KEEYASK GENERATION PROJECT

PHYSICAL ENVIRONMENT

SUPPORTING VOLUME

EFFECTS OF THE ENVIRONMENT ON THE PROJECT

June 2012

KEEYASK
Hydropower Limited Partnership

This page is intentionally left blank.

TABLE OF CONTENTS

This page is intentionally left blank.

12.0 EFFECTS OF THE ENVIRONMENT ON THE PROJECT

12.1 INTRODUCTION

The guidelines require information on how weather conditions and other natural hazards could affect the **Project** and potentially result in **impacts** to the **environment**. The guidelines also provide information on the Project's sensitivity to the longer-term **effects** of climate change. The guidelines ask for information on the planning, design and **construction** strategies to minimize potential **adverse** effects of the environment on the Project.

This section will discuss climate conditions considered during the planning of the Project, and the sensitivity to environmental factors, including climate change considerations.

12.2 PLANNING AND DESIGN

Manitoba Hydro has considerable experience in the design and operation of hydroelectric generation projects in northern Manitoba. This background has provided technical expertise within Hydro in dealing with severe climatic conditions in the region. Appropriate engineering design **parameters** for the Project have been developed according to current and anticipated environmental conditions. Design loads and other design requirements have been established through the application of a set of design criteria compiled for the Project. The design criteria were developed from the most current standards and guidelines relevant to the construction of a **hydroelectric generating station** in Manitoba. They include the requirements of the current Canadian Dam Association (CDA) Dam Safety Guidelines, the National Building Code of Canada (NBCC) with Manitoba Amendments, the Canadian Standards Association (CSA), American National Standards Institute (ANSI) and other codes and standards that must either be met by law, or which otherwise define the basis on which the **generating station** will be designed and constructed. The environmental factors considered in the Project design process included severe precipitation events (**hydrology**), severe ice conditions, earthquakes and high winds.

12.3 KEY CLIMATE FACTORS/HAZARDS

Several important factors related to climate conditions that could affect the Project are discussed below.

12.3.1 Hydrology

Manitoba Hydro operates and maintains a network of hydrometric stations throughout the Nelson River and Churchill River Watersheds. It also utilizes data from hydrometric stations operated by Environment Canada. As a result, Manitoba Hydro has developed a sound understanding of the historical hydrology of the **watershed** and this understanding has been incorporated into the Project design, for both construction and operation phases.

The **flow** of the lower Nelson River is regulated by the **Lake Winnipeg Regulation** Project and the **Churchill River Diversion**, as discussed in the Project Description Supporting Volume (PD SV, Section 1). The operation of these two major projects is well understood by Manitoba Hydro and has been factored into the design of the Project.

12.3.2 Construction Phase

During the construction phase, the Project structures will be designed to withstand flows and levels associated with a flood having an annual frequency of occurrence of 1:20 years. Both summer and winter conditions are considered when determining the flows and levels associated with the construction design flood. During construction of the Project (with the **ice boom** in place), the most adverse water levels may occur during low flow conditions in the winter because low winter flows can create an environment conducive to the formation of ice jams in the upper **reaches** of Stephens Lake, which results in higher water levels at the downstream end of Gull Rapids.

The winter water level in the vicinity of the Stage I **powerhouse cofferdam** during a construction design flood would be about 144 m (472 ft.). This level exceeds the open water construction design flood level and therefore it was used as the governing level for the construction of the powerhouse cofferdam.

For the upstream cofferdams (**rock groin**, north channel cofferdam and island cofferdam), the water levels at the upstream end of Gull Rapids during the open water (summer) construction design flood would be higher than during winter conditions. Therefore, the design elevation is based on open water conditions. The structures will have an additional 1.0 m (3.3 ft.) of freeboard for open water conditions and 1.5 m (4.9 ft.) for cofferdams under which winter conditions govern, allowing the passage of a larger flood without overtopping of the cofferdams. As discussed in the PD SV, emergency response plans will be developed for the possibility of exceeding the design event for the cofferdams so that worker safety is maintained.

12.3.3 Operations Phase

The Project has been designed to safely pass the probable maximum flood (PMF). The PMF is defined by the Canadian Dam Association as:

> "an estimate by the hypothetical flood (peak flow, volume and hydrograph shape) that is considered as the most severe 'reasonably possible' at a particular location and time of year, based on a relatively comprehensive hydro-meteorological analysis of critical runoff – producing precipitation (snowmelt if pertinent) and hydrological factors favourable for a maximum flood runoff." (Canadian Dam Association 2007).

Statistically, this flood represents an extremely remote event, less than a 1:10,000-year event, which is the largest potential flood that is thought could reasonably occur in the river **basin**.

The PMF is the flood that would result from the most severe hydrologic and meteorological conditions that could reasonably occur in the Nelson River Watershed at this location. It is based on analyses of local historic precipitation, snowmelt and other factors conducive to producing maximum flows. The estimated PMF for the Project is more than double the flow experienced during the summer of 2005, which is the highest recorded daily average flow up on record up to that time. The PMF is estimated at

12,700 m³ (448,480 ft.³/s). The PMF for the Project is considered to be greater in **magnitude** than the 1:10,000-year event.

The Project is designed to be able to pass the PMF without **surcharge** of the **reservoir** if the **turbines** are all operating. In addition, the design considers the potential situation where the turbines could not operate because of a concurrent outage of **transmission lines**. In such a case, the turbines would be operated at the speed-no-load discharge condition.

The speed-no-load discharge is the amount of water that can be passed through the powerhouse without risking damage to the generating units when no electricity is being produced. The total speed-no-flow load discharge for six of seven units, assuming one unit is shut down for maintenance, is 1,400 m³/s (49,439 ft.³/s). During the probable maximum flood event, 1,400 m³/s (49,439 ft.³/s) would pass through the powerhouse and 11,300 m³/s (399,041 ft.³/s) would pass over the **spillway**. In order for the spillway to accommodate this much flow, the reservoir level would surcharge higher than the **full supply level (FSL)** of 159.0 m (521.6 ft.) to an elevation of 160.3 m (525.9 ft.).

The spillway can pass an estimated 9,960 m³/s (351,721 ft.³/s) without the use of the powerhouse at the FSL of 159 m (521.6 ft.). It is therefore capable of passing a 1:1,000-year event flow of 8,705 m³/s (307,403 ft.³/s).

The **dykes** and **dams** have been designed to provide a freeboard of 1.7 to 2.3 m (5.6 to 7.5 ft.) above the maximum expected water level during the passage of a PMF.

The elevation of the north, central and south dams' **crests** will range between 162.0 m (531.5 ft.) and 162.6 m (533.5 ft.). The crest elevations of the dams have been set to accommodate the highest reservoir water levels arising during the passage of the PMF. The required crest elevations take into account the appropriate combined effects of the wind-generated waves and post-construction embankment settlements. Two design conditions were considered:

- With the reservoir at its normal maximum level (FSL 159.0 m [521.6 ft.]) a wave run-up and reservoir setup due to a wind having a return period of 1:1,000 years.
- With the reservoir at its extreme maximum level during the passage of the PMF (elevation 160.3 m [525.9 ft.]) plus an allowance for reservoir tilt, a wave run-up and reservoir set-up due to a wind having a return period of 1:2 years.

The north and south dykes contain the water in the reservoir and limit the extent of **flooding** in areas of relatively low-lying **topography**. A series of discontinuous earth **fill** dykes will be located along both sides of the river, extending 11.6 **km** (7.21 mi.) on the north and 11.2 km (7.0 mi.) on the south side of the river dyke. The crest of the dykes will vary between elevations 161.8 m (530.8 ft.) and 163.0 m (534.8 ft.) but may be somewhat higher in areas where the foundations are expected to settle over a period of time. The north dyke and south dyke will have maximum heights of about 20 m (65.6 ft.) and 13 m (42.6 ft.) respectively.

Since these dykes will be located within a discontinuous **permafrost** region, their design will account for the thawing of permafrost affected soils and the resultant potential for differential settlements. In order to minimize the settlements and the problems associated with thaw consolidation, in most areas the top layers of **peat** and clay will be removed and the dykes will be founded on **glacial till**. Explorations have indicated that the permafrost in the glacial deposits is of low moisture content (ice-poor) and is expected to result in relatively small settlements. Areas where the glacial deposits contain large amounts of visible ice are expected to be localized in extent and will be removed prior to placement of the fill.

The main dykes will be located on ground that is below the full supply level of the reservoir. Some of these dykes will be composed of an **impervious core**, **granular** filters, transition zones, and outer rockfill shells. This type of dyke will be located on glacial tills. Other dykes will consist of semi-pervious zones, a **downstream toe drain**, and slope-protection zones. These dykes will be used in areas of limited length where overburden affected by permafrost is relatively thick and excavation is impractical. These dykes are designed to limit seepage to a controllable volume and accommodate differential foundation settlements that will occur due to thaw consolidation of the permafrost-affected post-glacial clays.

A roadway will be constructed on top of the dykes and between the sections of dykes to facilitate inspection and maintenance.

12.3.4 Severe Wind Events

The crests of the dykes and dams have been designed to accommodate the safe passage of the design floods, combined with high winds and wind directions that would result in large waves and wave uprush. The dykes and dams are protected from **erosion** due to these windy conditions by rock **riprap**. A freeboard is provided, as discussed earlier. As stated in the Physical Environment Supporting Volume (PE SV), Section 12.3.3, the design conditions also allow for the Project to safely pass floods up the PMF under circumstances where winds may cause outage of the transmission line from the Project.

12.3.5 Seismic Activity

Manitoba in general is an area of very low seismicity. In particular, the **Precambrian Shield**, within which the Project is located, is also of very low seismicity. It is evident from the historical records since the 1600s and relatively recent seismic **monitoring** that no major earthquakes, and hence no important earthquake-generating fault **movements**, have occurred in Manitoba (see Section 5, Physiography).

A review of available data to assess the risk of active faulting and the risk associated with potential fault movement concluded that the existing faults at Keeyask are seismically inactive, and that the probability of reactivation of existing faults is infinitesimally small. The review also concluded that the depth of the Keeyask reservoir would be too shallow to induce a **significant** reservoir triggered seismic event.

Considerations to account for earthquake loads will be incorporated into the final design of the earthworks and **concrete** structures. The design criteria will incorporate design earthquake forces. The earth fill and concrete structures will be analyzed under both horizontal and vertical ground accelerations and hydrodynamic forces due to a seismic event. In addition, a seismic sensitivity analysis will be performed on the permanent structures.

12.3.6 Lightning

Lightning can potentially cause disruption of **transmission**. Provisions are in place for Manitoba Hydro to take the Project offline in the event that transmission is lost. The Project would then revert to an emergency **mode of operation** and this would not affect the integrity of the powerhouse.

Lighting can also cause forest fires. The Province has substantial experience in dealing with forest fires in the general area, as forest fires are fairly common in the region. There is low threat to the Project from forest fire.

12.4 CLIMATE CHANGE

As discussed in the PE SV, Section 2, it is recognized that the global climate is changing, as is regional climate, and these changes must be considered in the design of the Project, which is expected to last for many decades. A changing climate has the potential to alter the dynamics and characteristics of the watershed and thus the flow of the water can change and affect the generation of electricity over the life of the Project. Potential climate change scenarios for the region have been described in the Climate section of the PE SV (Section 2). These scenarios are linked to the Project region and do not necessarily correspond with changes that might occur in the overall larger lower Nelson River watershed.

Long-term **climate scenarios** for the region have been identified (PE SV, Section 2). The scenarios project a generally warmer and wetter climate in the Project region. As discussed in the PE SV, Section 4, the Nelson River and Churchill River watershed is very large and local runoff constitutes only about 3% of the Nelson River flows. The design approach to address potential changes in Nelson River flows has been to design for the PMF, as discussed in the PE SV, Section 12.3.1 (Hydrology), which represents the largest flood flow that is considered to potentially occur in the overall river basin. The potential warming trends in climate and their implications for design of the Project have been addressed, as discussed below.

The vulnerability of the Project to potential climate change was considered. Some observations as to potential climate change variables are discussed below.

12.4.1 Change in Nelson River Flow

As discussed in the PE SV, Section 11, the sensitivity of the Project to a ±10% change in flows across all flow **percentiles** was reviewed because there are no estimates of how climate change may affect flows in the lower Nelson River. It was observed that the operating range of the reservoir of 158.0 m to 159.0 m (518.4 ft. to 521.6 ft.) would remain unchanged regardless of the changes in the Nelson River flows (*i.e.*, ±10% change in river flows). As described in previous sections, the Project will be able to safely manage the flows in the future if river flows are substantially higher or lower. The **water regime** in the open water **hydraulic zone of influence** of the Project is not expected to change materially in response to increases or decreases in Nelson River flows.

The Project has been designed to safely pass the PMF, as discussed in Section 12.3.3.

12.4.2 Warmer Temperatures

The formation of ice cover on the reservoir could be delayed for a few weeks in the future and ice breakup could occur a few weeks earlier but these would not affect the functionality of the reservoir. The ice cover would likely be thinner and perhaps exert less force on structures than under the design conditions.

The design of the principal structures has considered the potential of permafrost melting.

12.4.3 Wind and Extreme Events

Climate change studies have suggested that wind and storm events could become more severe or extreme in the future (see Section 2.3.2.4). These conditions could result in transmission line outages. The Project will be capable of taking generating units off-load and, as discussed in the PE SV, Section 12.3.3, still safely pass floods up to the PMF.

12.4.4 Conclusions

The planning and design by Manitoba Hydro explicitly addresses potential effects that the environment may have on the Project resulting in a low risk to the Project itself from these key climate factors, as well as a low risk to the environment and the public.

12.5 REFERENCES

Canadian Dam Association 2007. Dam Safety Guidelines. http://www.cda.ca/cda_new_en/publications/dam%20safety/dam%20safety.html

This page is intentionally left blank.