KEEYASK GENERATION PROJECT

PHYSICAL ENVIRONMENT

SUPPORTING VOLUME

PHYSIOGRAPHY

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Hydropower Limited Partnership

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5.0 PHYSIOGRAPHY

5.1 INTRODUCTION

This section describes the **physiography** (physical geography) of the area and how the **existing environment** will change with the proposed **Keeyask Generation Project (the Project)**. Physiography is comprised of **bedrock**, surficial geology, soils, peatlands, and **permafrost**. The major physical land-based components of the Project are as follows:

- Temporary and permanent access roads to the Project site and within the **construction** area.
- Supporting **infrastructure** (*i.e.,* construction **camp**, contractor work areas, *etc.*).
- Major civil works for the principal structures (*i.e.,* **dykes**, **powerhouse**, **spillway** *etc.*).
- Source areas for construction material (*i.e.,* borrow pits and rock quarries).

Constructing each of these **project components** will have some **impact** on the various physiographic components. Aggregate will be removed from **borrow areas** to construct the access road and principal structures. Rock will be removed from quarries and used to construct the principal structures. The **landscape** will be altered as areas are cleared of vegetation and soils will be removed or placed at various locations adjacent to and within the Nelson River.

This section provides an overview of the general existing physiography of the area including the **topography**, geology and soils (including permafrost presence) within the broad region and the **local study area**. It then focuses on the direct **effects** of the proposed Project on the physical land mass in terms of **footprint** area and use of local materials to build the proposed Keeyask Project (*i.e.,* **gravel** borrow areas, rock quarries, *etc.*). This section also describes the potential effects on permafrost and the results of testing of materials (*i.e.,* **granular** and bedrock) to determine their leachability and suitability for exposure to oxygen and/or for placement in an **aquatic environment**. Vegetation is described in detail in the Terrestrial Environment Supporting Volume (TE SV). The potential indirect effects on soils are also addressed in the TE SV because of the strong interaction between soils and vegetation, and because an ecosystem analysis that considers other indirect effects (*e.g.,* **groundwater** changes) is required to analyze effects on soils. Potential indirect effects on **aquatic** life or **wildlife** are discussed in the Aquatic Environment Supporting Volume (AE SV) and TE SV.

As indicated in Section 1.1, changes to the existing water and **ice regimes**, shoreline **erosion** (both **mineral soil** and peatland), **sedimentation**, **debris**, groundwater and temperature and **dissolved oxygen** and the potential effect(s) of these changes are described in separate sections of this Physical Environment Supporting Volume (PE SV) (specifically Sections 4.0 through Section 9.0).

5.2 APPROACH AND METHODOLOGY

5.2.1 Overview to Approach

The information described in this section comes from a synthesis of data collected in the area and facts from a variety of literature sources and personal communications with persons having knowledge of the topography, geology and soils of the subject area (Section 5.2.3). Laboratory testing was also conducted on **peat** to gain a better understanding of characteristics, and on some of the construction materials (*i.e.,* granular material and bedrock), which are to be placed in the aquatic environment or become newly exposed to the atmosphere as part of the Project. The purpose of this latter testing was to determine the potential of this material to generate acidic leachate and/or release metals (Section 5.4.1.1).

The expected changes to the physiography are described qualitatively and quantitatively based on the engineering designs available at the time that this assessment was carried out. Details of the designs and construction are provided in the Project Description Supporting Volume (PD SV). This section utilizes information from that volume to describe the effects of the Project on the **environment**.

5.2.2 Study Area

In describing the general physiography, two different scales of **study area** were chosen: one more regional, the other more local (Map 5.2-1). These study areas match those in the TE SV (for more information, see TE SV). The 14,000 **km²** Keeyask **regional study area** was selected to be centered on, include, and in many cases extend beyond all of the other Physical Environment study areas, thereby providing a regional overview of physical features for these studies. The smaller, more localized, **local study area** was selected to more closely encompass the area where the majority of information/data was collected. It is centered on the **Project Footprints** and immediately surrounding areas, which were the most intensively studied areas. It was therefore the area where any effects from the Project on the physiography were expected to occur.

5.2.3 Information and Data Sources

Information on material requirements, footprint areas and physical land types for the various component parts were obtained from the PD SV as well as preliminary estimates of material requirements to construct the Poject (KGS Acres 2011). In terms of information about the physiography of the regional study area, this was gathered from:

- Published literature and reports on surficial geology and mineral soil properties.
- Numerous geotechnical investigations undertaken for more than 30 years as part of Manitoba Hydro's planning and design process.
- Research, studies and testing undertaken specifically for the development of this EIS.

Geotechnical investigations at the proposed Keeyask site were carried out in a number of phases. In the first phase of work material reconnaissance/seismic surveys, air photo studies and field trip observations of the site were undertaken in the early 1960s (Manitoba Hydro 1962, J.D. Mollard and Associates 1963, Geo-Recon Explorations 1963). More specific geological mapping was undertaken between Birthday Rapids to downstream of Gull Rapids in 1963 (G.E. Crippen and Associates 1964).

The second phase of geotechnical investigations began in the mid 1980s, with geophysical surveys, diamond drilling and geological mapping performed in the principal structures area and limited program of hand-dug test pits conducted in potential borrow deposits (Corkery 1985). Investigations were also undertaken to obtain initial assessment of the availability and suitability of potential construction material sources (Manitoba Hydro 1987). More site-specific geophysical (seismic, electromagnetic [EM], magnetic) surveys, diamond drilling and geological mapping was performed at both the Gull Rapids and Birthday Rapids sites (Geo-Physi-Con Co. Ltd. 1988; Manitoba Hydro 1988; 1989; 1991), with horizontal and vertical control surveys being conducted at Birthday Rapids, Gull Rapids and Conawapa in the summer of 1988 (Manitoba Hydro 1989). Work to investigate proposed dyke lines included seismic surveys, EM surveys and a limited auger-drilling program (Geophysics G.P.R. 1991; Geo-Physi-Con Co. Ltd. 1991); an aerial photograph terrain study (J.D. Mollard and Associates 1990); field terrain mapping (Crippen Acres Wardrop 1992) and sonic drilling, hollow stem augering, diamond drilling and test pitting (Manitoba Hydro 1993). Potential sources of granular and impervious borrow materials were investigated during the winter of 1991/1992, consisting of sonic drilling, and test pitting on both the north and south shores of the Nelson River (Manitoba Hydro 1995).

The third phase of geotechnical studies began as plans began to crystallize regarding the current Project configuration. Geophysical surveys and diamond drilling were performed by Manitoba Hydro in the fall of 1999 and winter of 2000, along the GR-3 Axis. This exploration also included the investigation of potential borrow areas for better definition and confirmation of quantity, quality and properties of construction materials. Investigation of a potential source of granular borrow materials was conducted by Manitoba Hydro during the winter of 2001/2002, and consisted of sonic drilling and test pitting on the south **shore** of the Nelson River at **Esker** E-1. Installation and pump tests were completed for the Phase I camp well in 2008. Additional field investigations were carried out in 2008 and 2009 for drilling along the proposed north and south access road alignments, respectively and in 2009 along the shorelines of Gull Rapids and Gull Lake.

Work undertaken specifically for the environmental assessment used mapping, fieldwork, and testing. Studies of the topography and geology of the area were defined based on available federal and provincial reports and site geological engineering studies (J.D. Mollard and Associates 1963; 1990; 2000; Acres Wardrop Consultants 1995a; 1995b; Klassen and Netterville 1985). Related studies in the Gillam, Stephens Lake and Lower Nelson areas were published by Klassen and Netterville (1980), Nielson *et al.,* (1986), Klassen (1986), Dredge (1992), Nielson and Dredge (1982), Dredge and Nielson (1985, 1987) and Dredge *et al.,* (1989).

Visualization of the existing geological setting, outside those areas where data had been collected, was facilitated by the use of Environmental Visualization System (EVS) software. Air photo terrain mapping and **shore zone** video were also obtained and assessed. This included stereoscopic air photos (1975, 1986, 1999, 2003 and 2006), which facilitated soil, ecosite and **surface permafrost** mapping.

Mapping enabled the careful planning of field studies, which also served to verify mapping data. This included multi-season field observations and photographs from boat, helicopter and shore traverses, shore zone bank material mapping, and soil **stratigraphy** data collected at more than 800 locations.

5.2.4 Assumptions

In describing the physiography of the Keeyask regional study area and local study area, the following general assumptions were made:

- The knowledge gained from field explorations, which was made available in published or unpublished reports and synthesized for this Project, represents current and future conditions.
- Global climate changes were not considered in this section of the assessment, but are dealt with in Section 11.
- No changes to the physiography will occur in the future due to catastrophic natural events.
- The land, geology and soils data collected from field explorations or gained from available government mapping is representative of the area(s) from which it was collected and could therefore, within some limitations, be reasonably extrapolated to represent the larger study area.

5.3 ENVIRONMENTAL SETTING

The environmental setting has been described based on available background data and the information collected in the course of the EIA studies.

Past **hydroelectric** and other forms of development have altered physiography in the Keeyask local study area. Past climate change has also affected soils, peatlands and permafrost. The Terrestrial Habitat and Ecosystems section of the TE SV describes the extent of **terrestrial** losses due to past **flooding** and infrastructure development. Total historical land losses to permanent human features, including their **zone of influence** on **habitat** composition, were estimated to be approximately 39,200 ha, or 3.2%, of the local study area (see TE SV Section 2.3.3.1). The indirect effects of human development are estimated to have altered an additional 22,000 ha, or 1.7%, of local study area land area. During a recent 45-year period, approximately 20% of the area in ground ice peatlands have converted to open water and other peatland types due to permafrost melting (see TE SV Section 2.3.3.2). Details regarding losses and alterations to soils, peatlands and surface permafrost are provided in the TE SV (Section 2.3.3).

5.3.1 General Overview

5.3.1.1 Regional Study Area

The majority of the regional study area is located within the **Boreal** Shield Ecozone (Map 5.2-1, Smith *et al.,* 1998). This **ecozone** is the largest in Canada and, therefore, the range of physiographic conditions is large (Smith *et al.,* 1998). The northeast portion of the regional study area extends into the

Taiga Shield Ecozone (Embleton Lake Ecodistrict) and a very small portion along the Nelson River in the east overlaps the Hudson Plains Ecozone (Winisk River Lowlands Ecodistrict).

The Nelson River bisects the study area and lakes of various sizes are densely scattered across the regional study area. Many lakes have shorelines composed of **unconsolidated** materials and often lie between drumlin ridges. Drainage is generally eastward along terrain that slopes approximately 0.6 m per **km** (Smith *et al.,* 1998).

5.3.1.2 Local Study Area

Most of the local study area and all of the project clearing and flooding footprints are within the Knee Lake ecodistrict, which is 23,000 km^2 in area. The physiography of the Knee Lake ecodistrict is generally that of a plains landscape, with undulating loamy **moraines** that erode into drumlin **crests** and ridges. Elevations range from 150 m to 213 m **above sea level** in the lowlands near Stephens Lake, with eskers (*i.e.,* long ridges of **sand** and gravel deposits) providing local **relief** to heights of 20 m to 30 m (Smith *et al.,* 1998). Peatlands occur on gentle slopes and throughout much of the **glaciolacustrine** lowlands in the area.

The local study area topography is dominated by gently sloping terrain with peat of varying thickness overlying fine-grained glaciolacustrine clay and **silt**. Steeper slopes are found on the flanks of elongated drumlins that formed in an approximate east-west orientation due to **movement** of the advancing continental glacier. Because gentle slopes surround most of the proposed Keeyask **reservoir**, relatively low bluffs and gently sloping **nearshore slopes** characterize the shore zone. Steeper nearshore slopes and higher bluffs are found where steeper sloping drumlins and **glaciofluvia**l ridges flank the shore zone.

Bog and **fen** peatlands are common, as is surface permafrost (Sections 5.3.3 and 5.3.4). Melting of ice rich permafrost peatlands has led to thermo-karsting and associated collapse scars across the landscape (Smith *et al.,* 1998).

5.3.2 Bedrock and Surficial Geology

5.3.2.1 Regional Study Area

The regional study area lies within the **Canadian Shield** near the boundary between the Churchill, and superior provinces. The glacial and post-glacial **geological overburden** thickness is estimated as being as much as 30 m over the **Precambrian bedrock** (Betcher *et al.,* 1995). The Precambrian bedrock generally consists of greywacke gneisses, granite gneisses and granites. The **overburden** stratigraphy is a result of the multiple glacial advances and retreats, followed by the inundation of much of Manitoba by Glacial Lake Agassiz after the last glacial retreat. Some preglacial sands and silty sands are found immediately above the bedrock formation but generally the overburden consists of a thick layer(s) of deposited glacial material (till) overlain by postglacial deposits in the form of alluvium (**cobbles** and **boulders** overlying sands and gravels) and Lake Agassiz silts and clays; the latter of which are commonly varved and relatively thin in nature (except in topographic lows) or absent (*e.g.,* on nearby ridges and knolls).

After Lake Agassiz drained to Hudson Bay and the Beaufort Sea, rising sea levels in Hudson's Bay resulted in the inundation of marine conditions toward the west, with a westernmost extent along the Nelson River valley reaching the location where the Kettle GS is now located. Widespread peat veneer and peat blanket deposits formed on the poorly drained flatlands and depressions, over the postglacial alluvium and clays.

Fine textured **lacustrine** deposits are the dominant surface materials in the regional study area (Fulton 1995; Agriculture and Agri-Food Canada 1996). As shown in Table 5.3-1 and on Map 5.3-1, fine lacustrine deposits cover 90% of the total area. These lacustrine deposits are considerably more abundant in the regional study area (and the local study area; Section 5.3.2.2) than in northern Manitoba as a whole. Glaciofluvial, till and marine deposits cover an estimated 6%, 2% and 2% of the regional study area, respectively. Glaciofluvial deposits are concentrated in several eskers while the marine deposits occur at the eastern extent of the regional study area (approaching Hudson Bay).

Larger scale mapping (Agriculture and Agri-Food Canada 1996) indicates that peat deposits predominantly occur as mosaics of **mesic** woody forest peat and lacustrine or morainal deposits. Mosaics of lacustrine deposits with mesic woody forest peat also occur in the western portion of the regional study area (Map 5.3-2). Mosaics of mesic woody forest peat with morainal deposits are most abundant in the northeast and southern portions of the regional study area.

Table 5.3-1: Surface Material Deposition Mode in the Study Area and Northern Manitoba as a Percentage of Total Area*

Surface Material Deposition Mode	Northern Manitoba	Regional Study Area	Local Study Area
Rock	4		
Till Blanket	25	2	
Till Veneer	12		
Glaciofluvial - - complex	1	5	4
Glaciofluvial - plain		1	
Alluvial	1		
Lacustrine - - coarse	2		
Lacustrine – - fine	28	90	93
Marine (glacio– - coarse)	2		
Marine (glacio– - fine)	11	2	3
Organic	3		
Water	11		
All	100	100	100

* Blank cells indicate a value of 0. Data source: Fuller 1995.

5.3.2.2 Local Study Area

Within the local study area, and specifically the Gulls Rapids area, the bedrock is generally metamorphic and cataclastic in texture (depending on specific locations). Further downstream, the bedrock consists of different groups of metasedimentary and igneous intrusive rocks (Manitoba Hydro 1993). Along the Stephens Lake shore zone, a boulder lag is present in places between the bedrock and the overlying glacial drift and some or all of the overburden units appear to be locally absent (J.D. Mollard and Associates (2010) Limited 2012).

As the last glacier retreated eastward, Glacial Lake Agassiz inundated much of Manitoba, including the area that is being proposed for the Keeyask reservoir. The proposed Keeyask reservoir area has been subjected to multiple glaciations that have deposited three till units containing varying amounts of gravel, cobbles, and boulders. In some locations, stratified water-laid deposits (thinly layered clay and silt) are present between till units. These fine-grained deposits are commonly varved and tend to be thicker in topographic lows than they are on nearby ridges and knolls where the postglacial **sediments** may be absent.

Ice contact glaciofluvial sediments were deposited during the latter stages of deglaciation. Stratified silt, sand and gravel were deposited in ice-walled channels. In local areas, saturated non-sorted till-like debris slumped into ice-walled channels and crevasses from the adjoining glacial ice. As a result, glaciofluvial deposits often contain randomly distributed pockets of till-like material.

As indicated in Section 5.3.2.1, fine-textured lacustrine deposits are considerably more abundant in the local (and regional) study area than in Manitoba as a whole. Till deposits are absent in the local study area in the 1:5,000,000 data (Fulton 1995) due to mapping scale. The 1:1,000,000 data (Agriculture and Agri-Food Canada 1996), however, shows till as a secondary material in 3% of the local study area (Table 5.3-2).

Widespread peat veneer and peat blanket deposits have developed on most of the post-glacial lacustrine mineral deposits and heterogeneous till mineral deposits. Permafrost affected ice rich **peat plateau bogs** formed in the poorly drained areas. These bogs are characterized by water-saturated thaw holes (thermokarst ice-collapse depressions) containing bog or fen peat.

Peat deposits have become the most widespread and abundant surface materials in the local (and regional) study area (Table 5.3-2 and Map 5.3-2). Mosaics of mesic woody forest peat with lacustrine deposits are more abundant in the local study area than in the regional study area and there is less area where mineral materials are the primary surface material (Table 5.3-2).

In terms of stratigraphy, the regional stratigraphy described in Section 5.3.2.1 is apparent in the local study area. Postglacial peat and clay have an average thickness ranging between 0.6 m and 1.3 m (Manitoba Hydro 1993). Median peatland depths (*i.e.,* combined thickness of peat, water and ice core) range from 0.5 m to 3.2 m in the reservoir area, depending on peatland type. Three separate till and/or till-like (intertill) horizons, which range in thickness between 2 m and 10 m (Manitoba Hydro 1993), have been identified as comprising the underlying deposited glacial material.

Table 5.3-2: Soil Parent Material in the Study Areas and Northern Manitoba as a Percentage of Total Land Area*

Primary Parent Material Type	Secondary Parent Material Type	Northern Manitoba	Regional Study Area	Local Study Area
Rock	Morainal (till)	1		
	Lacustrine	0		
	Mesic woody forest	1		
Morainal (Till)	None	0		
	Rock	13		
	Lacustrine	4		
	Marine	0		
	Mesic sedge	0		
	Mesic woody forest	14	0	
	Mesic woody sedge	2		
Glaciofluvial	None		1	
	Mesic woody forest	1	5	
	Bog	0		
Alluvial	Bog	0		
Lacustrine	None	0		
	Rock	6		
	Morainal (Till)	3	3	
	Mesic sedge	0		
	Mesic woody forest	7	17	6
Marine	Rock	0		
	Mesic sedge	3		
	Mesic woody forest	0		
Mesic sedge	Alluvial	0		
	Mesic woody forest	3		
Mesic woody forest	None	0		
	Rock	3		
	Morainal (Till)	15	21	3
	Lacustrine	9	52	87
	Mesic sedge	9	1	4

Primary Parent Material Type	Secondary Parent Material Type	Northern Manitoba	Regional Study Area	Local Study Area
	Bog	0		
Mesic woody sedge	Mesic sedge	0		
Fen	Mesic sedge	0		
Bog		0		
Fibric Sphagnum		3		
All		100	100	100

* Cells with 0 values are values that round to 0 while blank cells indicate a value of 0.
Data source: Agriculture and Agri-Food Canada 1996.

Because a wide range of **sediment** types are present in the Keeyask reservoir area, materials in the proposed shore zone include peat, clay and silt, till, sand and gravel, boulders and bedrock depending on the position of the shore zone in relation to the local stratigraphy at that location.

5.3.2.3 Borrow Material Resources

As indicated in Section 5.3.2, postglacial alluvium (specifically granular and impervious materials) is present on both the north and south sides of the Nelson River in the area surrounding the proposed Project site (Map 5.3-3). These, as well as a number of potential **quarry sites**, have been identified as potential local borrow material resources for Project construction. The quantity of rock, granular and impervious material found at each location is variable, depending on the extent of site-specific investigations and distance from the proposed **generating station** location.

The essential granular deposits identified for the Project are present along the riverbank and in the esker regions within the local study area. This includes borrow areas such as the areas immediately north of the riverbank, Gull esker, Limestone esker, and Birthday esker on the north side of the Nelson River; and the areas south of the riverbank as well as the Ilford-Butnau esker (including Deposit E-1) on the south side of the Nelson River. Specifically, the estimates of granular materials on the north side of the Nelson River range between 0.15 x 10^6 m^3 (Birthday esker region) 8.99 x 10^6 m^3 (Limestone esker region) and 25.15 x 10^6 m^3 (Gull esker region), while the corresponding granular deposits on the south side area range between 0.7 x 10^6 m^3 (south bank region) and 6.5 x 10^6 m^3 (Ilford-Butnau esker region).

5.3.3 Soils and Peatlands

5.3.3.1 Regional Study Area

Cryosols are the most common soils in the regional study area and northern Manitoba, associated with widespread permafrost in peatlands (Smith *et al.,* 1998). Mosaics where Organic Cryosol is the leading great group cover 73% of the regional study area, being considerably more abundant here than in northern Manitoba as a whole. Mesisols, the most common **organic order** soil at the 1:1,000,000 mapping scale, are generally derived from woody forest and sedge peat that developed into deep fens and shallow **veneer bogs**.

Exposed granitic bedrock occurs **sporadically** throughout the regional study area. Mineral soils occur throughout the regional study area (Map 5.3-4). Mineral soils tend to be imperfectly drained **Eutric** Brunisols (Smith *et al.,* 1998) developed in loamy to sandy calcareous till and sandy to gravelly fluvioglacial deposits. Gray Luvisols may be present on well to imperfectly drained clayey deposits. Gray Luvisols with Organic Cryosols as a secondary group are the second most abundant soils in the study areas, and are primarily associated with the fine mineral materials in the western portions of the regional study area (Map 5.3-4).

5.3.3.2 Local Study Area

Organic Cryosols are even more abundant in the local study area than the regional study area Section 5.3.3.1). The majority of these Cryosols co-occur with Gray Luvisols as a secondary type. Organic Cryosols with Eutric Brunisols as a secondary type are relatively scarce within the local study area compared to the regional study area, and confined to the southern extent. Areas with Mesisols as a secondary type are located at the eastern extent of the local study area, and have a higher **relative abundance** than in the regional study area Map 5.3-4. The only other soil group identified within the local study area is Gray Luvisols with Organic Cryosols as a secondary soil type. This Soil Great Group is confined to the western extent of the local study area (Map 5.3-4).

Large scale 1:15,000 mapping confirms the general pattern of the 1:1,000,000 small-scale mosaic mapping with a few exceptions. Cryosols are shown as less abundant while **Organics** are shown as more abundant in the large-scale mapping.

Based on the large-scale mapping, the Cryosolic soil order is the most common in the Local Study Area followed by the Organic and Brunisolic orders. Cryosols are primarily found in Sphagnum bogs, and to a lesser extent, feather moss bogs and are generally very poorly drained. Peaty phase mineral soils and shallow organic soils typically form the transition between upper slope mineral soils and down slope organic soils (Map 5.3-6). Mineral soils cover approximately 12% of the local study area (Map 5.3-5), primarily occurring along the Nelson River and the elevated portions of eskers and moraines. 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 deposits and moderately well drained soils. Luvisolic soils are also present within the study area, especially on relatively level terrain. The Luvisols are most commonly found on rapid to moderately well drained soils developed on till or glaciofluvial deposits.

Soil-profile sampling at almost 370 representative locations in the local study area confirmed that Cryosols are the most common soil order in the Local Study Area, comprising over 40% of the soil profiles. The Organic and Brunisolic orders were the next most abundant soil order comprising approximately 30% and 10% of the soil profiles, respectively. Gleysolic, Luvisolic and Regosolic orders were each found at less than 7% of locations.

As previously indicated, peatlands dominate the local study area (Map 5.3-5 and Map 5.3-6 and Table 5.3-3). Veneer bogs and **blanket peatlands** are the most common peatland types covering approximately 62% of the land area. Veneer bogs are thin peats *(i.e.,* less than 1.5 m thick) that primarily occur on slopes. Blanket peatlands are thicker than veneer bogs and occur on lower slopes, valleys and level areas. Peat plateau bogs are ice-cored bogs with a relatively flat surface that is elevated from the surroundings and has distinct banks. Peat plateau bogs and associated peatland types cover 16% of the land area. The peatland types that cover the remaining 8% of the land area are **horizontal peatlands**, **riparian peatlands**, thin **wet peatlands** and deep wet peatlands. These peatlands are generally found in lower slope and depressional locations; riparian peatlands occur along the shorelines of water bodies.

Table 5.3-3: Coarse Ecosite Composition in the local study area as a Percentage of Land Area

Coarse Ecosite	Local Study Area
Mineral	12
Shallow Peatland	39
Ground Ice Peatland	25
Deep Peatland	16
Riparian Peatland	4
Human	3
All	<1

5.3.4 Permafrost

Permafrost is defined as soil or rock that has a temperature below 0°C during at least two consecutive winters, with intervening summer (Brown and Kupsh 1974). Moisture in the form of ice may or may not be present. Permafrost will typically form in any climate where the mean annual air temperature is less than the freezing point of water. Permafrost is affected by the climate and the various terrain conditions. Permafrost presence and characteristics can differ substantially depending whether the focus is the surface or at depth. Surface permafrost is permafrost that occurs within the top 1 m to 2 m of the soil profile. Deep permafrost occurs at a depth that is more than 2 m below grade.

Geographically, permafrost continuity is divided into the following types:

- Continuous permafrost – >90% to 100% aerial coverage.
- Extensive discontinuous permafrost – >50% to 90% aerial coverage.
- Sporadic discontinuous permafrost – >10% to 50% aerial coverage.
- Isolate permafrost – >0% to 10% aerial coverage.
- No permafrost – 0% aerial coverage.

Permafrost presence in the regional and local study areas is discussed below.

5.3.4.1 Regional Study Area

National mapping by the Geological Survey of Canada (2005) indicates that the distribution of permafrost is discontinuous in the regional study area (Map 5.3-7). Both soil type and permafrost activity throughout the soil horizons contributes to the regional and local surface topography. Uneven soil horizon development in sediments with high clay content is evidence of permafrost effects on deeper soil layers. In surface layers, permafrost activity can be seen in the form of low earth hummocks (Smith *et al.,* 1998) and thermokarst features.

Surface permafrost is discontinuous throughout the regional study area, but is more frequent towards the northeast (Smith *et al.* 1998). It is mostly associated with organic Cryosols, but at the northeastern extent of the region, it is occasionally found in fine-textured mineral soil. Toward the southern extent of the region, permafrost is generally confined to deep organic deposits.

In terms of thickness, permafrost within the Keeyask regional study area ranges from less than 10 m to between 10 m and 50 m (depending on the location; Map 5.3-7). Dredge and Nixon (1992) report a 45 m permafrost depth at Lake Roseabelle (Churchill) and 60 m depth at Churchill, which is northeast of the regional study area, while Klassen (1986) reports that permafrost depths in the vicinity of Kettle and Long Spruce rapids commonly extend from the active layer to 4.5 m to 9 m depth. A Permafrost Map of Canada (1978) generally shows permafrost to be 25 m thick in the Gillam area.

5.3.4.2 Local Study Area

5.3.4.2.1 Surface Permafrost

Organic soils in the local study area frequently contain surface permafrost extending down to varying depths. The types of permafrost range from cold soil temperatures only to ice crystals, ice lenses or thick massive ice. Surface permafrost is uncommon in mineral soils. Surface permafrost generally occurs in all peatland types except for horizontal and riparian peatlands. The typical distribution of surface permafrost within a mapped ecosite polygon (Map 5.3-8) varies from none in mineral ecosites, horizontal peatlands, wet deep peatlands and riparian peatlands to sporadic patches in thin wet peatlands, discontinuous patches in veneer bogs, blanket peatlands and peat plateau bog transitional stages and continuous in peat plateau bogs.

Extensive discontinuous and sporadic discontinuous surface permafrost are widely distributed throughout the area, occurring in 78% of the local study area (Table 5.3-4). Sporadic discontinuous permafrost is the most abundant surface distribution type, occurring in 61% of the land area. Surface permafrost is usually absent in the surface organic layer of mineral soils and occurs as isolated patches in thin, wet peat peatlands. Discontinuous surface permafrost is associated with **shallow peatlands**, including veneer bogs and blanket bogs.

Most peatland types included in the general category of permafrost peatlands have extensive discontinuous surface permafrost. Surface permafrost in permafrost peatlands is continuous except for collapse scars, which are essentially water-filled craters that result from ground ice melting in peat plateau bogs. Permafrost is generally not found in the surface organic layers of deep peatlands, deep wet peatlands or **riparian** peatlands. The distribution of surface permafrost in the local study area is strongly associated with the distribution of **ecosite types** since this is an **attribute** used to classify ecosite type.

Table 5.3-4: Surface Permafrost Composition in the Local Study Area by Continuity Type as a Percentage of Total Land Area

Type	Local Study Area
Continuous	<1
Extensive Discontinuous	15
Sporadic Discontinuous	61
Isolated Patches	2
None	21
All	100
Note: See text for class definitions	

When characterizing surface permafrost, it is important to distinguish between permafrost occurrence and the proportion of that permafrost that is thick ground ice. Thick ground ice permafrost has important implications for peatland and habitat dynamics TE SV. The permafrost in peat plateau bogs is predominantly thick ground ice. As much as one-third of the permafrost area in a blanket peatland can contain thick ground ice. In general, peat plateau transitional bog is the only other organic ecosite type that generally has patches of thick ground ice.

5.3.4.2.2 Deep Permafrost

Temperature readings in 27 tubes installed during the winter 1990 and 1991 exploration program were obtained in the summer of 1991. The readings showed that the upper seasonally thawed zone (active zone), which had been frozen during winter drilling, usually ranged from 1 m to 3 m in depth, with an average of 2.1 m. Permafrost was verified in 21 of the holes. The depth to the bottom of permafrost varied from 7 m to over 18 m. Similar results were obtained in subsequent readings on these and additional temperature **monitoring** tubes installed after 1991.

During the various field investigation conducted between 1988 and 2003, observations of frozen soils were made on a selected number of soil samples retrieved from the drilling program. As the determination of permafrost soils is affected by the season of the investigation program, frozen soils may not be observed in some holes. Conversely, winter drill holes usually encountered frozen soils in the upper zone, which may either be indicative of permafrost or seasonal frost.

Map 5.3-9 shows the depth of frozen soils observed during the various drilling programs within the local study area. The boreholes were mainly selected along the proposed dyke lines and access roads, which typically were selected and designed in areas where the presence of permafrost will be avoided. While this figure shows little about the presence of permafrost in the region, it does characterize permafrost at depth where the principal structures will be located and where permafrost would be affected by the Project.

5.3.5 Seismic Activity

Movement along faults generally results in earthquakes and hence the level of seismicity in a given area is a general indicator of fault activity. Exceptions, however, exist in the case of aseismic (noncapable) faults.

Manitoba in general is an area of very low seismicity. In particular, the **Precambrian Shield**, within which the proposed Keeyask Project is located (Section 2.3.2.1), is also of very low seismicity. It is evident from the historical records since the 1600's and relatively recent seismic monitoring as shown in Map 5.3-10, which presents the distribution of **magnitude** 3 and greater earthquakes in Canada since 1627 (Natural Resources Canada 2008), that no major earthquakes, and hence no **significant** earthquake generating fault movements, have occurred in Manitoba.

Map 5.3-11 shows a plot of the smaller earthquakes (microseismic events) that have occurred within 600 km of Thompson, Manitoba since 1965 (Natural Resources Canada 2007). Scattered earthquakes up to magnitude 3 have occurred and several magnitude 4 events have occurred in a cluster along the Hudson Bay coast. The latter may indicate local hot spots at depth in the Precambrian Shield. There is, however, no pattern of microseismic activity in the Churchill-Superior faulted contact. A Magnitude 1 event has occurred near the Kettle GS, which is just downstream of the Project.

The microseismic activity indicates that although seismic activity is at a very low level in Manitoba, it is not at the zero level.

5.3.5.1 Reservoir Triggered Seismic Activity

Reservoir triggered seismicity (RTS) is a result of a physical change to an existing environment. It results from the **impoundment** of reservoirs. The impoundment of a reservoir may cause changes to the ambient stresses in the rock, which in turn, may facilitate movement along existing fault planes and the generation of seismic activity. RTS is usually associated with very large reservoirs with characteristics where the reservoir capacity exceeds 10 km^3 and with depths exceeding 80 m or greater. At the Keeyask Project, the maximum reservoir depth and volume are 30 m and 0.5 km^3, respectively. Given that Manitoba is relatively inactive seismically compared to other project areas which have experienced RTS in the world, and that no RTS activity has occurred at the Kettle GS reservoir, which is immediately downstream of Keeyask and is in similar geological conditions, such potential seismic activity as a result of the reservoir impoundment is remote. In addition, the ground accelerations resulting from RTS activity are considerably less than the design acceleration assumed for the maximum design earthquake for any given project.

5.3.6 Post-Glacial Rebound

Land areas that were subjected to the Wisconsin Glaciation, such as Canada and Europe, were depressed significantly as a result of the great weight of ice over hundreds of thousands of years. As the ice melted, uplift occurred, known as post-glacial (or isostatic) rebound. This rebound has continued through the recent geological past and is likely still continuing. The rebound is most likely to occur in the surface bedrock where the greatest compression occurred in the past. The rebound may occur uniformly over large areas or can be concentrated along pre-existing fractures, such as a fault or a joint.

Adams (1981; 1989) of the Geological Survey of Canada has described the phenomenon of faulting, caused by **isostatic rebound**, as having mostly developed in the last 14,000 years. Movement on individual planes is generally vertical and less than 0.15 m offset. They commonly occur in sets. Groups of such planes in close proximity have shown a total movement up to 2.0 m. Lengths of these faults may be up to several kilometres.

Other types of rock deformation have also been linked to glaciation such as ice thrusting, which is shear failure in the uppermost bedrock due to glacier override. This type of deformation, which can be interpreted as faulting, commonly occurs in horizontally-bedded sedimentary rocks. Another type of deformation that occurs in sedimentary rocks is the "pop-up" structures, due to stress relief following rapid unloading.

Figure 5.3-1 shows several glacial isostatic rebound emergence curves for data collected in northeastern Manitoba and other parts of Hudson Bay (Dredge and Nixon 1992). Applying a linear trend to the most recent 1,000 years of the Nelson-Hayes curve suggests rebound rates in the order of 2.5 mm/y.

Regional rebound rates estimated from Earth-loading theory **models** are presented in Lambert (1996). Canada-wide results from two such models are shown in Map 5.3-12 and suggest rebound rates of approximately 5 mm/y in the local study area.

5.3.7 Future Conditions/Trends

5.3.7.1 Bedrock and Surficial Geology

5.3.7.1.1 Soils and Peatlands

It is expected that without the development of the Project, and assuming that climatic and **watershed** conditions remain as they currently are, that soils and peatlands would continue to change in response to ongoing shoreline erosion and past climate change. The Shoreline Erosion Processes section of the PE SV predicted that land losses due to future Nelson River shoreline erosion over the 2017 to 2047 year period (coinciding with the 30-year **post-Project** period) are estimated to be 0.9 km^2. The Terrestrial Habitat and Ecosystems section of the TE SV predicted that at least 20% of the peat plateau bog in the local study area will disappear over the 41 years from 2006 to 2047 (TE SV Section 2.3.3.2). Other changes to soil and peatland composition are also anticipated. As noted in the introduction, details regarding future conditions and trends in soils and peatlands are provided in the TE SV.

5.3.7.1.2 Permafrost

It is expected that without the development of the Project, and assuming that climatic and watershed conditions remain as they currently are, surface permafrost would continue to change in response to past climate change. The Terrestrial Habitat and Ecosystems section of the TE SV predicts that at least 20% of the massive ground ice in the local study area will disappear over the 41 years from 2006 to 2047 (TE SV Section 2.3.3.2). Other changes to surface permafrost are also anticipated. As noted in the introduction, details regarding future conditions and trends in surface permafrost are provided in the TE SV.

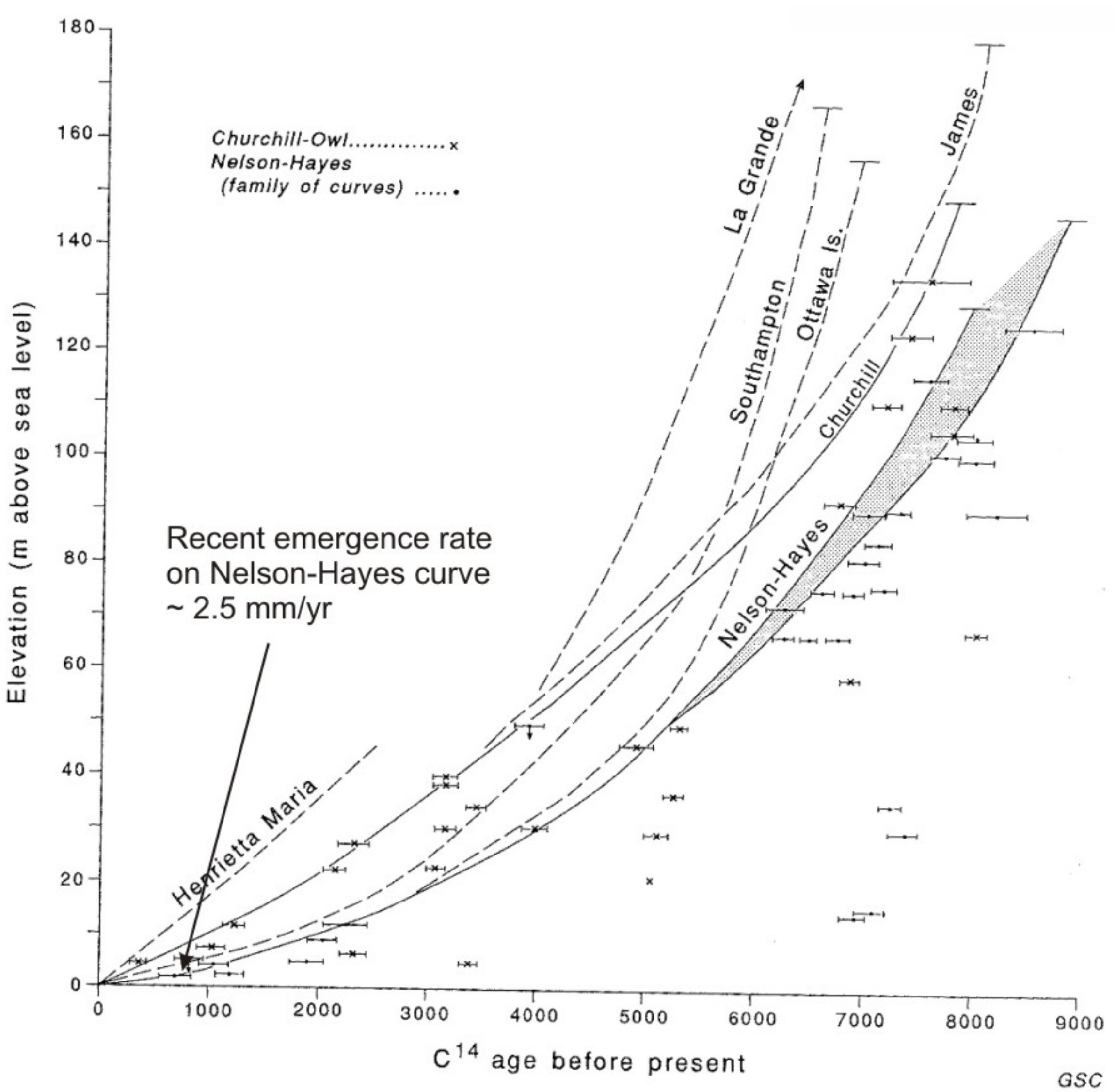

Figure 5.3-1: Emergence Curves for North Eastern Manitoba and other Parts of Hudson Bay (after Dredge and Nixon 1992)

5.4 PROJECT EFFECTS, MITIGATION AND MONITORING

The proposed Project will affect the physical environment both during construction (*e.g.,* excavation activity, roads, camp, construction of generation station etc.) and during operations (*e.g.,* flooding of lands). This section describes the predicted changes to the physiography due to the Project. The first section describes the predicted changes during the construction phase and the second section during the operating phase. A summary of residual and cumulative effects is also provided. Methods to mitigate Project effects are then summarized. Proposed monitoring activities during the construction and operating phases is also included. Potential indirect effects on aquatic **biota**, wildlife, vegetation, and habitat are discussed in the AE SV and TE SV. Detailed descriptions of the construction activities and schedule, descriptions of supporting infrastructure and principal structures as well as the operating period are provided in the PD SV. This section draws information from the Project Description and the preliminary estimates of materials required (KGS Acres 2011) in order to characterize the effects of the Project on the physiography.

5.4.1 Construction

Constructing the following components of the Project will result in physical changes to the environment:

- Access roads.
- Site clearing for supporting infrastructure (including construction camp and contractor work site), immediate reservoir and generating station (GS).
- Off-site construction-material extractions (*e.g.,* impervious and granular borrow sources and quarries).
- GS construction (excavation, powerhouse and spillway structures, dykes, **dams**).

The potential effects of the construction work are primarily related to modifications of the local environment surficial soils, geology and permafrost. This is associated with the 'footprint' area of construction and the use of local borrow material. The 'Project Footprint' is predicted to affect 8,193 ha, or 3.3%, of the local study area during construction (Map 5.4-1). As shown in Table 5.4-1, reservoir clearing accounts for the highest percentage of the Project Footprint area during construction, followed by borrow areas and quarries.

Following Project construction, some components of the supporting infrastructure will be removed and areas rehabilitated as defined in the **Environment Protection Plan**. Overall, however, Project construction and its resulting final footprint on the physical landscape (both land and river bottom) will create an unavoidable, long-term, localized effect on the physical environment as described further in the following subsections. The **significance** of the changes to the physical environment to the aquatic, terrestrial and socioeconomic environments and resource use is discussed in those respective Supporting Volumes.

Indirect Project effects on soils, surface permafrost and ecosites in areas outside of the Project Footprint are addressed in the terrestrial habitat and ecosystems section of the TE SV.

Table 5.4-1: Summary of Lands (Area) Required for the Project and as a Percentage of the Project Footprint

Footprint Category	Area (ha)*		Percent of Footprint	
	Construction Phase	Operation Phase	Construction Phase	Operation Phase
Roads[1]	621	634	4.6%	4.6%
Road Corridors[2]	122	119	0.9%	0.9%
Infrastructure	317	208	2.4%	1.5%
River Management	27	1	0.2%	0.0%
Borrow Areas[3]	1,321	1,052	9.9%	7.6%
Camp and Work Areas	154	154	1.2%	1.1%
Excavated Material Placement Area	181	99	1.4%	0.7%
Mitigation and Compensation Area	133	--	1.0%	0.0%
Possible Disturbed Area	672	219	5.0%	1.6%
Reservoir Clearing[4]	3,602		27.0%	0.0%
Areas Unlikely to be Used[5]	945	936	7.1%	6.8%
Existing Water Surface Area[6]	5,161	5,038	38.6%	36.4%
Dewatered Area	100	100	0.7%	0.7%
Flooded Area		4,463		32.3%
Reservoir Expansion (First 30 Years)		800		5.8%
Total Construction/Operating Phase	*13,354*	*13,824*	*100.0%*	*100.0%*

Note:
1. Haul road alignments are preliminary.
2. Road corridor provide flexibility for realignment during final design and construction. Includes road corridors located outside the reservoir.
3. Area is the maximum amount of borrow area that may be used, the actual area required for construction will likely be much smaller.
4. Reservoir Clearing Area includes road corridors and unlikely to be used areas that are within the reservoir. This area excludes the mitigation and compensation area.
5. Areas unlikely to be used are areas that may be required by the designers and contractors but have a low probability of being utilized. The items includes all unlikely to be used areas outside the reservoir.
6. Existing Water Surface Area is depicted in the footprint maps within the PD SV as Altered Water Level or Flow.

5.4.1.1 Bedrock and Surficial Geology

Project construction will result in the addition and subtraction/relocation of geological materials within the local study area as discussed below and in the PD SV. Table 5.4-2 summarizes the material excavation and placement (KGS Acres 2011) associated with Project construction that will permanently alter the physiographic environment.

5.4.1.1.1 Permanent Access Roads

As detailed in the PD SV a new permanent, gravel-surfaced all weather access roads will be constructed to meet the construction, operational and maintenance requirements of the Keeyask GS, as follows:

- North access road - 25 km in length, providing primary access linking PR280 to the Keeyask construction site, on the north side of the Nelson River.

Table 5.4-2: Summary of Material Excavation and Placement Altering the Physiography

Description	Volume
Earthfill Required*	8,076,000m^3
Unclassified Excavation & Disposal	3,892,000m^3
Rock Excavation	3,217,000m^3
Cofferdam Removal	555,000 m^3
Concrete**	362,000 m^3

* Does not include earthfill required for camp

** Does not include concrete for access roads and camp

- South access road - linking the Keeyask Project to the Butnau Dam and to Gillam, on the south side of the Nelson River (approximately 14 km new road from Keeyask to Butnau Dam and 20 km upgraded roadway from Butnau Dam to Gillam).

These two access roads will be connected by a permanent crossing over the Nelson River via the Keeyask GS's north dam, powerhouse, central dam, spillway, and south dam.

The north access road was the subject of a separate submission under *The Environment Act* (Manitoba) ("Keeyask Infrastructure Project", submitted to Manitoba Conservation in July 2009). The predicted effects of this access road on the physical environment have therefore been assessed and presented. Accordingly, no further discussion is provided herein.

The south access road will be routed within the **right-of-way** to support the operational phase of the Project. Granular material for the south access road will be required for the base course, road topping and **culvert** gravel required for the access road. It will also be required for **fill** to construct the embankment over stream crossings and through permafrost affected areas. Any usable material will be excavated from the ditches and backslopes and compacted into the embankment. This would supplement material excavated from borrow pits located outside the right-of-way limits and hauled to the embankment fill areas as required. The waste material, including slash and surface organics, will be placed on the spoil banks at the top of the backslope to promote vegetation growth. It is anticipated that the majority of **granular fill** required for the south access road will be produced by crushing and screening of rock obtained from the **Quarry** Q-1 or other near surface rock deposits located in close proximity to the road's alignment. Granular material will also be obtained by crushing material that has been blasted from roadway excavations.

The north and south access roads will remain in place after the completion of the Project, resulting in an effect on the bedrock and surficial geology until at least the time of Project **decommissioning** (Section 5.6). The **duration** of this effect may be longer because Manitoba Infrastructure and Transportation has indicated it will assume ownership of these roads and responsibility for the ongoing operation and maintenance of these roads as part of the provincial transportation system. Manitoba Infrastructure and Transportation will assume ownership of the roads once construction of the Project is completed.

5.4.1.1.2 Temporary Structures

As described in detail in the PD SV, the start-up camp and main camps (both Phase I and II) will consist of various facilities and utilities. Construction materials are expected to be hauled in or extracted from local borrow areas to support the development of these camps. Details of site **rehabilitation** are discussed in the Keeyask GS Environment Protection Plan.

Construction of the Stage I **cofferdams** will involve the placement of approximately 612,100 m^3 of rockfill, granular and impervious materials, of which approximately 64% will be contained within the Stage I spillway and powerhouse cofferdams. The Stage II cofferdams will require the placement of approximately 547,000 m^3 of rockfill, granular and **impervious fill** materials, the largest proportion of which will be in the **tailrace** summer level cofferdam (268,000 m^3). It is expected that most of material required for the construction of these cofferdams will be sourced from borrow areas located on the north side of the Nelson River.

Portions of the cofferdams will be removed once the cofferdams are no longer required. For the Stage I cofferdams, this will involve removing approximately 175,000 m^3 of unclassified material as well as 136,000 m^3 of rock. The Stage II cofferdams will require removal of approximately 91,000 m^3 of unclassified material and 153,000 m^3 of rock. In total, 51% of the Stage I cofferdams and 45% of the Stage II cofferdams will be removed. Those portions of the cofferdams that are unable to be removed due to the hydraulic effects of the river during removal (*e.g.,* wash out of unclassified materials), however, will become part of the landscape and may be transported downstream as suspended sediment (see Sedimentation Sec. 7.4.1).

5.4.1.1.3 Permanent Structures

The construction of the intake/powerhouse complex and associated channels will require the excavation of approximately 1,077,900 m^3 of overburden and 1,581,000 m^3 of rock. To accommodate the spillway structures and its associated approach and discharge channels, 17,200 m^3 of overburden and 400,000 m^3 of rock will be removed.

The construction of the Project will require the manufacturing and placement of approximately 362,000 m^3 of **concrete**. The production of this much concrete requires approximately 163,000 m^3 of fine aggregates, and 320,000 m^3 of coarse aggregate. The difference in concrete volume and aggregate volume occurs because aggregates have a lower density and some concrete will be wasted.

The upstream and downstream channels for the spillway and powerhouse will require excavation of bedrock through drilling and blasting. The sides of the channels will be almost vertical. The overburden and bedrock will either be hauled to a temporary stockpile for future use as impervious or **rock fill** in the dams and dykes, or hauled for final disposal.

As described in the PD SV, materials for the construction of the dams will largely be derived from the necessary excavations or from quarries and borrow deposits. Prior to the start of the fill placement, joints and fissures in the bedrock will be sealed with grout, so as to establish a suitable surface on which to seal the dam to its foundation. This will be a permanent alteration of the local geology.

5.4.1.1.4 Excavated Material Placement Areas

As indicated above, a considerable amount of earth and rock material will be excavated during construction of the site. The majority will be used for construction; however, it is estimated that approximately 4.0 million m^3 of unclassified material and 300,000 m^3 rock material will not be utilized for construction. This material will be deposited in excavated material placement areas in the immediate vicinity of the site and will be placed within areas located near the principal structures. Some of the materials will be placed in excavated material placement areas within the reservoir and will be submerged once the reservoir is impounded. The remainder of the excavated material requiring disposal will be placed in designated areas outside the reservoir. These designated placement areas are shown Map 5.4-1.

5.4.1.1.5 Local Borrow Material Resources

The materials required for the GS and the supporting infrastructure (including camps) will include impervious fill, granular fill/crushed rock, rockfill, **riprap** and **concrete aggregate** obtained from a number of sources. As indicated in Section 2.3.2.3, borrow deposits can be exploited within the Project site, both on the north and south bank of the Nelson River (Map 5.3-3). Similarly, potential quarry sites are located within the Project site area at both the north (Site Q7) and south bank (Sites Q1 and Q8) of the Nelson River.

The clearing estimate for the granular borrow sources is based on clearing the ground surface to exploit the required suitable fill materials within the limits of each deposit that is located outside the limits of the reservoir (Table 5.4-3; KGS Acres 2011). Borrow areas E-1 (40 ha), S-5 (3 ha), S-4 (42 ha), S-17b (1 ha) and S-11 (266 ha) (total area of 352 ha) are unlikely to be used, but depending on the contractors actual construction plans, they may be required and are therefore included in the Project footprint in Table 5.4-1 (part of the Areas Unlikely to be Used footprint of 945 ha) but not in Table 5.4-3.

Table 5.4-3: Estimated Borrow and Quarry Area Utilization

Borrow Area	Total Area (ha)	Estimated Utilization Area (ha)	Percent of Total Available Area
G-1	209	11	5%
G-3	283	10	3.5%
Q1	39	39	100%[1]
Q7	45	45	100%[1]
Other Quarries (Q8+Q9)	13	13	100%[1]
N-5	94	94	100%[1]
N-6	83	3	4%
N-21	182	58	32%
S-2	248	51	21%
S-17	40	12	30%
S-18	85	13	15%

1. Quarries assumed to have entire area disturbed.

As previously indicated, construction of the cofferdams will involve the placement of rockfill, granular and impervious materials and it is expected that virtually all of the construction materials required for the cofferdams will be sourced from borrow areas located on the north bank of the river.

The north and south dykes will extend on both sides of the river upstream of the Keeyask GS approximately 11.6 km and 11.2 km, respectively, from their respective tie points with the north and south dams. As detailed in the PD SV, each dyke is divided into sections utilizing one of four different designs: zoned **impervious core** embankment dyke, **freeboard dyke**, granular dyke or road section. The volume of the north and south dykes comprise nearly 41% of the total fill placement for the Project.

The proposed Keeyask Project will also utilize a **transmission tower spur** to support the foundations for the first row of transmission towers on the downstream side of the powerhouse. At present, it is planned that the spur would be located along the southern edge of the tailrace channel. The transmission tower spur will require 148,000 m^3 of earth fill.

During construction of the permanent structures, the intent is to maximize the use of rock obtained from the excavations required for the construction of the primary concrete structures (PD SV). The exact locations and details for sourcing and processing the required construction material will be left to the discretion of the contractors. Table 5.4-4 summarizes all potential borrow sources that will, or may be, used.

These resources are non-renewable, however, as indicated in Table 5.4-3 and discussed in the PD SV, the estimated quantity of material to be used in construction is a small fraction of that which is locally available.

Table 5.4-4: Preliminary Borrow and Quarry Material Utilization Plan

Project Component	Impervious Borrow Sources[1]						Granular Borrow Sources[1]			Rock Quarries[1]			
	N-5	N-6	N-21	S-2	S-17	S-18	G1	G2	G3	Q1	Q7	Q9	Other[2]
South Access Road[3]				317,870						240,000		240,000	475,300
Local Site Roads	107,590				106,730		211,300			93,790	44,600		76,920
Stage 1 Cofferdams			203,710				82,050				236,320		
GCC Cofferdams	70,630		98,780				37,630		23,650				241,870
Permanent Construction Dams and Permanent Structures	733,230		21,450	195,220			118,700		102,730	112,540			1,091,110
Permanent Dykes	166,780	80,000	40,450	187,730	62,580	62,580	424,680		862,865	456,750			366,990
Aggregate for Concrete									197,520				
Additional Quarried Rockfill											205,100		

Note:

(1) All volumes are in cubic metres (bank cubic metres; i.e., undisturbed condition in the borrow/ quarry area)

(2) Sourced from rock excavations from powerhouse and spillway area or other quarries.

(3) Borrow sources for south access road are currently being evaluated.

Following construction, the borrow sites listed in Table 5.4-4 will be rehabilitated as described in *The Environment Protection Plan* and the *Manitoba Mines and Minerals Act* (1991; C.C.S.M. c.M162).

5.4.1.1.6 Assessing Environmental Sensitivity of Borrow and Quarry Rock Material

Acidic leachate is generated as a result of the oxidation of sulphur compounds (*i.e.*, formation of sulphuric acid) once previously unexposed rock is exposed to atmospheric oxygen. Sulphide oxidation may also results in release of trace metals. Depending on the nature of the acid generation, it may appear shortly after the rock is exposed to the air, or may require a number of years to appear (MEND 1991).

The suitability of the local construction materials (*i.e.,* granular materials and rock) for placement in an aquatic or terrestrial environment was assessed to consider potential effects on the physical environment. The goal of the assessment was to investigate the potential of these local construction materials to generate acidic leachate. The approach adopted was similar to that undertaken previously on other Manitoba Hydro GS projects (*e.g.,* Wuskwatim). In general, this approach involved the selection of appropriate samples for submission to a Canadian Association for Environmental Analytical Laboratories (CAEAL) accredited laboratory for analysis and the subsequent review of the analytical results.

In total, 25 granular and 16 rock samples from the Keeyask GS area were selected for laboratory testing. Samples were shipped to Maxxam Analytics in Burnaby, BC, for testing in spring 2010 (granular borrow samples, specific and bulk rock samples) and winter 2010-2011 (specific and composite rock samples). The analysis requested for the granular materials included soluble metals using MEND guidelines for water-extractable metals (MEND 2000). The requested analyses on the rock samples included total sulphur, sulphate, neutralization potential and metal content using standard Maxxam methods and quality assurances and quality control procedures (Sobek *et al.,* 1978, MEND 1991).

With respect to the quarry rock, there are a number of different indicators for the generation of acidic drainage and therefore a weight-of-evidence approach is typically applied. Using this approach, the assessment of the Keeyask rock samples concluded that the risk of acidic drainage is low.

The analytical results indicated that aluminum (Al), copper (Cu), chromium (Cr), cadmium (Cd) and iron (Fe) are metals of concern associated with the granular material. While it is not expected that the use of the granular material will pose an environmental concern, attention to the final fate of the specific granular materials will be required and, as necessary, runoff and/or seepage quality may need to be predicted to ensure proper dilutions of the identified metals of concern are achievable in the receiving environment.

5.4.1.2 Soils and Peatlands

The land areas in this and the following section will differ from those in Table 5.4-1 because they include land areas only (*i.e.*, deeper portions of waterbodies are excluded). The total area of land required for the construction of the Project supporting infrastructure and permanent facilities is approximately 7,711 ha, of which 7,434 ha is soils and peatlands. Most of this Project Footprint is peatland (Table 5.4-5). The peatland proportion is much lower for Project Footprint than for the local study area as a whole because the non-flooding footprints are concentrated on mineral surface deposits (Table 5.4-1).

Project construction will require clearing and/or grubbing of lands within the footprint. Up to 5,070 ha of the footprint would need to be cleared just for the reservoir and borrow/quarry areas, comprised of 3,397 ha of upland an peatland in the reservoir and 1,673 ha of borrow/quarry area (total of all borrow/quarry areas, including those unlikely to be used). Clearing on borrow/quarry areas that are likely to be used is expected to be much lower than the total area based on the estimated utilization area of 349 ha (Table 5.4-3). However, actual utilization and clearing requirements are not yet known because the exact locations and details for sourcing and processing the required construction material will be left to the discretion of the contractors. Clearing will involve the removal of woody material including bushes and trees while grubbing will include the additional removal of all root systems in the area. Grubbing will only be undertaken where essential, including the area where the access roads and drainage ditches are located and the site infrastructure area. The flooded areas will be cleared of vegetation but not grubbed.

Table 5.4-5: Coarse Ecosite Composition of the Project Footprint as a Percentage of Land Area

Coarse Ecosite	Project Footprint
Mineral	17
Thin Peatland	37
Shallow Peatland	21
Ground Ice Peatland	13
Deep Peatland	3
Riparian Peatland	6
Shoreline Wetland	3
All	100
Total Upland and Peatland Area (ha)	7,434
Total Shoreline Wetland Area (ha)	277
Total Land Area (ha)	7,711

Clearing will also be required for the excavated material placement areas (*i.e.,* areas to receive surplus unclassified material; see Section 5.4.1.1) outside the perimeter of the principal structures and dyke line.

Topsoil, cleared from the borrow pits, which supports vegetation will be stockpiled for replacement after required borrow material has been excavated.

Any service roads on site not required after the completion of the Project will be removed and the landscape rehabilitated.

With respect to temporary Project areas, studies conducted in existing borrow areas created for highway maintenance and past Hydro projects show that there is very limited long-term vegetation and soil recovery and that soil erosion can be substantial. Similar but lesser effects are expected at other temporary Project areas, such as the camp and work areas. The portions of temporary trails that are most susceptible to long-term conversion are the ice-cored peatlands. Patchy long-term effects are expected in the shallow peatlands.

Some lands will be fully rehabilitated and others will be partially rehabilitated, depending on the final land use (PD SV). General rehabilitation requirements are presented in the Keeyask GS **Environmental Protection Plan** (**EnvPP**) and detailed rehabilitation plans will be developed.

5.4.1.3 Permafrost

Vegetation clearing and soil disturbance associated with Project construction will lead to surface permafrost melting and long-term conversion to other ecosite types in some areas. Extensive discontinuous and continuous surface permafrost occur in 13% of the Project footprint land area. Table 5.4-6 shows that sporadic discontinuous surface permafrost is found in approximately 56% of the Project footprint.

Permafrost affected soil will likely be encountered sporadically throughout the length of the south access road. To address this issue, the road embankment will be constructed within these areas by using granular fill material placed directly on top of the unstripped peat. To mitigate the anticipated subsidence (settlement) of these sections of the access road, additional granular fill will be placed as required during construction. Where sub grade conditions are poor, geotextiles will be used as a separation between the granular fills and the underlying sub grade.

Table 5.4-6: Permafrost Distribution in the Project Footprint as a Percentage of Land Area

Permafrost Type	Project Footprint
Continuous	1
Extensive Discontinuous	12
Sporadic Discontinuous	56
Isolated Patches	1
None	30
All	100
Total Land Area (ha)	7,711

Additionally, as detailed in the PD SV, all-weather gravel service and haul roads will be developed to provide access for construction equipment between the construction areas, the borrow areas, and the excavated materials placement areas. The precise layout and extent of these haul roads is unknown at this time and will be subject to the construction methodology developed by the Contractor. Particular care will be taken in areas of permafrost to prevent thawing. Service roads not required for operation will be closed and rehabilitated in accordance to the EnvPP.

5.4.1.4 Seismic Activity

The proposed Project is located in an area of very low seismicity (Section 5.3.5), where no major earthquakes, and hence no significant earthquake-generating fault movements, have occurred since historical records began in the 1600. Further, there has been no pattern of microseismic events recorded in the local study area. The proposed Project is not likely to affect, or be affected by, the existing very low seismic activity in northern Manitoba.

5.4.1.5 Post-Glacial Rebound

As discussed in Section 5.3.6, current data and models suggest post-glacial rebound rates between 2.5 mm/year and 5 mm/year for the local study area. The proposed Project will not affect, nor be affected by, post-glacial rebound.

5.4.2 Operation

The completion of the proposed Keeyask Project will result in water levels rising from about 140.2 m to 159.0 m in the immediate reservoir of the GS resulting in an initial inundation of 45 km² between the outlet on Stephens Lake to Clark Lake (Map 5.4-2). The reservoir will expand over time due to **peatland disintegration** and shoreline erosion increasing the reservoir area by about 7 km² to 8 km². As shown in Table 5.4-1, flooding accounts for a high percentage of the Project footprint area and is an unavoidable effect of the Project. As a result of the Project, Gull Rapids will no longer exist. This is also an unavoidable effect of the Project. The significance of these changes to the aquatic, terrestrial and socioeconomic environments and resource use is discussed in the other supporting volumes.

5.4.3 Decommissioning of Generating Station

Two stages of decommissioning are outlined below. The construction phase refers to the removal of equipment following completion of the Project. This phase is outlined in the schedule provided in PD SV. The decommissioning of the generating station outlines the plan in place when the Keeyask GS is no longer in service.

5.4.3.1 Decommissioning of Construction Resources

As indicated in the PD SV, the completion of the Keeyask GS is anticipated to occur in 2022. Some lands will be fully rehabilitated and others will be partially rehabilitated depending on the final land use. Borrow sites will be rehabilitated as described in *The Environment Protection Plan* and the *Manitoba Mines and Minerals Act* (1991; C.C.S.M. c.M162).

5.4.3.2 Decommissioning of the Generating Station

As discussed in the PD SV, if and when the project is decommissioned at some future date, it will be done so according to legislative requirements and industry standards prevalent at that time.

5.4.4 Residual Effects

Residual effects of the Project with respect to physiography are summarized below in Table 5.4-7.

Table 5.4-7: Summary of Physiography Residual Effects

RESIDUAL EFFECTS	Magnitude	Extent	Duration	Frequency
During the construction phase, the Project will have a footprint of 8,193 ha, or 3.3%, of the local study area, where reservoir clearing accounts for the highest percentage of the Project Footprint area during construction, followed by borrow areas and quarries. During the operating phase the footprint is predicted to expand by 800 ha (6.3%) due to shoreline erosion and peatland disintegration. (Note: 800 ha is predicted during the first 30 years of operation.)	Large	Small	Long-Term	Continuous
Approximately 8.08 million m^3 of earthfill will be removed from the landscape and permanently relocated to construct the Project. These resources are non-renewable, however, the estimated quantity is a small fraction of that which is locally available.	Large	Small to Medium	Long-Term	Continuous
Approximately 3.2 million m^3 of rock will be excavated from Gull Rapids and nearby quarries resulting in permanent changes to the local geology.	Large	Small	Long-Term	Continuous
Construction of the Principal structures (dykes, powerhouse, spillway) and supporting infrastructure (roads) will alter the physiographic environment.	Large	Small	Long-Term	Continuous

RESIDUAL EFFECTS	Magnitude	Extent	Duration	Frequency
Approximately 7,434 ha of soils and peatlands will be affected by clearing activities required for the Project. Clearing inside the reservoir prior to reservoir impoundment accounts for 3,446 ha (46%) of the total clearing.	Large	Small	Long-Term	Continuous
Melting of surface permafrost will occur in areas where vegetation is cleared and soils disturbed for the construction of supporting infrastructure.	Large	Small	Long-Term	Continuous

5.4.5 Interaction with Future Projects

This section will consider the interactions of the Project effects with reasonably foreseen and relevant future projects and activities and their effects.

There are several foreseeable projects in the area, including the following:

- Proposed Bipole III DC **Transmission Line**.
- Proposed Keeyask Construction Power and Generation Outlet Transmission Lines.
- Potential Conawapa GS.

The potential Conawapa station is located downstream of Keeyask. The Conawapa station physical footprint would have no spatial overlap with the Keeyask GS Project footprint. A brief description of these projects is provided in the Keeyask Generation Project: Response to EIS Guidelines document (Chapter 7).

Bipole III is proposed as a 500-kV high voltage direct current (HVDC) transmission line from a new convertor station near the potential east side of the City of Winnipeg. The Bipole project is a separate project and is undergoing a separate environmental review. Similarly, the **construction power** and generation outlet transmission lines comprise a separate project that will have its own EIA and regulatory review. This project consists of a 138 kV transmission line from an existing power line to the proposed Keeyask GS (to provide **power** for construction purposes) and three transmission lines from the proposed Keeyask GS to the existing Radisson convertor station which will provide a connection from the Keeyask GS to the Manitoba Hydro **transmission** system.

5.4.5.1 Soils and Peatlands

Soil and peatland effects during the construction and operation phases of the proposed foreseeable transmission projects would overlap spatially and temporally with the Keeyask GS Project. As noted in the introduction, Project effects on soils and peatlands are addressed in the TE SV because of the strong interaction between soils and vegetation, and because an ecosystem analysis that considers other indirect effects (*e.g.,* groundwater changes) is required to analyze interaction effects on soils and peatlands.

5.4.5.2 Permafrost

Surface permafrost effects during the construction and operation phases of the proposed foreseeable transmission projects would overlap spatially and temporally with the Keeyask GS Project. As noted in the introduction, Project effects on surface permafrost are addressed in the TE SV because of the strong interaction between surface permafrost and vegetation, and because an ecosystem analysis that considers other indirect effects (*e.g.,* groundwater changes) is required to analyze interaction effects on surface permafrost.

5.4.6 Environmental Monitoring and Follow-Up

Physiography specific monitoring and follow-up is not proposed for the Keeyask Project. Certain aspects of the Project related to physiography, such as revegetation of work areas, will be monitored under the Terrestrial Environment studies.

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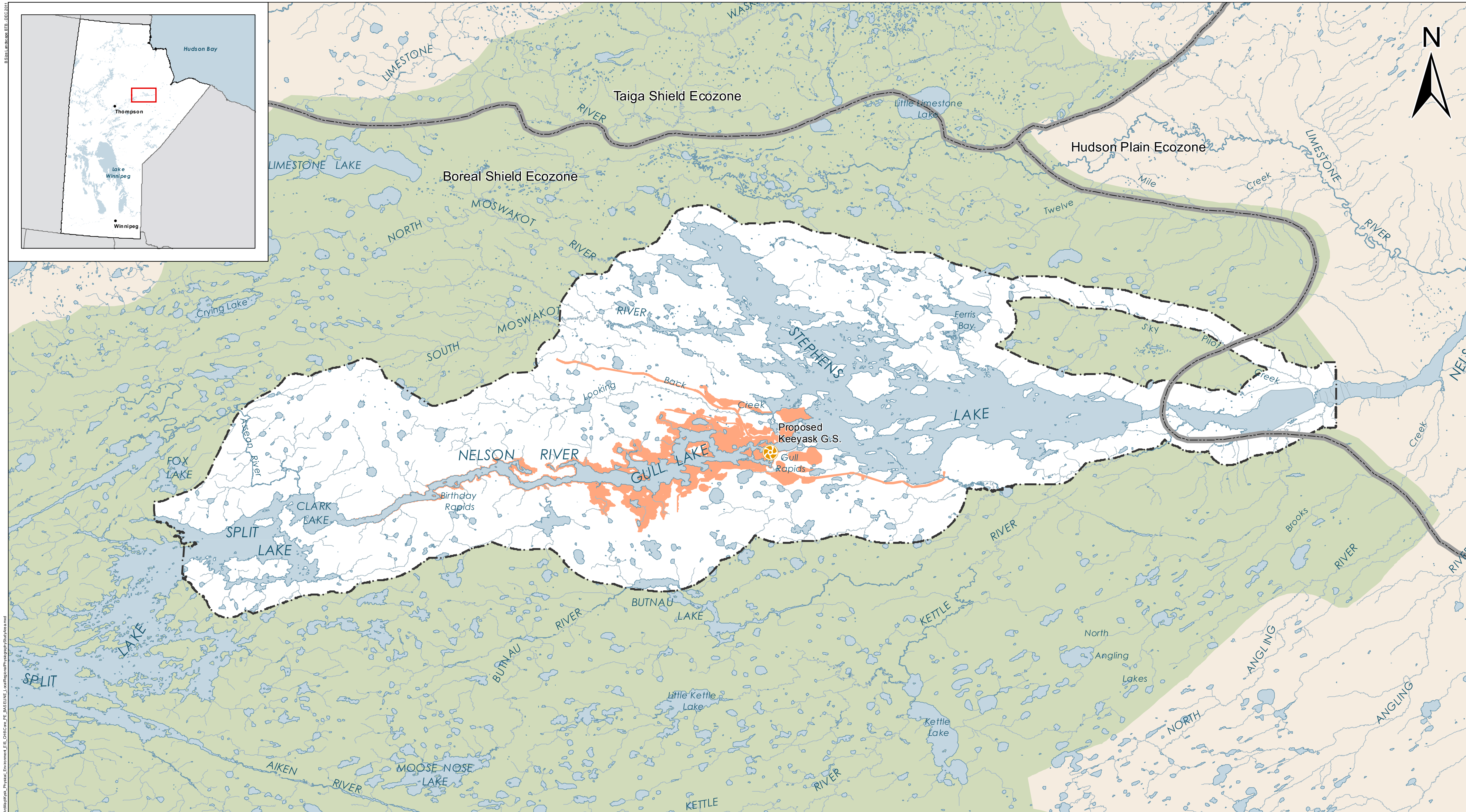

DATA SOURCE:
Province of Manitoba, Manitoba Hydro, Stantec Consulting Ltd., NTS, Natural Resources Canada.

CREATED BY:
Stantec Consulting Ltd.

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0 4 8 Kilometres / 0 3 6 Miles	VERSION NO: 1.0	QA/QC: APPROVED

Legend

- Generating Station (Planned)
- Project Footprint and Surrounding Areas (intensely studied)
- Local Study Area
- Regional Study Area
- Ecozone
- Waterbody

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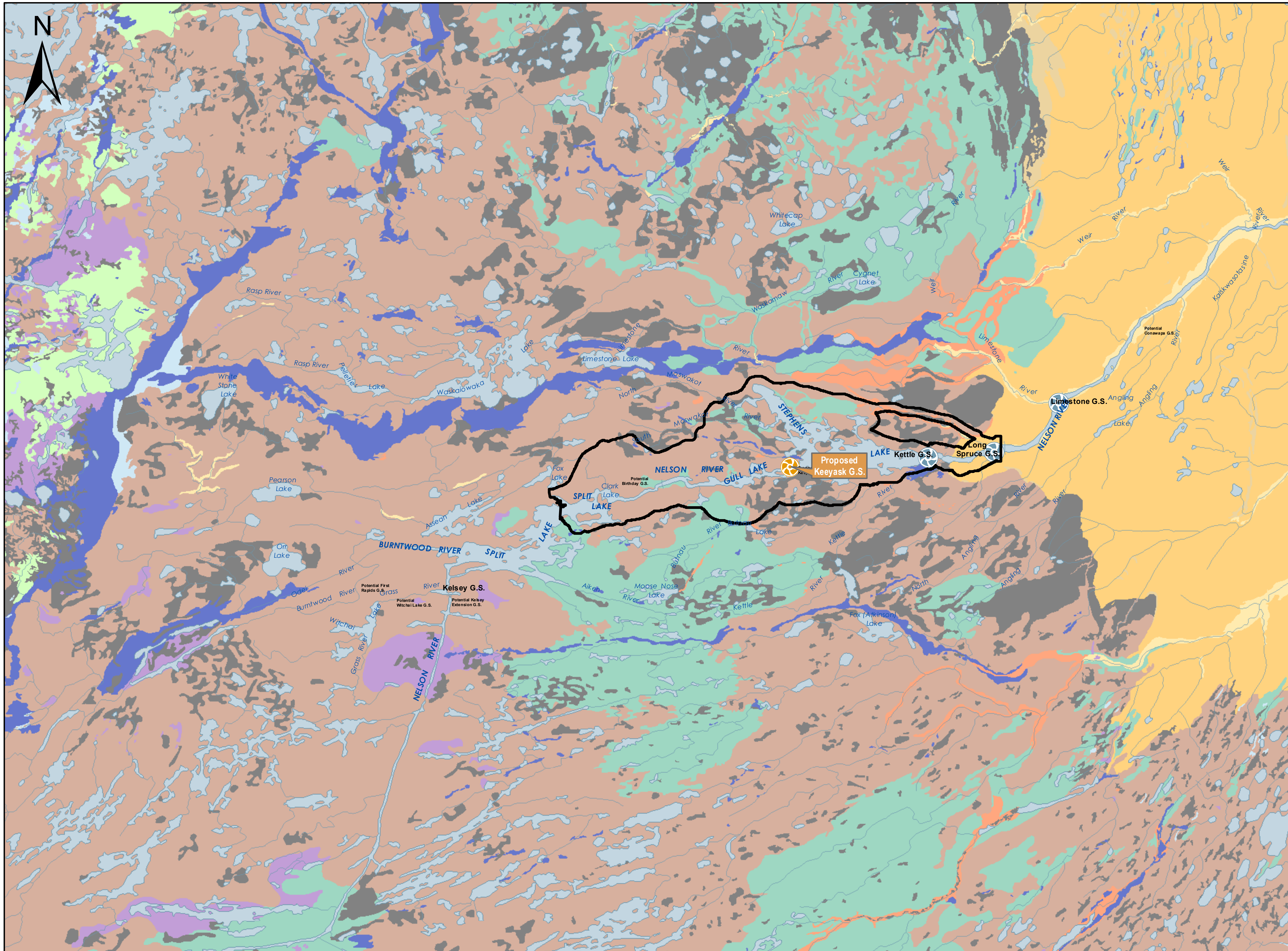
Local and Regional Physiography Study Areas

Map 5.2-1



Legend

Study Areas

- Local Study Area

Soil Parent Material

- Organic Deposits
- Shoreline Sediments
- Colluvium
- Eolian
- Alluvial Sediments
- Marginal Glaciomarine Sediments
- Offshore Glaciomarine Sediments
- Marginal Glaciolacustrine Sediments
- Offshore Glaciolacustrine Sediments
- Distal Glaciofluvial Sediments
- Proximal Glacialfluvial Sediments
- Clay Diamict
- Silt Diamict
- Sand Diamict
- Mesozoic Terrane
- Paleozoic Terrane
- Precambrian Terrane

Generating Stations

- Existing G.S.
- Planned G.S.

Projection: NAD 83, UTM Zn 15N
Data Source: Surficial Geology of Manitoba (Manitoba Geological Survey), Manitoba Hydro, ECOSTEM Ltd.

0 10 20 40 km
0 5 10 20 30 mi

Surface Material Deposition Mode

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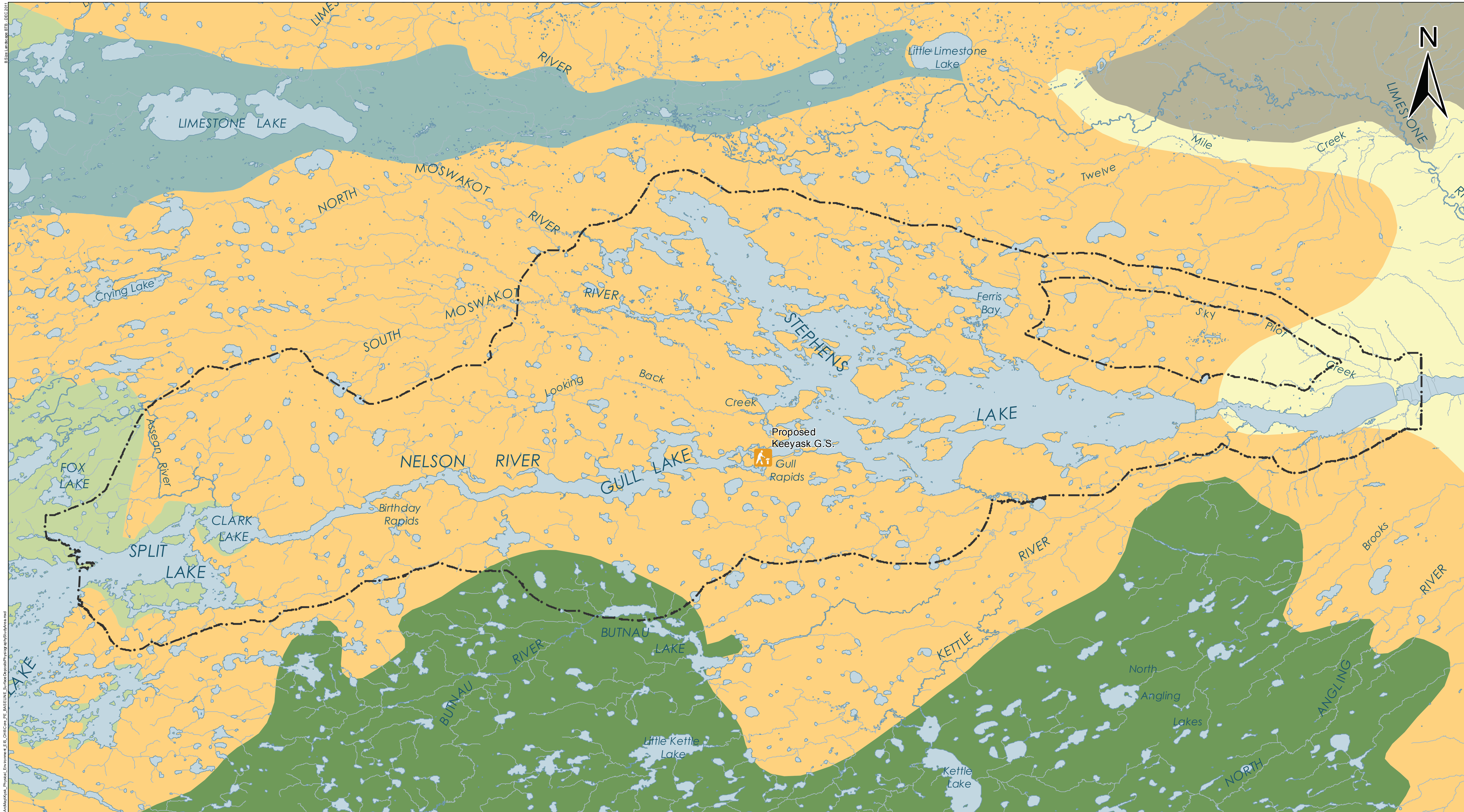
Map 5.3-1



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DATA SOURCE:
Province of Manitoba, Manitoba Hydro, Stantec, Consulting Ltd., NTS, Natural Resources Canada, Soil Landscapes of Canada (Version 2.2), Agriculture and Agrifood Canada, ECOSTEM.

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Stantec Consulting Ltd.

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UTM NAD 1983 Z15N	13-JAN-10	10-FEB-12
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Legend

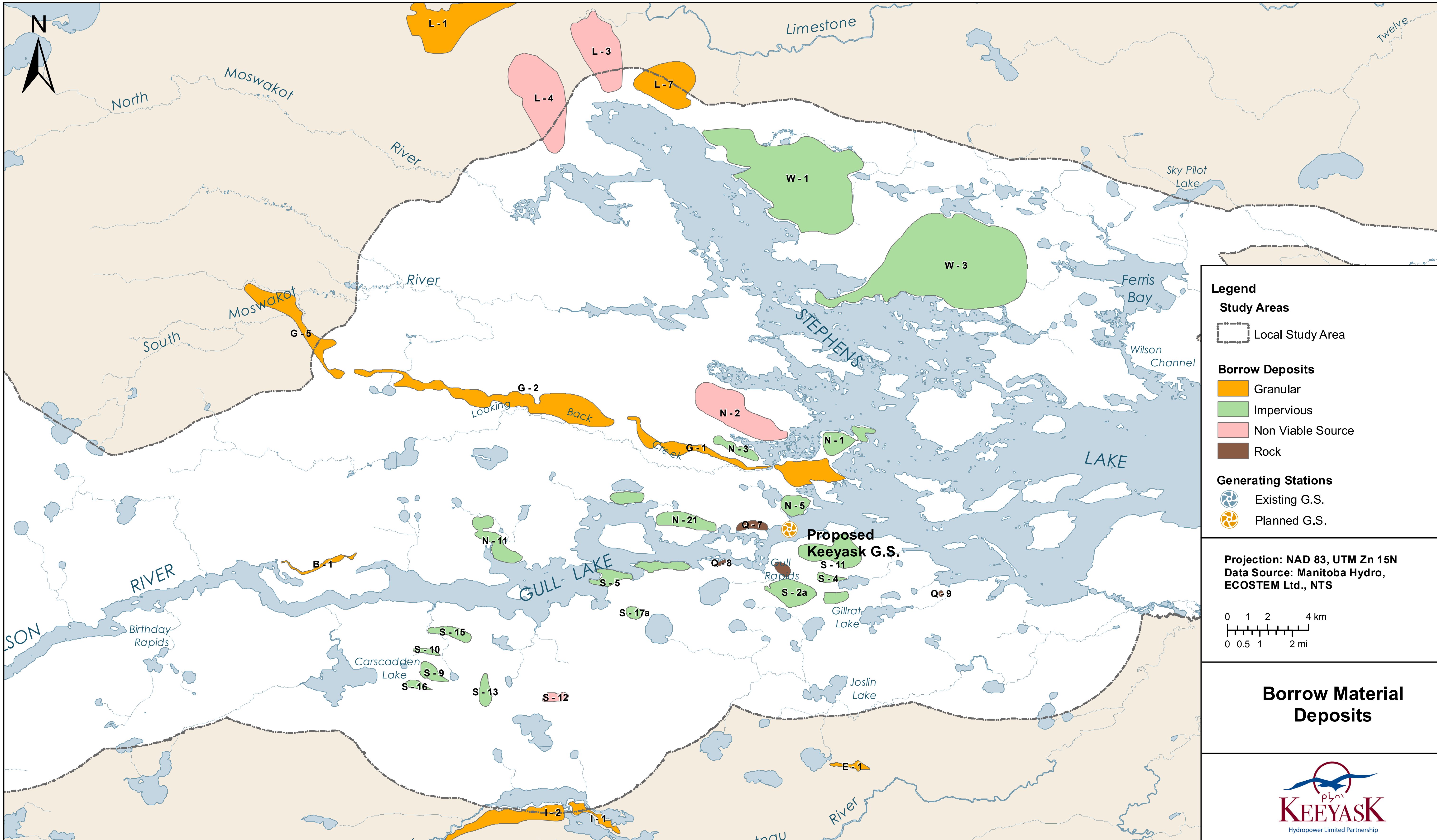
- Generating Station (Planned)
- Local Study Area
- Waterbody

Soil Parent Material

- Fluvioglacial
- Lacustrine
- Lacustrine - Mesic Woody Forest
- Morainal
- Mesic Woody Forest
- Mesic Woody Forest - Morainal
- Mesic Woody Forest - Lacustrine
- Mesic Woody Forest - Mesic Sedge

Surface Deposits in the Physiography Study Area

Map 5.3-2



Borrow Material Deposits

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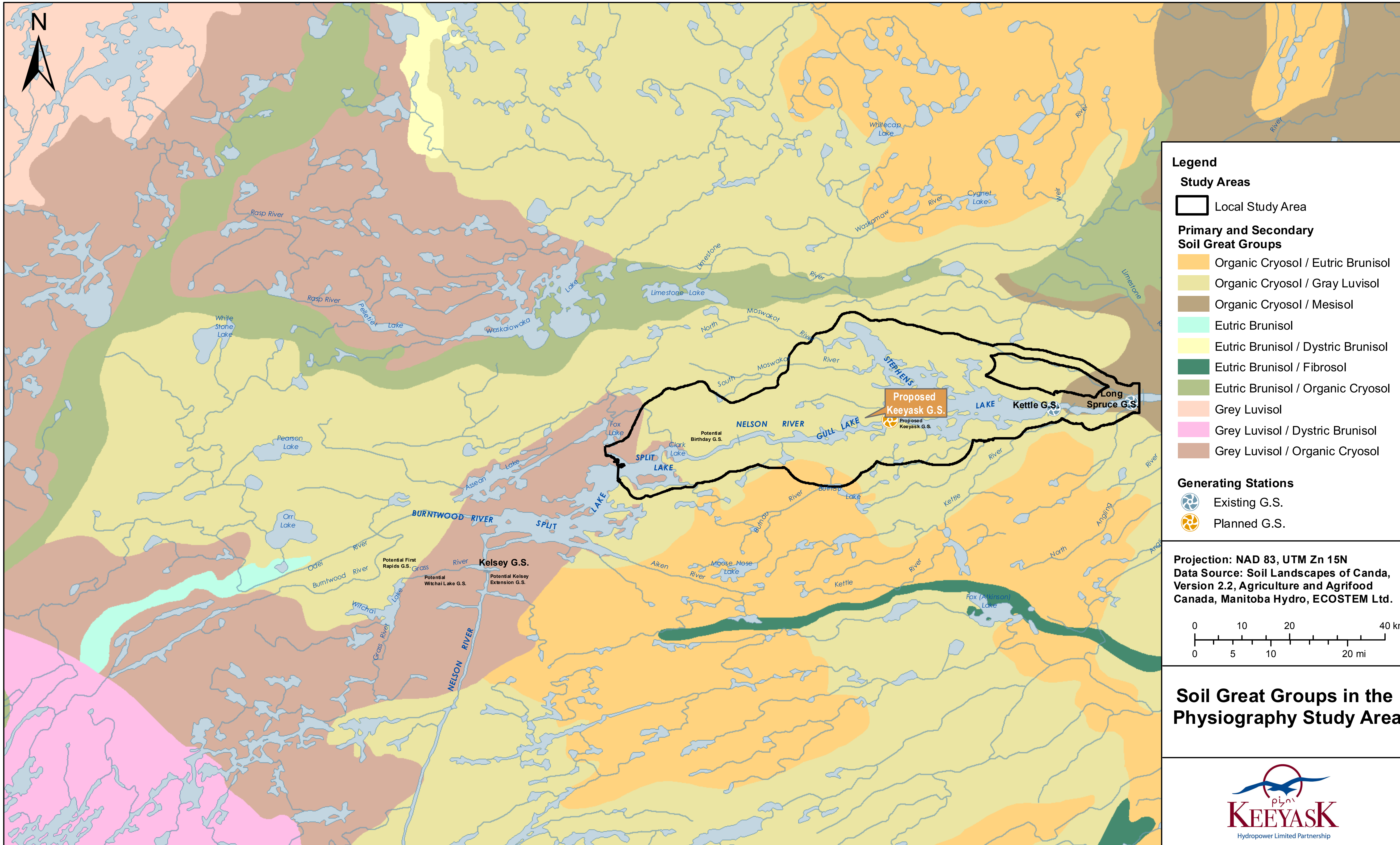
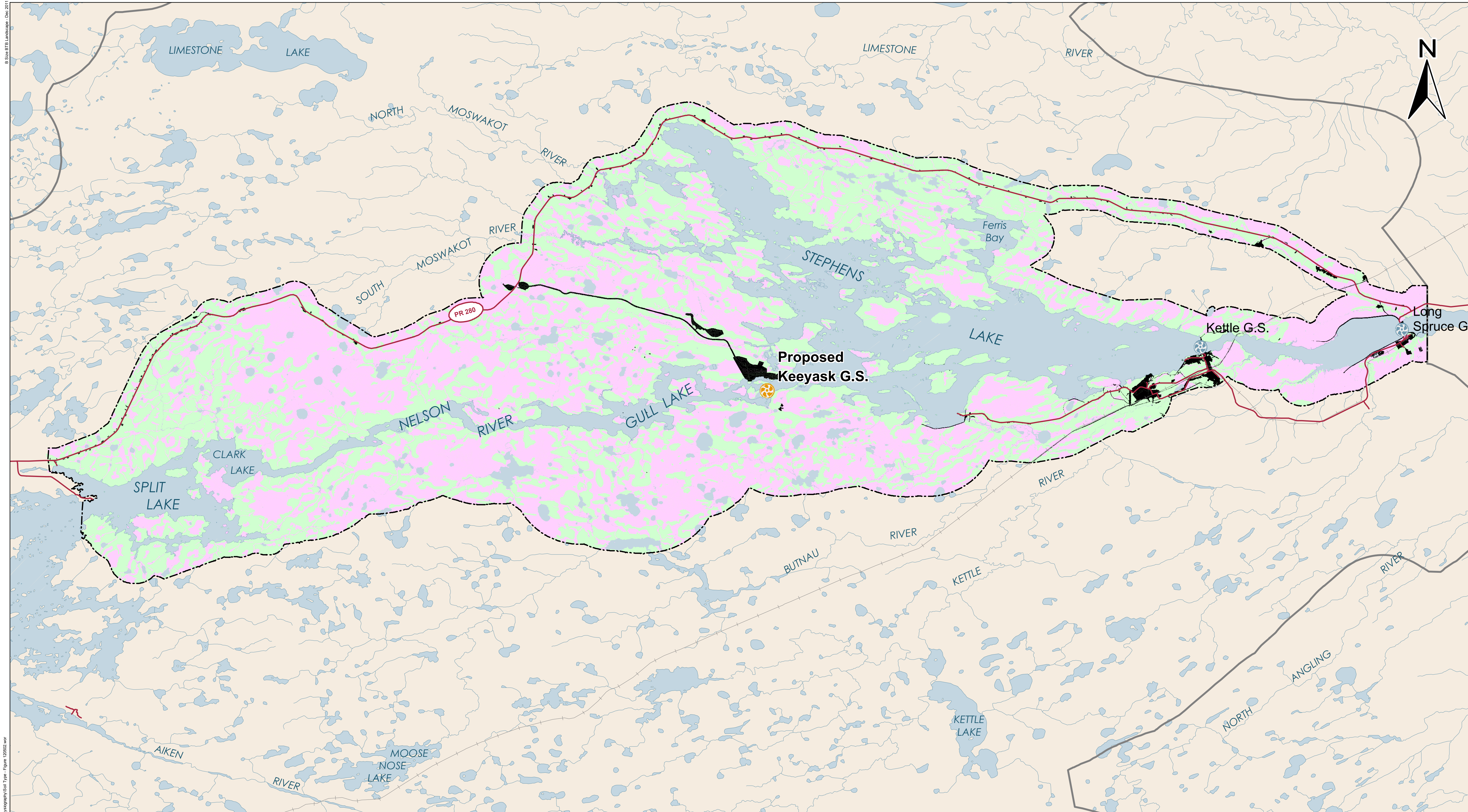
Map 5.3-3



Soil Great Groups in the Physiography Study Area



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DATA SOURCE:
Study areas, soil data and Nelson River shoreline - ECOSTEM Ltd.; Water - NTS; Roads and rail - Manitoba Conservation.

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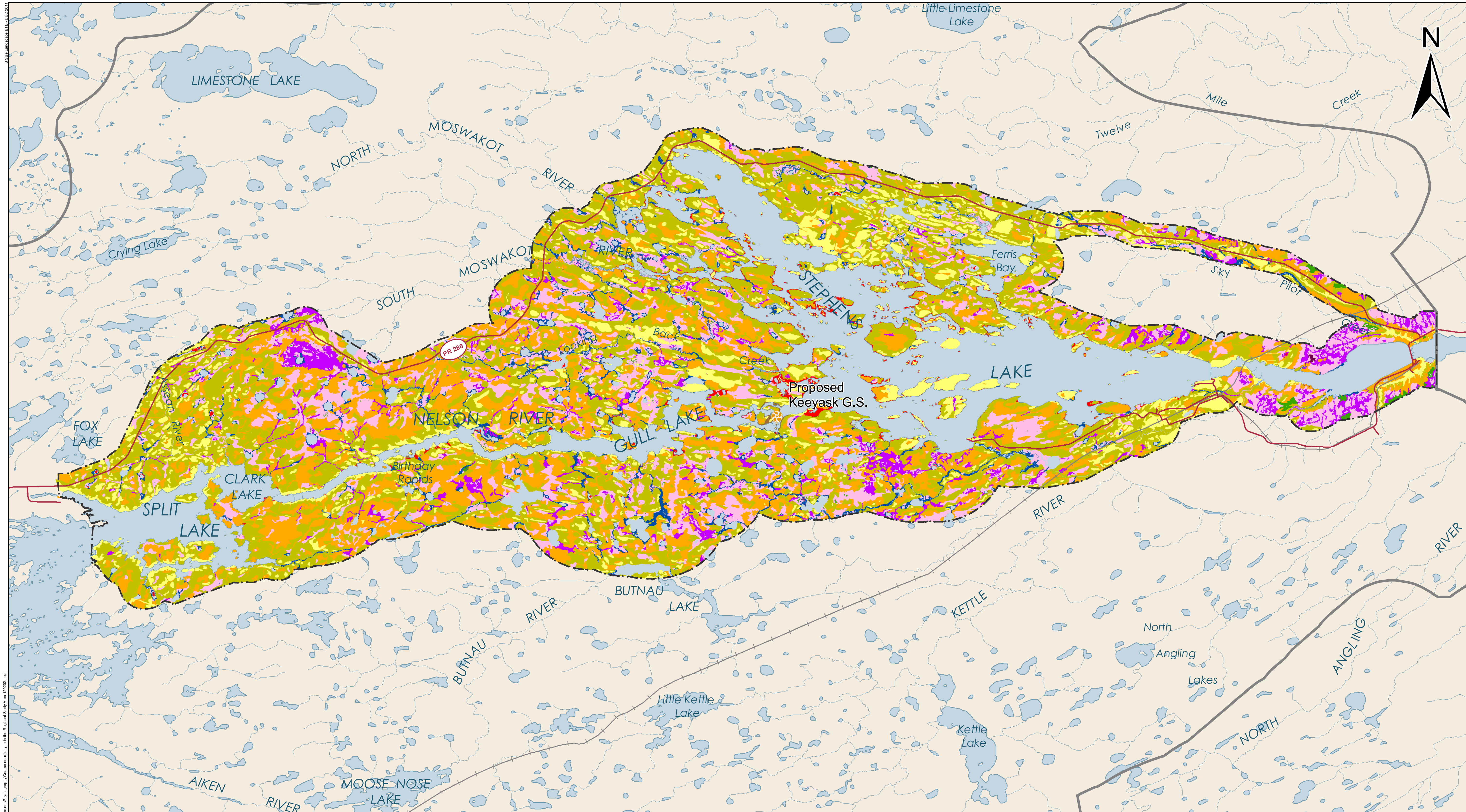
0 4 8 Kilometres / 0 2 4 Miles	**VERSION NO:** 1.0	**QA/QC:** APPROVED

Legend
Soil Type
- Non-soil
- Mineral or Thin Peatland
- Peatland
- Water

- Physiography Local Study Area
- Physiography Regional Study Area

Soil Type

Map 5.3-5



DATA SOURCE:
Study areas, ecosite data and Nelson River shoreline - ECOSTEM Ltd.; Water - NTS; Infrastructure - Manitoba Hydro; Roads and rail - Manitoba Conservation.

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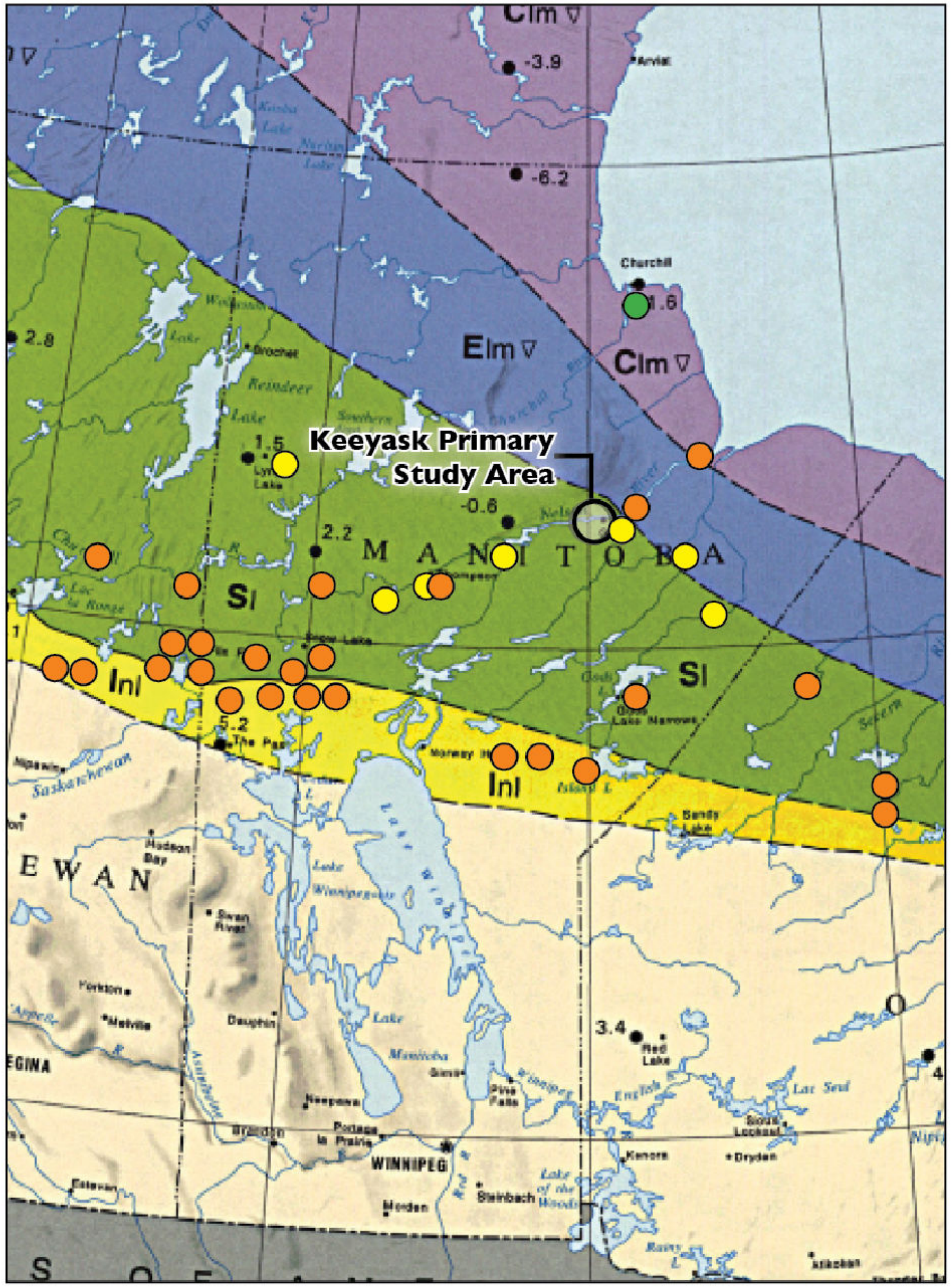
Legend

Coarse Ecosite
- Mineral
- Thin Peatland
- Shallow Peatland
- Ground Ice Peatland
- Permafrost Peatland - Other
- Deep Peatland
- Wet Deep Peatland
- Riparian Peatland
- Ice Scour - Mineral
- Shoreline Wetland
- Waterbody

- Physiography Local Study Area
- Physiography Regional Study Area

Coarse Ecosite
in the Physiography Local Study Area



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PERMAFROST AND GROUND ICE

Extent of permafrost (% of land area underlain by permafrost)

Ground ice content in the upper 10-20 m of the ground (% by volume of visible ice)

Includes segregated ice, intrusive ice, reticulate ice veins, ice crystals and ice coatings on soil particles

	High (>20%)		Medium (10-20%)		Low (<10%)		Nil (0%)
Continuous Permafrost (90-100%)	Ch	Cmh	Cm	Clm	Cl		
Extensive Discontinuous Permafrost (50-90%)			Em	Elm	El	Enl	
Sporadic Discontinuous Permafrost (10-50%)				Slm	Sl	Snl	
Isolated Patches (0-10%)				Ilm	Il	Inl	In
No Permafrost (0%)							
Subsea Permafrost				Olm			

Boundaries of permafrost and ground ice units
Defined (derived from physiographic boundaries, after Bostock, 1970)
Gradational or estimated (derived in part from permafrost zone boundaries, after Brown, 1978)

General distribution of known occurrences of large bodies of ground ice
▼ ▽ Ice wedges (abundant, sparse)
Massive ice bodies (abundant, sparse)
Pingo ice (abundant, sparse)

Permafrost temperature (°C)
● -3.0 Mean annual ground temperature at base of the layer of annual temperature fluctuations

Permafrost thickness (m)
■ 100 Measured or interpolated
■ (120) Extrapolated or calculated
■ 140/175 Range of thickness in nearby boreholes
◆ 680 Thickness of subsea permafrost
Glaciers

EXPLANATION OF LEGEND

Variations in the extent of permafrost are shown by colours (hues). Variations in the amount of ground ice are shown by colour intensity and, for the large bodies of ground ice, by symbols. Letter codes assist in determining to which basic permafrost and ground ice class any particular unit belongs. The symbols for the large bodies of ground ice are an essential component of the definition of the map units. For example,

Elm ▽

indicates a unit underlain by extensive discontinuous permafrost with low to moderate ice content, and characterized by sparse ice wedges, no massive ground ice, but abundant pingo ice.

Research by J. A. Heginbottom, Terrain Sciences Division, Geological Survey of Canada, Natural Resources Canada. Additional research and adaptation for the National Atlas of Canada by M. A. Dubreuil and P. T. Harker, National Atlas Information Service, Geomatics Canada, Natural Resources Canada. Cartography and production support by A. Caron, P. Paul and I. Rose, National Atlas Information Service.

Permafrost Extent Source: National Atlas Information Service, Canada Centre for Mapping, Geomatics Canada, and Terrain Sciences Division , Geological Survey of Canada, Natural Resources Canada. Printed 1995

Permafrost Thickness (m)

- 50-100
- 10-50
- <10

Permafrost Thickness Source: Natural Resources Canada. Geological Survey Canada 2006

KEEYASK Hydropower Limited Partnership

DATA SOURCE: Natural Resources Canada - Geological Survey of Canada Printed in 1995, accessed in 2006. Note: Map scale may not be accurate			
CREATED BY: Stantec Consulting Ltd.			
COORDINATE SYSTEM: UTM NAD 1983 Z15N		DATE CREATED: 18-JUL-11	REVISION DATE: 18-JAN-12
0 80 160 Kilometres; 0 60 120 Miles		VERSION NO: 1.0	QA/QC: APPROVED

Permafrost Thickness and Distribution in Manitoba

Map 5.3-7

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DATA SOURCE:
Study areas, permafrost data and Nelson River shoreline - ECOSTEM Ltd.; Water - NTS; Infrastructure - Manitoba Hydro; Roads and rail - Manitoba Conservation.

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0 2 4 Kilometres / 0 3 6 Miles	VERSION NO: 1.0	QA/QC: APPROVED

Legend

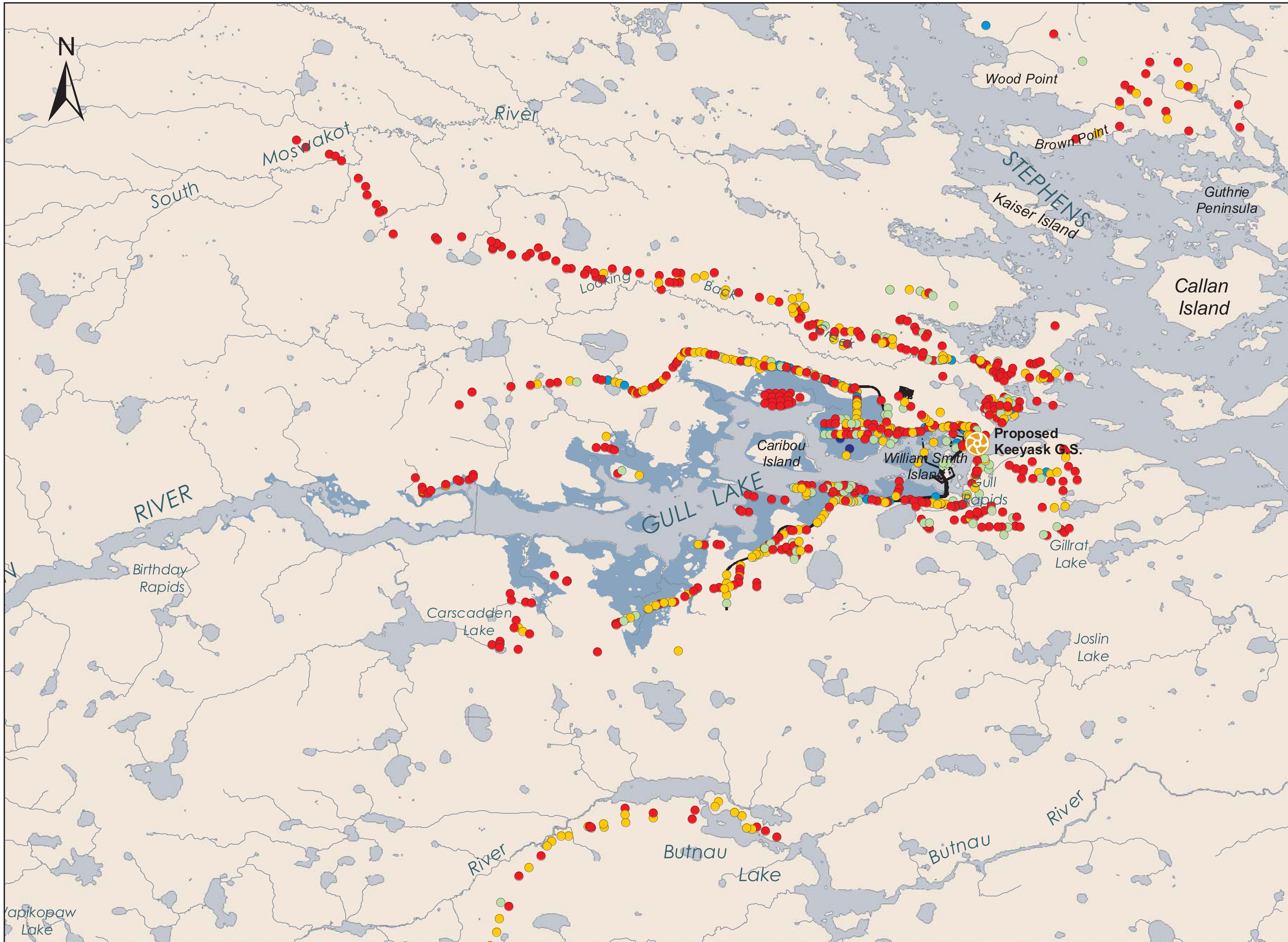
Permafrost Continuity

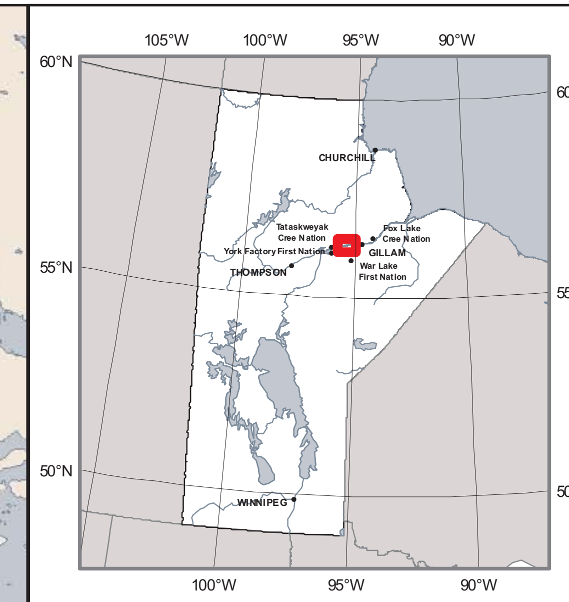
- Continuous
- Extensive Discontinuous
- Sporadic Discontinuous
- Isolated Patches
- None

- Physiography Local Study Area
- Physiography Regional Study Area

Surface Permafrost
in the Physiography Local Study Area

Map 5.3-8





Legend

Depth to Bottom of Permafrost

- 0.05 - 1.61 meters
- 1.61 - 3.54 meters
- 3.54 - 6.87 meters
- 6.87 - 14.67 meters
- 14.67 - 27.18 meters
- Area of Impoundment
- Potential G.S.

Projection: UTM Zone 15,NAD 1983
Data Source: Manitoba Hydro and NTS of Canada

0 2.5 5 10 Km
0 1.25 2.5 5 Miles

Depth to Bottom of Permafrost as Observed from Field Drilling Investigations

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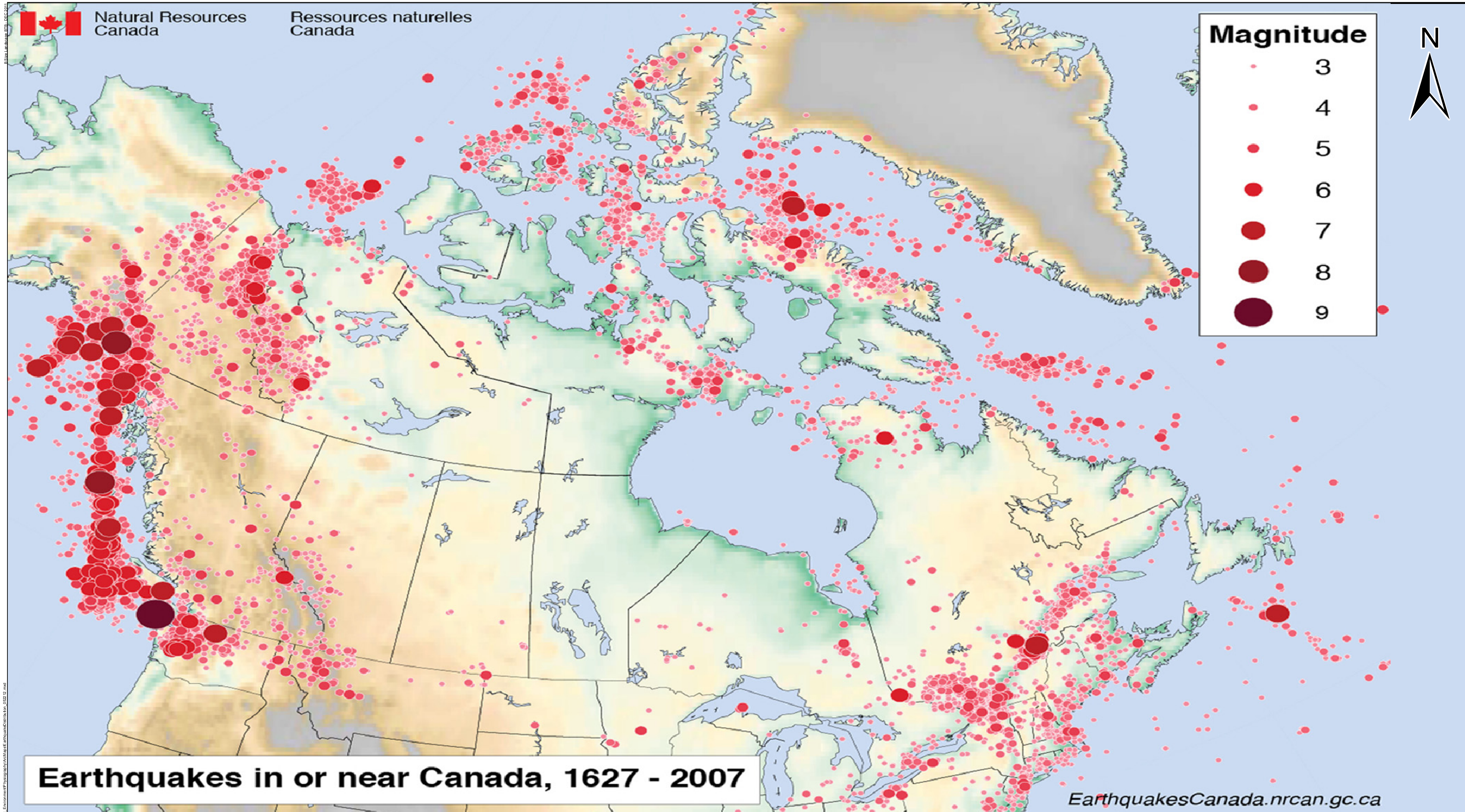
Map 5.3-9



KEEYASK Hydropower Limited Partnership

DATA SOURCE: Natural Resources Canada EarthquakesCanada.nrcan.gc.ca			
CREATED BY: Stantec			
COORDINATE SYSTEM: UTM NAD 1983 Z15N	DATE CREATED: 10-02-10	REVISION DATE: 23-MAY-12	
	VERSION NO: 1.0	QA/QC: APPROVED	

Earthquakes in or Near Canada, 1627-2007

Map 5.3-10

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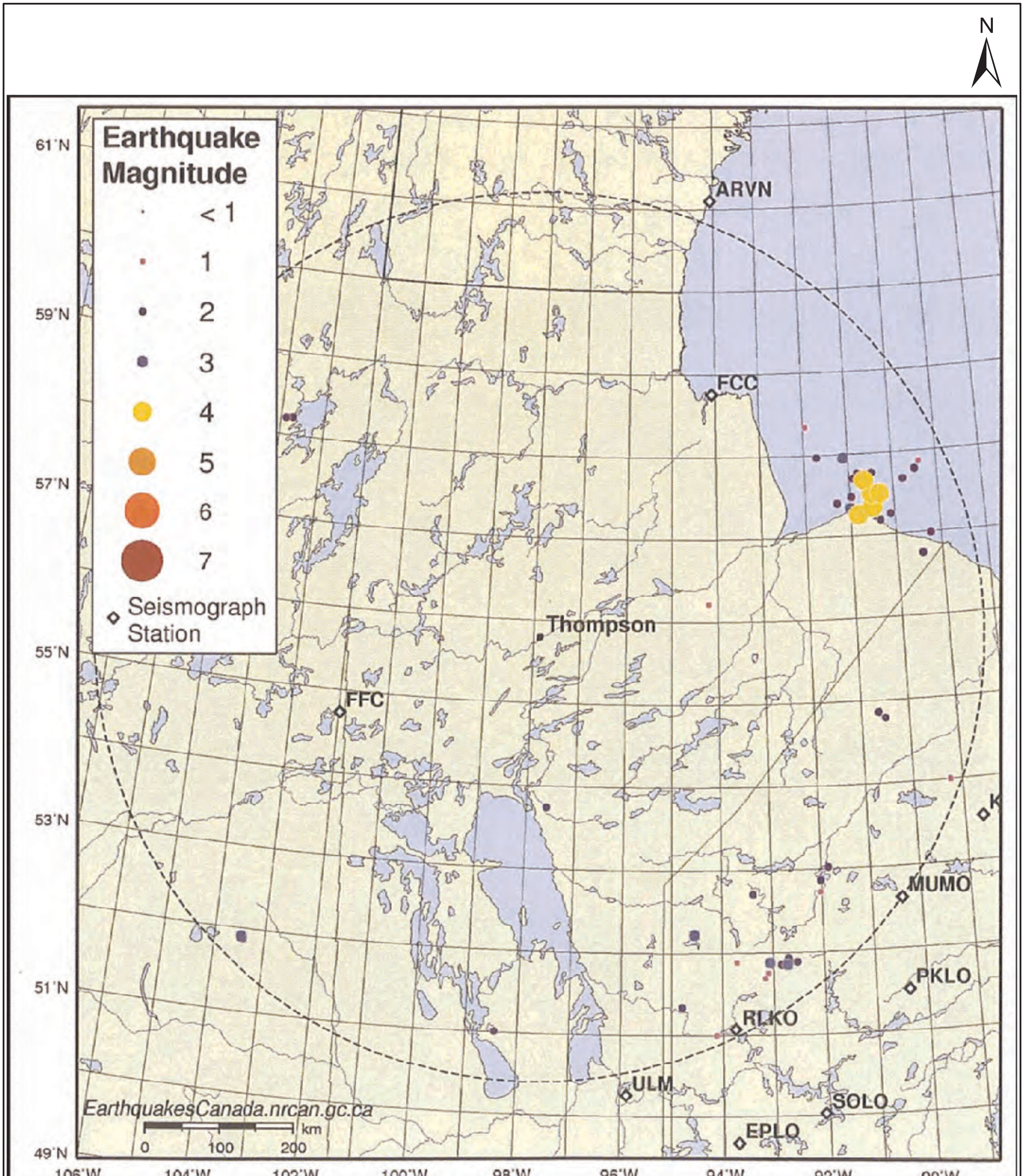


KEEYASK Hydropower Limited Partnership

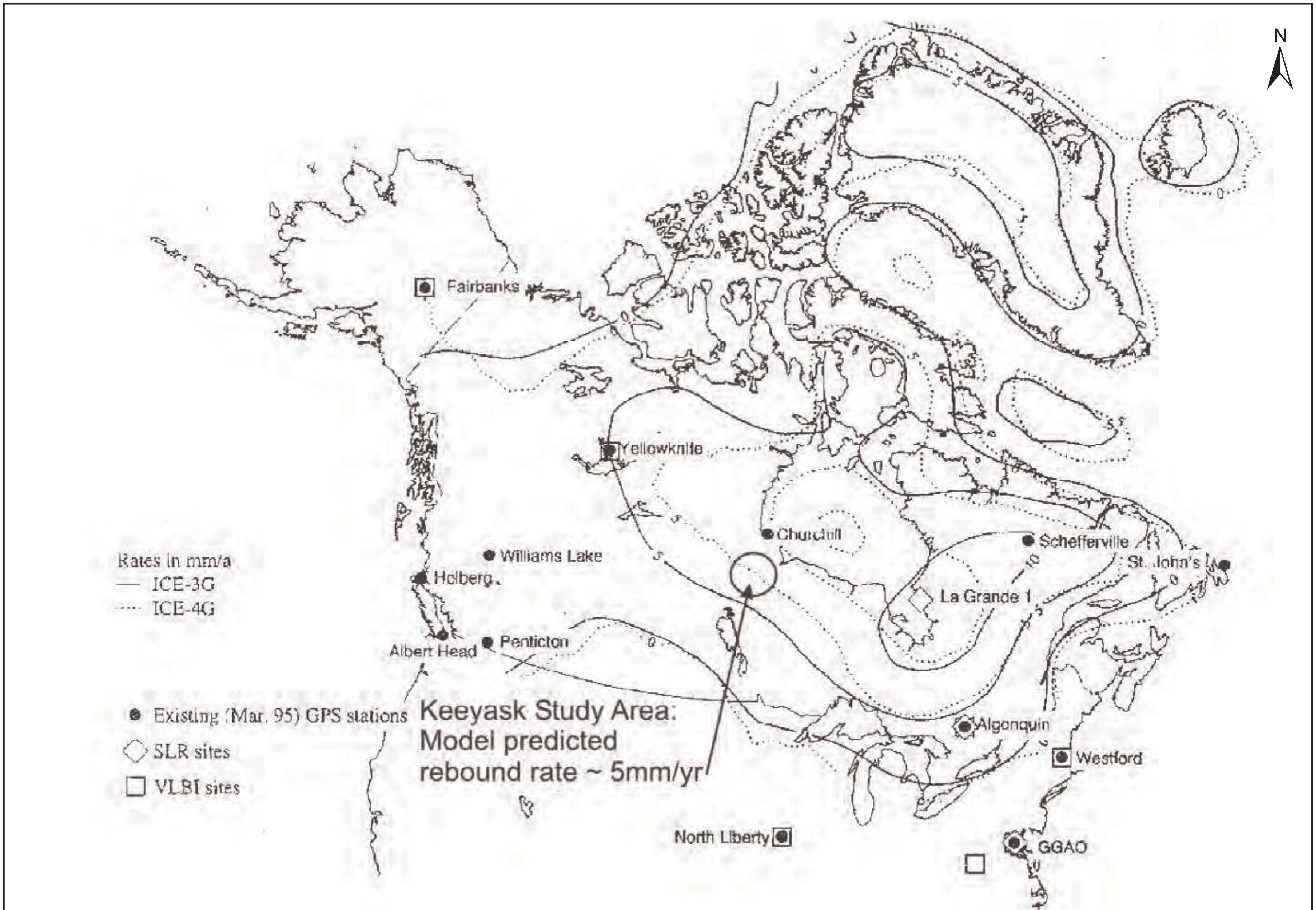
0 37.5 75 150 Kilometers
0 25 50 100 Miles

Projection: UTM NAD83, Zone 15N
Data Source: Natural Resources Canada.

Note: Map scale may not be accurate

Earthquakes within 600km of Thompson, Manitoba, 1965-2007

Map 5.3-11



KEEYASK Hydropower Limited Partnership

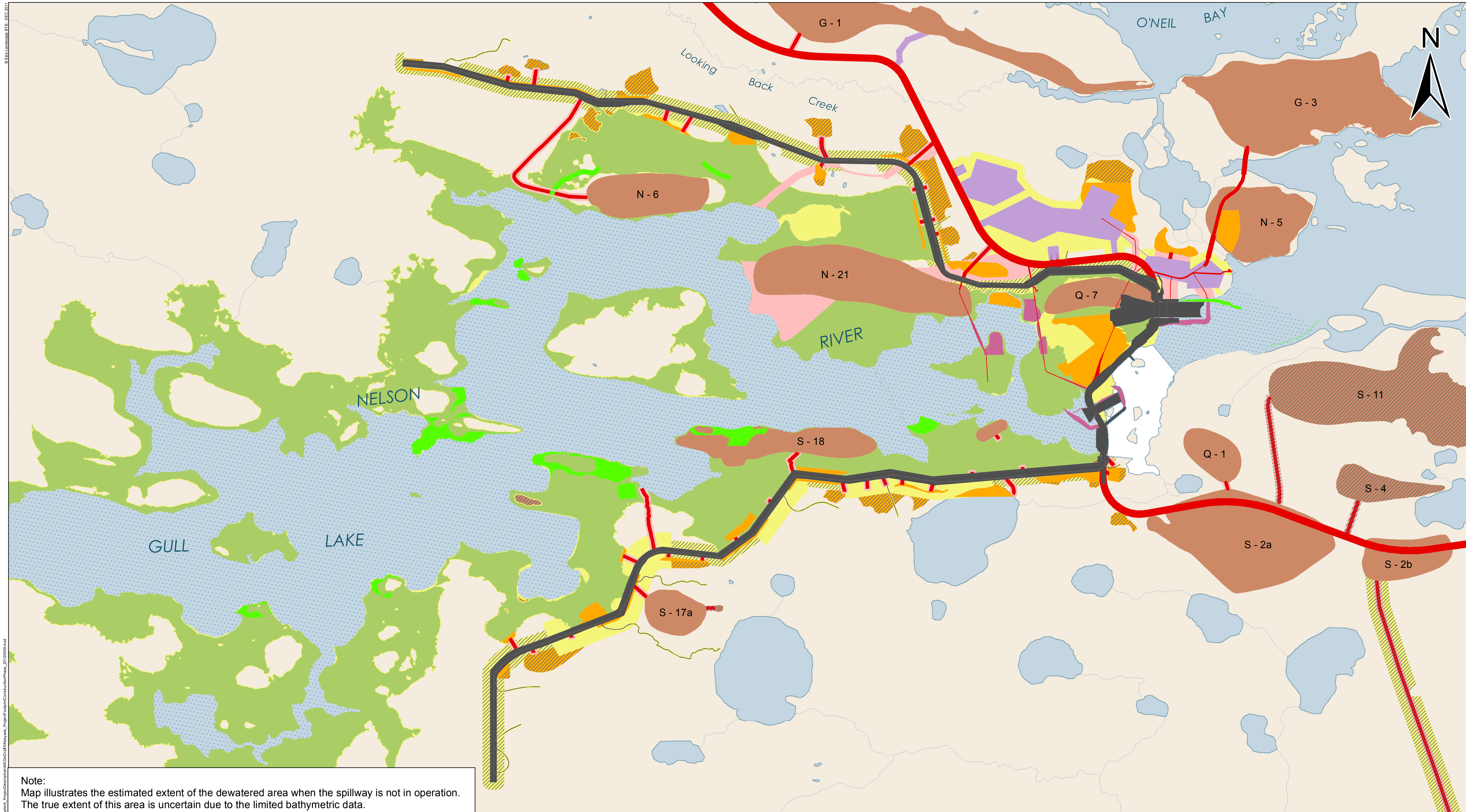
0 375 750 1,500 Kilometers
0 250 500 1,000 Miles

Projection: UTM NAD83, Zone 15N
Data Source: Natural Resources Canada.

Note: Map scale may not be accurate

Model Predicted Glacial Isostatic Rebound Rates (Lambert 1996)

Map 5.3-12



Note:
Map illustrates the estimated extent of the dewatered area when the spillway is not in operation. The true extent of this area is uncertain due to the limited bathymetric data.

KEEYASK Hydropower Limited Partnership

DATA SOURCE:
Manitoba Hydro; Government of Manitoba; Government of Canada; ECOSTEM

CREATED BY:
Hydro Power Planning - Keeyask & Burntwood Planning Section

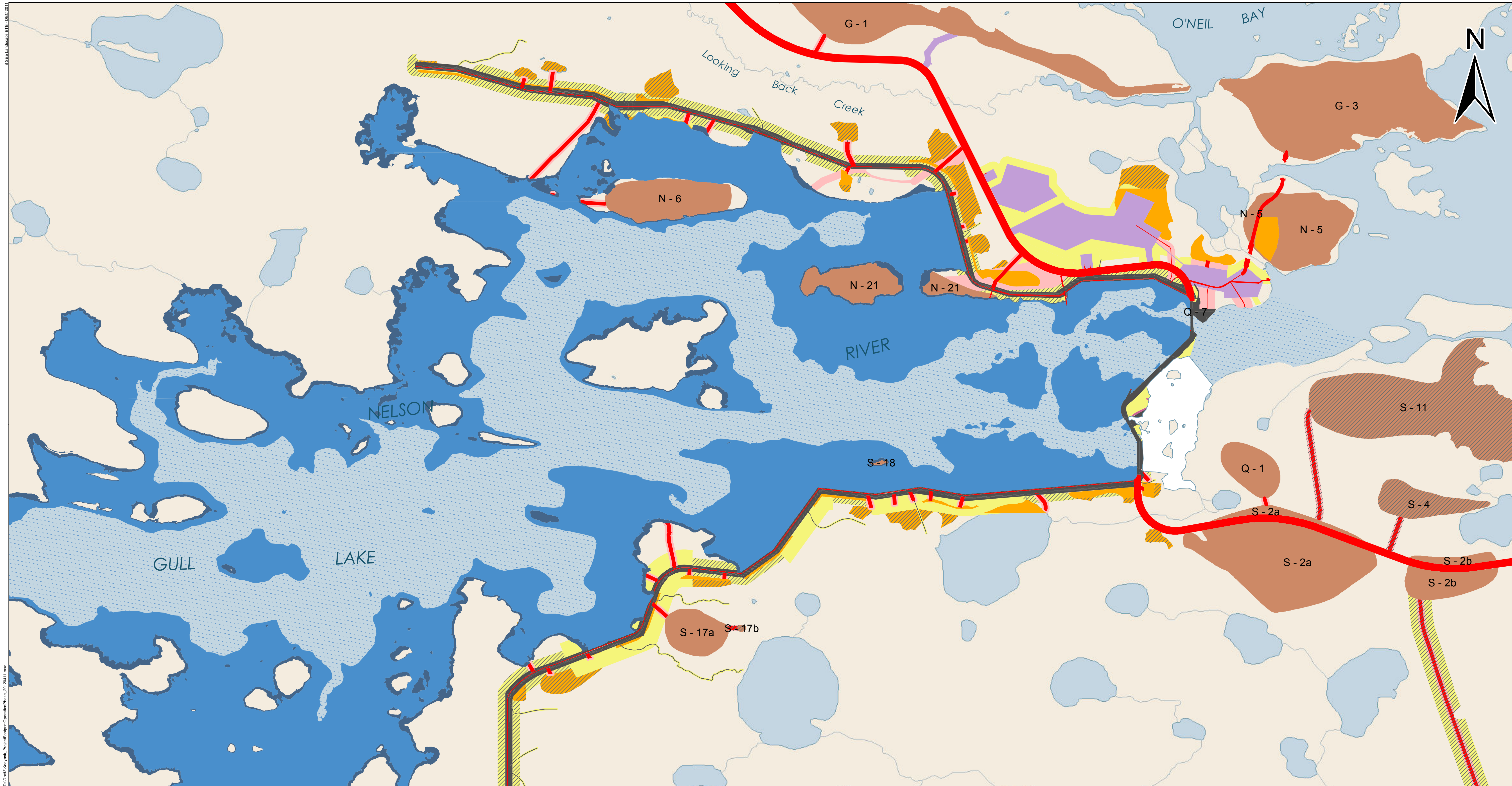
COORDINATE SYSTEM:	DATE CREATED:	REVISION DATE:
UTM NAD 1983 Z15N	18-JAN-12	09-MAY-12
0 0.6 1.2 Kilometres / 0 0.5 1 Miles	VERSION NO: 3.0	QA/QC: APPROVED

Legend

- Road
- Road Corridor
- Infrastructure
- River Management
- Borrow Area
- Camp and Work Area
- Excavated Material Placement Area
- Mitigation Area
- Possible Disturbed Area
- Reservoir Clearing
- Altered Water Level or Flow
- Potential Dewatered Area
- Existing Water Surface Area
- Areas Unlikely to be Used

Project Footprint Construction Phase
Site Level

Map 5.4-1



Note:
Map illustrates the estimated extent of the dewatered area when the spillway is not in operation. The true extent of this area is uncertain due to the limited bathymetric data.

KEEYASK
Hydropower Limited Partnership

DATA SOURCE:
Manitoba Hydro; Government of Manitoba; Government of Canada; ECOSTEM

CREATED BY:
Hydro Power Planning - Keeyask & Burntwood Planning Section

COORDINATE SYSTEM:	DATE CREATED:	REVISION DATE:
UTM NAD 1983 Z15N	18-JAN-12	18-APR-12
0 0.55 1.1 Kilometres / 0 0.45 0.9 Miles	VERSION NO: 3.0	QA/QC: APPROVED

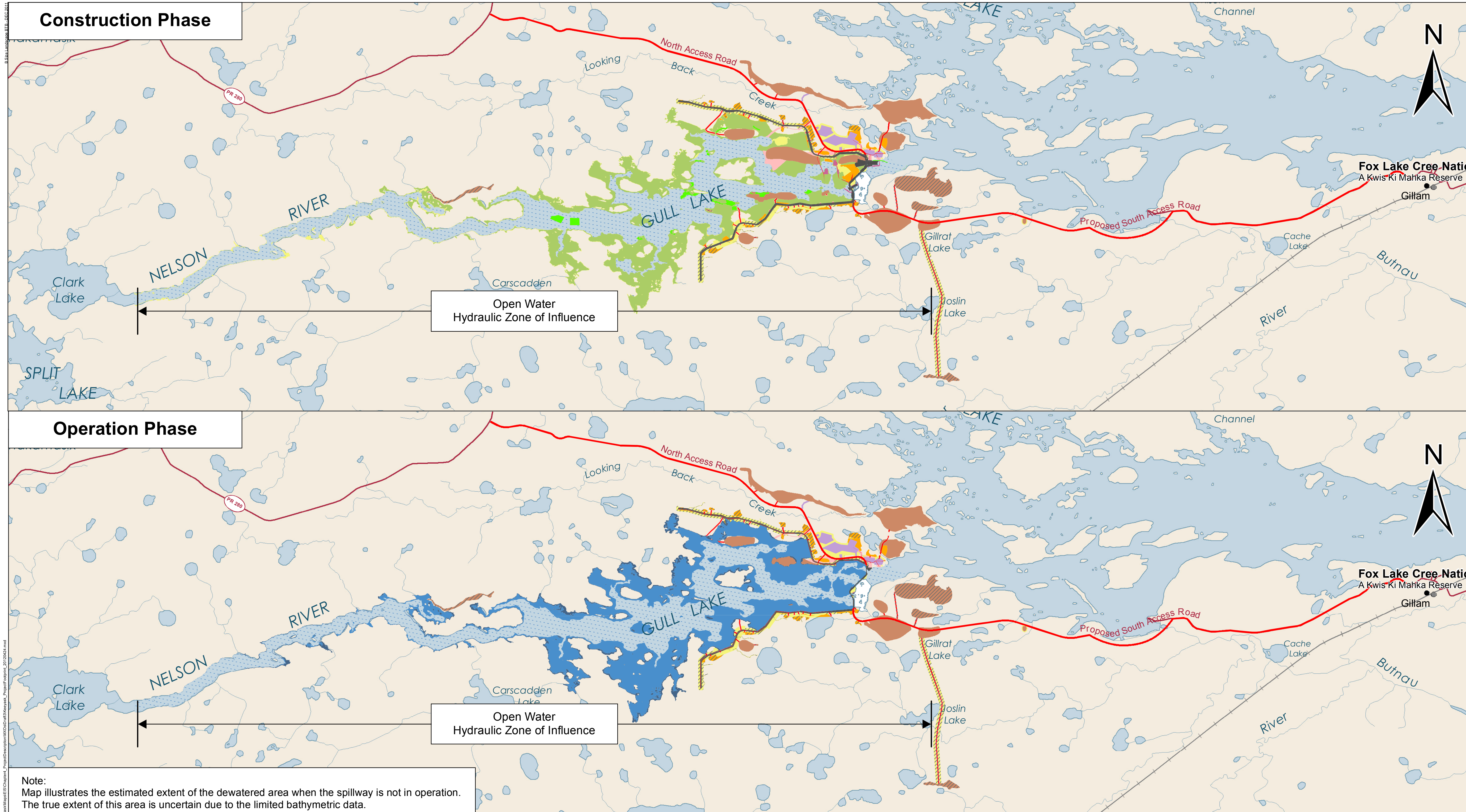
Legend

- Road
- Road Corridor
- Infrastructure
- River Management
- Borrow Area
- Camp and Work Area
- Excavated Material Placement Area
- Mitigation Area
- Possible Disturbed Area
- Initial Flooded Area (159 m)
- 30-year Reservoir Expansion Area (159 m)
- Altered Water Level or Flow
- Potential Dewatered Area
- Existing Water Surface Area
- Areas Unlikely to be Used

Project Footprint Operation Phase

Site Level

Map 5.4-2



Note:
Map illustrates the estimated extent of the dewatered area when the spillway is not in operation. The true extent of this area is uncertain due to the limited bathymetric data.

KEEYASK
Hydropower Limited Partnership

DATA SOURCE:
Manitoba Hydro; Government of Manitoba; Government of Canada; ECOSTEM

CREATED BY:
Manitoba Hydro - Hydro Power Planning

COORDINATE SYSTEM:	DATE CREATED:	REVISION DATE:
UTM NAD 1983 Z15N	18-JAN-12	25-APR-12
0 3 6 Kilometres / 0 2 4 Miles	VERSION NO: 3.0	QA/QC: APPROVED

Legend

- Road
- Road Corridor
- Infrastructure
- River Management
- Borrow Area
- Camp and Work Area
- Excavated Material Placement Area
- Mitigation Area
- Possible Disturbed Area
- Reservoir Clearing
- Initial Flooded Area (159 m)
- 30-year Reservoir Expansion Area (159 m)
- Altered Water Level or Flow
- Potential Dewatered Area
- Existing Water Surface Area
- Areas Unlikely to be Used

Project Footprint Overview
Construction and Operation Phase

Map 5.4-3

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