback resulting from five years of high water levels (2005 to 2010).

Table 8-4: Shoreline with available helicopter photo coverage along the Gull proxy area shoreline

Shoreline with photo coverage	Length of shoreline (km)	Percentage of shoreline
Searched shoreline	120.5	70
Disturbed shoreline *	46.3	27
Eroding/ ice scoured shoreline	5.6	3
Total proxy area shoreline (km)	*172.4*	100

Notes:* Recent disturbances due to fire and vegetation clearing in 2011.

Tree dieback was recorded along 49.3 km, or 41%, of the searched shoreline. The width of dieback ranged from 3 to 60 m, with nearly 91% of the dieback being less than 10 m wide (Table 8-5). After weighting for shoreline length, overall mean dieback width was 5.3 m in the portion of the shoreline with tree dieback. When averaged over the entire searched shoreline, this value dropped to 2.2 m.

Nearly 56% of tree dieback was associated with peat banks, followed by till and clay (Table 8-6). Compared to shoreline where dieback was absent, dieback occurred along a higher proportion of shoreline with peat banks, and a lower proportion of shoreline with clay banks.

Approximately 79% of the dieback was associated with an absence of elevated banks, with most of the remaining dieback (17%) associated with low banks (<1 m high), or mixed areas of low and absent banks (Table 8-7). Dieback extending more than 25 meters inland occurred only where elevated river banks were absent, as was nearly all the dieback extending more than 10 meters inland.

Table 8-5: Dieback width class in the Gull proxy area as a percentage of total affected and total searched shoreline length

Dieback width class	Length (km)	Percentage of affected length	Percentage of total length searched
~0 m	71.2	n/a	59.1
1 to 10 m	44.7	90.7	37.1
11 to 25 m	4.0	8.1	3.3
26 to 50 m	0.5	0.9	0.4
51 to 75 m	0.1	0.2	0.1
Total shoreline (km)	*120.5*	*49.3*	*120.5*
Overall mean width of effects (m)		5.3	2.2

Table 8-6: Distribution of dieback presence among the different bank material types as a percentage of total searched shoreline length

Bank Type	Shoreline Composition	Dieback	
		Present	Absent
Bedrock	6.3	4.0	7.8
Boulder till	1.2	1.6	0.9
Sand with Cobbles	0.2	0.6	0.0
Sand	8.3	10.4	6.8
Sand with Till	3.5	3.3	3.6
Till	12.3	11.2	13.0
Clay with Till	7.9	3.8	10.7
Clay	19.6	8.8	27.0
Peat with Cobbles	0.3	0.0	0.5
Peat with Rock	1.9	3.0	1.2
Peat	38.0	52.7	27.8
Unknown	0.6	0.6	0.6
All	100.0	100.0	100.0
Total shoreline (km)	*120.5*	*49.3*	*71.2*

Table 8-7: Distribution of dieback presence among the different bank height classes as a percentage of total searched shoreline length

Bank Height	Dieback		Entire Searched Shoreline
	Present	Absent	
None	79	47	60
Mixture of none & low	2	2	2
Low (~< 1m)	15	43	31
Mixture of low & medium	2	4	4
Unclassified	2	4	3
All	100	100	100
Total shoreline length (km)	*49.3*	*71.2*	*120.5*

At least 52% of tree dieback was associated with visible water inundation inland of the 2003 tree line (Table 8-8). Tree dieback was present without visible inundation inland of the 2003 shoreline along at least 13% of the shoreline.

Tree dieback was most common along Gull Lake shorelines (Map 8-1). Upstream of Gull Lake, dieback occurred in small segments scattered along the shoreline where bank elevation was less than 1 meter high. In Gull Lake, dieback was nearly continuous along the searched shoreline. Tree dieback exceeding 10 meters wide was confined to low-relief bays in Gull Lake and along the Nelson River.

Table 8-8: Water inundation class in the Gull proxy area and tree dieback as a percentage of affected shoreline length, and percentage of total shoreline length searched

Water Inundation	Length of shoreline (km)	Percentage of affected length	Percentage of total length searched
None	36.1	8.3	30.0
Present	18.1	27.4	15.0
High	15.8	25.0	13.1
Present but substantial dieback	2.4	4.9	2.0
Inadequate photo coverage	48.1	34.3	39.9
All	100.0	100.0	100.0
Total shoreline with dieback (km)	*120.5*	*49.3*	*120.5*

8.3.2 Kettle Proxy Area

Approximately 160 km of shoreline was searched for tree dieback resulting from five years of high water levels (2005 to 2010). The remaining portions of the 350 km of Kettle proxy area shoreline in the photo coverage area were excluded due to recent disturbances or ongoing erosion (Table 8-9).

Table 8-9: Shoreline with available helicopter photo coverage along the Kettle proxy area shoreline

Shoreline with Photo Coverage	Length (km)	%
Searched shoreline	159.7	46
Disturbed shoreline[1]	113.7	32
Eroding/ ice scoured shoreline	76.9	22
Total shoreline (km)	*350.3*	100

[1] Recent disturbances due to fire and shoreline vegetation clearing in 2011.

Tree dieback was identified along 21% (34.3 km) of the searched shoreline, at widths ranging from 3 to 70 m. Most of the dieback (96%) was less than 10 m wide, with most of the remaining being in the 11–25 m width class (Table 8-10). Averaged over the total affected shoreline, overall mean dieback width was 4.7 meters. When averaged over the entire searched shoreline, this value dropped to approximately one meter.

Most of the dieback (60%) was associated with thin peatland (veneer bog on slope) shoreline edge ecosites, followed by mineral edge ecosites (19%, Table 8-11). Comparatively, portions of the shoreline with tree dieback had a higher percentage of thin peatland, and a lower percentage of mineral ecosites than shoreline without dieback Overall, dieback distribution among the remaining ecosite types appeared to be reflective of the overall proportions of those ecosite types along the searched shoreline. Tree dieback more than 10 meters wide was mostly associated with thin peatland, blanket bog and ground ice peatland ecosites (Table 8-12).

Table 8-10: Tree dieback width class in the Kettle proxy area as a percentage of total affected and total searched shoreline length

Tree Dieback Width Class	Length (km)	Percentage of affected length	Percentage of total length searched
~0m	125.4	n/a	78.5
1 to 10m	32.9	96.0	20.6
11 to 25m	1.3	3.8	0.8
26 to 50m	0.0	0.1	0.0
51 to 75m	0.0	0.1	0.0
Total shoreline (km)	*159.7*	*34.3*	
Overall mean width of effects (m)		4.7	1.0

Notes: "0" values are values that round to zero. Absence is represented by "-".

Table 8-11: Distribution of dieback presence among the different shoreline edge fine ecosite types as a percentage* of total searched shoreline length

Shoreline Edge Ecosite Type	Dieback		Entire Searched Shoreline
	Present	Absent	
Deep dry mineral	18.6	9.8	11.7
Veneer bog on slope	60.2	14.9	24.6
Veneer bog	5.3	1.1	2.0
Blanket bog	9.2	2.5	3.9
Slope bog	0.7	0.4	0.5
Peat plateau bog	2.2	0.5	0.8
Peat plateau bog transitional stage	0.9	0.0	0.2
Peat plateau bog/ collapse scar peatland mosaic	2.2	0.7	1.0
Riparian fen	0.7	0.5	0.6
Unclassified	-	69.6	54.7
All	100.0	100.0	100.0
Total shoreline (km)	*34.3*	*125.4*	*159.7*

Notes:* "0" values are values that round to zero. Absence is represented by "-".

Table 8-12: Distribution of tree dieback among the different fine ecosite types along the shoreline as a percentage* of total searched shoreline length by width class

Shoreline Edge Ecosite Type	Dieback Width Class			
	0 to 10m	11 to 25m	26 to 50m	51 to 75m
Deep dry mineral	19.2	3.5	-	-
Veneer bog on slope	60.5	49.5	100.0	100.0
Veneer bog	5.5	-	-	-
Blanket bog	8.4	30.3	-	-
Slope bog	0.7	-	-	-
Peat plateau bog	2.3	-	-	-
Peat plateau bog transitional stage	0.7	7.3	-	-
Peat plateau bog/ collapse scar peatland mosaic	2.0	9.3	-	-
Riparian fen	0.7	-	-	-
All	100.0	100.0	100.0	100.0
Total affected length (km)	*32.9*	*1.3*	*0.0*	*0.0*

Notes:* "0" values are values that round to zero. Absence is represented by "-".

Most of the searched shoreline did not have adequate photo coverage to compare inland water inundation in 2011 and 2003. Keeping this proviso in mind, at least 21% of tree dieback was associated with visible water inundation inland of the 2003 tree line (Table 8-13). At least 5% of the shoreline dieback was present without visible water inundation inland of the 2003 shoreline.

Tree dieback was distributed throughout the searched shoreline of the Kettle proxy area, with the highest concentrations occurring around the islands and in the bays on the west side of the reservoir (Map 8-2).

Table 8-13: Water inundation class in the Kettle proxy area as a percentage of total affected and total searched shoreline length

Water inundation	Length (km)	Percentage of affected length	Percentage of total length searched
None	87.7	4.0	53.5
Present	7.3	10.4	4.5
High	3.9	10.1	2.4
Present but substantial dieback	0.3	0.9	0.2
Inadequate photo coverage	64.6	74.5	39.4
Total shoreline with dieback (km)	*163.8*	*49.3*	*163.8*

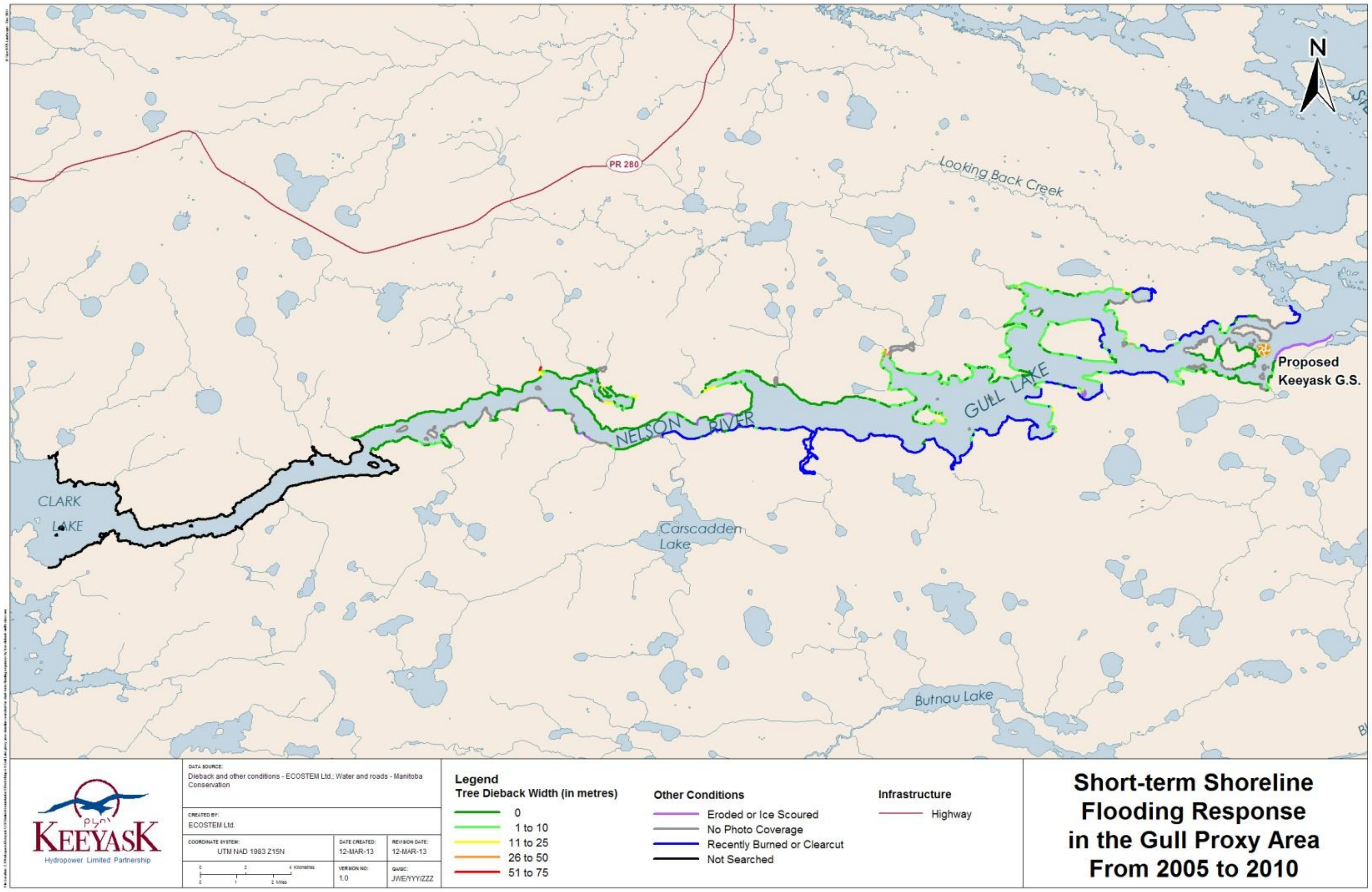
8.4 DISCUSSION

Tree dieback was recorded for a substantially larger proportion of the searched shoreline in the Gull compared with the Kettle proxy area (41% vs. 21%; Table 8-5 and Table 8-10). Where it was present, the width of the dieback was very similar between the two proxy areas, with almost all dieback extending less than 25 meters inland from the shoreline. The higher proportion of mortality along the Gull shoreline was attributed to water level increases at Gull being higher relative to historical levels compared with Kettle.

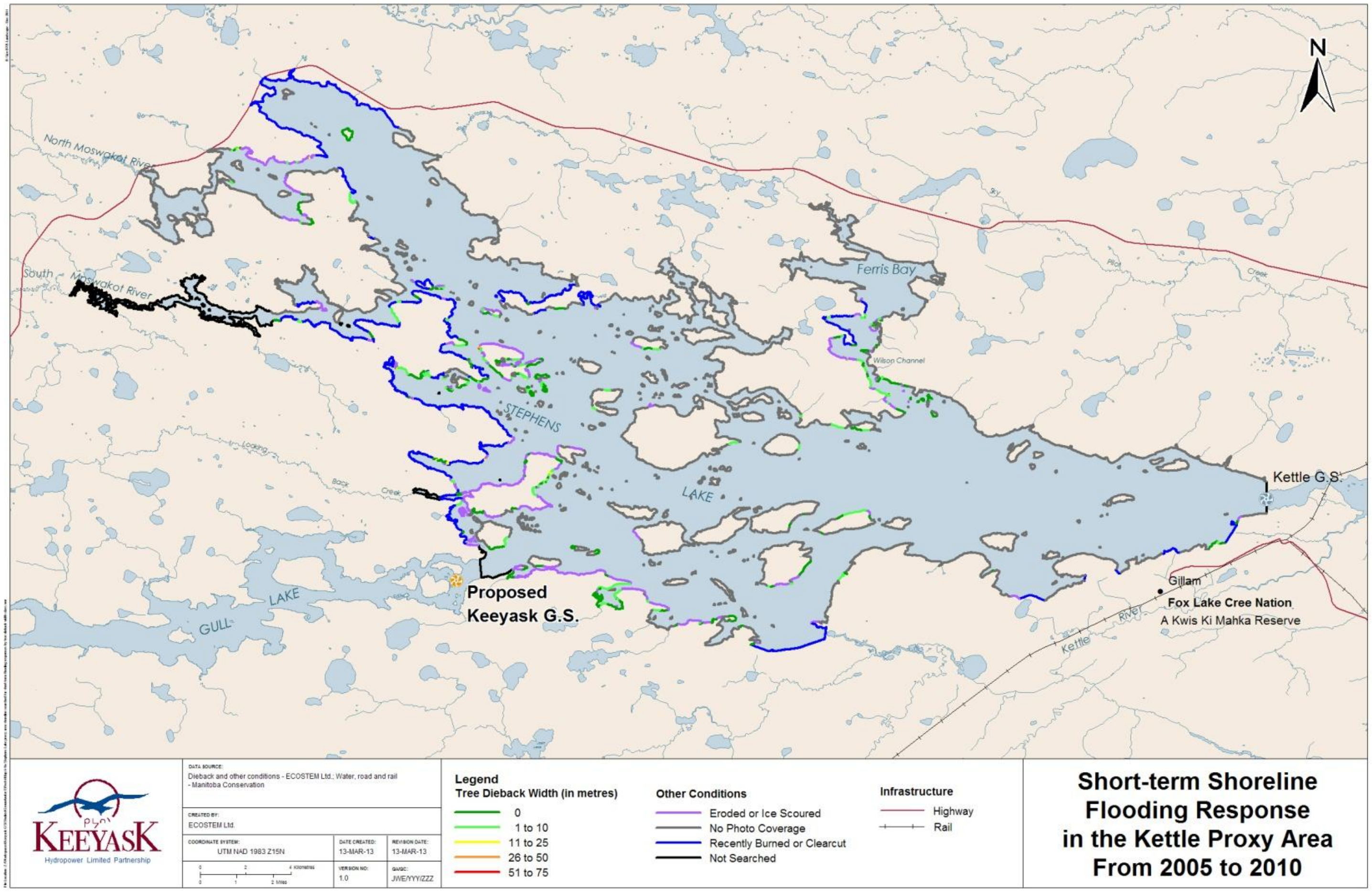
Comparing associations with bank material in the Gull proxy area, and ecosite in the Kettle proxy area, more than half of the dieback in both proxy areas was generally associated with low-relief organic banks or organic ecosite types. Recent prolonged high water levels may have accelerated prior erosion rates along sections of low mineral banks by exposing the upper bank to higher wave energy and/or removing the mineral layers underlying shallow organic veneers. This could suddenly saturate the organic substrates resulting in tree mortality along the eroded fringes of the shoreline.

Recent tree dieback along Gull and Kettle proxy area shorelines demonstrated that tree mortality occurs along the shoreline within five years of flooding. This is supported by findings from studies in Wuskwatim, where tree mortality along the shoreline occurred within one year of high water levels (ECOSTEM Ltd. and Calyx Consulting 2003). In Gull and Kettle, helicopter photography showed that the dead trees predominantly remained standing and showed little decay at this stage. When combined with evidence from Sections 5 and 7, this suggests that mortality occurs within the first five years of flooding, while blowdown and structure change to an extent detectible in stereo photos occurs primarily between five and fifteen years after flooding. There was similar evidence for the delay in structure change in the Kelsey proxy area, where it was evident that five years after flooding there was still no apparent blowdown or structure change along the new shoreline in areas that showed shore zone change by 1991.

8.5 MAPS



Map 8-1: **Gull proxy area shoreline searched for short-term flooding responses by tree dieback width class**



Map 8-2: Kettle proxy area shoreline searched for short-term flooding responses by tree dieback width class

9 DISCUSSION

Five studies were conducted to document the extent and nature of past flooding and/or water regulation effects on terrestrial shore zone habitat along the Nelson River. To support these studies, data were developed for four Nelson River reaches previously exposed to hydroelectric development (the proxy areas) using historical air photos, recent air photos and/or aerial surveys, depending on the particular study.

Three general types of potential flooding and/or water regulation effects were examined. First, inland effects, which were those effects only transmitted through a deep groundwater layer running from the Nelson River to an inland area (Section 1.5.3). Second, shore zone wetland losses in the beach and shallow water zones due to CRD/LWR water regime changes and the development of the Kettle generating station. Third, shore zone effects transmitted through a surface groundwater layer, surface water regime and/or ice processes, thereby occurring from the shallow water areas to the inland side of the shoreline.

This section synthesizes results from the studies included in this report with findings from post-CRD studies conducted for the Notigi reservoir and Wuskwatim Lake reaches of the Burntwood River, bringing the total number of proxy areas to six.

9.1 INLAND EFFECTS

The inland groundwater effects study (Section 4) found no conclusive evidence of inland groundwater effects in the Kelsey or Kettle proxy areas. Although potential signs of groundwater-related effects on inland terrestrial habitat were initially mapped for approximately 1% of the area searched in both of the proxy areas, conditions such as height above the reservoir indicated that most of these observed changes were actually due to causes unrelated to flooding and/or water regulation (e.g., natural vegetation succession, age-related tree mortality, naturally occurring ground ice permafrost melting). After eliminating these situations, no more than 0.1% of the terrestrial habitat area in each proxy area was classified as having at least a limited likelihood of being a groundwater effect. Even some of these situations appeared to be the result of surface hydrological connections with the reservoir through peatlands extending from the reservoir to the inland area.

The findings were not surprising given that there are physical limitations to where inland groundwater effects can occur. The top of a deep groundwater layer can only be raised a limited height above a waterbody that is driving groundwater changes, and such a deep groundwater layer change can only be manifested where there is an opening or a permeable connection through the impermeable deposits that otherwise isolate the deep groundwater layer from the surface groundwater layer. In terms of surface elevations, the landscape level terrain typically slopes towards the Nelson River (Smith et al. 1998) so that the potential zone for deep groundwater effects does not extend very far from the shoreline. On a local scale, there is often a rapid elevation increase at mineral shoreline segments (see the representative photos provided in Section 4.3).

9.2 SHORE ZONE EFFECTS

The extent and nature of shore zone effects, as well as the pathways and drivers for change, were documented using a time series of historical air photos for several existing reservoirs in northern Manitoba. Since historical air photos are often the only means for documenting effects of impacts that occurred decades ago, recent low level photos acquired from a helicopter were used to verify the documented patterns to the extent feasible, as well as to provide higher resolution data and an oblique perspective for effects.

Shore zone studies addressed the following questions:

- How much wetland area in the beach and shallow water zones was lost to hydroelectric development in the Gull, Kettle and Long Spruce proxy areas?
- What proportion of the shoreline exhibited inland edge habitat effects due to flooding and/or water regulation?
- What was the typical width of flooding and/or water regulation effects on terrestrial habitat located on the inland side of the shoreline (i.e., how wide was the inland edge zone in Figure 1-5)?
- What were the key factors interacting with flooding and/or water regulation to drive inland edge zone habitat change?
- What were the pathways of inland edge habitat change and how rapid was the response to elevated water levels?

The above questions are used to organize the discussion that follows.

9.2.1 Historical Vegetated Wetland Loss in the Shallow Water Zone

Analysis of historical air photos indicated that, prior to flooding and water regime changes from Lake Winnipeg Regulation and the Churchill River Diversion, unvegetated shallow water comprised 78% and 95% of Gull and Kettle shoreline length, respectively. All of the vegetated wetland types were more prevalent in Gull than in Kettle.

Fen was the most common wetland type confirmed to have vegetation, comprising 6.5% and 0.2% of the pre-development Gull and Kettle reach shorelines, respectively. Tall shrub meadow was the next most common wetland type overall, accounting for 1.8% of the mapped shorelines.

The extent to which the herb/low shrub meadow zone was vegetated could not be mapped due to the air photo scale. Based on the photo-interpreted extent of the upper beach zone, the potential extent of herb/low shrub meadow wider than 10 m was less than 11% of shoreline length.

Marsh was rare on the Nelson River in the Gull and Kettle proxy areas (less than 2% of shoreline length). Historical data were not available to explain why such a low proportion of the shallow water area available for marsh was actually vegetated, especially in the Kettle reach. Possible causes included high river flows, ice scouring and/or several successive high water years.

Measured as a percentage of shoreline length, Kettle flooding removed more vegetated beach and shallow water wetlands in off-system waterbodies than on the Nelson River.

9.2.2 Proportion of Shoreline with Inland Edge Habitat Effects

Of the reservoir shoreline with suitable historical photos and not subsequently disturbed, inland edge habitat effects were detected on approximately 4% of the Kelsey shoreline, 41% of the Kettle shoreline and less than 1% of the Long Spruce shoreline after approximately 31 years of project operation. Identical results were obtained from recent low altitude photos acquired from a helicopter, which was a second method for obtaining data to document the extent of inland edge habitat effects. The factors contributing to the proxy area differences are discussed in Section 9.2.4.

9.2.3 Width of Inland Edge Habitat Effects

Where present, potential shore zone effects (e.g., tree mortality, vegetation composition change) that were not attributable to peat plateau bog disintegration or to natural changes such as age-related tree mortality, vegetation succession, permafrost melting or soil development, typically extended less than 25 meters inland from the initial flooding shoreline in the Kelsey, Kettle and Long Spruce proxy areas, with the vast majority extending less than 50 meters. The effects width was less than 10 m for at least 65% of the searched shoreline in all three proxy areas, and was as high as 97% for Kelsey. There were localized areas where confirmed effects extended more than 75 m, but these locations comprised less than 1.5% and 0.6% of the Kelsey and Kettle shorelines, respectively.

After weighting for shoreline length, the overall mean width of potential effects over the entire searched shoreline length was approximately 6 m and 14 m for Kelsey and Kettle, respectively, assuming an average 5 m effect even where none were observed. Effects width was not measured for Long Spruce but is expected to by less than that observed for Kelsey given that only 1% of the shoreline had observable potential effects.

Based on a comparison of the treeline position in 1965 and in 1991, shoreline erosion did not remove potential shore zone effects before they could be detected in the next time step of historical air photos (note that this excludes disintegrating peat plateau bogs, which are discussed below).

9.2.4 Controlling Factors for Inland Edge Habitat Effects

The following provides broad generalizations regarding the factors controlling the extent of inland edge habitat effects, both in terms of proportion of shoreline affected and the width of the edge effects. Due to the number of potential controlling factors, there will be localized exceptions to these generalizations.

The Kelsey, Kettle and Long Spruce proxy areas represented a range of conditions for water energy, water regime, local relief and shoreline ecosite composition. Much of the Long Spruce reservoir was a riverine environment while the Kettle reservoir was predominantly a lacustrine environment, and Kelsey was a mixture of riverine and lacustrine environments. Relief adjacent to the initial post-flooding shoreline was generally somewhat higher in the Kelsey and Long Spruce proxy areas compared with Kettle. The normal range of growing season water level fluctuations also varied between proxy areas.

Local relief was a key factor contributing to differences in inland edge effects observed both between and within proxy areas. Kelsey and Long Spruce had less than 2% of their mapped shoreline length exhibiting inland edge effects not related to ice scouring after 30 years of flooding and water regulation whereas almost 40% of mapped Kettle shorelines had inland edge habitat effects. Kelsey and Long Spruce were dominated by high shoreline relief while Kettle had a mixture of low and high shoreline relief. Additionally, within each proxy area, inland edge habitat effects extending at least 10 m from the initial flooding shoreline predominantly occurred in low relief shore segments. A similar pattern was observed for Wuskwatim Lake where, with a few minor exceptions, dead trees in the forest edge were confined to shoreline segments that were either low to medium slope clay, organic soil or peatland (ECOSTEM and Calyx 2003).

The importance of local relief was attributed to two factors. First, most boreal plant species have a shallow rooting system as an adaptation to wet and/or cold soils. For this reason, elevated groundwater must come relatively close to the surface before it can affect vegetation. Second, as noted above, there are physical limitations to how much raised water levels on the Nelson River can elevate shore zone groundwater and substantially change the rooting zone moisture regime.

There was a strong correspondence between local relief and ecosite type. With the exceptions of veneer bog on slope, slope bog and slope fen, the overall surface of the remaining peatland ecosite types is level. Where reservoir flooding and/or higher flows from LWR/CRD raised water levels close to the peatland surface, inland edge effects were observed.

As demonstrated by Kelsey, ice scouring was an additional factor influencing the proportion of shoreline with inland effects, even in shoreline segments where local relief was too high for groundwater effects to occur. In the riverine portion of Kelsey, ice scouring affected vegetation at greater heights above the river high water level than observed for groundwater effects.

Compared with the other proxy areas, Kettle's higher normal range of growing season water levels (Table 2-7) may have also contributed to the higher prevalence of groundwater effects along the mapped shorelines.

Ecosite type and local inland relief were also important factors determining the width of inland edge habitat effects. In the Kelsey and Kettle proxy areas, the widest inland edge effects tended to be in shore segments with deep wet peatlands (i.e., horizontal fen, basin bog, flat bog) on the inland edge, while the narrower width classes were associated with mineral, thin peatland and shallow peatland ecosite types (a qualitative evaluation of the Long Spruce photos found similar patterns). As noted above, there was a strong correspondence between ecosite type and surface slope. Level ecosite types were expected to demonstrate inland edge habitat effects further inland than a sloped ecosite type. Deep wet peatlands typically had level surfaces whereas the underlying mineral/bedrock layer in thin or shallow peatlands, or the substrate surface in mineral ecosites, typically rose gradually to rapidly from the shoreline. Raising the water table in deep wet peatlands would move the groundwater into the plant rooting zone if it wasn't already there prior to reservoir flooding.

In Kelsey, the widest shore zone effects tended to be associated with deep wet peatlands while the narrower width classes were associated with mineral and thin to shallow peatlands, Kettle differed in that most of the shoreline with effects greater than 50 meters were associated with mineral and veneer bog on slope (although, where deep wet peatlands were affected, the effects tended to be wide). In Kettle, the mineral and veneer bog on slope shore segments with wide effects had relatively low surface slopes. Effects in deep wet and riparian peatlands are overstated in the results because the entire polygon was classified as having an edge effect even if effects were only observed near the water's edge.

Peat plateau bog shore segments were not included in the shoreline proportions presented in Sections 5 and 7 of this report. Including these segments would reduce the reported proxy area shoreline proportions with inland edge habitat effects extending at least 10 m from the initial flooding shoreline because such effects were not observed in these shore segments.

In peat plateau bog shore segments, pre- and post-flood soil conditions were unchanged except in locations where Nelson River water levels were raised to close to the surface of the peat plateau bog. Under natural conditions, peat plateau bogs are elevated above the surrounding areas and their banks undergo recession due to ground ice melting (ECOSTEM 2011c). Consequently, the inland edge habitat simply collapses or subsides into the reservoir before groundwater-related habitat effects can occur (ECOSTEM 2012a).

9.2.5 Pathways of Inland Edge Habitat Effects

In Kettle, which was the proxy area most similar to the Keeyask area and had the best air photo time series, the predominant pathway of changes inland edge vegetation was as follows: tree mortality within the first five years; vegetation structure change due to a deceased tree canopy in most of the affected shoreline by 15 years after flooding; and then further vegetation composition and structure change as tall shrubs colonization and/or expand their cover in the shore zone. It appeared that most of the habitat change was complete by year 30, given that the shoreline composition resembled that of non-reservoir proxy areas (i.e. Gull Lake). Assuming all other influences remain constant, it is unlikely that past flooding and water regulation will lead to further changes in the width of the shore zone along shoreline segments not undergoing peatland disintegration.

The rapid response of trees to higher water levels was also documented by short-term responses of shore zone trees to flooding study (Section 8) and by studies of Wuskwatim Lake (ECOSTEM and Calyx 2003).

Almost all of the shore zone effects during the 1986 to 2003/2006 time period occurred along shoreline that was already affected by 1986. By 1986, tree mortality and the associated vegetation structure change were the dominant shore zone effect, and by 2003/2006, the dominant shore zone effect along these shorelines was vegetation composition and further structure change as a tall shrub band developed in the shore zone (Figure 6-2). Further tree mortality occurred during the 1986–2003/2006 period, but most of the mortality had already occurred prior to 1986.

Most of the recorded ecosite conversions were to riparian fen or riparian bog. As described in Section 6.3.1.1, these changes were largely definitional rather than representing a dramatic vegetation change. That is, because a peatland adjacent to water is by definition a riparian peatland so that reservoir flooding to an inland peatland by definition converts it to a riparian peatland. Pre-flooding vegetation structure of riparian peatlands was very similar to that of basin bog and horizontal fen because the groundwater is close to the surface in all three types. For the same reason, vegetation composition of riparian bog and basin bog are similar, as are riparian fen and horizontal fen.

A limitation of the inland edge effects studies was that plant community changes relating to understorey plants, plant growth forms shorter than tall shrubs, and possibly some canopy and ecosite effects could not be detected from the photos. Results from other studies (ECOSTEM 2012b; ECOSTEM upubl.) and field observations indicated that changes not observable in the air photos were typically subtle beyond approximately 5 m from the inland edge.

In general, the studies in this report did not address inland habitat effects on peat plateau bog shore zone segments. As noted above, inland edge effects were not observed on disintegrating peat plateau bogs. This was attributed to the fact that the surface of most peat plateau bogs remained sufficiently elevated above the reservoir water level to protect plant roots from being submerged until the ground ice melted and the surface subsided. ECOSTEM (2012a), which included data from Kettle and the Notigi reservoir found that reservoir-related ground ice melting typically did not extend more than 1 m inland. However, once a peat plateau bog has disintegrated, vegetation change in the shore zone may proceed in a similar manner as above. Pathways of change for shorelines undergoing peatland disintegration processes are described in ECOSTEM (2012a).

10 GLOSSARY

Aquatic plant:	Any plant adapted to grow in water or aqueous habitats.
Attribute:	A readily definable and inherent characteristic of a plant, animal, or habitat.
Beach:	The exposed organic or mineral substrate that is submerged by fluctuating water levels for sufficiently long periods to discourage the establishment of shrubs and trees.
Bedrock:	A general term for any solid rock, not exhibiting soil-like properties, that underlies soil or other surficial materials.
Biomass:	Total mass of living matter, within a given unit of area or volume.
Blanket peatland:	Bog, fen or mixtures of these types with peat of intermediate thickness (*i.e.*, up to approximately 2 m thick) and a featureless surface that cover gentle slopes.
Bog:	A type of peatland that receives nutrient inputs from precipitation and dryfall (particles deposited from the atmosphere) only. Sphagnum mosses are the dominant peat forming plants. Commonly acidic and nutrient poor.
Boreal:	Of or relating to the cold, northern, circumpolar area just south of the tundra, dominated by coniferous trees such as spruce, fir, or pine. Also called taiga.
Brunisol/Brunisolic:	A soil order in the Canadian System of Soil Classification which includes soils that are not well developed but are more developed than regosols (must include a Bm, Btj, or Bfj horizon).
Churchill River Diversion (CRD):	The diversion of water from the Churchill River to the Nelson River and the impoundment of water on the Rat River and Southern Indian Lake as authorized by the CRD Licence.
Collapse scar:	A circular or oval shaped depression formed by ground ice melting in perennially frozen peatland, causing the peat surface to collapse. Drainage is often impeded by the surrounding ground ice.
Cryosol/Cryosolic:	A soil order in the Canadian System of Soil Classification which includes soils that have permafrost within 1m of the surface, or 2m if highly disturbed by cryoturbation.

Deposit type: Mode of surface material deposition. Refers to the dominant form of development in the case of organic deposits developed in situ.

Disturbance regime: The frequency, size, intensity, severity, patchiness, seasonality and sub-type of a particular type of disturbance or continual fluctuation.

Drainage regime: A classification of the typical speed at which water inputs drain from the soil.

Driver: Any natural or human-induced factor that directly or indirectly causes a change in the environment.

Driving factor: Any natural or human-induced factor that directly or indirectly causes a change in the environment.

Ecodistrict: A subdivision of Ecoregions from the National Ecological Framework for Canada into areas characterized by distinctive assemblages of relief, geology, landforms and soils, vegetation, water, fauna and land use.

Ecoregion: A subdivision of Ecozones from the National Ecological Framework for Canada into areas characterized by distinctive regional ecological factors including climate, physiography, vegetation, soil, water, fauna and land use.

Ecosite type: A classification of site conditions that have important influences on ecosystem patterns and processes. Site attributes that were directly or indirectly used for terrestrial habitat classification included moisture regime, drainage regime, nutrient regime, surface organic layer thickness, organic deposit type, mineral soil conditions and permafrost conditions.

Ecosystem: A dynamic complex of plant, animal and micro-organism communities and their non-living components of the environment interacting as a functional unit (Canadian Environmental Assessment Agency).

Ecozone: A classification system that defines different parts of the environment with similar land features (geology and geography), climate (precipitation, temperature, and latitude), and organisms.

Edge effect: The effect of an abrupt transition between two different adjoining ecological communities on the numbers and kinds of organisms in the transition between communities as well as the effects on organisms and environmental conditions adjacent to the abrupt transition.

Effect: Any change that the Project may cause in the environment. More specifically, a direct or indirect consequence of a particular Project impact.

The impact-effect terminology is a statement of a cause-effect relationship (see **Cause-effect linkage**). A terrestrial habitat example would be 10 ha of vegetation clearing (*i.e.*, the impact) leads to habitat loss, permafrost melting, soil conversion, edge effects, *etc*. (*i.e.*, the direct and indirect effects).

Emergent: A plant rooted in shallow water and having most of its vegetative growth above water.

Environmental assessment: Process for identifying project and environment interactions, predicting environmental effects, identifying mitigation measures, evaluating significance, reporting and following-up to verify accuracy and effectiveness leading to the production of an Environmental Assessment report. EA is used as a planning tool to help guide decision-making, as well as project design and implementation (Canadian Environmental Assessment Agency).

Evapotranspiration: The process by which water is transferred to the atmosphere through evaporation, such as plants emitting water vapour from their leaves.

Fen: Peatland in which the plants receive nutrients from mineral enriched ground and/or surface water. Water chemistry is neutral to alkaline. Sedges, brown mosses and/or Sphagnum mosses are usually the dominant peat forming vegetation.

Flooding: The rising of a body of water so that it overflows its natural or artificial boundaries and covers adjoining land that is not usually underwater.

Generating station: A complex of structures used in the production of electricity, including a powerhouse, spillway, dam(s), transition structures and dykes.

Glaciofluvial: Pertaining to streams fed by melting glaciers, or to the deposits and landforms produced by such streams.

Glaciolacustrine: Pertaining to lakes fed by melting glaciers, or to the deposits forming therein

Gleying: A soil condition that develops under long-term anaerobic, reducing conditions. These soils are generally grayish, bluish, or greenish in color and are characteristic of many water-logged soils.

Graminoid: Grasses and grasslike plants such as sedges and rushes.

Groundwater: The portion of sub-surface water that is below the water table, in the zone of saturation.

Habitat: The place where a plant or animal lives; often related to a function such as breeding, spawning, feeding, etc.

Habitat attribute: A readily definable and inherent characteristic of a habitat patch.

Habitat effect: Regarding terrestrial habitat, any change in a habitat attribute that results from the Project.

Habitat loss: Conversion of terrestrial habitat into human features or aquatic areas.

Herb/low shrub meadow: A shoreline wetland that occurs on intermittently flooded, sloping beaches in the transition zone between open water and uplands. Herbaceous cover, woody vegetation less than 25%.

Horizontal peatland: Large, flat, featureless peatland; peat depth is generally intermediate to deep. May have a buried water layer.

Hydroelectric: Electricity produced by converting the energy of falling water into electrical energy (*i.e.*, at a hydro generating station).

Ice regime: A description of ice on a water body (*i.e.*, lake or river) with respect to formation, movement, scouring, melting, daily fluctuations, seasonal variations, *etc.*

Impact: Essentially, a statement of what the Project is in terms of the ecosystem component of interest while a project effect is a direct or indirect consequence of that impact (*i.e.*, a statement of the cause-effect relationship). A terrestrial habitat example would be 10 ha of vegetation clearing (*i.e.*, the impact) leads to habitat loss, permafrost melting, soil conversion, edge effects, etc. (*i.e.*, the direct and indirect effects). Note that while *Canadian Environmental Assessment Act* requires the proponent to assess project effects, Manitoba legislation uses the terms impact and effect interchangeably. See also Effect.

Impermeable: Relating to a material through which substances, such as liquids or gases, cannot pass.

Infrastructure: Permanent or temporary structures or features required for the construction of the principal structures, including access roads, construction camps, construction power, batch plant and cofferdams.

Inland peatland: A peatland that is beyond the direct influence of a water body’s water regime and ice regime.

Inland wetland: A wetland that is beyond the direct influence of a water body's water regime and ice regime.

Lacustrine: Of or having to do with lakes, and also used in reference to soils deposited as sediments in a lake.

Landscape: The ecological landscape as consisting of a mosaic of natural communities; associations of plants and animals and their related processes and interactions.

Local study area: The spatial area within which potential Project effects on individual organisms, or individual elements in the case of ecosystem attributes, may occur. Effects on the populations to which the individual organisms belong to, or the broader entity in the case of ecosystem attributes, were assessed using a larger regional study area; the spatial area in which local effects are assessed (i.e., within close proximity to the action where direct effects are anticipated.

Luvisol/luvisolic: A soil order in the Canadian System of Soil Classification which includes soils that have a light-colored, eluvial horizon and an accumulation of clay in the B horizon.

Marsh: A class in the Canadian Wetland Classification System which includes non-peat wetlands having at least 25% emergent vegetation cover in the water fluctuation zone.

Mineral soil: Naturally occurring, unconsolidated material that has undergone some form of soil development as evidenced by the presence of one or more horizons and is at least 10 cm thick. If a surface organic layer (*i.e.*, contains more than 30% organic material or 17% organic carbon by weight) is present, it is less than 20 cm thick.

Model: A description or analogy used to help visualize something that cannot be directly observed. Model types range from a simple set of linkage statements or a conceptual diagram to complex mathematical and/or computer model.

Moisture regime: The usual amount of water available for plant growth during the growing season.

Monitoring: Measurement or collection of data to determine whether change is occurring in something of interest. The primary goal of long term monitoring of lakes and rivers is to understand how aquatic communities and habitats respond to natural processes and to be able to distinguish differences between human-induced disturbance effects to aquatic ecosystems and those caused by natural processes; a continuing assessment of conditions at and surrounding the action. This determines if effects occur as predicted or if operations remain within acceptable limits, and if mitigation measures are as effective as predicted.

Mottling: A soil condition soil that develops under periodic anaerobic, reducing conditions as indicated by irregular spots of different colors than the soil matric and vary in number and size. Mottling generally indicates impeded drainage.

Network linkage diagram: A schematic diagram that shows the states, driving factors, relationships and direction of flows in a complex system such as an ecosystem; a simple diagrammatic representation of a cause-effect relationship between two related states or actions that illustrates an impact model.

Off-system: Water body or waterway outside of the Nelson River hydraulic zone of influence.

Organic: The compounds formed by living organisms.

Organism: An individual living thing.

Parameter: Characteristics or factor; aspect; element; a variable given a specific value.

Parent material: The unconsolidated mineral or organic material from which the soil develops.

Peatland: A type of wetland where organic material has accumulated at the surface.

Peatland disintegration: Processes related to flooded peat resurfacing; breakdown of non-flooded and resurfaced peatlands and peat mats; and, peat formation on peatlands and peat mats that have hydrological connections to a regulated area.

Peat plateau bog: Ice-cored bog with a relatively flat surface that is elevated from the surroundings and has distinct banks.

Permafrost: Ground area where the temperature remains below 0°C for two or more consecutive years.

Polygon: An area fully encompassed by a series of connected lines.

Polyline: A series of connected straight lines.

Population: A group of interbreeding organisms of the same species that occupy a particular area or space.

Post-project: The actual or anticipated environmental conditions that exist once the construction of a project has commenced.

Project footprint: The maximum potential spatial extent of clearing, flooding and physical disturbances due to construction activities and operation of the Project, including areas unlikely to be used.

Proxy area: Ecologically comparable areas previously exposed to impacts similar to those expected for the Keeyask Generating Station.

Rapids: A section of shallow, fast moving water in a stream made turbulent by totally or partially submerged rocks.

Reach: A section, portion or length of stream or river.

Regime: The frequency, size, intensity, severity, patchiness, seasonality and sub-type of a periodic event or continual fluctuation.

Regional study area: The regional comparison area used for a particular key topic. Alternatively, the spatial area within which cumulative effects are assessed (*i.e.* extending a distance from the project footprint in which both direct and indirect effects are anticipated to occur).

Relative abundance: The number of individuals of one species compared to the number of individuals of another species. The number of individuals at one location or time compared to the number of individuals at another location or time. Generally reported as an index of abundance.

Relief: The difference in surface elevations between two points.

Reservoir: A body of water impounded by a dam and in which water can be stored for later use. The reservoir includes the forebay.

Riparian: Along the banks of rivers and streams.

Riparian peatland: Peatland that borders a water body or waterway. The portion adjacent to the water is usually floating.

Riverine: Of or having to do with rivers.

Shallow water: A class in the Canadian Wetland Classification System which includes open water areas that are typically less than 2 m deep, that may be periodically dewatered, and having less than 25% emergent vegetation cover.

Shallow peatland: A broad ecosite type which includes peatlands that typically have peat that is at least 100 cm thick, lack continuous or extensive discontinuous ground ice and have a water table that is typically more than 20 cm below the surface.

Shoreline wetland: A wetland where surface water level fluctuations, water flows and ice scouring are the dominant driving factors.

Shore zone: Areas along the shoreline of a waterbody including the shallow water, beach, bank and immediately adjacent inland area that is affected by the water body.

Shrub Meadow: A shoreline wetland that occurs on intermittently flooded, sloping beaches in the transition zone between open water and uplands. Tall shrub cover 25% or greater.

Site type: A plot or smaller area classification of site conditions that have important influences on ecosystem patterns and processes. Site attributes that were directly or indirectly used for habitat classification included moisture regime, drainage regime, nutrient regime, surface organic layer thickness, organic deposit type, mineral soil conditions and permafrost conditions.

Soil order: The highest level of soil classification in the Canadian System of Soil Classification. Soil orders group soils based on soil forming processes.

Stand: A relatively uniform area in terms of vegetation, vegetation age, soils and topography that ranges from approximately one to one hundred hectares in size

Stratigraphy: Scientific study of rock strata, especially the distribution, deposition, correlation and age of sedimentary rocks. Also can refer to the layering of materials or soil horizons at a location.

Study area: The geographic limits within which effects on a VEC (valued environmental component) or supporting topic is assessed.

Swamp: One of five classes in the Canadian Wetland Classification System. Includes treed or tall shrub dominated wetlands, on either mineral or

	organic soil with a water table that is typically at least 20 cm below the surface.
Taxa:	Plural of taxon.
Taxon:	A group of organisms that are treated as a classification unit. Usually a taxon is given a name and a rank, although neither is a requirement.
Terrestrial:	Belonging to, or inhabiting the land or ground.
Terrestrial habitat:	Terrestrial habitats include forests and grasslands (among others). They are typically defined by factors such as plant structure (trees and grasses), leaf types (*e.g.*. broadleaf and needleleaf), plant spacing (forest, woodland, savannah) and climate.
Terrestrial habitat shoreline:	The visible historical extent of water and ice regime effects on vegetation and overburden.
Thin peatland:	A fine type in the hierarchical ecosite classification that includes veneer bogs that occur on slopes or crests.
Till:	An unstratified, unconsolidated mass of boulders, pebbles, sand and mud deposited by the movement or melting of a glacier.
Topography:	General configuration of a land surface, including its relief and the position of its natural and manmade features.
Transect:	A line located between points and then used to investigate changes in attributes along that line.
Trophic:	In ecology, **trophic level** describes an organism's position in the food chain.
Uncertainty:	For the purpose of the EIS, the lack of certainty or a state of having limited knowledge where it is difficult or impossible to exactly describe an existing state or a future outcome, or there is more than one possible outcome. In environmental assessment, uncertainty is not knowing, with high confidence, the nature and magnitude of environmental effects or the degree to which mitigation measures would prevent or reduce adverse effects.
Upland:	A land ecosystem where water saturation at or near the soil surface is not sufficiently prolonged to promote the development of wetland soils and vegetation.

Vegetation Composition: In habitat mapping, refers to the proportions of species forming the dominant vegetation layers at the stand level (e.g. tall shrub, black spruce, trembling aspen).

Vegetation Structure: In habitat mapping, refers to the referring to vertical layers of vegetation formed by different species (e.g. low vegetation, tall shrubs or trees), and horizontal distribution pattern of trees and shrubs (i.e. density).

Veneer bog: Bogs with thin peats (*i.e.*, generally less than 1.5 m thick) that generally occurs on gentle slopes and contain discontinuous permafrost.).

Waterbody: An area with permanent surface water

Wetland: A land ecosystem where periodic or prolonged water saturation at or near the soil surface is the dominant driving factor shaping soil attributes and vegetation composition and distribution. **Peatland**s are a type of wetland.

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