Keeyask Generation Project

Environmental Impact Statement

Supporting Volume

Physical Environment

KEEYASK

Hydropower Limited Partnership

June 2012

KEEYASK GENERATION PROJECT

PHYSICAL ENVIRONMENT SUPPORTING VOLUME

CLIMATE

June 2012

KEEYASK
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ACKNOWLEDGEMENTS

We acknowledge the international modelling groups for providing their data for analysis, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) for collecting and archiving the model data, the JSC/CLIVAR Working Group on Coupled Modelling (WGCM) and their Coupled Model Intercomparison Project (CMIP) and Climate Simulation Panel for organizing the model data analysis activity, the Intergovernmental Panel on Climate Change Working Group 1 Technical Support Unit (IPCC WG1 TSU) for technical support and Ouranos for providing the CRCM data, technical support and document review.

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2.0 CLIMATE

2.1 INTRODUCTION

This section of the Physical Environment Supporting Volume (PE SV) describes the climate of the **existing environment**, projects future **climate scenarios**, and estimates the **effect** of the Project on the climate. The **cumulative effects** of the **Project** and climate change will be addressed in other sections of this supporting volume as well as in other supporting volumes on **aquatic environment**, terrestrial environment and the socio-economic environment. This section concludes with a summary of the efforts made by Manitoba Hydro in order to deal with the issue of climate change. This supporting volume addresses requirements of the Guidelines outlined in Section 1 (Introduction).

Climate and weather typically both refer to variables such as temperature, precipitation, and wind. The difference between the two terms is that weather refers to the daily variations in temperature, rainfall, snowfall, wind and other weather elements, whereas climate is defined as the average weather in terms of its means and variability in a specific area over a specific time span.

The Intergovernmental Panel on Climate Change (IPCC) defines to the term climate change when there is a statistically **significant** variation to the mean state of the climate (or of its variability) that usually lasts for decades or longer and which includes changes in the frequency and **magnitude** of **sporadic** significant weather events as well as the slow continuous rise in global mean surface temperature (IPCC 2001). The climate system is extremely complex with many physical, chemical, and biological interactions occurring along temporal and spatial scales. Any changes, either natural or by human activities, in a component of the system of external forcing can cause climate change (IPCC 2001).

Climate and weather have an influence on the **environment** in the Project area. They influence aspects such as water **flows** and temperature, ice formation and break-up and these in turn influences environmental components such as fish **spawning** timing and success, as well as the **productivity** of the generation station.

In turn, the Project also has implications that affect climate change. The net implication considers **greenhouse gas (GHG)** emissions resulting from the **construction** and operation of the Project as well as the avoided GHG emissions that would have been required from other sources of generation in absence of the Project.

2.2 APPROACH AND METHODOLOGY

2.2.1 Overview

The approaches used to study the existing climate and to project the future climate scenarios are described in more detail in the following sub-sections. This report adheres to the accepted standards set by the World Meteorological Organization (WMO) when characterizing the existing climate and the

guidance of the IPCC's Task Group on Data and Scenario Support for Impact and Climate Assessment when developing future climate scenarios.

2.2.1.1 Existing Climate

Climate normals are used to describe the average climatic conditions of a particular location. The current climate normal period set by the WMO is from 1971-2000. The WMO has set the following standards when describing climate normal data representing averages (*i.e.,* temperature and wind speed): the '3/5' rule is applied, which states that if more than three consecutive daily values are missing or more than five daily values in total in a given month are missing, the monthly mean should not be computed and the year-month mean should be considered missing." For normal data representing totals (*i.e.,* precipitation data), an individual month must be 100% complete.

Growing degree days are a measure of heat accumulation typically used to predict the growth of vegetation or the life cycle of insects. Growing degree-days are calculated by averaging the daily maximum and minimum temperatures and then subtracting a **threshold** base temperature. Typically, a base temperature of 5°C or 10°C is used. An average growing degree-days for the 1971-2000 period was calculated using both base temperatures.

The frost-free season is the period normally free of sub-freezing temperatures. Frost-free days are calculated as the number of consecutive days where the minimum temperature is above 0°C. In other words, it is the period from the last frost in spring to the first frost in autumn.

2.2.1.2 Future Climate Change Scenarios

The future climate scenarios produced for this report were developed by following the guidelines established by the IPCC's Task Group on Data and Scenario Support for Impact and Climate Assessment (Carter 2007).

The future climate scenarios are based on results from 24 Global Climate Models (GCMs) each run with up to three different GHG emissions scenarios (A2, A1B and B1) and one Regional Climate Model (RCM) with the A2, and A1B greenhouse gas emission scenarios. The future climate scenarios were analyzed on 30-year average periods: for the 2020s (average of 2010-2039), the 2050s (2040-2069), and the 2080s (2070-2099).

The **Delta Method** was used to correct for **model** bias and adjust the existing climate of the Project **study area** to future conditions. This involved finding the difference or ratio between the period-averaged results for the GCM/RCM experiments and the corresponding averages for the GCM/RCM simulated baseline run (*e.g.,* 1971-2000). In order to develop future scenarios, differences were applied to the existing climate for temperature changes (*e.g.*, 2010-2039 minus 1971-2000) while ratios were applied for precipitation changes (*e.g.*, 2010-2039 divided by 1971-2000). RCM data was used to assess changes in future rates of **evapotranspiration**. However, since long-term baseline measured values are not available; an unbiased projection of future rates of evapotranspiration is not possible

2.2.1.3 Life-Cycle Assessment

The earth's climate system is closely linked to the carbon cycle, which is the cycling of carbon through land, oceans, atmosphere and the earth's interior. The rate of change in atmospheric GHG, and implication for climate change, is related to the balance between carbon emissions resulting from human activities and the dynamics of **terrestrial** and **aquatic** processes that remove or emit carbon. It is within this context of examining changes to carbon emissions and sinks resulting from the Project that climate change implications are assessed within this section.

Life-Cycle Assessment (LCA) was used to estimate the GHG emissions resulting from the construction, land use change, operation, and **decommissioning** of the Project. The LCA was conducted by The Pembina Institute using the ISO "Environmental Management - Life-Cycle Assessment - Principles and Framework" in ISO 14040:2006. In addition, the levelized life-cycle emissions for the Project were compared with published life-cycle emissions for other common forms of generation. The Project was compared to common electricity generating technologies based on the life-cycle GHG emissions produced in delivering one **gigawatt** hour (GWh) to the electrical distribution network.

While the facility would result in some GHG emission implications from construction and land use change, it contributes more significantly towards the displacement of emissions. An analysis of the electricity markets was conducted to estimate the displacement of generation and corresponding avoided GHG emissions due to additional **energy** injected into the regional energy markets from Manitoba. It is expected that a mixture of both coal and natural gas-fired generation of varying technologies and efficiencies will be the marginal sources of energy displaced by increased energy exports due to the project.

The net effect of the Project on climate change reflects the small life-cycle emissions of the project minus the much more significant emission reductions that result from the displacement of high emission intensity sources of generation.

2.2.2 Study Areas

2.2.2.1 Keeyask Biophysical Study Area

The Gillam airport weather station (56°21'N 94°42' W) which is located on the south-east side of Stephens Lake approximately 35 **km** east of the Project study area is used to characterize the existing climate of the Project study area (Map 2.2-1). This gauge is operated by Environment Canada (Identification # 5061001).

2.2.2.2 Future Climate Change Scenarios

The GCM and the RCM grid points in close proximity of the Project study area, delimited by 54.3°N to 58.3°N in latitude and 93.2°W to 98.2°W in longitude, were used to establish the future climate of the Project study area (Map 2.2-2 and Map 2.2-3).

2.2.2.3 Life-Cycle Assessment

The LCA study area is not restricted geographically. The assessment, utilizing activity maps highlighting the major materials and processes, focused on four distinct components of the project: construction, land use change, operation and maintenance, and decommissioning. Considering the magnitude and uniqueness of a hydro **generating station**, raw materials, manufacturing and distribution take on an international aspect. In excess of 30% of the GHG emissions occur off-site and are related to manufacture of building materials and transportation.

2.2.3 Data and Information Sources

2.2.3.1 Existing Climate

The climate normals for the Gillam airport weather station were calculated by Environment Canada and can be found at: http://www.climate.weatheroffice.gc.ca/climate_normals/index_e.html.

2.2.3.2 Future Climate Change Scenarios

The **ensemble** of GCMs compiled for use in this report come from the latest projections prepared for the IPCC Fourth Assessment Report. In total, an ensemble of 139 GCM simulations were used which consisted of 24 GCMs, each run with up to three different greenhouse gas emissions scenarios (A2, A1B and B1). A number of GCMs also had experiments which assumed identical radiative forcing but slightly different initial conditions referred to as members. Details pertaining to the ensemble of GCMs can be found in Table 2.2-1.

The RCM used for this report was the Canadian Regional Climate Model 4.2.3 (CRCM4.2.3). This model was generated by the Ouranos Climate Simulation Team in collaboration with the Canadian Centre for Climate Modelling and Analysis of Environment Canada. CRCM4.2.3 was run over North America with a 45 km horizontal grid-size mesh and is nested within the Canadian Global Climate Model 3.1 (CGCM3.1), European Centre Hamburg Model 5 (ECHAM5) and Centre National de Recherches Météorologiques Climate Model 3 (CNRM CM3) global climate models. Currently, CRCM4.2.3 is only available for the SRESA2 and SRESA1B emission scenario for the 2020s (two members), 2050s (five members), and 2080s (two members) time periods.

2.2.3.3 Life-Cycle Assessment

The majority of the data used in the LCA was based on early design stage material estimates provided internally by Manitoba Hydro in response to enquiries from The Pembina Institute. This data was supplemented with information from a similar life-cycle study prepared for the Wuskwatim Hydro project (McCulloch and Vadgama, 2003) and public life-cycle data sets when necessary. A custom LCA model was then developed to calculate results and analyze data provided.

Table 2.2-1: Ensemble of Global Climate Models

Model ID, Vintage	Sponsor(s), Country	Scenarios	Members	Atmosphere Resolution	Number of Grid Points in Study Area
BCCR-BCM2.0, 2005	Bjerknes Centre for Climate Research, Norway	A1B, A2, B1	1	T63 (2.8º x 2.8º) L31	2
CGCM3.1(T47), 2005	Canadian Center for Climate Modelling and Analysis, Canada	A1B, A2, B1	1, 2, 3, 4, 5	T47 (~3.8º x 3.8º) L31	2
CGCM3.1(T63), 2005		A1B, B1	1	T63 (~2.8º x 2.8º) L31	2
CNRM-CM3, 2004	Météo-France/Centre National de Recherches Meteorologiques, France	A1B, A2, B1	1	T42 (~2.8º x 2.8º) L45	2
CSIRO-MK3.0, 2001	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia	A1B, A2, B1	1	T63 (~1.9º x 1.9º) L18	6
CSIRO-MK3.5, 2001		A1B, A2, B1	1	T63 (~1.9º x 1.9º) L18	6
GFDL-CM2.0, 2005	U.S. Department of Commerce/National Oceanic and Atmospheric Administration (NOAA)/Geophysical Fluid Dynamics Laboratory (GFDL), USA	A1B, A2, B1	1	(2.0º x 2.5º) L24	4
GFDL-CM2.1, 2005		A1B, A2, B1	1	(2.0º x 2.5º) L24	4
GISS-AOM, 2004	National Aeronautics and Space Administration for (NASA)/Goddard Institute Space Studies (GISS), USA	A1B, B1	1, 2	(3.0º x 4.0º) L12	2
GISS-EH, 2004		A1B	1, 2, 3	(4.0º x 5.0º) L20	1

Model ID, Vintage	Sponsor(s), Country	Scenarios	Members	Atmosphere Resolution	Number of Grid Points in Study Area
GISS-ER, 2004		A2, B1	1	(4.0º x 5.0º) L20	1
		A1B	2,4		
FGOALS-g1.0, 2004	National Key Laboratory of Numerical Modelling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG)/Institute of Atmospheric Physics, China	A1B, B1	1, 2, 3	T42 (~2.8º x 2.8º) L26	2
INGV-SXG ECHAM4, 2005	National Institute of Geophysics and Volcanology, Bologna, Italy	A1B, A2	1	T106 (~1.1º x 1.1º)	20
INM-CM3.0, 2004	Institute for Numerical Mathematics, Russia	A1B, A2, B1	1	(4.0º x 5.0) L21	1
IPSL-CM4, 2005	Institut Pierre Simon Laplace (France)	A1B, A2, B1	1	(2.5º x 3.75º) L19	4
MIROC3.2 (hires), 2004	Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	A1B, B1	1	T106 (~1.1º x 1.1º) L56	20
MIROC3.2 (medres), 2004		A1B, A2, B1	1, 2, 3	T42 (~2.8º x 2.8º) L20	2
MIUB-ECHO-G, 1999	Meteorological Institute of the University of Bonn, Meteorological Research Institute of Korea Meteorological Administration (KMA), and Model and Data Group, Germany/Korea	A1B, A2, B1	1, 2, 3	T30 (~3.7º x 3.7º) L19	2
MPI-ECHAM5/ MPI-OM, 2005	Max-Planck-Institute for Meteorology (Germany)	A1B	1, 2, 3, 4	T63 (~1.9º x 1.9º) L31	6
		A2, B1	1, 2, 3		

Model ID, Vintage	Sponsor(s), Country	Scenarios	Members	Atmosphere Resolution	Number of Grid Points in Study Area
MRI-CGCM2.3.2, 2003	Meteorological Research Institute, Japan	A1B, A2, B1	1, 2, 3, 4, 5	T42 (~2.8º x 2.8º) L30	2
NCAR-CCSM3, 2005	National Centre for Atmospheric Research, USA	A1B	1, 2, 3, 5, 6, 7, 9	T85 (1.4º x 1.4º) L26	9
		A2	1, 2, 3, 4		
		B1	1, 2, 3, 4, 5, 6, 7, 9		
NCAR-PCM, 1998		A1B, A2	1, 2, 3, 4	T42 (~2.8º x 2.8º) L26	2
		B1	2, 3		
UKMO-HadCM3, 1997	Hadley Centre for Climate Prediction and Research/Met Office, UK	A1B, A2, B1	1	(2.5º x 3.75º) L19	4
UKMO-HadGEM1, 2004		A1B, A2	1	(~1.3º x 1.9º) L38	9

2.2.4 Assumptions

2.2.4.1 Existing Climate Data

The historical record of climate variables in northern Manitoba is very limited. However, the Gillam airport weather station, which is approximately 35 km east of the Project study area, is assumed to be a good representation of the climate in the Project study area.

2.2.4.2 Future Climate Change Scenarios

Climate scenarios from GCMs and a RCM were determined using the Delta Method, assuming no change in the frequency or variability of weather events, compared to present-day. Therefore, the pattern of day-to-day and inter-annual variability of climate remains unchanged. It also assumes that any biases in the simulation of present-day climate are the same as in the simulation of future climate.

2.2.4.3 Life-Cycle Assessment

The LCA is based on several important assumptions and notable facility details that influence the results of the analysis. The most significant assumptions and notable details are described below.

2.2.4.3.1 Delivered Electricity

Transmission losses, a reduction of energy through the process of delivering energy, occurs when energy is transmitted via **transmission lines** from the generation source to the load **consumer** resulting with less delivered energy than the originally generated amount. Incorporating transmission losses into the LCA will reduce the amount of consumable energy at major load centers and correspondingly increases the GHG, NO_x and SO_2 emission intensity of the project facility. It is expected that the Keeyask GS will add 4,000 GWh to the Manitoba grid for use at major load centers.

2.2.4.3.2 Cement Production and Transportation

At the time of the LCA, Manitoba Hydro had not contracted cement suppliers. This assessment assumes that all cement is produced in Edmonton and then transported to the construction sites by truck. Manitoba Hydro has in the past sourced cement from Edmonton for the construction of hydro facilities.

2.2.4.3.3 Steel Production and Transportation

Steel components used in the Project, including rebar, structural steel and mechanical steel (such as steel in **turbines**), may be sourced from many different locations around the world. For example, the **generators** and turbines could come from South America, southeast Asia or eastern Europe. With China being the largest steel producer in the world, this assessment assumes all steel used in the generating station is sourced from China and is transported to site by cargo ship, train and truck unless a more specific location is known. For example, Manitoba Hydro expects rebar for the Keeyask Project to come from St. Paul, Minnesota. While steel production contains a significant portion of recycled iron, the

analysis contained in this report assumes 100% virgin material. These assumptions ensure the analysis is conservative.

2.2.4.3.4 Replacement Components

All the mechanical steel, such as steel in the turbines and generators, is replaced once during the life of the project. However, **concrete**, rebar and structural steel will not be replaced over the life of the Project.

2.2.4.3.5 Recycling

All replaced components, this analysis assumes all mechanical steel is replaced, and all steel removed at the end of the project life is recycled. Emissions from steel recycling are included in the assessment. Manitoba Hydro is not credited for displacing virgin steel.

2.2.4.3.6 Land Use Change

This assessment assumes that only disturbances that will last the **duration** of the Project, approximately 100 years, will lead to a net increase in GHG emissions. The area of disturbances that are temporary in nature (less than 100 years permanent disturbance), such as clearing for the borrow sources area, are not included in net GHG production calculations. Using the above assumptions, the Project will disturb 5,920 ha of forested or semi-forested land. Separate assessments were conducted for disruptions or changes that will last the duration of the project such as **flooding**, roads, transmission lines and **dykes**. It was estimated that flooding accounts for the majority of this land use change (80%). Road, transmission line and dyke construction will disturb the remaining 20% of the project area.

The GHG emissions for clearing and flooding due to the **reservoir** were calculated based on IPCC guidance. During the initial years, after flooding, reservoirs may produce GHG emissions by converting a portion of the flooded carbon in vegetation and soils primarily to CO_2 with some CH_4, (N_2O negligible). After the passage of roughly 10 years, GHG emissions from reservoirs resemble those of surrounding lakes and other water bodies. Additional detail may be found in Appendix 2A.

For the calculations of net GHG emissions associated, with land use change for the construction of the dykes and transmission lines, it is assumed that all non-flooding disturbances convert the current land type into grassland or low shrubs. For example, when a transmission line is constructed a forest may be cleared; however, once construction is complete grassland or low shrubs are allowed to grow beneath the transmission lines.

2.2.4.3.7 Operation Phase

Emissions during the operational phase are primarily associated with equipment replacement and reservoir emissions. The previous LCA report of the Wuskwatim Hydro **dam** concluded that other operational tasks such as transporting crews to the generating station for site maintenance accounted for less than 0.01% of onsite emissions.

2.2.4.3.8 Greenhouse Gas Displacements

Manitoba Hydro operates an electrical system that facilitates the sale of surplus electricity to interconnected neighbouring provinces and states. It is assumed that the energy produced by the Project

(less transmission losses) will displace a variety of fossil-fuelled generation outside of Manitoba. Current information indicates that electricity exports from Manitoba currently displace mainly coal-fired generation (that emits at a rate of about 1 tonne CO_2/**MWh**). A more conservative assumption of 0.75 tonne CO_2/MWh is used to estimate the GHG reductions within the broader regional electricity market that we are interconnected with.

2.2.5 Description of Models

2.2.5.1 Global Climate Models and Regional Climate Models

GCMs are designed to project the climate into the future over the entire globe under various GHG emission scenarios. These models aim to calculate the full three-dimensional characteristics of the atmosphere and/or ocean by solving a series of equations that describe the **movement** of energy, momentum, and the conservation of mass (McGuffie *et al.,* 1997). These models typically divide the atmosphere and oceans into a horizontal grid with a resolution of 2°to 4° latitude and longitude (between 250 km and 600 km) and up to 10 to 20 vertical levels in the atmosphere and as many as 30 layers in the oceans (McGuffie *et al.,* 1997).

Regional Climate Models project the climate over a limited area (*i.e.,* North America) and are forced at their boundaries by projections from a Global Climate Model. A Regional Climate Model uses dynamical **downscaling** to improve its representation of **topography** and includes physical and dynamical processes as well as land surface characteristics which are at a finer resolution than Global Climate Models.

The emission scenarios used by the GCMs and the RCM come from the report published by the IPCC titled "Special Report on Emissions Scenarios – SRES" (Nakicenovic *et al*., 2000). This report defined emission scenarios (*i.e.,* SRESA1B, SRESA2, and SRESB1), which represents different demographic, economic, social, technological, and environmental developments and their relationship between the forces driving emissions over the entire globe. SRESA2 describes a very heterogeneous world where economic development is primarily regionally oriented and technological changes are more fragmented and slower than in other scenarios. A2 has the highest projected carbon dioxide emissions relative to the A1 and B1 Storyline. In terms of global warming, the A2 storyline is projected to have the greatest warming effect by year 2100 SRESB1 describes a convergent world with reductions in material intensity, and the introduction of clean and resource-efficient technologies. B1 has lowest projected carbon dioxide emissions. In terms of global warming, the B1 storyline is projected to have the lowest warming effect by year 2100. SRESA1B describe a future world with the rapid introduction of new and more efficient technologies and the source of energy is a balance between **fossil fuels** and other sources. A1 has projected carbon dioxide emissions between to the A2 and B1 Storyline. In terms of global warming, the A1 storyline is projected to have a mid-level warming effect by year 2100. Each scenario is equally valid with no assigned probabilities of occurrence (Carter 2007).

2.2.5.2 Life-Cycle Assessment

A customized Excel® based life-cycle model was used to contain all the data and calculate the life-cycle results in the model. A high level diagram of the model and a brief description is available below in Figure 2.2-1.

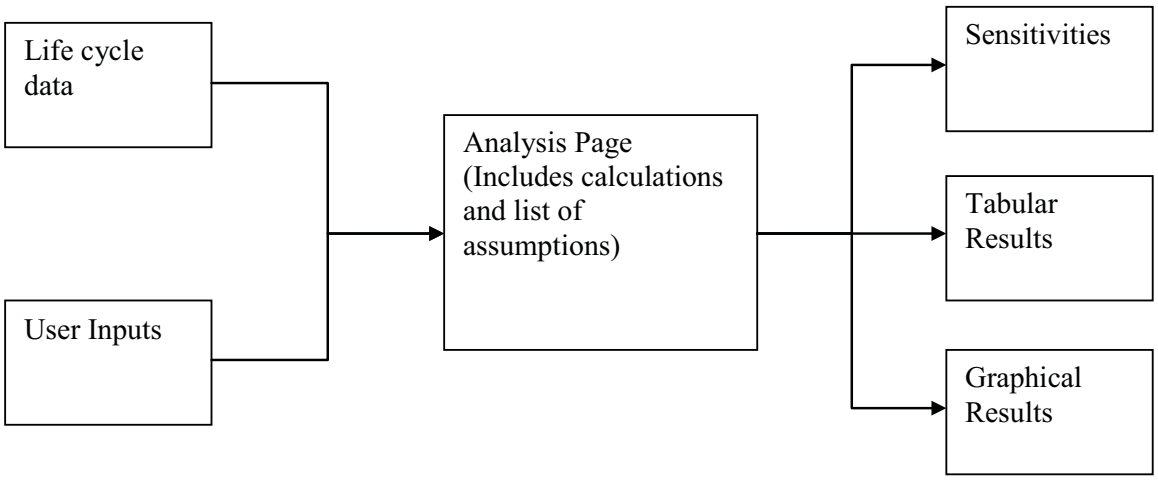

Figure 2.2-1: High Level Life-Cycle Model

In general, the model can be broken down into three components, input, calculations and output. The input data includes all the life-cycle data sets for activities such as concrete and steel manufacture. In addition, key factors such as transport distances, can be varied in the user input section. The analysis combines all the life-cycle data and user inputs to calculate emissions for all of the stages of the **hydroelectric** facility including construction, operation and decommissioning. The analysis outputs the calculations to the various results formats such as graphs and tables. The sensitivities are also outputted separately in the model.

GHGs include all gases that absorb infrared radiation emitted by the Earth's surface. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the principal GHGs relevant to the Project. These gases' innate abilities to contribute to climate change are expressed in terms of CO_2 equivalency (CO_2eq). Forster *et al.,* (2007) provided the following global warming potentials for these gases which were used in the LCA:

- CO_2 = 1 CO_2eq;
- CH_4 = 25 CO_2eq; and
- N_2O = 298 CO_2eq.

2.3 ENVIRONMENTAL SETTING

This section of the Physical Environment Supporting Volume (PE SV) describes the climate of the Project study area. It documents the existing climate over the 1971-2000 period and projects potential future temperature and precipitation changes due to climate change. Future changes in temperature and precipitation are projected by examining an **ensemble** of GCMs and a RCM. While the ensemble of GCMs portrays a variety of possible futures, the RCM depicts the climate projection of only one GCM, but in a refined, high resolution projection. Together, these two types of future projections provide a more comprehensive picture of the potential future climate in the Project study area.

2.3.1 Existing Climate

This section of the report focuses on the existing climate of the Project study area. It documents the baseline climate in terms of temperature, precipitation and wind for the 1971-2000 period. The Project study area is located, generally, within the sub-arctic climate zone, which is characterized by long, usually very cold winters, and short, cool to mild summers (Smith *et al.,* 1998).

2.3.1.1 Temperature

Canadian Climate Normal daily average, minimum, maximum and extreme temperature data is illustrated in Figure 2.3-1. The average annual temperature is approximately -4.2°C. Average daily temperatures range from +11.4°C to +15.3°C from early June to late August and from -25.8°C to -22.0°C from early December to the end of February. The months of March to May range from -15.1°C to +4.4°C, while September to November range from -12.1°C to +7.0°C. The months of May through September have experienced average daily maximum temperatures between +10.5°C to +21.4°C, while December, January and February have experienced average daily minimum temperatures between -27.1°C to -30.5°C. An examination of extreme events indicates the most pronounced extreme maximum and extreme minimum recordings were +36.8°C in June (2002) and -46.1°C in January (1975). It is not uncommon for temperatures to approach these extremes for days or even weeks at a time during extended cold snaps or warm spells.

2.3.1.2 Growing Degree Days

The total accumulated growing degree days, with a 5°C threshold base temperature, are 969.6 at Gillam A. Using a 10°C threshold base temperature, the accumulated growing degree days are 428.6.

2.3.1.3 Frost Free Days

The average number of frost-free days at Gillam A is 91.9 days for the period of 1971-2000. This value falls into the frost-free range reported for the northern forest zone of Canada, which is between 60 to 110 days.

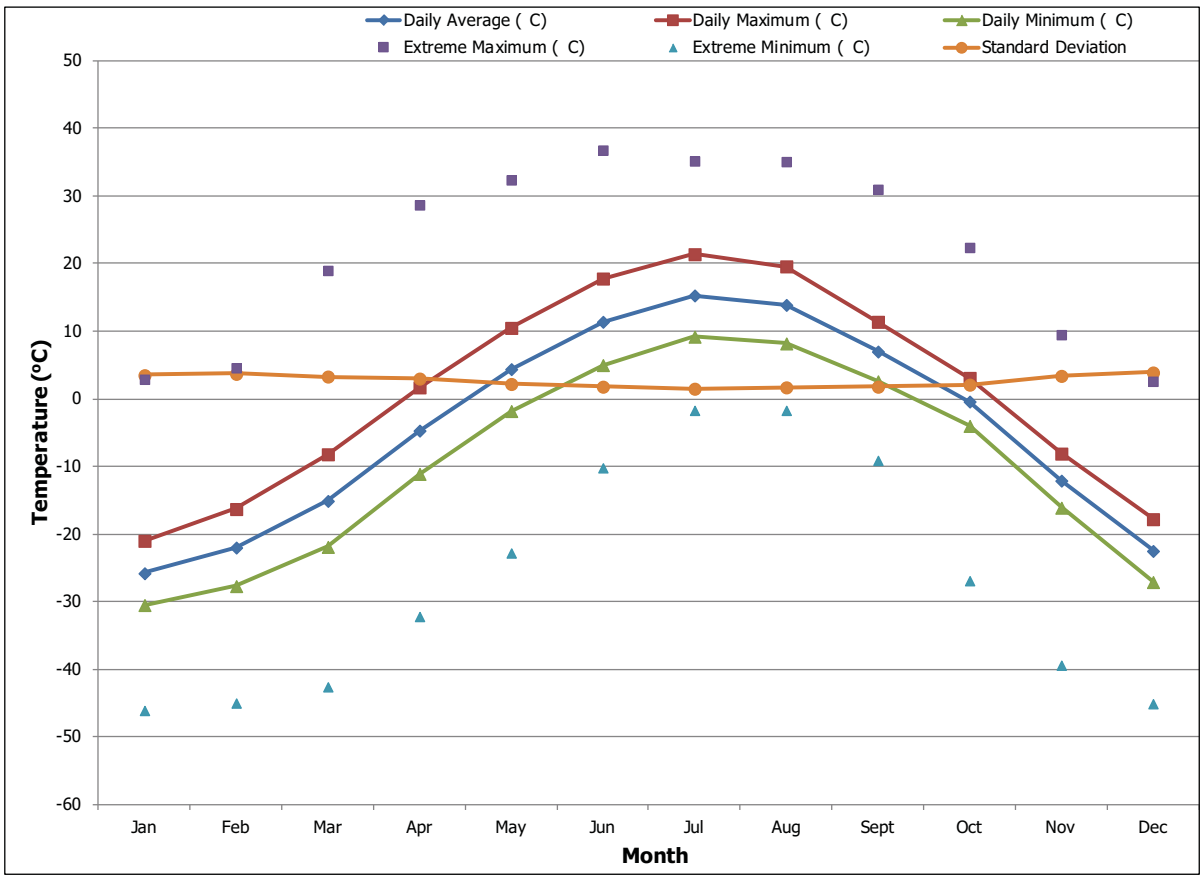

Figure 2.3-1: Temperature Normals (1971-2000)

2.3.1.4 Precipitation

Canadian climate normal average monthly rainfall, snowfall, precipitation and extreme data are illustrated in Figure 2.3-2. Average total annual precipitation is approximately 499.4 mm. Of the total annual precipitation, rainfall accounts for approximately 63% while snowfall accounts for 37%. Precipitation over the months of November through April is mainly in the form of snow while July and August is in the form of rain. During the transitional months of May, September and October precipitation can fall as either rain or snow depending on the air temperature. Snow depth builds during the winter and becomes greatest just before spring melt, which typically begins in late April, early May. The average total annual snowfall is 228.6 cm and the average March snow depth is 56 cm. The maximum daily rainfall event occurred in July 2000 at 64.4 mm while the maximum daily snowfall event occurred in May 1988 at 36.6 cm.

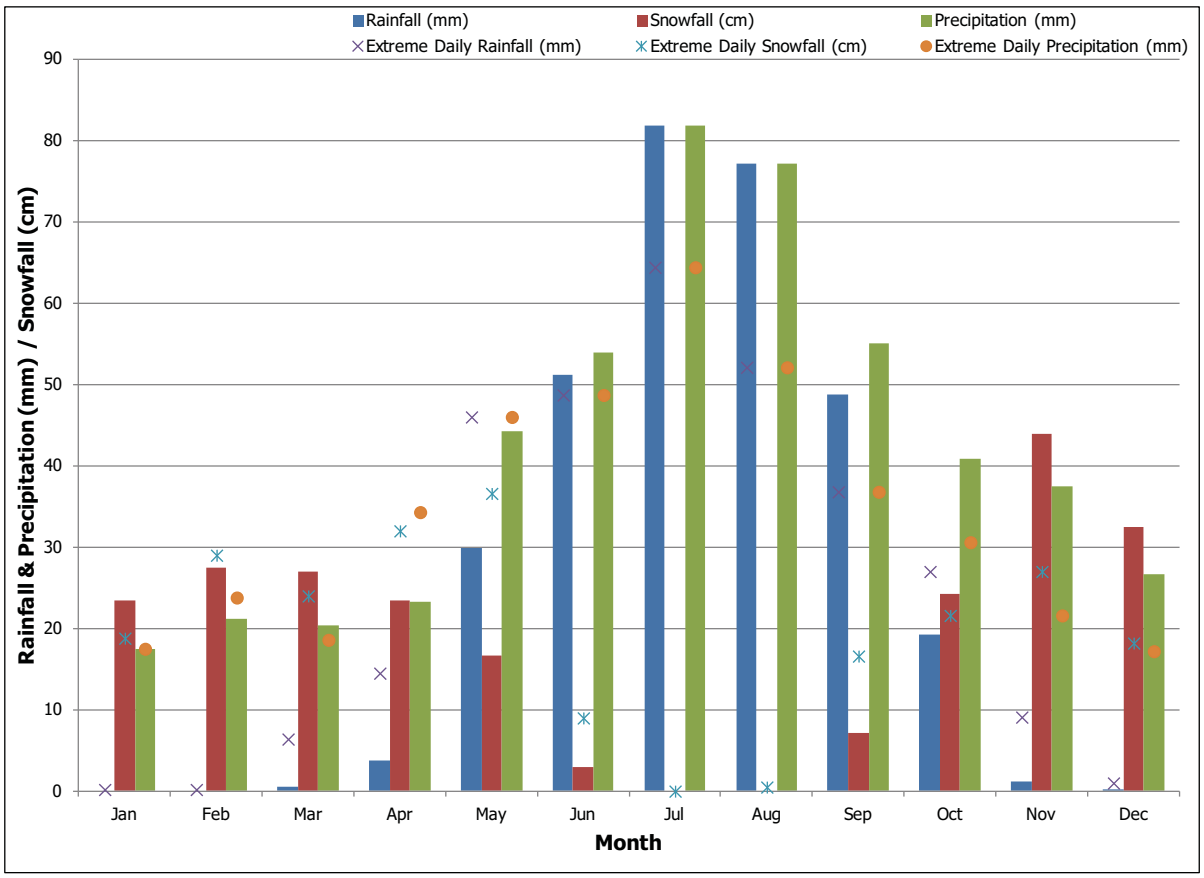

Figure 2.3-2: Precipitation Normals (1971-2000)

2.3.1.5 Wind

Canadian climate normal hourly wind data is illustrated in Figure 2.3-3 in the form of a windrose. A windrose illustrates the frequency of the wind direction and the intensity of the wind blowing in that direction. Wind direction is divided into 16 segments, each representing 22.5 degrees of coverage. The length of each bar is proportional to the frequency of the wind direction. Therefore, the longest bar represents the predominant wind direction.

Average wind speeds range between 14.0 km/h to 17.8 km/h. The winter months (December, January, and February) are frequently comprised of the lowest wind speeds between 14.0 km/h to 14.8 km/h with a frequent wind direction of west. Spring (March, April and May) has speeds slightly higher than winter and range between 14.0 km/h to 15.4 km/h with a predominate direction from the north-east. The summer months (June, July, and August) experience wind speeds that range between 15.1 km/h to 15.8 km/h and are frequently from the north. The average wind speeds in autumn (September, October and November) range between 16.4 km/h to 17.8 km/h and are frequently from the west. The maximum hourly wind speed recorded was 83 km/h in September 1981 while the maximum gust speed was 107 km/h in July 1991.

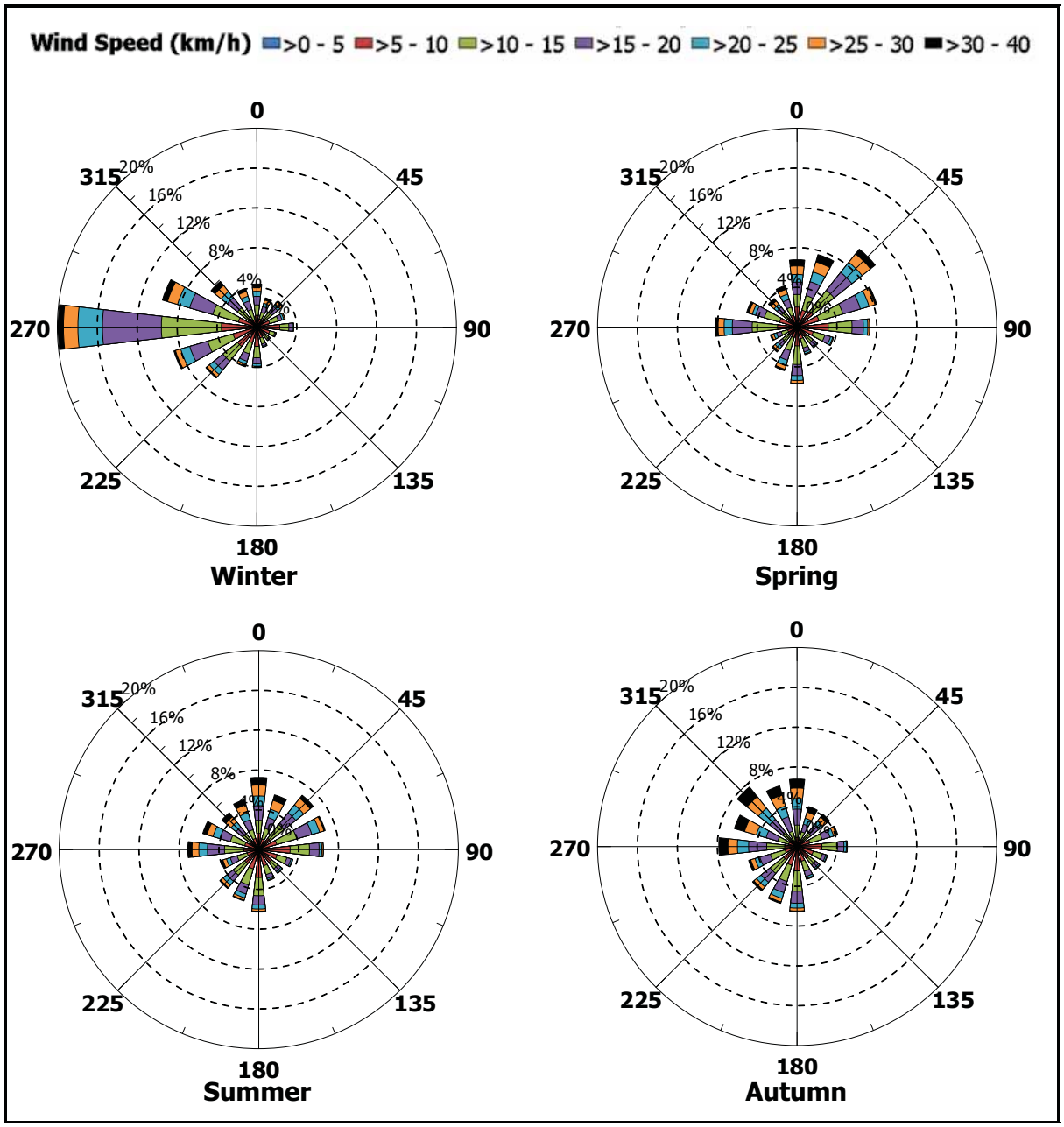

Figure 2.3-3: Wind Rose for Hourly Wind Speed

2.3.2 Future Climate Change Scenarios

The future climate scenarios in this report are based on an ensemble of GCMs and one RCM. The range of projected future climate scenarios includes **uncertainties** in both GCMs and GHG emissions scenarios (A1B, A2, and B1). Uncertainties arise from differences in the way the GCMs represent the climate. Additional uncertainties arise from GHG emissions scenarios because future technological

developments and policy choices that influence GHG emissions are unknown. Climate scenarios derived from the RCM are from a single RCM forced by CGCM3.1 (A2), ECHAM5 (A2) and CNRM CM3 (A1B). It is preferable to analyze multiple RCMs to better assess the **uncertainty** of a given projection. However, there is only one RCM available for this region at this time.

2.3.2.1 Temperature – Global Climate Model Ensemble

Figure 2.3- 4 illustrates the baseline temperature (1971-2000) plotted with an envelope that represents the ensemble of future climate scenarios projected by the GCMs for the 2020s, 2050s and 2080s. This ensemble shows a pattern of steadily increasing temperature in relation to the 1971-2000 baseline. The average annual temperature is projected to increase with time: 1.5°C for the 2020s, 2.8°C for the 2050s and 4.1°C for the 2080s. Generally, the winter months are projected to experience the greatest increase in mean temperature.

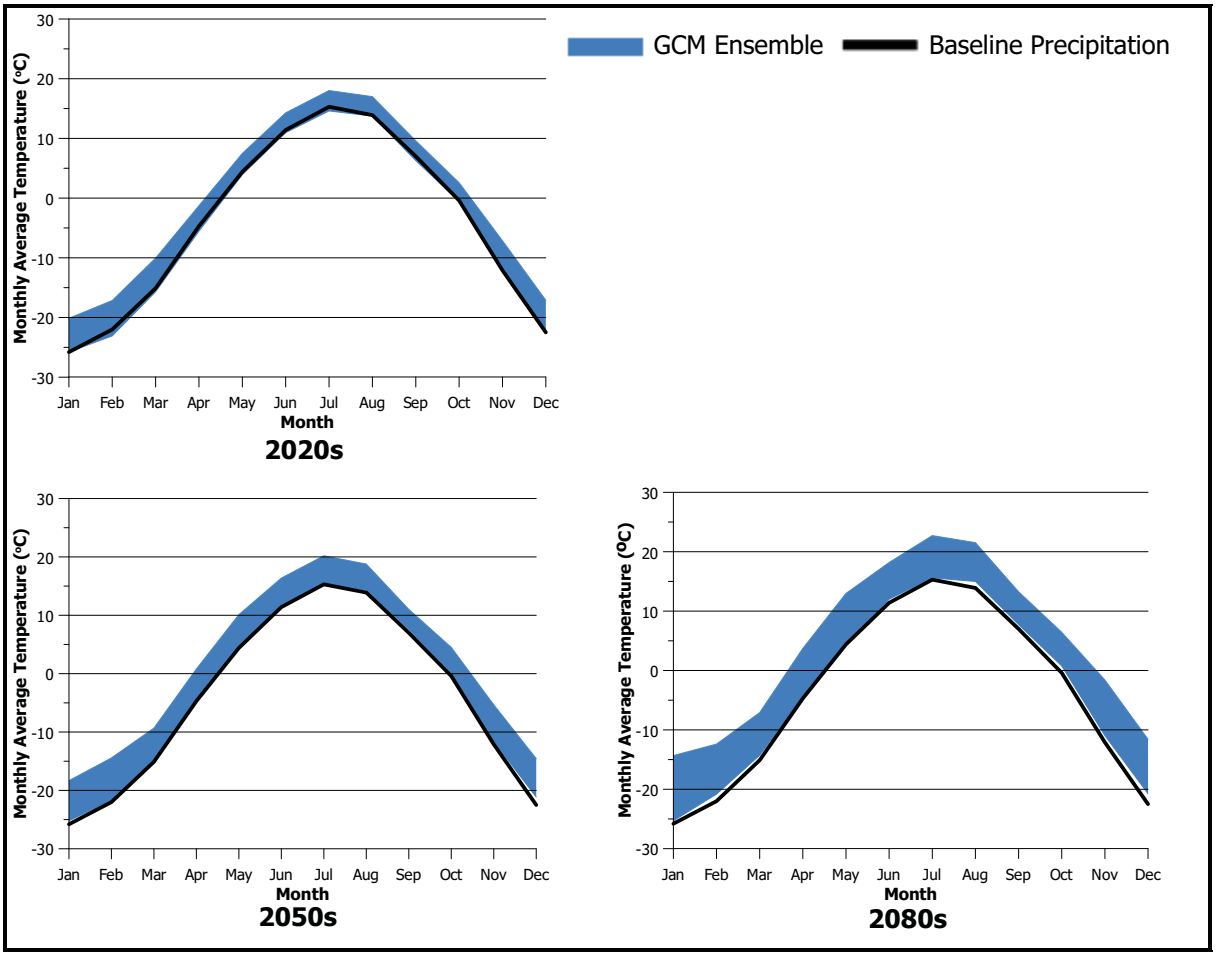

Figure 2.3-4: Monthly Average Temperature Climate Scenarios from Global Climate Model Ensemble

2.3.2.2 Precipitation – Global Climate Model Ensemble

Figure 2.3-5 illustrates the baseline precipitation (1971-2000) plotted with an envelope that represents the ensemble of future climate scenarios projected by the GCMs for the 2020s, 2050s and 2080s. This ensemble shows a pattern that on average indicates increasing precipitation in relation to the 1971-2000 baseline. However, there are some projections for drier conditions into the future. The annual precipitation is projected to increase with time: 5% for the 2020s, 10% for the 2050s and 14% for the 2080s. In general, the winter months are projected to experience the largest increase in precipitation.

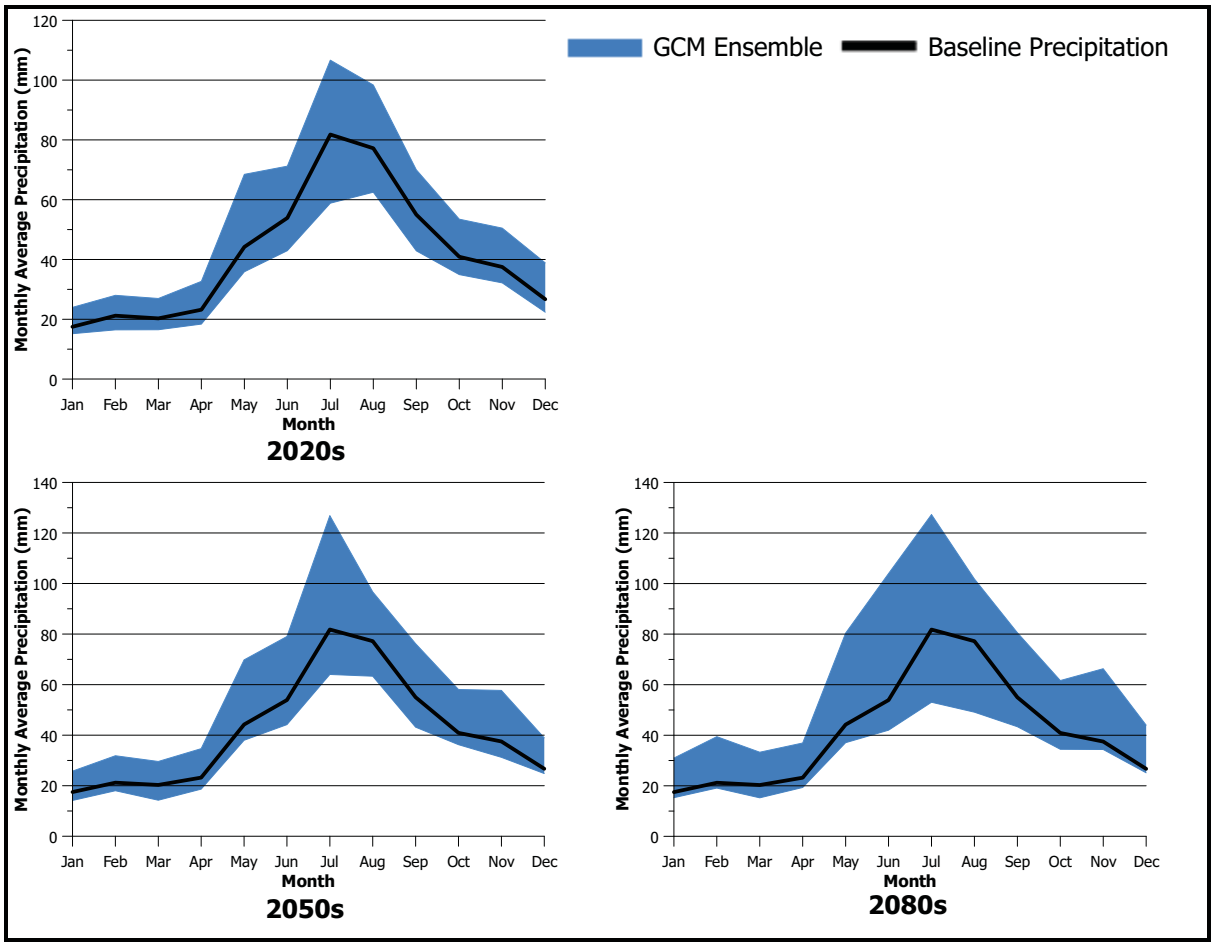

Figure 2.3-5: Monthly Average Precipitation Climate Scenarios from Global Climate Model Ensemble

2.3.2.3 Temperature, Precipitation and Evapotranspiration – Regional Climate Model

Figure 2.3-6 illustrates the annual percent change in precipitation and change in temperature for the 2020s, 2050s and 2080s as illustrated by the RCM (shown in red) and the ensemble of GCMs (driving models shown in color and the remaining GCMs shown in gray). Generally, the RCM projections fall within the same range as those from the ensemble of GCMs. The ensemble averages project increasing evapotranspiration for most months, however, some individual models indicate a decrease for certain months in certain future horizons. The ensemble average projects annual evapotranspiration to increase with time into the 2020s, 2050s and 2080s. It is important to note that these projections are from only one RCM (forced by CGCM3.1 (A2), ECHAM5 (A2) and CNRM CM3 (A1B)). It is preferable to analyze multiple models to better assess the uncertainty of a given RCM projection. However, at time of this study, additional RCMs for this area were not available.

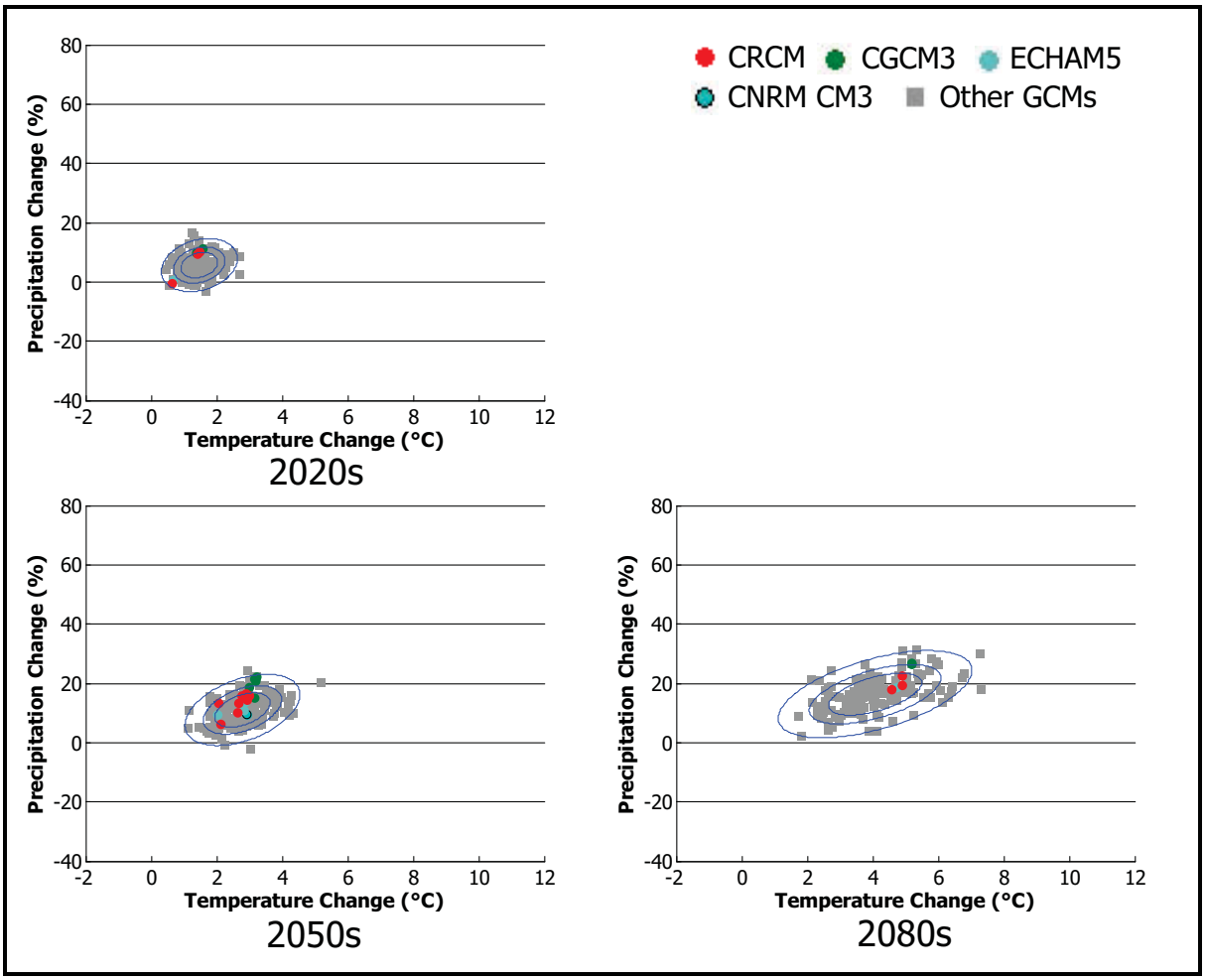

Figure 2.3-6: Annual Temperature and Precipitation Change Scenarios for Keeyask from Canadian Regional Climate Change Model

2.3.2.4 Wind and Extreme Events

According to the IPCC "….the type, frequency and intensity of extreme events are expected to change as Earth's climate changes, and these changes could occur even with relatively small mean climatic changes…a number of modelling studies have also projected a general tendency for more intense but fewer storms outside the tropics, with a tendency towards more extreme wind events…." (Meehl *et. al.,* 2007). Current studies on changes in wind conditions and extreme events are applied to a global scale and do not allow for a detailed analysis to be conducted in this study area.

2.4 PROJECT EFFECTS, MITIGATION AND MONITORING

2.4.1 Effect of the Project on Climate Change

2.4.1.1 Life-Cycle Assessment

The construction phase includes all emissions on and off the Project site that occur while the facility is being constructed. The operation phase includes all emissions from the first day of operation to when the Project is decommissioned. Decommissioning includes only emissions associated with decommissioning the facility and recycling available materials. Land use change emissions are broken out separately and include emissions that occur during the construction phase, land clearing, and emissions during the operation phase. Results are summarized in Table 2.4-1 below.

GHG emissions associated with the construction phase of the Project account for approximately 46% of life-cycle GHG emissions. The majority, 60%, of the construction phase emissions result from building material manufacture. GHG emissions from the transportation of the materials and components to site are relatively high contributors to the construction phase emissions. The lengthy transportation distances assumed (10,000 km for most steel components) and the significant quantity of steel required (greater than 60,000 tonnes) is responsible for the conservatively high life-cycle transport emissions. Emissions from onsite construction activities result from diesel combustion in construction equipment including trucks, backhoes, excavators and bulldozers.

Estimated land use change emissions account for 51% of all GHG emissions. The majority of land use change emissions are associated with the flooding of the reservoir (95%). The remaining 5% result from land cleared for roadways, transmission lines and the dykes. GHG emissions during the operation phase of the Project are primarily associated with offsite activities such as the production of replacement equipment, recycling of the damaged or worn steel components and concrete replacement. This assessment assumes that over the life of the project 10% mechanical steel will be replaced.

The majority of the GHG emissions associated with decommissioning result from recycling of steel components and onsite diesel combustion in demolition equipment.

Figure 2.4-1 presents the results broken down by phase.

Table 2.4-1: Summary Results - Keeyask Life-Cycle Analysis

		Greenhouse Gas (tCO_2eq/GWh)
Construction	Building Material Manufacture	0.68
	Transportation	0.12
	On-Site Construction Activities	0.34
Land Use Change	Clearing for Roads, Transmission and Reservoir	1.24
Operation	Generation	0.00
	Maintenance and Refurbishment	0.03
Decommissioning	Decommissioning Activities	0.05
	Total	**2.46**

Figure 2.4-1 shows that 46% of life-cycle GHG emissions are associated with the construction phase of the Project (5% from transportation, 13% from onsite construction activities and 28% from building material manufacture). GHG emissions from land use change, including reservoir flooding and clearing land for roads and transmission lines accounts for an additional 51% of emissions. Operation phase emissions, primarily steel recycling and replacement material manufacturing, accounts for 1% of life-cycle GHG emissions. The remainder, 2%, is a result of decommissioning activities including steel recycling and diesel combustion in demolition equipment.

A comparison of the life-cycle results for the alternative **power** generating technologies and the Project demonstrate life-cycle GHG emissions on a per GWh basis are significantly lower for the Project case than for all of the fossil fuel alternatives, pulverized coal (PCC), natural gas combined cycle (NGCC), natural gas single cycle (NGSC) and coal with carbon capture and storage (CCS), Figure 2.4-2. In addition, the generating station is lower than the two non-fossil fuel options, nuclear and large commercial scale wind generation. The data contained within this figure was assembled by The Pembina Institute based on published life-cycle values for the comparison technologies. For each alternative technology, multiple sources were used and the resulting median was taken as the basis for comparison. In all cases, the median presented the most conservative (lowest intensity value) for the purposes of comparison.

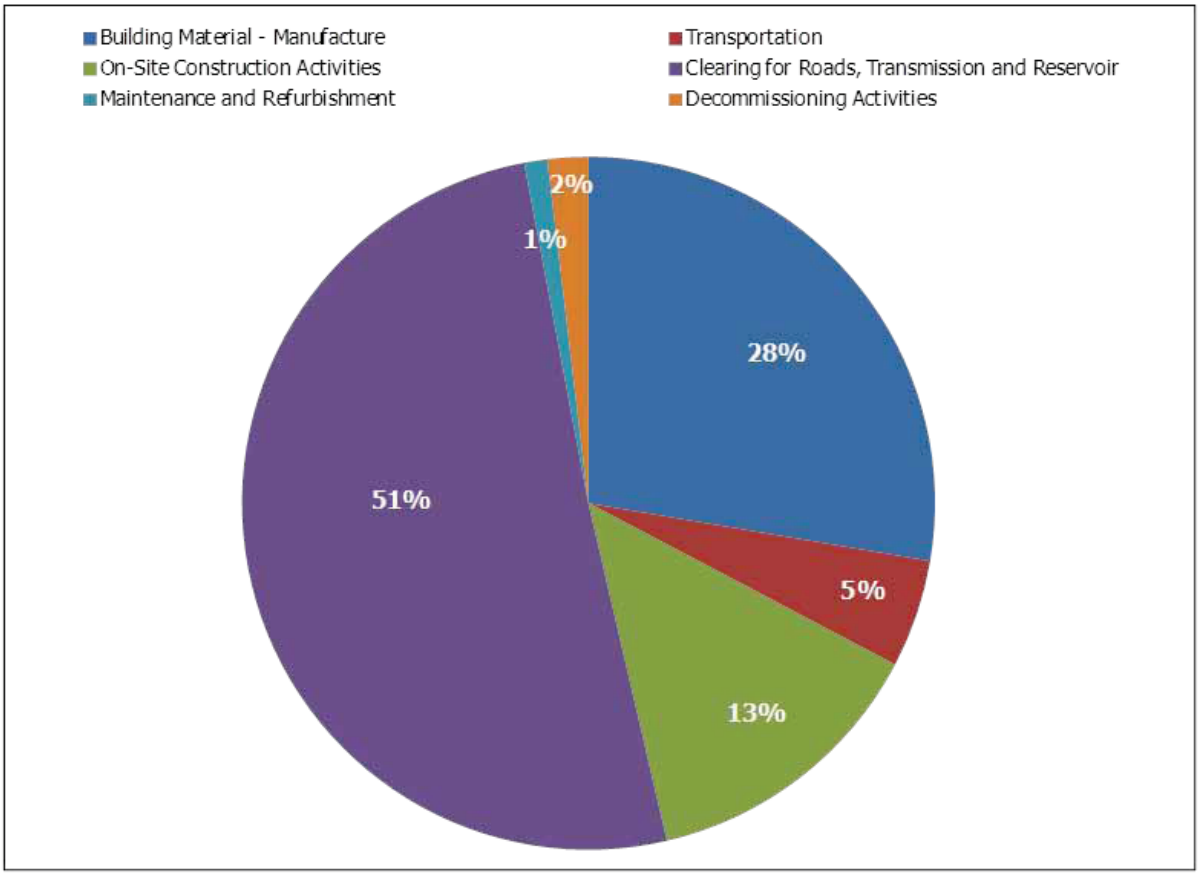

Figure 2.4-1: Breakdown of GHG Emissions per Primary Activity

To illustrate the magnitude of the difference between technologies, consider that over its 100-year life, the Project is estimated to result in 980,000 tonnes of CO_2e. Using the data from the above figure, an identically sized coal facility would release the same emissions over only 60 days of continuous operation at capacity.

2.4.1.2 Greenhouse Gas Displacement

An increase in electricity exports generated from Manitoba hydroelectric facilities results in a reduction of CO_2 emissions from fossil-fuel generation. The electricity sector is very integrated and changes to the Manitoba Hydro system have effects beyond the provincial borders of Manitoba. Displacement analysis illustrates that the neighbouring US mid-west which Manitoba Hydro is interconnected with and exports energy to, relies heavily on fossil fuel generation. The energy from the Project is assumed to displace other generation with an intensity of 0.75 tonnes CO_2/MWh or 750 tonne CO_2e/GWh.

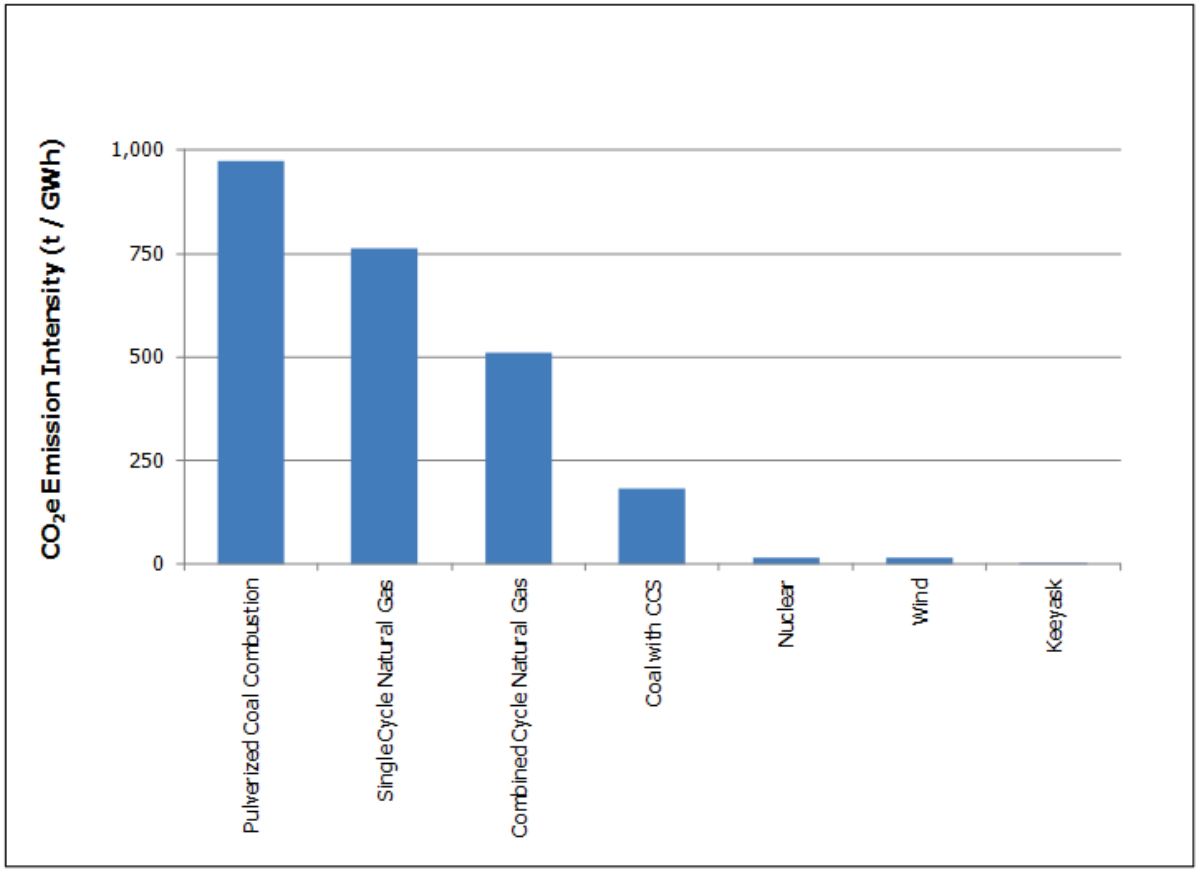

Figure 2.4-2: Generation Life-Cycle Comparison

2.4.2 Mitigation

2.4.2.1 Keeyask Project

The Keeyask Project design strove to reduce flooding to the extent practical. As illustrated in this report, no significant negative GHG implications and overall net climate change benefit considering displacement of emissions through energy exports. No further **mitigation** required.

2.4.2.2 Manitoba Hydro's Climate Change Strategies

Through the Corporate Strategic Plan, Manitoba Hydro has established measures and targets related to GHGs that drive strategies and actions to understand, adapt, report and reduce GHG emissions as well as influence government policy. Manitoba Hydro is committed to reduce its GHG emissions and to contribute to global emission reductions through development of renewable and Power Smart resources. Manitoba Hydro has adopted a voluntary commitment to keep gross annual greenhouse gas emissions to 6% below its 1990 baseline.

Refer to Appendix 2B for a description of additional initiatives.

2.4.3 Summary of Residual Effects

The life-cycle analysis estimates the GHG created from the construction, land use change, operations, and decommissioning of the Keeyask GS to be 2.46 tonne CO_2eq/GWh. There are three key factors which contribute to this low GHG intensity*:* very modest LCA calculated emissions; the long life of the hydro facility producing vast amounts of energy; and no emissions from the daily generation as characteristic of other fossil fuel generating resources.

The net effect of the project on climate change can be characterized as follows:

- LCA GHG - Displaced GHG = Net Effect of Project on Climate Change.
- 2.46 tCO_2eq/GWh - 750 tCO_2e/GWh = -748 tCO_2e/GWh.

The net benefit of the Project is therefore a reduction of 748 tCO_2eq/GWh, which is the basis for the assessment of the Project effects on climate (Table 2.4- 2).

Table 2.4-2: Summary of Climate Residual Effects

Physical Environment Climate Change Effects	Magnitude	Extent	Duration	Frequency
The Project climate change benefit of displacing up to 748 tonne CO_2eq/GWh	High and Positive	Large	Long-term	Continuous

2.4.4 Interaction with Future Projects

Similar to the Keeyask GHG life-cycle assessment that estimated the emissions resulting from the construction, land use change, operation, and decommissioning of the Project, analysis is being completed for the Conawapa GS and Bipole III projects. Although final life-cycle assessments are not complete, preliminary results suggest that the GHG emission intensity for Conawapa will be very small, similar to that of Keeyask. There is no interactive climate change effects between the construction of generating stations and each is analyzed independently.

Preliminary assessment of the total life-cycle GHG emissions associated Bipole III indicate that the emissions will be on the same order of magnitude as that of the Keeyask project. While the assessment of the life-cycle GHG emissions associated with Bipole III does not interact with that of the generating stations they can be considered as additive for some purposes. Even if all of the life-cycle GHG emissions from Bipole III were assigned to the Keeyask project, the combined life-cycle GHG emission intensity is still less than half of the wind technology value shown in Figure 2.4-2 and less than 1% of the life-cycle GHG emission intensity associated with super critical pulverized coal combustion technology,

also shown in Figure 2.4-2. Since the electricity delivered from these projects displaces emissions much greater than those of the projects themselves, they result in a significant net benefit.

2.4.5 Monitoring and Follow-Up

Since 2008, Manitoba Hydro has conducted field studies to measure **pre-impoundment** CO_2 and CH_4 **concentrations** at the site of the proposed Keeyask reservoir, at upstream and downstream locations along the Nelson River, and at nearby reference lakes (Maps 2.4-1 and 2.4-2). Pre-Project data will continue to be collected and analyzed to determine the magnitude and composition of GHG concentrations, seasonal and annual trends, and spatial variation. These monitoring results will be used to refine pre-project GHG emissions at the proposed Keeyask reservoir. GHG monitoring will continue prior to and after reservoir establishment.

2.5 REFERENCES

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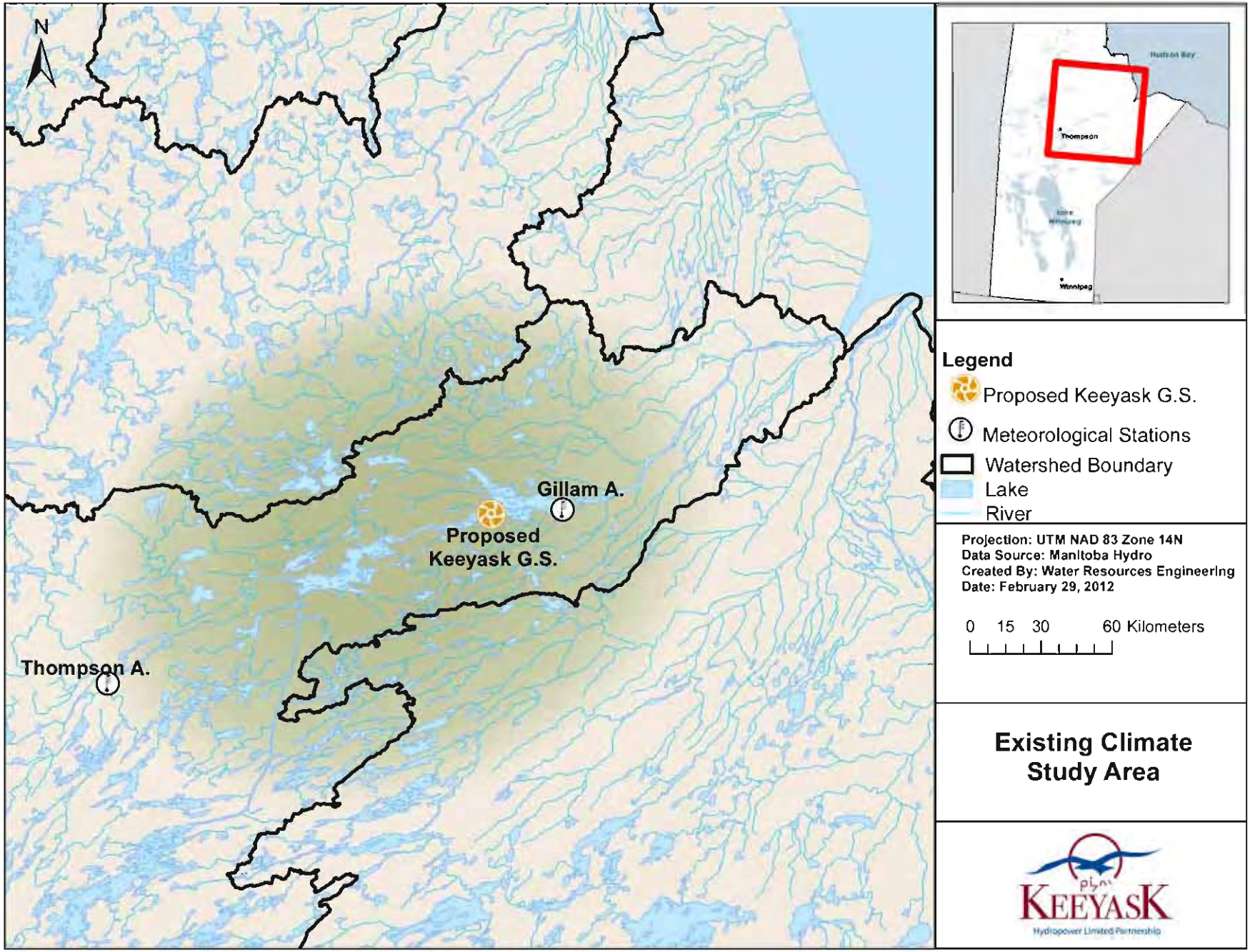
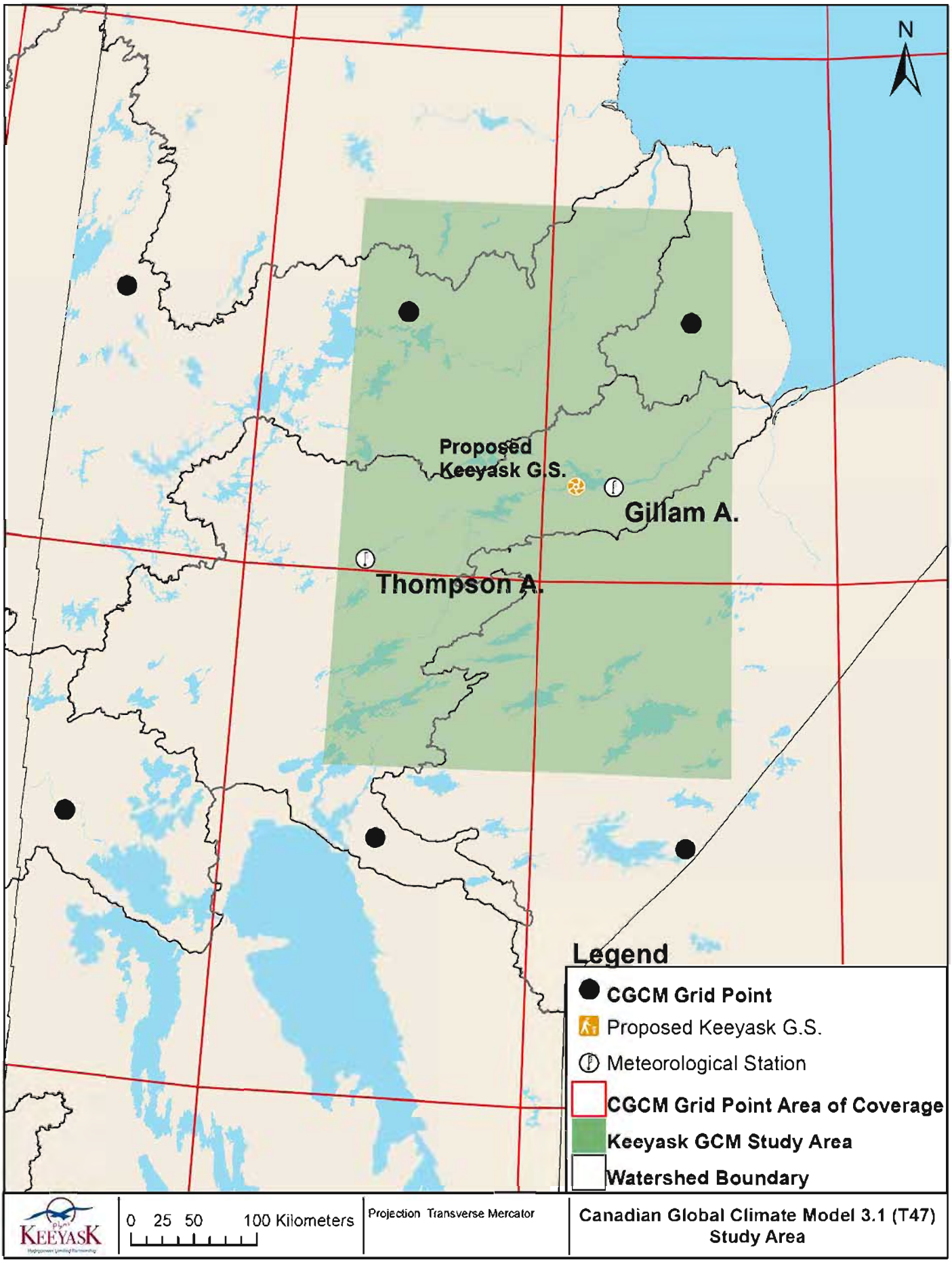
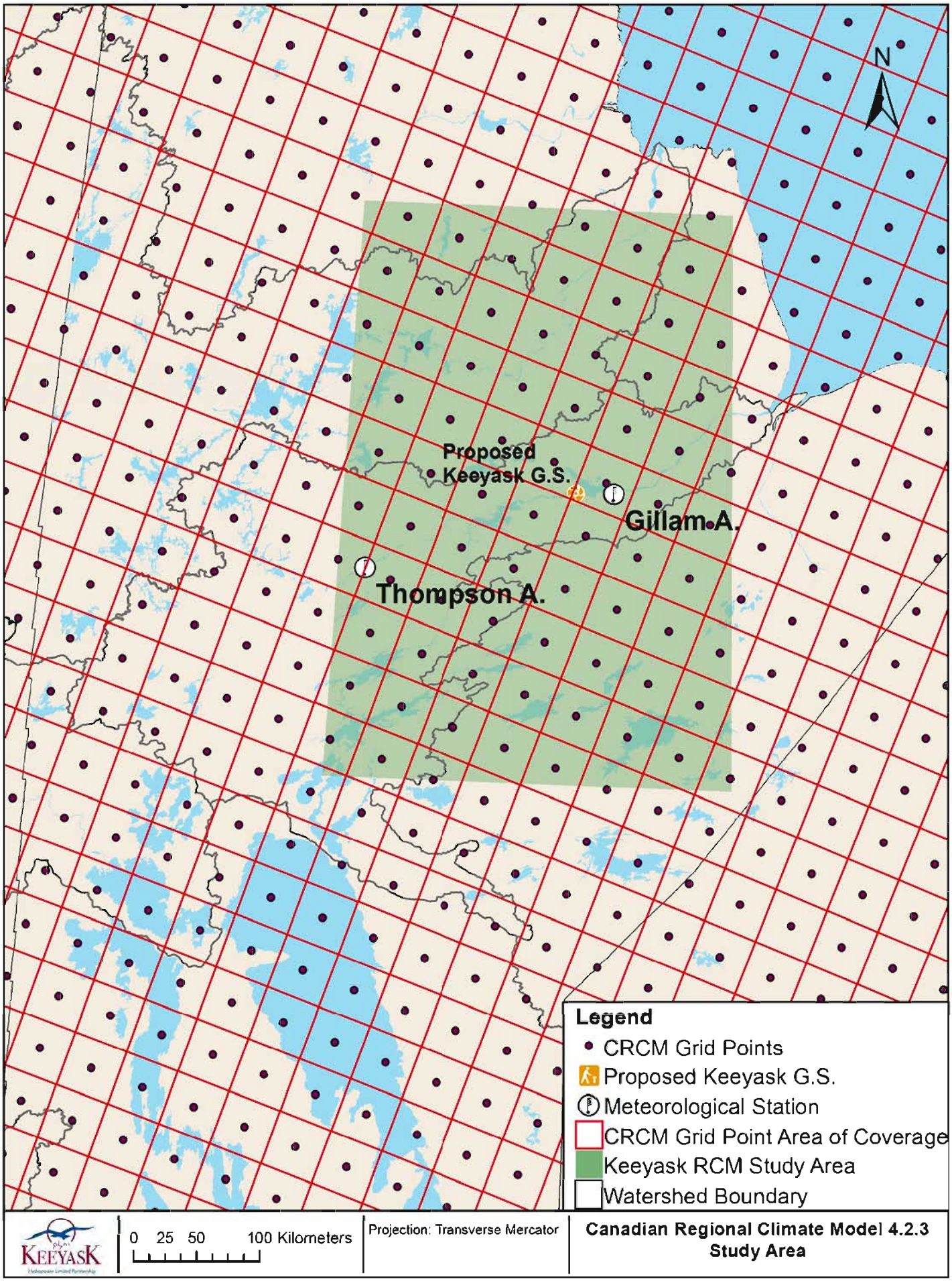

N
Gillam A.
Proposed
Keeyask G.S.
Thompson A.
Thompson
Winnipeg
Legend
Proposed Keeyask G.S.
Meteorological Stations
Watershed Boundary
Lake
River
Projection: UTM NAD 83 Zone 14N
Data Source: Manitoba Hydro
Created By: Water Resources Engineering
Date: February 29, 2012
0 15 30 60 Kilometers
Existing Climate
Study Area
KEEYASK
Hydropower Limited Partnership

Map 2.2-1


N
Proposed
Keeyask G.S.
Gillam A.
Thompson A.
Legend
CGCM Grid Point
Proposed Keeyask G.S.
Meteorological Station
CGCM Grid Point Area of Coverage
Keeyask GCM Study Area
Watershed Boundary
KEEYASK
0 25 50 100 Kilometers
Projection Transverse Mercator
Canadian Global Climate Model 3.1 (T47)
Study Area

Map 2.2-2



Canadian Regional Climate Model 4.2.3 Study Area

Map 2.2-3

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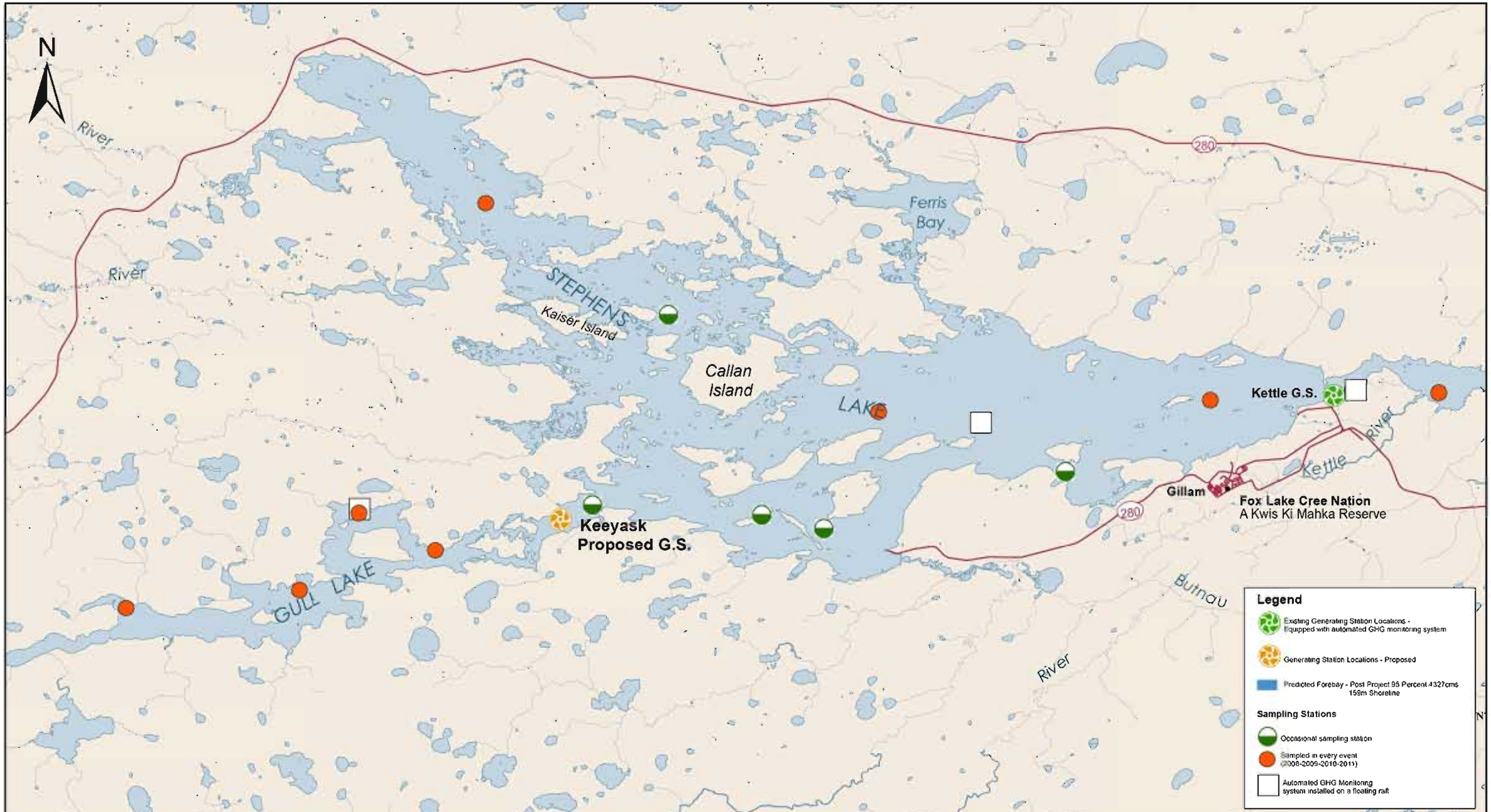


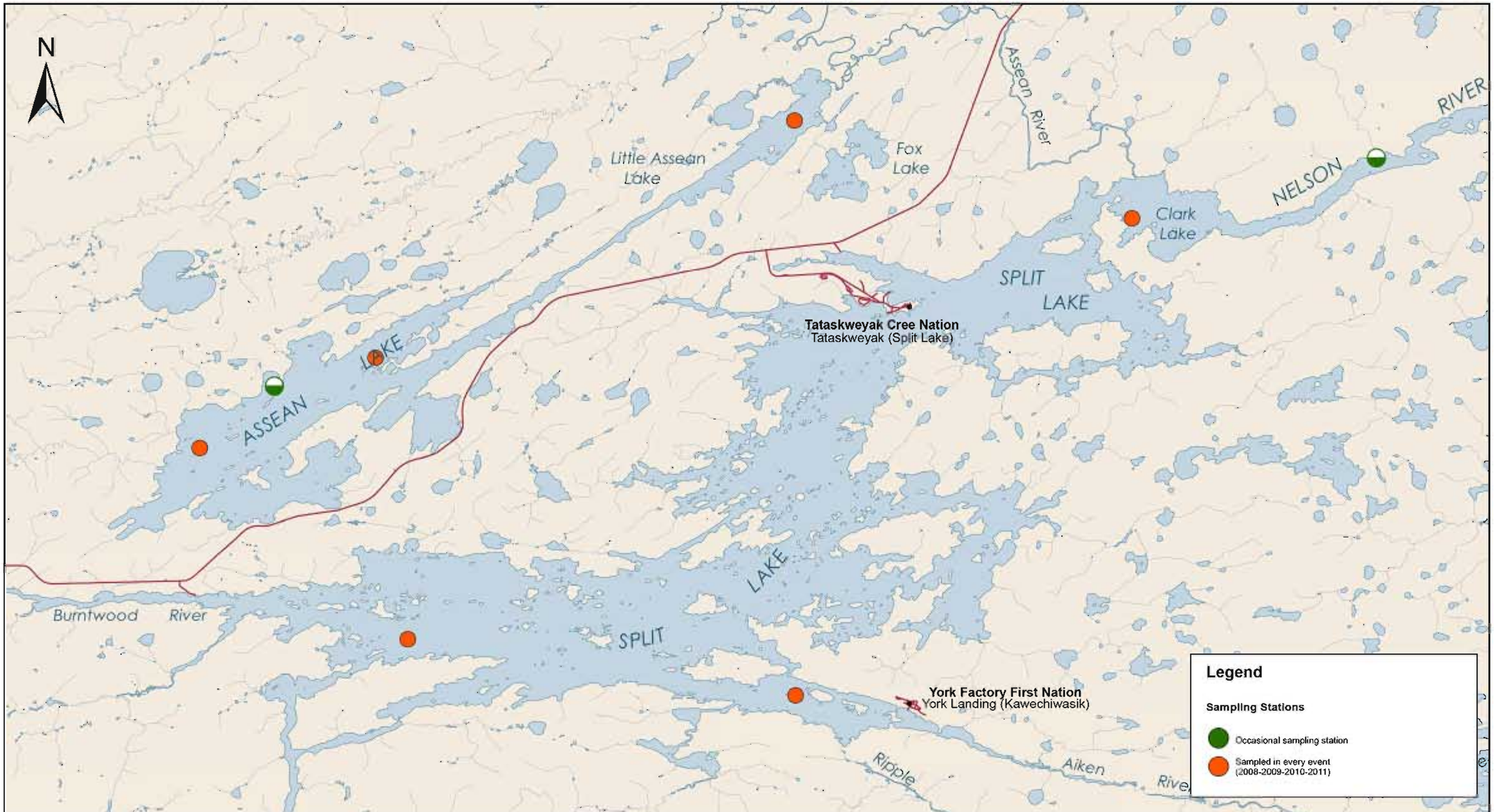
KEEYASK

0 2 4 8 Kilometres

Projection: UTM NAD 83 Zone 14N
Data Source: Environnement Illimité inc./Carto-Média, & Manitoba Hydro

Keeyask Area - Upstream & Downstream Pre-Project Greenhouse Gas Sampling Stations

Map 2.4-1



0 2 4 8 Kilometres

Projection: UTM NAD 83 Zone 14N
Data Source: Environnement Illimité inc./Carto-Média, & Manitoba Hydro

Split Lake Area - Pre-Project Greenhouse Gas Sampling Stations

Map 2.4-2

APPENDIX 2A

RESERVOIR GREENHOUSE GAS SCIENCE AND QUANTIFICATION

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2A.0 RESERVOIR GREENHOUSE GAS SCIENCE AND QUANTIFICATION

2A.1 GENERAL

Many natural processes, such as biological respiration and decay of organic matter, produce Greenhouse gas (GHGs). These occur in natural environments including lakes as illustrated conceptually in Figure 2A-1.

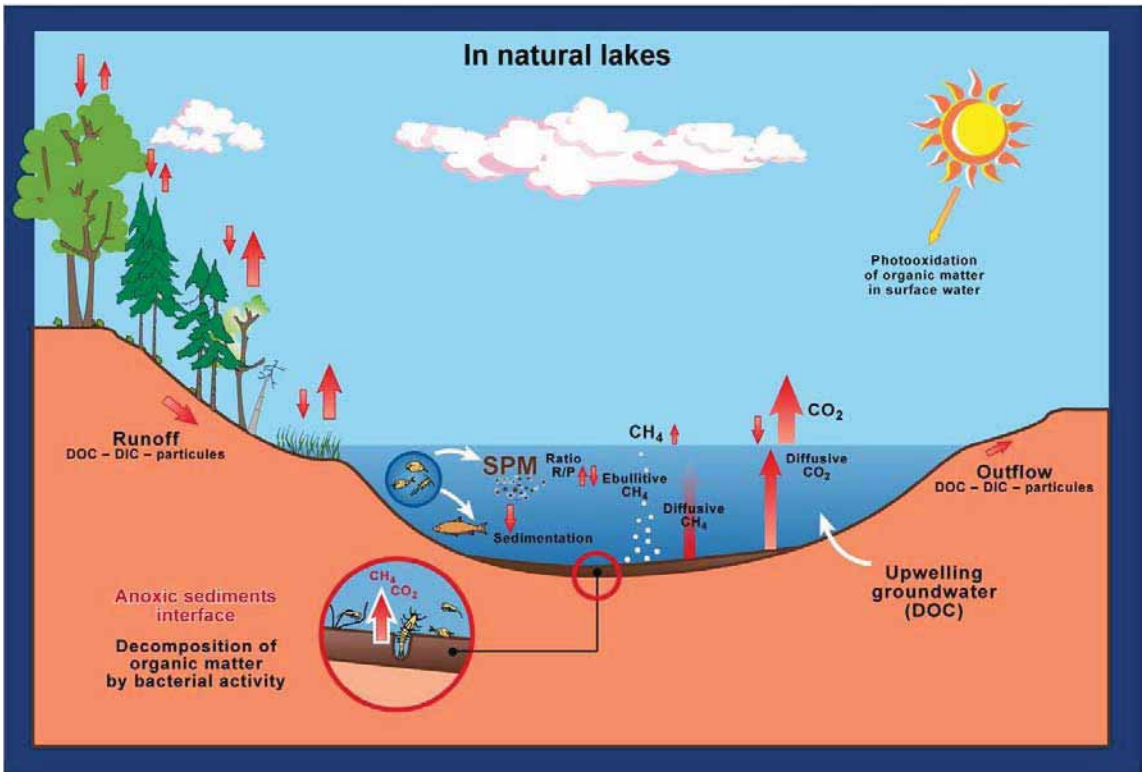

Figure 2A-1: Major Processes Occurring in Natural Lakes

Other natural landscapes such as forests, wetlands, and peatlands also exchange GHGs with the atmosphere. Many anthropogenic processes produce GHGs. These include fossil fuel combustion, agricultural practices, and land use changes.

GHGs are exchanged naturally with the atmosphere by terrestrial and aquatic ecosystems. Current research indicates that in general, boreal forests are net sinks of GHGs although they can act as sources or tend towards a state of equilibrium with atmospheric GHGs, depending on forest age and environmental parameters (Blais *et al.,* 2005). They are typically net consumers of CO_2 and CH_4 and emit minor amounts of N_2O. Boreal peatlands sequester atmospheric CO_2 as peat while emitting atmospheric CH_4 through decomposition (Gorham 1991; Gorham 1995; Strack *et al.,* 2008). Though highly specific

both geographically and temporally, recent estimates of GHG budgets indicate that northern peatlands can be net sources of GHGs, primarily through the release of CH_4, while simultaneously accumulating small quantities of CO_2 (Blais *et al.,* 2005). Aquatic systems are generally net sources of GHGs, releasing CO_2, CH_4 and very minor amounts of N_2O (Adams, 2005; Tremblay *et al.*, 2005).

The chemical, morphological, and biological processes that create and exchange GHGs in reservoirs are similar to those of naturally occurring aquatic systems. However, some of these processes may be temporarily altered during reservoir creation from the flooding of terrestrial ecosystems. A portion of the readily available organic matter in the flooded soils, plant material, and wood decomposes and emits GHGs, primarily in the form of CO_2 and CH_4.

Regional increases in temperature resulting from global climate change are expected to cause sporadically occurring permafrost mounds in the Keeyask region to partially or completely melt, forming wet depressions. Turetsky *et al.,* (2002a) showed that net carbon accumulation in wet depressions exceeds that in permafrost mounds for at least 100 years after permafrost melting at the site they investigated. However, in another study, Turetsky *et al.*, (2002b) determined that local CO_2 and CH_4 emissions would increase 1.6 and 30 fold, respectively, in response to permafrost melting. These apparently conflicting results demonstrate that the effect of permafrost melting on GHG emission rates is highly dependent upon site-specific conditions and, therefore, difficult to predict.

2A.2 BASELINE CONDITIONS AND GREENHOUSE GAS EMISSIONS

The gross mean fluxes of GHGs from Canadian boreal lakes and rivers have been estimated to vary from 179 to 2,810 mg per square metre per day ($mg/m^2/d$) for CO_2 and 0 to 11 ($mg/m^2/d$) for CH_4. Within the Keeyask region, Manitoba Hydro assessed GHG fluxes from two (2) reference lakes: Assean Lake and Gull Lake. For Assean Lake, the ranges of these fluxes were estimated to be -29 to 1,649 mg $CO_2/m^2/d$ and 0.8 to 0.8 mg $CH_4/m^2/d$. For Gull Lake, the ranges were 148 to 167 mg $CO_2/m^2/d$ and 0.4 to 1.3 mg $CH_4/m^2/d$. This range of values provides an estimate of anticipated emissions from the proposed Keeyask reservoir after an initial establishment period.

Before impoundment, approximately 48.0 km^2 of the proposed Keeyask reservoir site comprises aquatic environments (Section 4.3, Map 4.3-4). An average year will experience roughly 170 ice-free days in the Keeyask region. Based on average climatic values and the range of CO_2 and CH_4 fluxes from the findings above aquatic ecosystems in the Keeyask area are estimated to emit 152 to 13,727 tonnes CO_2eq annually prior to hydroelectric development.

GHG emissions from terrestrial environments vary according to the type and age of vegetation cover, the composition of land type (*e.g.,* peatlands or mineral soils) and the size of area involved.

Current research indicates that in general, Boreal forests are net sinks of GHGs. They are typically net consumers of CO_2 as vegetation is growing, consume CH_4 through soil activity, and emit minor amounts of N_2O through soil formation processes.

Due to frequent saturated conditions, ecosystems such as wetlands and peatlands have characteristics of both terrestrial and aquatic ecosystems. Depending primarily upon the level of the local water table, such ecosystems may behave as GHG sources or sinks. However, this behaviour may attenuate or even reverse depending upon local climatic conditions. Nevertheless, boreal peatlands may be net sources of GHGs, mostly as CH_4, as organic matter in water saturated soils decomposes.

The flooded land area of approximately 45 km^2 comprises forest and non-forested areas, on mineral soils and peatlands. This translates to an estimated overall GHG flux ranging from -1,543 to 3915 mg $CO_2eq/m^2/d$.

With an average annual growth period of 180 days, terrestrial ecosystems in the Keeyask area are estimated to emit approximately -12,889 to 32,705 tonnes CO_2eq annually prior to hydroelectric development.

Combining the estimated aquatic and terrestrial gross annual emissions values results in an overall gross emission of -13,041 to 46,432 tonnes CO_2eq annually from the Keeyask area prior to hydroelectric development.

2A.3 PREDICTED RESERVOIR GREENHOUSE GAS EMISSIONS

The planned hydroelectric development in the Keeyask area will result in flooding of terrestrial and aquatic environments, incorporating them into the Keeyask reservoir.

Studies indicate that GHG emissions from boreal hydroelectric reservoirs increase rapidly shortly after flooding and return towards levels similar to those of natural waterbodies within a period of 10 years following impoundment (Tremblay *et al.,* 2008; Tremblay *et al.,* 2009). Research by Tremblay *et al.,* (2009) on a newly flooded Boreal reservoir in Québec drew the following conclusions:

- Gross CO_2 and CH_4 emission fluxes peaked within the first year after impoundment.
- The magnitude of GHG emission peak fluxes was four to five times those of nearby natural lakes and rivers.
- Emission fluxes of CO_2 returned to background levels of surrounding lakes and rivers within 3 years.
- Emission fluxes of CH_4 returned to background levels of surrounding lakes and rivers within 2 years.
- GHG emissions from boreal hydroelectric reservoirs appear to be low.

These observations may be considered generally representative of reservoirs established in boreal environments with discontinuous permafrost.

The Québec reservoir is located in a climatic zone where permafrost occurs in "isolated" patches (whereas permafrost occurs "sporadically" in the Keeyask region), according to Natural Resources Canada (2003). Therefore, the effect on GHG contributions from flooding permafrost may have been inadvertently incorporated into the findings of Tremblay *et al.*

Maximum GHG emissions have been observed relatively quickly after impoundment. This is due to decomposition of some of the readily available organic matter in the terrestrial ecosystem that was flooded. This organic matter has been observed to decay generally during the 10-year period following impoundment. GHG emissions peak and then return to levels similar to those of natural waterbodies. Adopting 2006 IPCC guidance, total annual GHG emissions during this 10-year establishment period are estimated to be 958 to 37,414 tonnes CO_2eq/year.

Manitoba Hydro has studied the GHG concentrations from four of its reservoirs beginning in 2003 using automated, continuous monitors. All Manitoba Hydro reservoirs were and are well over 10 years old and therefore, GHG concentrations from newly established hydroelectric reservoirs in Manitoba have not been measured. The reservoirs included in the study are located on the Winnipeg (McArthur GS and Pointe du Bois GS), the Saskatchewan (Grand Rapids GS), and the Nelson Rivers (Jenpeg and Kettle GS) as shown in Map 2A-1. Both Kettle and Jenpeg GS are located in permafrost zones and therefore, impacts due to flooding of discontinuous permafrost may be inadvertently reflected in these findings. However, these studies were not specifically designed to investigate this effect.

The following mean GHG flux ranges were estimated from gas concentrations observed at the four Manitoba Hydro reservoirs:

- 190 to 553 mg $CO_2/m^2/d$; and
- 0.16 to 1.63 mg $CH_4/m^2/d$.

Similar ranges were estimated from gas concentration data collected from two well established (*i.e.,* established at least 10 years prior to study) Québec reservoirs using the same measurement techniques, as follows:

- 278 to 1,402 mg $CO_2/m^2/d$; and
- -0.05 to 0.37 mg $CH_4/m^2/d$.

These findings indicate the range of reservoir GHG emissions that could be emitted from the Keeyask site, once the reservoir matures roughly 10 years after impoundment. It is anticipated that the Keeyask reservoir will behave similarly to those reservoirs described above; that is, somewhat elevated GHG emissions are expected within the first few years after impoundment only to return to levels similar to background within 10 years.

To estimate the value of increased GHG emissions following reservoir creation, the 2006 Intergovernmental Panel on Climate Change (IPCC) guidance was adopted along with the following physical/climatic characteristics of the proposed development:

- Area of flooded terrestrial environment = 45.1 km^2, expanding to 52.4 km^2 after 30 years.
- Total reservoir area (including pre-flooded area) = 93.1 km^2, expanding to 100.4 km^2 after 30 years.
- Number of ice-free days = 170 days.

Within the first 10 years, the newly established Keeyask reservoir is estimated to emit 1,000 to 38,000 tonnes CO_2eq/year, adopting IPCC published minimum and maximum GHG emission factors

and guidance (2006). This range represents peak GHG emissions resulting from the impoundment and is illustrated by the green profile shown in Figure 2A-1. The Keeyask reservoir is expected to expand from 45.1 km^2 to 52.4 km^2 over 30 years due to peatland disintegration. Reservoir GHG emissions estimates incorporate the 52.4 km^2 area immediately after flooding and are therefore considered to be conservative.

The 2006 IPCC guidelines account for burned non-merchantable timber that is cleared to make way for hydroelectric reservoirs. At Keeyask, one-time GHG emissions produced by burning are estimated as approximately 172,000 tonnes CO_2eq. The methodology is conservative, however, as it assumes that this biomass remains in place when calculating reservoir GHG emissions due to flooding of forested land. Therefore, the methodology could "double count" some of this biomass, thereby producing inflated GHG emission estimates (IPCC 2006).

After roughly 10 years have passed, GHG emissions are estimated to stabilize at 300 to 7,000 tonnes CO_2eq/year. These emissions are similar to those of surrounding natural lakes and rivers in the Keeyask region. Over the lifetime (approximately 100 years) of the Keeyask reservoir, including the initial 10-year peak GHG emission period, a total of 32,000 to 975,000 tonnes of CO_2eq are estimated.

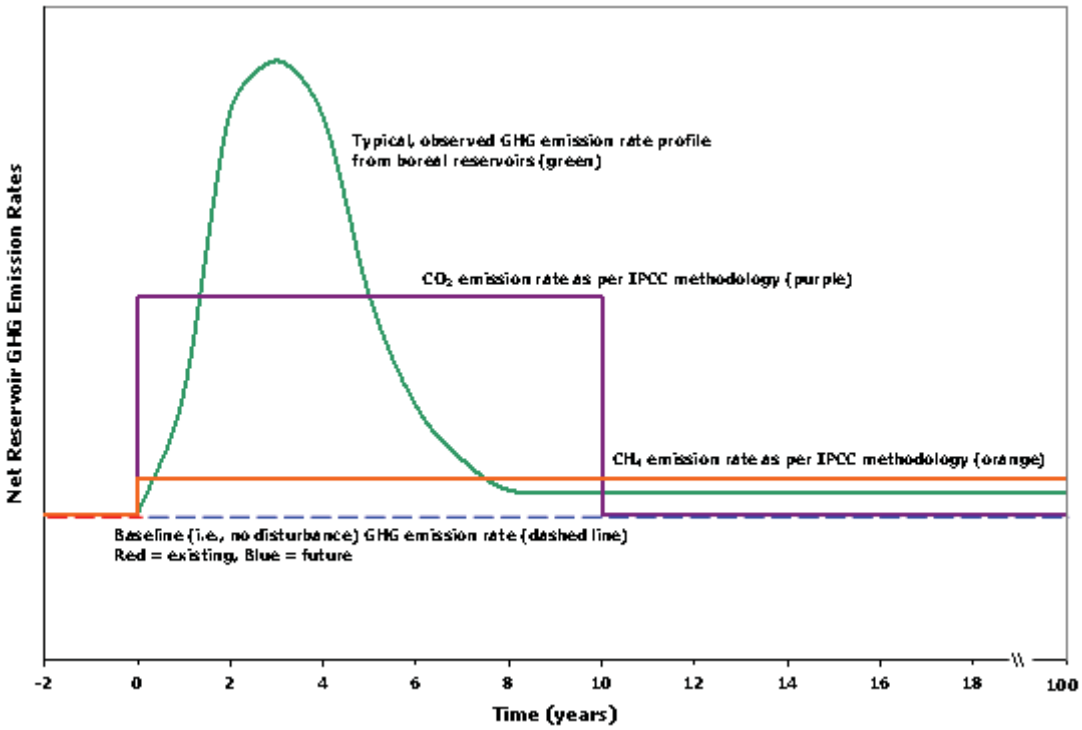

Figure 2A-1: Post-Flooding Boreal Reservoir GHG Emissions: Predictions Based on IPCC Methodology and Observed Conceptual Pattern

2A.4 IMPACTS

Following an initial period of roughly 10 years, reservoir GHG emission rates from this development are anticipated to resemble those of the nearby lakes and rivers in the Keeyask area.

2A.5 MONITORING

Since 2008, Manitoba Hydro has conducted field studies to measure pre-impoundment CO_2 and CH_4 concentrations at the site of the proposed Keeyask reservoir, at upstream and downstream locations along the Nelson River, and at nearby reference lakes. These locations are shown in Map 2.4-1 and Map 2.4-2.

Pre-impoundment data will continue to be collected and analyzed to determine the magnitude and composition of GHG concentrations, seasonal and annual trends, and spatial variation. These monitoring results will be used to refine baseline GHG concentrations at the proposed Keeyask reservoir. GHG monitoring will continue prior to and after reservoir establishment. Monitoring results will be communicated.

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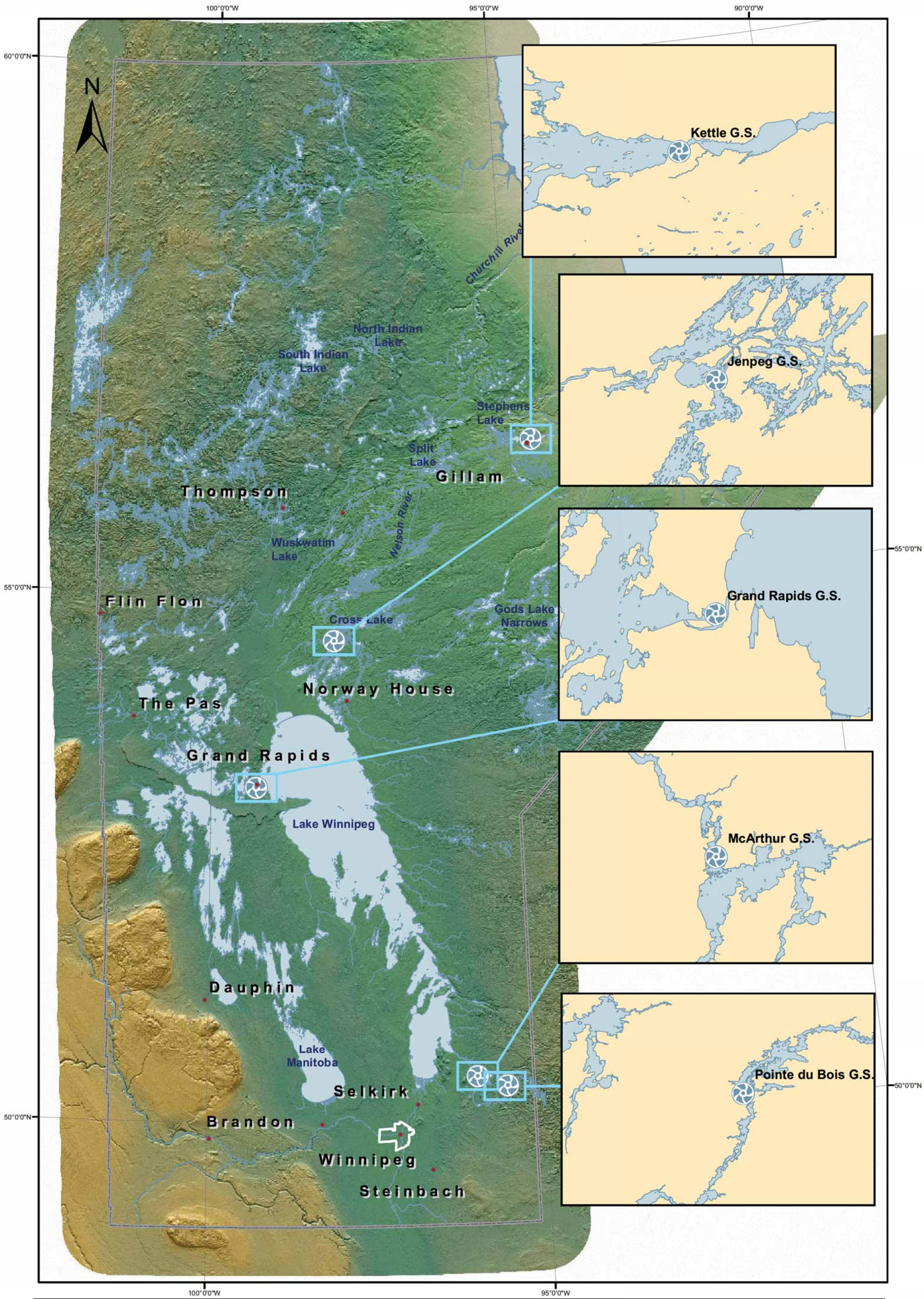

KEEYASK Hydropower Limited Partnership

0 25 50 100 Kilometers
0 12.5 25 50 Miles

Coordinate System: UTM NAD1983 Z14N
Data Source: Manitoba Hydro

Manitoba Hydro Continuous Greenhouse Gas Monitors

Map 2.A-1

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APPENDIX 2B

MANITOBA HYDRO'S CLIMATE CHANGE STRATEGIES

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2B.0 MANITOBA HYDRO'S CLIMATE CHANGE STRATEGIES

2B.1 GENERAL

Manitoba Hydro is committed to balancing the social, economic and environmental needs and interests of all its stakeholders. To support the commitment to the environment and drive change, the Corporation has established an environmental goal within the Corporate Strategic Plan to:

- Be proactive in protecting the environment and be the leading utility in promoting sustainable energy supply and service.

Through the Corporate Strategic Plan, Manitoba Hydro has established measures and targets related to greenhouse gases that drive strategies and actions to understand, adapt, report and reduce greenhouse gas emissions as well as influence government policy.

2B.2 RESEARCH AND OTHER INITIATIVES

The United Nations Environment Programme and the World Meteorological Organization have established the Intergovernmental Panel of Climate Change (IPCC), which is the leading body for the assessment of climate change. The IPCC provides the world with a clear scientific view on the current state of climate change. Manitoba Hydro makes all efforts to follow the guidance of the IPCC.

Manitoba Hydro is also currently undertaking a number of initiatives to understand the potential impacts of climate change within its hydraulic system. Manitoba Hydro is an affiliated member of Ouranos, in Montreal, which is a consortium of scientists from around the world studying climate change with a focus on Canada. With this affiliation, Manitoba Hydro gains access to the Canadian climate change community including their databanks, expertise and training.

Manitoba Hydro is funding a collaborative dynamical downscaling climate change research project through its Research Management Board with the University of Manitoba, École de Technologies Superièure in Montreal, Ouranos and Hydro-Québec. This study will investigate dynamical downscaling techniques to assess the long-term impacts of climate change on selected sub-basins within Manitoba Hydro's system.

Manitoba Hydro is funding a project through its Research Management Board with the University of Manitoba to test various statistical downscaling techniques at selected sub-basins within Manitoba Hydro's system. These statistical downscaling techniques are designed to provide more defined projections of climate change.

Manitoba Hydro has also participated in a number of research initiatives to study past climates, using both statistical techniques and techniques that employ indicators of past extremes such as tree-rings and

lake sediments with the objective of defining the probability of recurrence of the worst drought on record and the likelihood of more extreme drought events in the future.

2B.3 RESERVOIR GHGS

Manitoba Hydro endeavors to advance reservoir GHG science and measurement technology through their own research and by actively participating in Canadian and international initiatives.

The Corporation is involved with the United Nations Educational, Scientific and Cultural Organization (UNESCO)/International Hydropower Association project to develop a guidance document for a standardized measurement protocol to assess net GHG emissions from hydropower reservoirs.

Manitoba Hydro has supported Fisheries and Oceans Canada research scientists to develop reservoir GHG monitoring devices, which are currently being used by the Corporation.

Manitoba Hydro is collaborating with industry and other private sector partners to develop new GHG sensor technology to improve GHG measurement accuracy and equipment reliability.

Working with their research partners, Manitoba Hydro is publishing their reservoir GHG measurement techniques and research findings in scientific journals. Their reservoir GHG work is being presented at conferences and workshops, which involve the hydropower industry and the scientific community. The goal is to advance reservoir GHG science through information exchange and to make improvements to Manitoba Hydro's reservoir GHG program if appropriate.

2B.4 NATURAL GAS OPERATIONS

Manitoba Hydro (and Centra Gas Manitoba Inc.) has been actively engaged with the Canadian natural gas industry for more than 10 years to develop and continuously refine GHG measurement protocols, annual GHG inventories and GHG reduction measures.

The Corporation has employed engineering and operational changes to minimize GHG emissions from its natural gas operations. Manitoba Hydro's GHG emissions from its natural gas operations are amongst the lowest of natural gas distribution companies in Canada.

The Corporation is supporting the Canadian gas industry's evaluation of integrating alternative energy sources with natural gas to improve energy efficiency and reduce GHG emissions for its pipeline operations and for commercial and residential end-users. Ground source energy and solar thermal energy are being assessed.

Through the Canadian Gas Association, Manitoba Hydro is supporting the Quality Urban Energy Systems of Tomorrow (QUEST) initiative. QUEST promotes an integrated approach to land-use, energy, transport, water and wastewater management in communities and urban centres in order to address energy end-use and reduce GHG emissions.

2B.5 CLIMATE CHANGE ADAPTATION STRATEGIES

Manitoba Hydro is in the process of investigating how best to factor climate change impacts into long-term planning and operation of its system. The first stage of this process will be developing a range of plausible scenarios that incorporate a broad range of factors that have the potential to be impacted by future climate including water supply, regulation of major reservoirs, domestic load and demand-side management, energy policy and environmental policy. The intent is to use these scenarios to test the robustness of current development options, and where there appears to be strong evidence of impacts on our operations, develop appropriate adaptation strategies. The impacts must first be considered at a system-wide scale (Nelson-Churchill watershed) before they can be considered at the local regional scale (*e.g.,* for the Keeyask Project study area).

At this time it is not feasible to propose site-specific strategies that deal with potential impacts of climate change on the local environment of the Keeyask Generation Project. This is due to the complexity and uncertainty about the key factors that could potentially be affected such as water temperature, inflow variability, and the frequency and intensity of system-wide drought. Through ongoing research and sensitivity analyses, Manitoba Hydro will continue to advance the state of knowledge of climate change impacts at the system-wide scale and improve our understanding of how these impacts could affect the Keeyask Project environment. The initial stages of the process will draw on the knowledge of future water regime gained by modelling of future climate scenarios, as discussed in the following sections.

2B.6 GREENHOUSE GAS REPORTING AND COMMITMENTS

In addition to Manitoba Hydro's requirement to submit mandatory annual reports under Environment Canada's GHG reporting program, Manitoba Hydro simultaneously reports through and maintains two voluntary greenhouse gas emissions reduction commitments.

Beginning in 2008, the Corporation has adopted a revised voluntary commitment to reduce gross annual greenhouse gas emissions to 6% below the 1990 baseline. This new measure and associated target is in effect until such time as federal regulations are in place. Manitoba Hydro recognizes that meeting this target emission level will be subject to variability in water flows and resulting levels of hydraulic and thermal generation.

Previously, and in the 2008 to 2009 Corporate Strategic Plan, Manitoba Hydro's greenhouse gas measure committed the Corporation to reduce cumulative average net emissions over the 1991 to 2007 period to 6% below the 1990 level. This commitment was originally established under the Voluntary Challenge & Registry (VCR) Program however, many changes have taken place and emissions reduction programs have evolved, resulting in aspects of this commitment becoming dated.

In 2003 as a charter member, Manitoba Hydro committed its voluntary participation in the Chicago Climate Exchange (CCX). Manitoba Hydro committed to progressively step up its GHG emission reductions to 6% of its baseline emissions (defined as average emissions over the 1998 to 2001 period) by 2010. Manitoba Hydro is in full compliance with the CCX target.

2B.7 GREENHOUSE GAS REDUCTIONS

Manitoba Hydro is a national leader in managing its GHG emissions. While Manitoba Hydro's GHG emissions are small compared to other sources within the province and among most other Canadian utilities, Manitoba Hydro's GHG emissions reduction actions have been very proactive. Manitoba Hydro has taken a number of actions to increase its reliance on renewable generation, to reduce its own GHG emissions, and to contribute to GHG emission reductions outside of Manitoba. Actions since 1990 include the following:

- Long-term shutdown of Brandon GS Units 1 to 4.
- Conversion of Selkirk GS from coal to natural gas (subsequently awarded Honourable Mention in the 2002 CCME P2 Awards – Greenhouse Gas Reduction Category).
- Development of the most aggressive Demand Side Management (DSM, actions that result in long-term reduction in energy consumption thereby reducing the need for long-term energy and/or capacity needs) program in North America. At the end of 2008/2009 by reducing electricity consumption in Manitoba, Power Smart Programs reduced greenhouse gas emissions globally by 1,046 kilotonnes of CO_2e.
- Development of the new 200 MW Wuskwatim Hydroelectric GS (currently under construction).
- Development of the Limestone GS supplying more than 1300 MW of new renewable hydropower.
- Natural Gas DSM Programs - The plan outlines a conservation effort that will attempt to reach annual natural gas savings of approximately 41.4 million cubic meters by 2008/2009. At the end of 2008 emission savings associated with natural gas DSM totalled 243.6 kilotonnes CO_2e.
- Development of an environmental dispatch premium policy.[1]
- Extension of the power grid to eight remote northern communities, reducing to four from 12 the number of communities that are served by diesel generation.
- Purchased the output of a 100 MW wind farm under the terms of the 25 year Power Purchase Agreement.

[1] The environmental dispatch premium is an adder that is intended to capture greenhouse gases and other externalities. This premium is considered in addition to the marginal operating cost when determining if Brandon's coal-fired unit should be dispatched.

- Development of the Corporation's state-of-the-art energy efficient head office building project in downtown Winnipeg, with the goal of reducing building energy consumption by 60% compared to a modern conventional office building.
- Leadership in promoting energy saving geothermal heat pump systems, with 756 residential installations for 2008/2009. Manitoba Hydro provides Residential Earth Power loans to assist customers in financing these systems.
- Promotion of the use of hybrid vehicles and biodiesel in fleet services. Manitoba Hydro has purchased several hybrid vehicles and uses biodiesel in some of its fuel tanks.

In addition to these past actions, Manitoba Hydro's GHG strategy includes the aggressive pursuit of many other non-emitting or low-emitting resources to contribute to further reductions in global GHG emissions in the future. Specific actions being pursued include: additional DSM programming, new hydro, wind, landfill gas, biogas, and other technologies. By supplying non-emitting electricity to the marketplace, Manitoba Hydro displaces the production of energy that would otherwise be generated from fossil-fuel-fired sources.

Another key component of Manitoba Hydro's GHG strategy is participation in the Chicago Climate Exchange. Manitoba Hydro became a founding member of the CCX in 2002 and committed to participating in the exchange during its first 4-year phase of operations (2003 to 2006). Manitoba Hydro is also participating in the exchange during its second 4-year phase of operations, which will run from 2007 to 2010. Under this program, Manitoba Hydro is committed to an increasing schedule of emission reductions, culminating in a reduction of 6% below baseline by 2010.

2B.8 GREEN PROCUREMENT PRACTICES

In addition to the direct operational greenhouse gas reduction actions summarized in the previous section, Manitoba Hydro has instituted a Green Procurement Practice in which the company is working towards ensuring that the procurement process takes into consideration potential environmental and social consequences in each step of the product life- cycle, planning, design, specification, purchasing, decommissioning and disposal. Through the Green Procurement Practices, Manitoba Hydro is striving to incorporate the environment and correspondingly climate change into its procurement decisions and influence Manitoba Hydro indirect implications on the environment.

When planning any procurement, including purchasing of goods and services for the Keeyask Project, Manitoba Hydro will consider the following guidelines:

- Protect human health and well-being.
- Promote environmentally sustainable economic development.
- Conserve resources.
- Conserve energy.
- Promote pollution prevention, waste reduction and diversion.

- Evaluate value, performance and need.
- Promote environmental stewardship among suppliers and contractors.
- Increase employee awareness.
- Apply fair and transparent process.
- Monitor and continually improve.

2B.9 GREENHOUSE GAS POLICY

Manitoba Hydro directly and in coordination with provincial government and industry association has been very active in promoting and influencing the design and development of greenhouse gas policy. In addition to participating in influencing the Canadian National GHG Program, Manitoba Hydro has been participating in regional initiatives such as the Western Climate Initiative and the Midwestern Greenhouse Gas Accord.

Other committees and forums in which Manitoba Hydro participates related to climate change includes participation on the Chicago Climate Exchange as an Offset Committee Member, the National Round Table on the Environment and the Economy (NRTEE) on the Expert Advisory Committee, and The Climate Registry in the role of Technical Advisor.