Keeyask Generation Project

Environmental Impact Statement

Supporting Volume

Physical Environment

Keeyask

Hydropower Limited Partnership

June 2012

APPENDIX 8A
GROUNDWATER
MODEL DESCRIPTION

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8A.0 GROUNDWATER MODEL DESCRIPTION

8A.1 MODEL SELECTION

FEFLOW (Finite-Element Subsurface-Flow System) and Visual MODFLOW (MODular Three-Dimensional Finite-Different Groundwater System) models were taken into consideration for their ability to address the potential effects of the proposed Keeyask Project on the environment. Both numerical groundwater-software applications are widely accepted by groundwater modellers as tools capable of simulating groundwater flow and contaminant transport under saturated and unsaturated conditions.

For the purpose of this study and considering specific advantages over the other, FEFLOW (Version 5.4; Diersch 2002) modelling software was selected for the Keeyask groundwater assessment. The advantages of using FEFLOW included its ability to model fluctuating surface water/groundwater interactions in the center of the study area, as well as its capability to define the irregular shape of the complex model boundaries. Additionally, FEFLOW would better handle time-varying aquifer properties, required to simulate Project development. Furthermore, FEFLOW is known to outperform Visual MODFLOW in coping with numerical instability issues (*e.g.,* wetting-drying cells).

FEFLOW is a computational groundwater model that applies a finite element analysis to solve mathematical groundwater-flow equations in porous media under saturated and unsaturated conditions. Unlike MODFLOW, FEFLOW allows the creation of a flexible mesh with refinement on polygon borders and varied mesh densities for the specific area(s) of interest. FEFLOW is also capable of solving naturally complex boundary conditions. These capabilities include specifying boundary constraints for different types of boundary conditions and interpolation schemes with and without time-level factors.

8A.2 MODEL CONSTRUCTION

8A.2.1 Model Domain

The model domain chosen encompassed the major surface drainage basin in the area (566 km^2) and covered the upstream and downstream of the Nelson River near Split Lake and Stephens Lake, respectively.

8A.2.2 Assumptions

A number of assumptions were made in the development of the model, as follows:

- The recharge, described as a percentage of 'water yield', was determined externally to the groundwater-flow model and calculated as the amount of precipitation minus surface runoff and evapotranspiration at land surface with accounting for snowmelt processes that employs a degree-day method. The percentage of time-varying water yield was assumed uniform for the entire model area, except under the water bodies (river and lakes) where the percent of yield directed to groundwater, as recharge, is very low due to the fine sediment on the bottom of a lake that retards the percolation into the groundwater.
- In assigning the hydraulic conductivity values to each stratum, it was assumed (as is typical model practice) that the horizontal hydraulic conductivity of each stratum was equal in all directions and was greater (by an order of magnitude) than the vertical hydraulic conductivity of the stratum (*i.e.,* Kx = Ky > Kz).
- To establish a relationship between the model system and the surrounding environment, several flow-boundary conditions were assumed and specified in the Keeyask groundwater-flow model.
    - A perimeter model boundary was assigned as a constant head-boundary condition to allow water to enter and exit the model domain.
    - Existing and future reservoir shorelines along both sides of the Nelson River were modelled as transfer-boundary conditions to represent the flow of the river and water transfers (exfiltration and infiltration) between river and groundwater systems through a colmation layer along the river.
    - Uniform recharge over the entire area of the model domain was used as a flux-boundary condition to represent the net recharge that changed over time.

8A.2.3 Mesh Development and Layering

The model mesh was developed using 6-nodal triangular prism. To ensure the ability to model the Post-project environment and assess any resulting small-scale effects (rather than developing a second local-scale model), a relatively uniform mesh was assigned across the model domain. This mesh was then refined along the:

- Existing shoreline of the Nelson River.
- Existing and future reservoir shorelines.
- Existing and future islands.

- Most likely affected areas.
- Groundwater monitoring wells.
- Future locations of the North and South Dykes.

The Keeyask groundwater-assessment area was discretized as shown in Map 8A-1.

Eight geological layers representing the stratigraphic sequence of geological horizons beneath the study area were then defined in the model as follows (Figure 8A.2-1):

- Peat deposits – found as the uppermost layer of the Keeyask study area with a thickness ranging between 0.2 m and 5.05 m. The organic peat deposits often demonstrate a strong interconnection between a dynamic groundwater system and surface-water environment.
- Clay deposits – underlying the peat blanket with the thickness ranging between 0.1 m and 12.1 m. The presence of confined overburden clay deposits indicates a constraint of water movement (or infiltration) to the groundwater system.

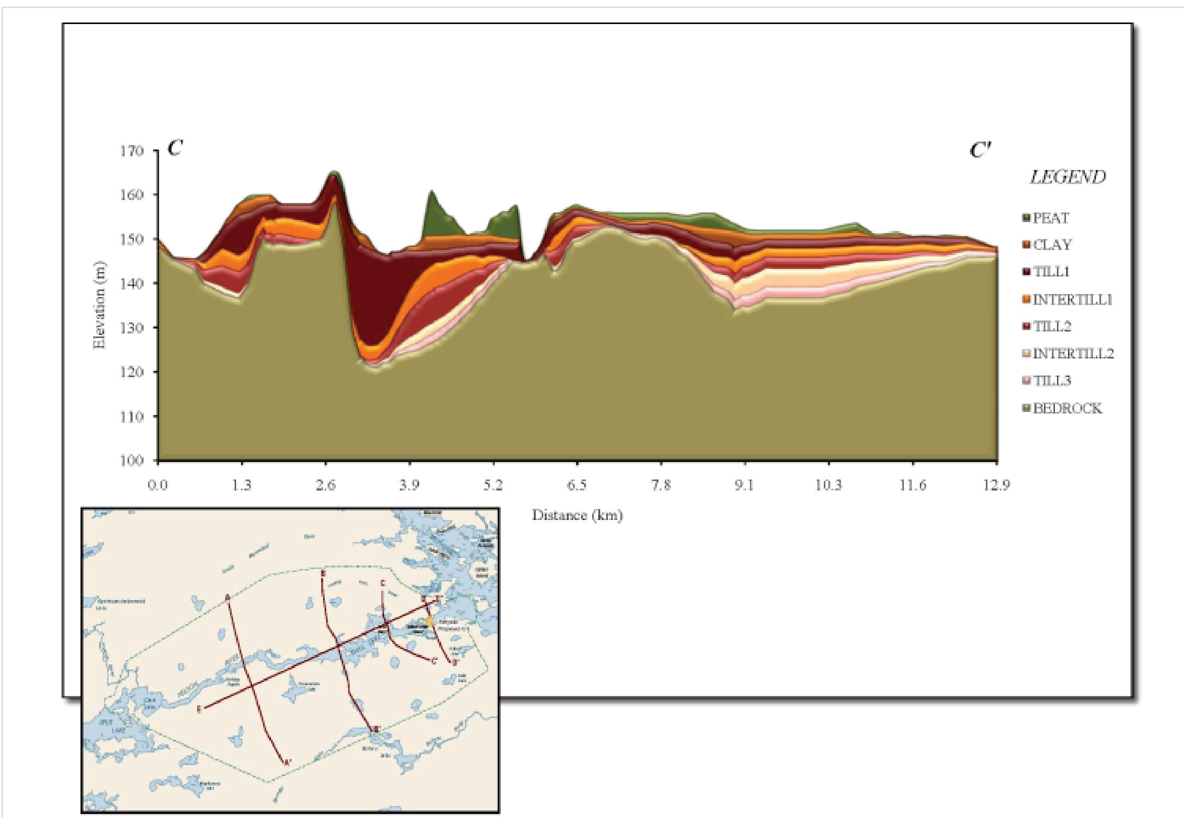

Figure 8A.2-1: Stratigraphy Along North-South Cross-Section (C-C') Through Study Area

- Till and intertill deposits – underlying the clay deposits, there are five separate till and intertill deposits. The key differences between these deposits were the soil physical properties (*e.g.,* hydraulic conductivity). For example, Till 1A and Till 1B (1 x 10^{-6} m/s) are found to have a higher hydraulic conductivity than Till 2 and Till 3 (1 x 10^{-7} m/s). Till 1A and Till 1B range in thickness between 0.05 m and 30.4 m and 0.16 m and 15.9 m, respectively. The intertill layers have soil thickness ranging between 0.19 m and 11.43 m, while Till 2 and Till 3 layers range in thickness between 0.3 m and 23.25 m and 1.27 m and 14.95 m, respectively.
- Bedrock basement – underlying the till deposits, these meta-sedimentary and igneous intrusive rocks comprise the bottom layer of the model.

8A.2.4 Recharge and Evapotranspiration Assignments

Recharge and evapotranspiration (ET) are key components in the development of a site-specific groundwater model because they represent the two main components of the water-balance system. Recharge was defined, in the groundwater study, as water that percolates to the saturated groundwater system. The process of precipitation falling onto the surface area and infiltrating through the unsaturated zone was not modelled. ET involves natural processes in which the moisture held in the ground is transferred to the atmosphere either by direct evaporation or through biomass transpiration. However, the estimation of these parameters and its relationship with the snowfall and rainfall could be locally complex in cold-climate region like Keeyask. Because snowfall accumulates over the winter months and then begins to melt, this results in a small yield over an extended period. Furthermore, not all of the snow that falls turns into an equivalent volume of water because of sublimation. By contrast, precipitation in the form of rainfall can be equated to yield, but depending on the type of precipitation event, it may not significantly contribute to the recharging of the groundwater table (*i.e.,* may result in more surface runoff "sheet flow"). Taking into account these differences resulted in a better, more refined estimate of year-round recharge. The model developed to conduct this analysis (and to refine the related assumptions in the underlying groundwater model) is herein referred to as the "Rainfall/Snowmelt" (R/S) model.

The development of the R/S model involved model calibration in which a record of meteorological data between 1998 and 2004 provided the acceptable R/S model calibration parameters (*i.e.,* snow depth). The calibration parameters obtained from the 1998 to 2004 rainfall/snowmelt model were applied to the historic meteorological data between 1971 and 2008 and the water-yield estimates were obtained. As the study site is located at a northern latitude where ET rates are usually relatively small, it was assumed that evaporation did not need to be directly addressed. Accordingly, the Keeyask groundwater flow model takes into account the rate of ET at land surface and the unsaturated zone by deducting it from the rate of precipitation in the calculation of a net recharge rate.

Identical recharge rates (representing 5th [dry], 50th [typical] and 95th [wet] percentile of the total annual precipitation from the historic meteorological record for the area) were applied for both simulation runs without and with the Project, however the area where these recharge rates were specified was altered for the simulation runs of the future environment with the Project. For the "With Project" simulation runs, recharge rates were applied to a smaller area; specifically that area outside the future flooded shoreline.

8A.2.5 Aquifer Parameter Assignments

Aquifer properties are variables that change from location to location, but do not generally change over time. Examples of aquifer properties are hydraulic conductivity and storativity. These variables define how an aquifer system will respond when placed under stress. In modelling the system, an attempt is made to acquire as much information as possible about aquifer properties to assist in model development. Where this information is not available, attempts to estimate these parameters are done as part of the calibration process.

The available hydraulic conductivity values were averaged and the averaged value was adopted for the initial setup of the model. Calibration was then later undertaken to refine these values. Table 8A.2-1 provides the values resulting from model calibration, which were ultimately adopted and assigned, as appropriate to the corresponding geological layers or areas (in the case of the eskers).

Table 8A.2-1: Hydraulic Conductivity Values Assigned in Model

Material	Hydraulic Conductivity (K_x) (m/s)
Peat	1.2×10^{-4}
Eskers	5.2×10^{-4}
Lake Agassiz Clay	5.0×10^{-9}
Till 1 (1A, 1B)	1.3×10^{-7}
Till 2 and Till 3	1.8×10^{-8}
Intertill	2.0×10^{-5}
Bedrock Layer	8.1×10^{-7}

8A.2.6 Specification of Boundary Conditions

To establish a relationship between the model system and the surrounding environment, several flow-boundary conditions were specified in the Keeyask groundwater-flow model. The following describes designated boundary conditions for the model:

- Perimeter boundary was specified using a head-boundary condition to allow water to enter and exit the model domain.

- Shorelines along both sides of the Nelson River were modelled as transfer-boundary conditions to represent the flow of the river and exfiltration and infiltration between river and groundwater systems through a colmation layer along the river.
- Recharge over the entire area of the model domain was specified as a flux-boundary condition to represent water that enters the groundwater system.

8A.3 MODEL CALIBRATION AND SENSITIVITY ANALYSIS

8A.3.1 Model Calibration

Calibration is an essential process in groundwater-model development. It involves comparing and matching output values from the model with actual field/measured values. In general, the level of calibration, and thereby the ability to accurately predict future conditions, is highly dependent upon the amount of information available for use to construct and calibrate the model. The model calibration was performed using PEST optimization tool which adjusts the selected model parameters until the fit between selected model outputs and a complementary set of field measurements is reduced to a minimum in the weighted least-squares sense. This calibration was accomplished by finding a set of parameters (*e.g.*, hydraulic conductivity and storativity in layers 1 through 3) that produced simulated heads that matched field measured values within an acceptable range of error. The hydraulic conductivity value of layer was automatically adjusted during the model calibration for all elements in that layer. This procedure was applied to the other two layers and assumed to be reasonable for the level of this study. Similarly, the storativity assigned to the first three layers was automatically adjusted for all elements in that layer. This automatic calibration method utilized a systematic adjustment approach to achieve the appropriate parameters that best represented the actual flow conditions.

A well-developed model resulting from a good transient calibration process will increase confidence in modelling results of estimates and predictions. Accordingly, details regarding the transient model-calibration process are reported below.

In the transient condition, the process of model calibration under the transient condition utilized the pre-established initial heads and model-input parameters from the steady-state calibration as its initial setup. The model-input parameters were then re-adjusted to achieve a better match with the observed heads. More specifically, transient calibration of the groundwater-flow model to hydrologic conditions measured between August 3, 2007 and November 28, 2008 attempted to match the change over time of the simulated hydraulic head distribution with the change over time of the measured hydraulic head distribution. This was done by measuring the changes in various hydrologic stresses that affected the distribution of hydraulic heads and simulating those stresses in the model. This applied procedure ensured that the model developed for the Project was as robust as possible.

In general, a hydrologic stress on the groundwater-flow system means any change in river stage or recharge that causes a resulting groundwater-regime change (in particular, a change[s] in the distribution of the hydraulic heads). Each stress period in the transient calibration of the Keeyask groundwater-flow model was 1 week in length. The groundwater-level data were recorded every 15 minutes, however, the change of the water levels within this short period of time was considered to be too small. Accordingly, the 15 minutes records were averaged into a daily water-level time interval, then a weekly interval. As a result 66 time steps, spanning from August 3, 2007 to October 28, 2008, were considered for model calibration.

Simulated river water levels obtained at a daily time step were processed into a weekly time interval and assigned to each river shoreline at the 23 different cross-sections. All nodes along the shoreline between two cross-sections were linearly interpolated. Once the river stages along the shoreline were specified, an area between both shorelines and the two upstream downstream edges of the model domain was created. Within this wetted area of the Nelson River/Gull Lake, there were water transfers from the groundwater system to the river system or vice versa. The direction of water transfer depended upon the river conductance at the bottom of the river (referred to as "colmation layer") and hydraulic gradient between the assigned river stage and groundwater elevation adjacent to the river.

As previously indicated, the hydraulic head data and recharge rates used for transient calibration of the groundwater-flow model were obtained from August 3, 2007 to October 28, 2008. The initial hydraulic head for each element node therefore needed to be prepared representing as closely as possible the groundwater elevation distribution during the first week of August 2007. The areal distribution of initial head conditions was also subject to change during this period. The change of the initial heads was based on the topographic elevations of the top layer subtracting some numbers that were more or less the same as the average groundwater depth.

An overall comparison of simulated and observed groundwater levels for the entire calibration period (August 3, 2007 to October 28, 2008) is shown in Figure 8A.3-1. This graphical presentation suggests that the simulated groundwater levels resulting from the groundwater-flow model developed in four monitoring wells (G-0547, 03-042, G-0561, and 03-045) are in good agreement with those observed (*i.e.,* field measured). The simulated water levels were matched with the observed water tables over almost the entire calibration period for G-0547, 03-042 and G-0561. For monitoring well 03-045, the simulated water levels were slightly lower than the observed groundwater levels at the beginning and end of the calibration period, but were higher in the middle of the calibration period.

At the other three monitoring locations, G-0359, G-0348A, and G-5086, the groundwater-flow model developed for the Keeyask Groundwater Study simulated water levels that were, in general, higher than the water levels recorded (field measured) at these three locations at the end of the calibration period (Figure 8A.3-1). The simulated and observed water levels at groundwater-monitoring well G-0359 matched in the beginning of the calibration period but distanced away from the measured values by the end of the calibration period. At G-0348A, the simulated water levels were in the range of the observed water levels, but lower and higher at the beginning and end of the calibration period, respectively. For G-5086, the pattern of the simulated water levels was similar in trend but 2 m higher than the observed water levels. It is important to note, however, that G-5086 is outside of the major watershed of the study area, and the characteristics of the study area watershed may be different than the characteristics of the neighbouring watershed.

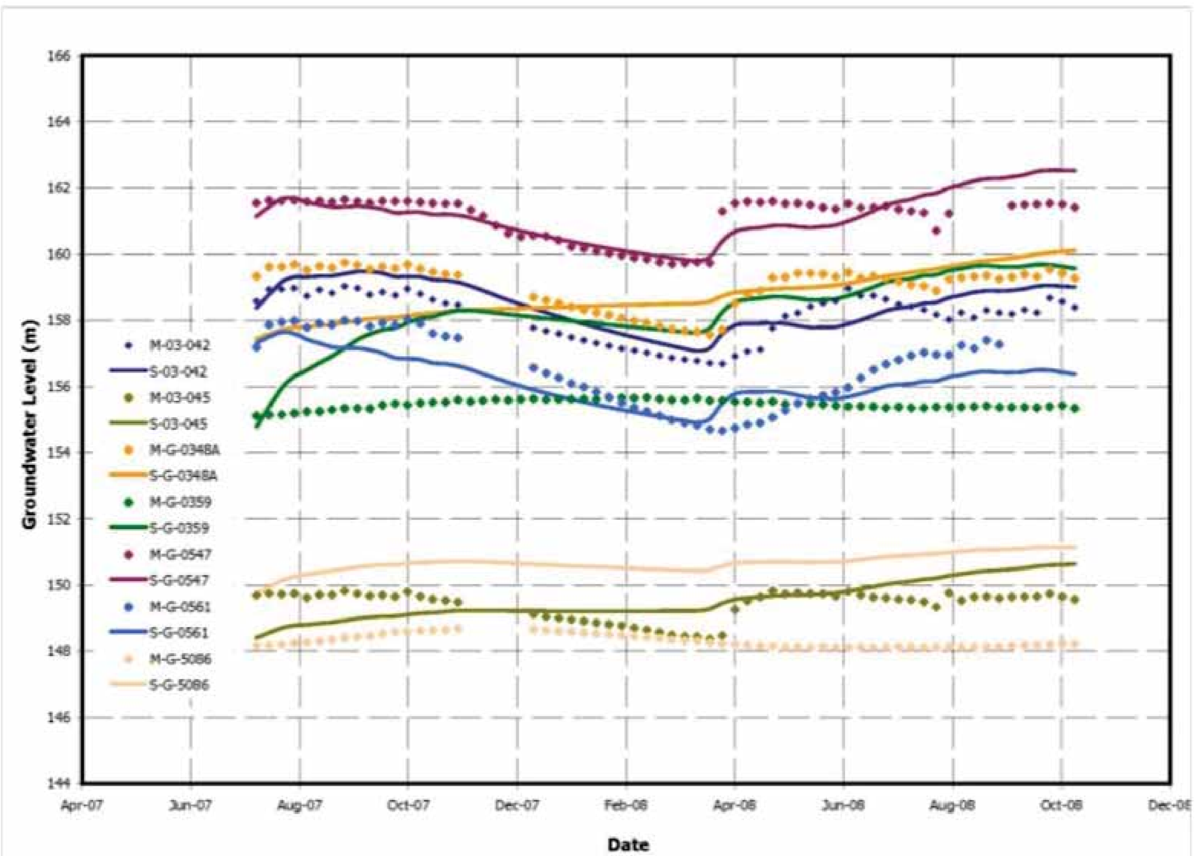

Figure 8A.3-1: Calibration Results (Transient-State Condition) of Groundwater Elevations at Seven Monitoring-Well Locations (Solid Lines are Simulated and Markers are Observed)

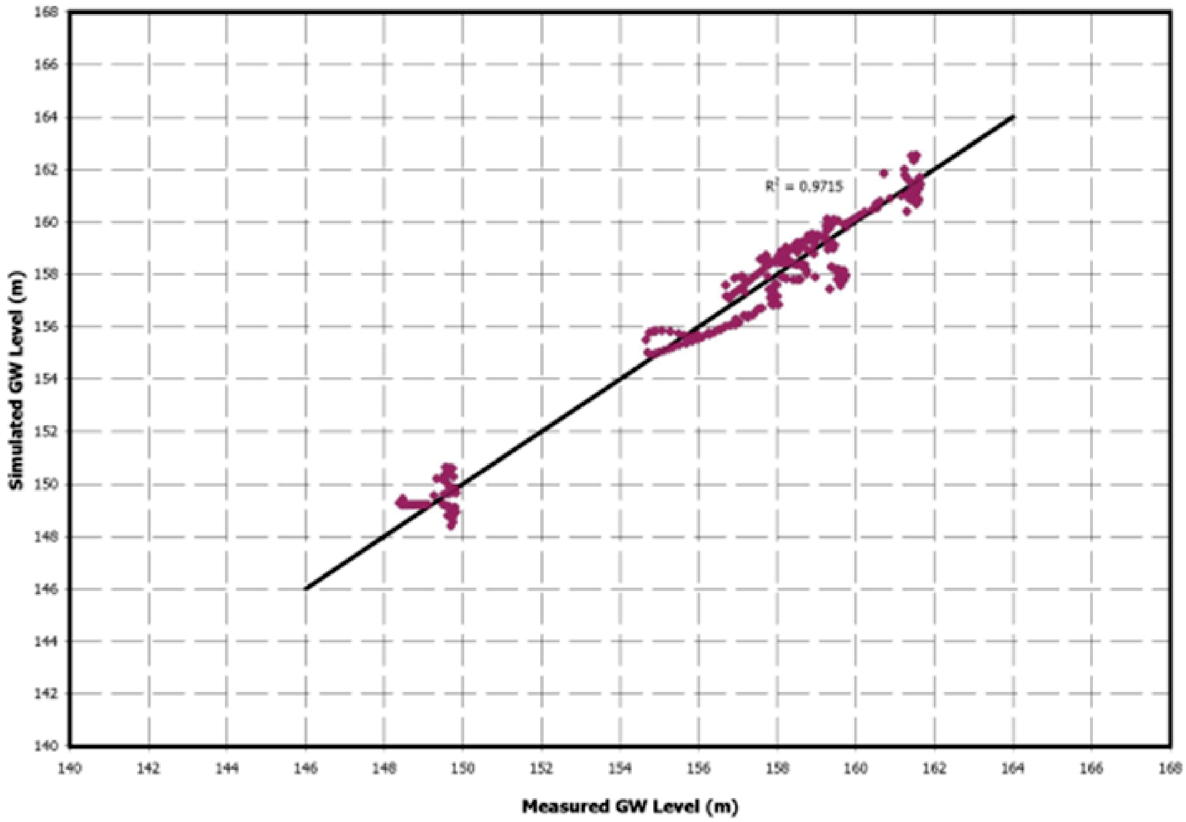

Figure 8A.3-2: Observed vs. Simulated Groundwater Elevations at the Seven Monitoring-Well Locations

The results of the model calibration process were also plotted in a 45-degree line (Figure 8A.3-2), the simulated groundwater tables plotted on the x-axis and the observed groundwater tables plotted on the y-axis. As shown in this figure, the majority of the points lied on this line, even though they were spotted in two clusters indicating they were not in the same range of elevations. This plot suggested that there was a high degree of correlation between the simulated and observed groundwater tables with a coefficient of determination (R2) value of 0.97.

Both plots, simulated versus observed groundwater tables and 45° line, were used to illustrate the performance of the groundwater-flow model calibration developed for the Keeyask Groundwater Study. The model calibration performance could be further validated when a statistical analysis performed on the deviation of the simulated values from the observed values. BestFit (Palisade Corporation 2002) was used to identify a distribution function that matched the simulated values subtracting from the observed values (residual error). The residual errors follow the weibull distribution with a mean error value of -0.187. The residual error statistics indicated that:

- 10% of the simulated values fall between -0.27 m and -0.12 m of the observed values.
- 50% were between -0.59 m and +0.21 m of the observed values.
- 90% were between -1.12 m and +0.77 m of the observed values.

This suggested that the groundwater-flow model was reasonably developed and could be used to predict the groundwater regime in a future environment with, and without, the proposed Project.

8A.3.2 Sensitivity Analysis

Sensitivity analysis of a calibrated model is an important aspect of good modelling practice. Specifically, the sensitivity of the model's output to variations in the input parameters should be determined and reported. The most common practice for carrying out sensitivity analysis is to repeat simulations by changing a series of selected parameter values, and to compare the results with those obtained using the calibrated values. This identifies the main contributors to the observed variation in results, and is performed iteratively.

A groundwater-flow model is considered to be sensitive to a parameter when a change of an input parameter value alters the distribution of the simulated hydraulic head. When a groundwater flow model is particularly sensitive, even small changes to an input parameter can result in large changes in hydraulic head. Conversely, when a model is insensitive to an input parameter, large changes to the input parameter do not cause any significant changes in the distribution of the hydraulic head.

In conducting sensitivity analysis on the Keeyask groundwater-flow model, several important parameters were reviewed (rather than focusing solely on the potential implications of permafrost presence). The investigated input parameters included recharge, hydraulic conductivity, storativity and initial and boundary conditions as well as transfer in and out-parameters in the colmation layer. Each of these was varied (within a reasonable range) during systematic changes to assess the response of the model. Based on the parameter ranking from the automatic and manual calibrations, it was found that the Keeyask groundwater flow model is relatively sensitive to the assigned storativity and hydraulic conductivity in the first layer and initial head conditions. The aquifer properties of storativity had the most influence on the results of the simulated groundwater tables. A small change in storativity of about one order of magnitude (*e.g.*, from 0.1 to 0.01) resulted in change in the groundwater heads of approximately 1.5 m. The hydraulic conductivity in the top layer and initial head conditions were also observed as the second and third parameters that have influence on the model results while the groundwater flow model was found to be insensitive to recharge, river and perimeter boundary conditions as well as the transfer-in and -out values.

8A.4 MODEL SIMULATIONS

After setting up the model for the existing environment, calibrating it to the available field data and modifying the simulation periods and several important input parameters (*e.g.,* river-boundary conditions, recharge rates, initial conditions, etc.), three simulation runs were performed to predict each of the future environments of the Keeyask groundwater regime (*i.e.,* without and with the Project) as follows:

- 50th percentile river-flow and meteorological conditions – to represent a future "typical" year.
- 95th percentile river-flow and meteorological conditions – to represent a future "wet" year.
- 5th percentile river-flow and meteorological conditions – to represent a future "dry" year.

Initial conditions were specified within the model area and consisted of three different sets of water levels: estimated from the recorded 2008 HOBOs and DIVERs, approximated from the surface topography, and simulated river-water levels. For each 5th, 50th, and 95th simulation runs, these initial conditions were first used to reach a condition when the simulation with a selected time step (1 week) was numerically stable. The groundwater elevations at the end of the stabilized simulation run were used as the initial conditions for each model run.

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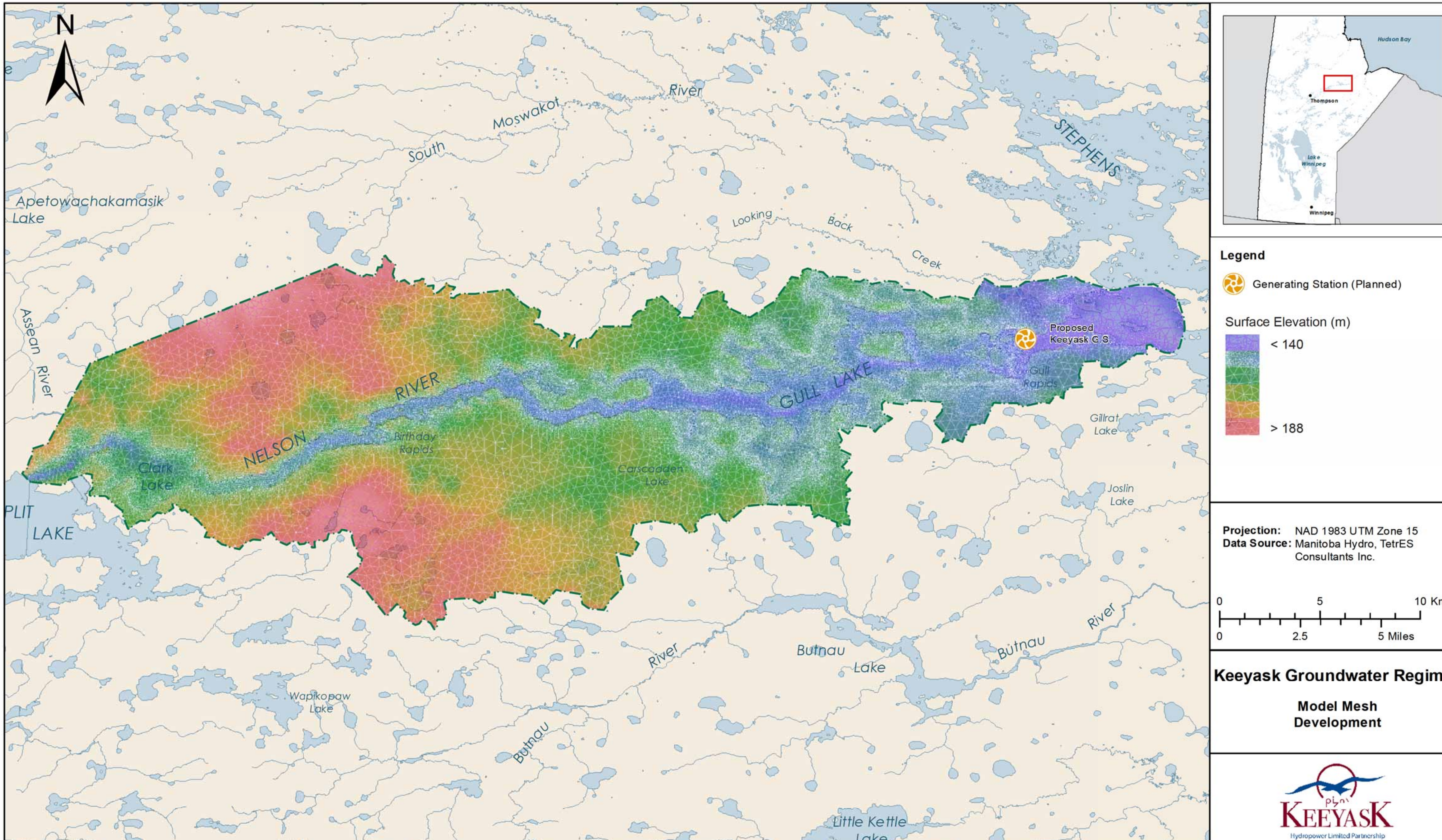
N
South
Moswakot
River
STEPHENS
Apetowachakamasik
Lake
Looking
Back
Creek
Assean River
NELSON RIVER
GULL LAKE
Proposed
Keeyask G.S.
Gull
Rapids
Birthday
Rapids
Clark
Lake
Carscadden
Lake
Gillrat
Lake
Joslin
Lake
PLIT
LAKE
Butnau
River
Butnau
Lake
Butnau River
Wapikopaw
Lake
Little Kettle
Lake
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Generating Station (Planned)
Surface Elevation (m)
< 140
> 188
Projection: NAD 1983 UTM Zone 15
Data Source: Manitoba Hydro, TetrES Consultants Inc.
0 5 10 Km
0 2.5 5 Miles
Keeyask Groundwater Regime
Model Mesh Development
KEEYASK
Hydropower Limited Partnership

Map 8.A-2.1

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APPENDIX 8B
GROUNDWATER
ADDITIONAL MAPS

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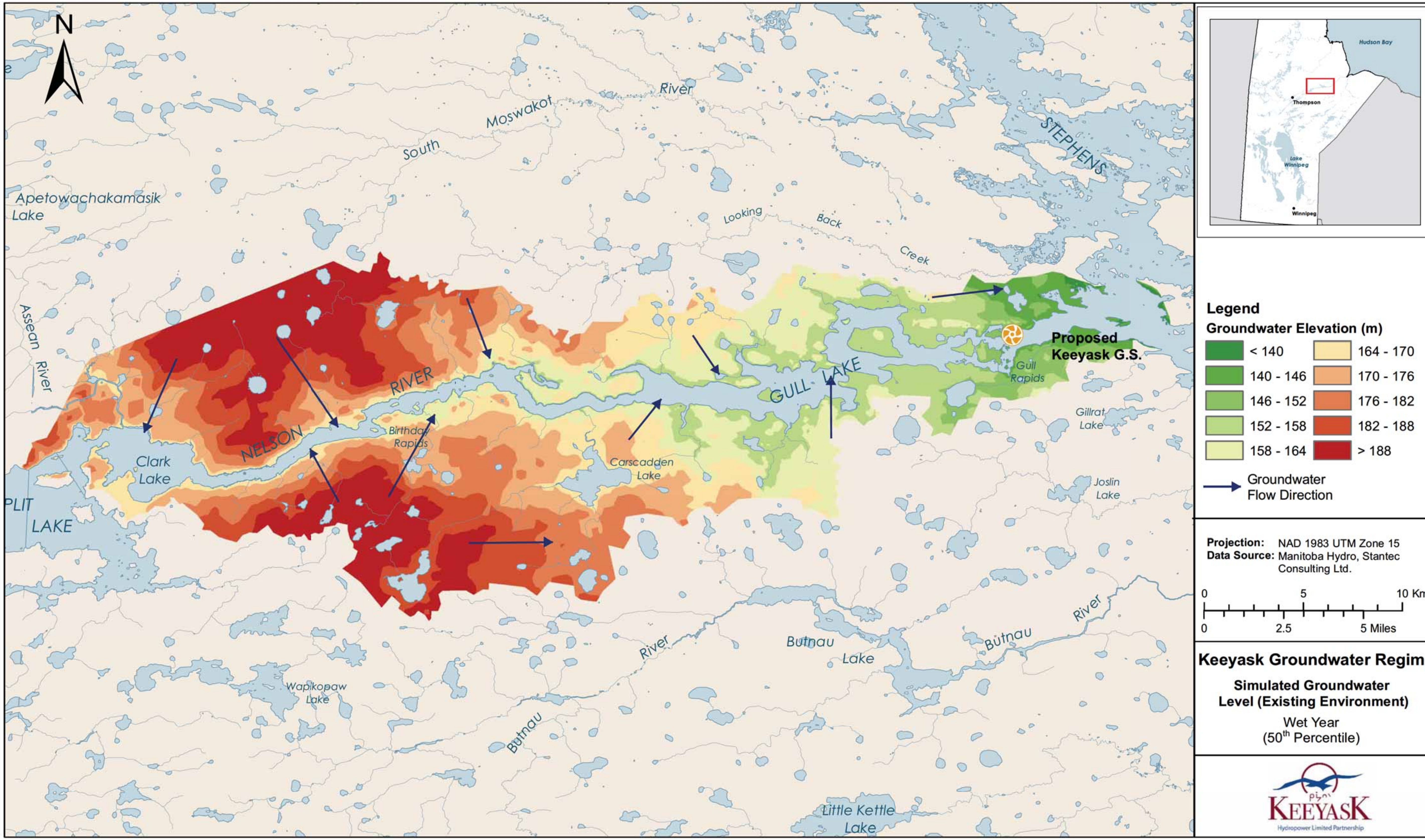

N
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STEPHENS
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Lake
Looking
Back
Creek
Assean
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Proposed
Keeyask G.S.
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Rapids
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Butnau
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Wapikopaw
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Butnau
Little Kettle
Lake
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Groundwater Elevation (m)
< 140
140 - 146
146 - 152
152 - 158
158 - 164
164 - 170
170 - 176
176 - 182
182 - 188
> 188
Groundwater
Flow Direction
Projection: NAD 1983 UTM Zone 15
Data Source: Manitoba Hydro, Stantec Consulting Ltd.
0
5
10 Km
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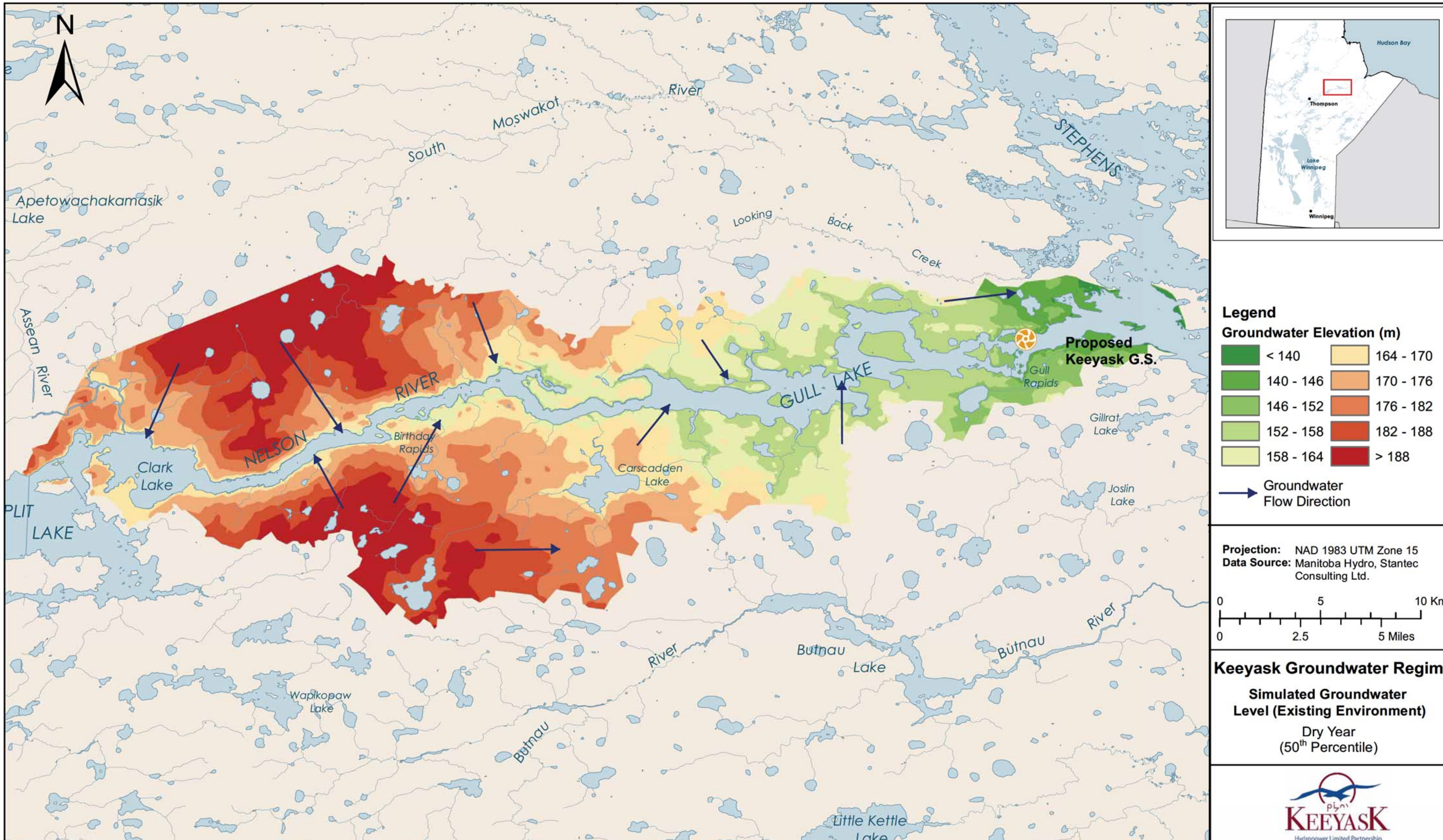
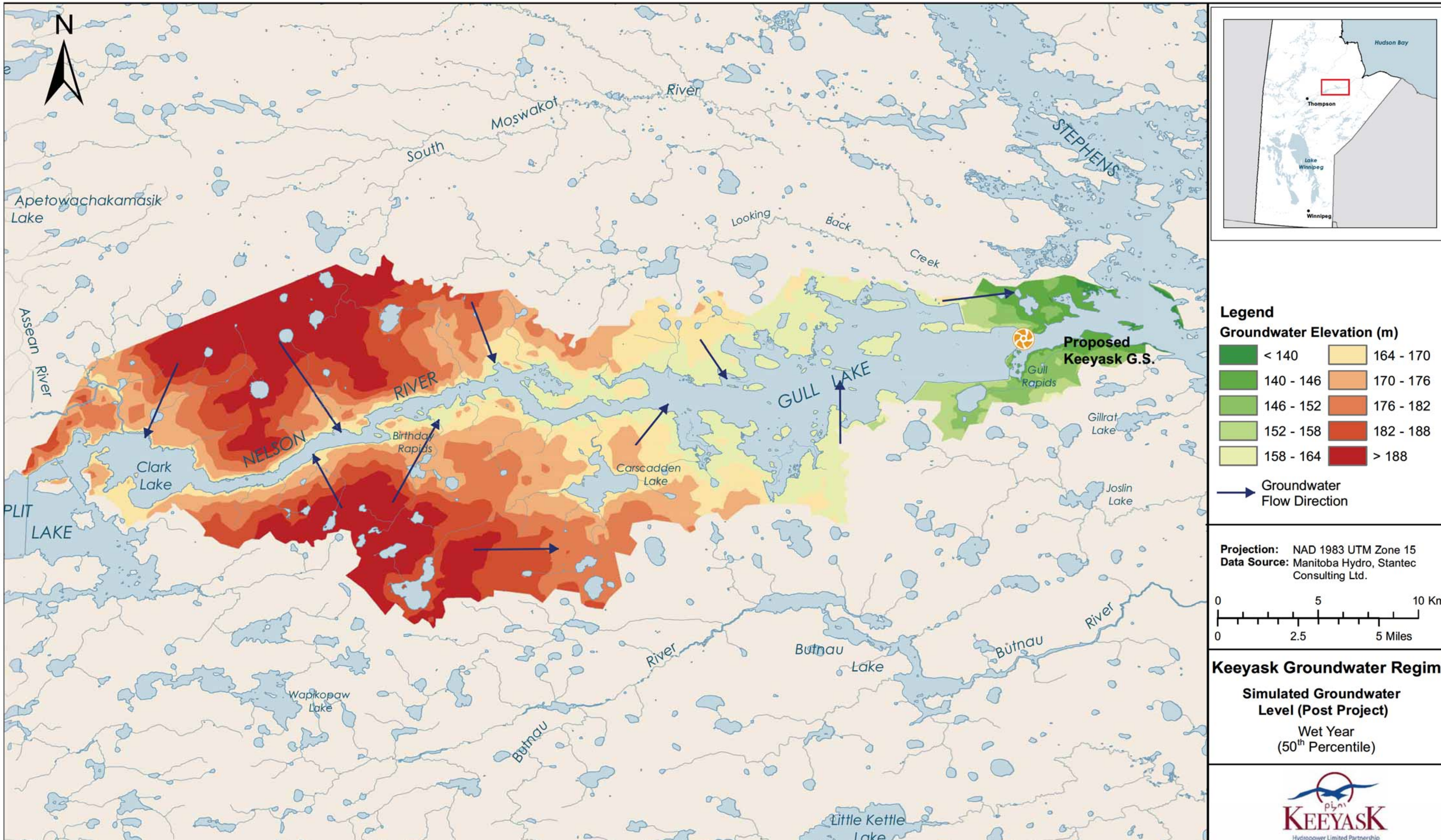
2.5
5 Miles
Keeyask Groundwater Regime
Simulated Groundwater
Level (Existing Environment)
Wet Year
(50th Percentile)
KEEYASK
Hydropower Limited Partnership

Map 8.B-1



N
Apetowachakamasik Lake
South Moswakot River
Assean River
Looking Back Creek
STEPHENS
NELSON RIVER
Birthday Rapids
Clark Lake
SPLIT LAKE
Carscadden Lake
GULL LAKE
Gull Rapids
Proposed Keeyask G.S.
Gillrat Lake
Joslin Lake
Butnau Lake
Butnau River
Wapikopaw Lake
Little Kettle Lake
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Groundwater Elevation (m)
< 140
140 - 146
146 - 152
152 - 158
158 - 164
164 - 170
170 - 176
176 - 182
182 - 188
> 188
Groundwater Flow Direction
Projection: NAD 1983 UTM Zone 15
Data Source: Manitoba Hydro, Stantec Consulting Ltd.
0 5 10 Km
0 2.5 5 Miles
Keeyask Groundwater Regime
Simulated Groundwater Level (Existing Environment)
Dry Year (50th Percentile)
KEEYASK
Hydropower Limited Partnership

Map 8.B-2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STEPHENS
Assean River
NELSON
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Birthday Rapids
Clark Lake
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GULL LAKE
Proposed Keeyask G.S.
Gull Rapids
Gillrat Lake
Joslin Lake
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Butnau Lake
Butnau
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Wapikopaw Lake
Butnau
Little Kettle Lake
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Groundwater Elevation (m)
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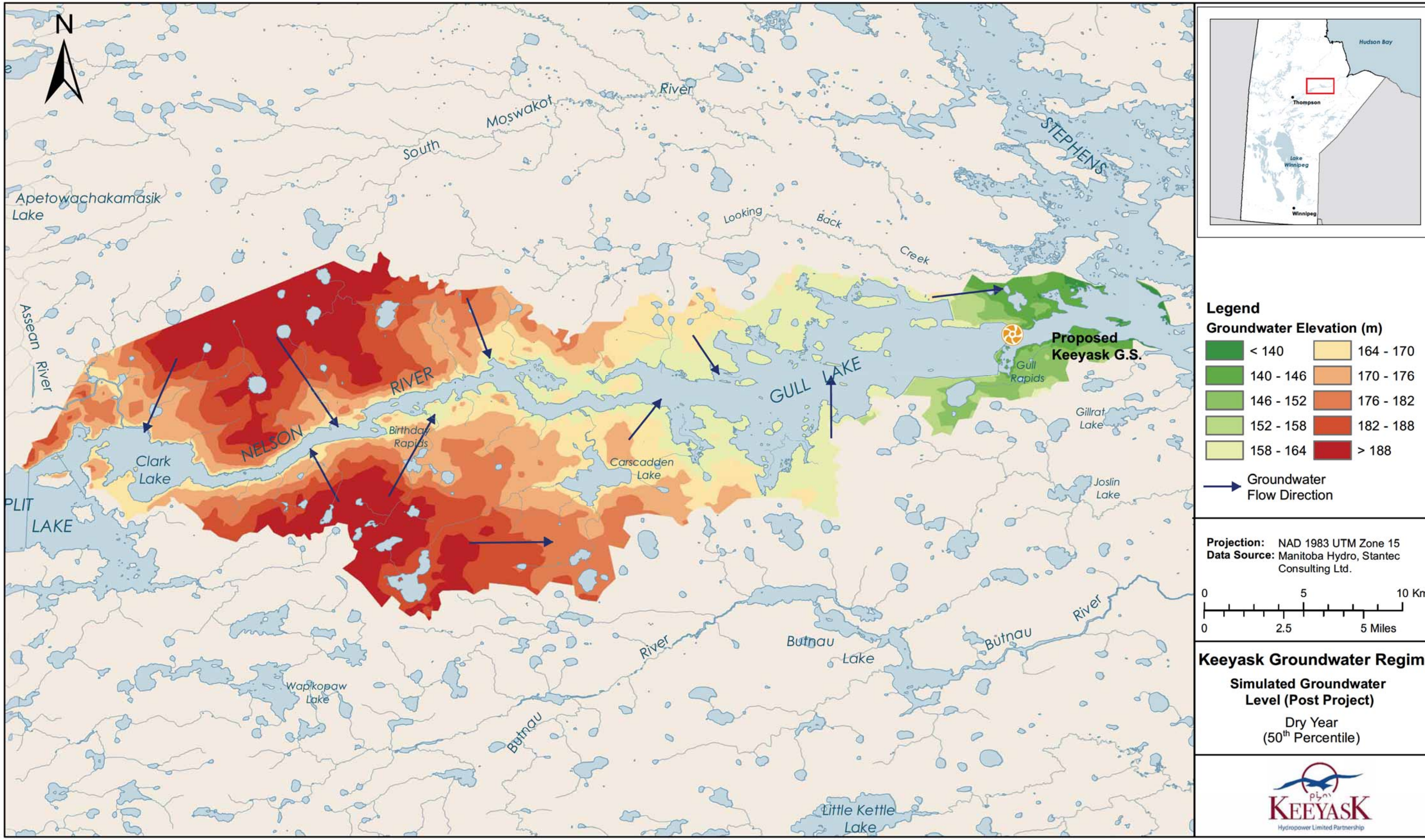
146 - 152
152 - 158
158 - 164
164 - 170
170 - 176
176 - 182
182 - 188
> 188
Groundwater Flow Direction
Projection: NAD 1983 UTM Zone 15
Data Source: Manitoba Hydro, Stantec Consulting Ltd.
0 5 10 Km
0 2.5 5 Miles
Keeyask Groundwater Regime
Simulated Groundwater Level (Post Project)
Wet Year (50th Percentile)
KEEYASK
Hydropower Limited Partnership

Map 8.B-3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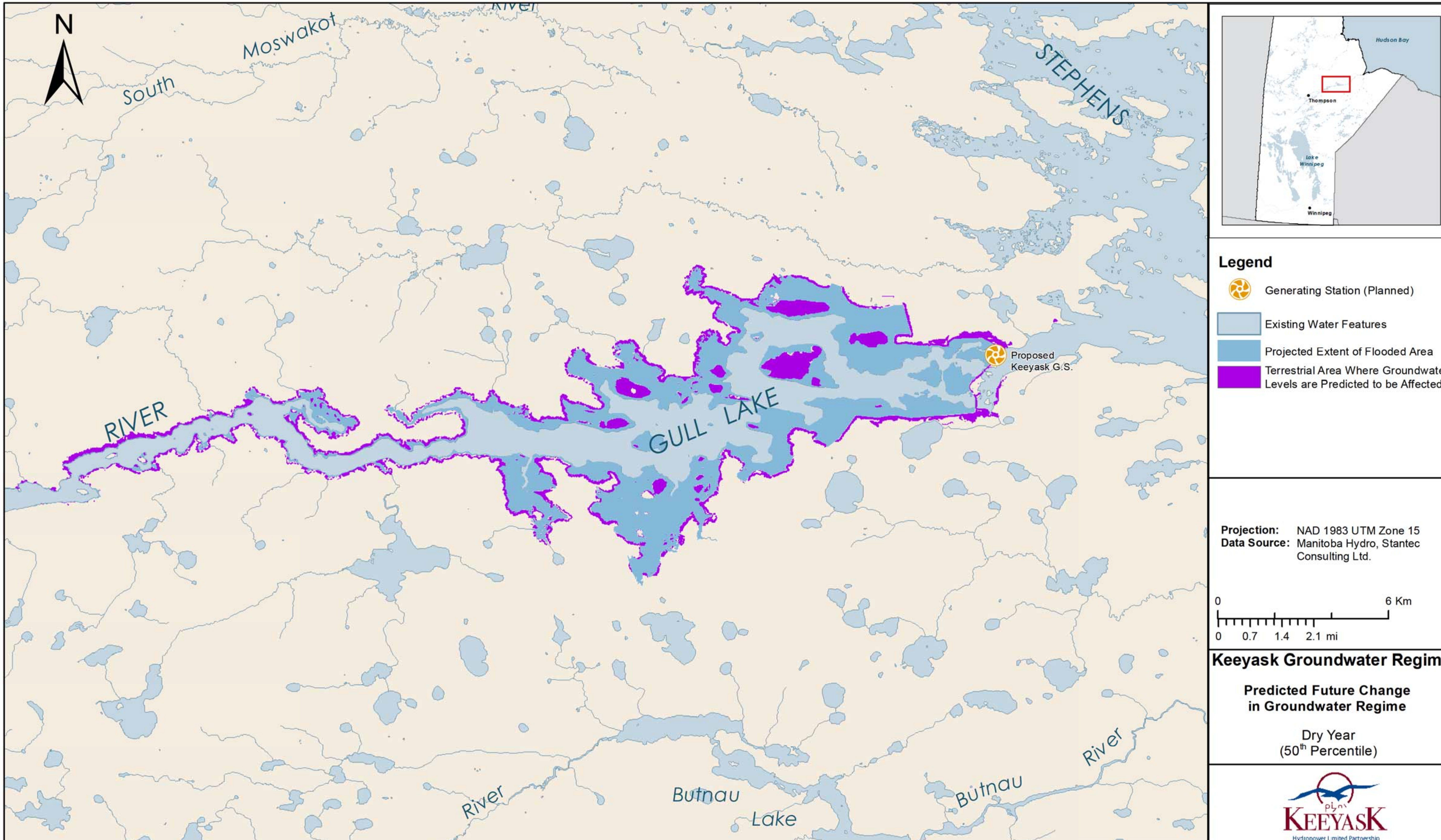
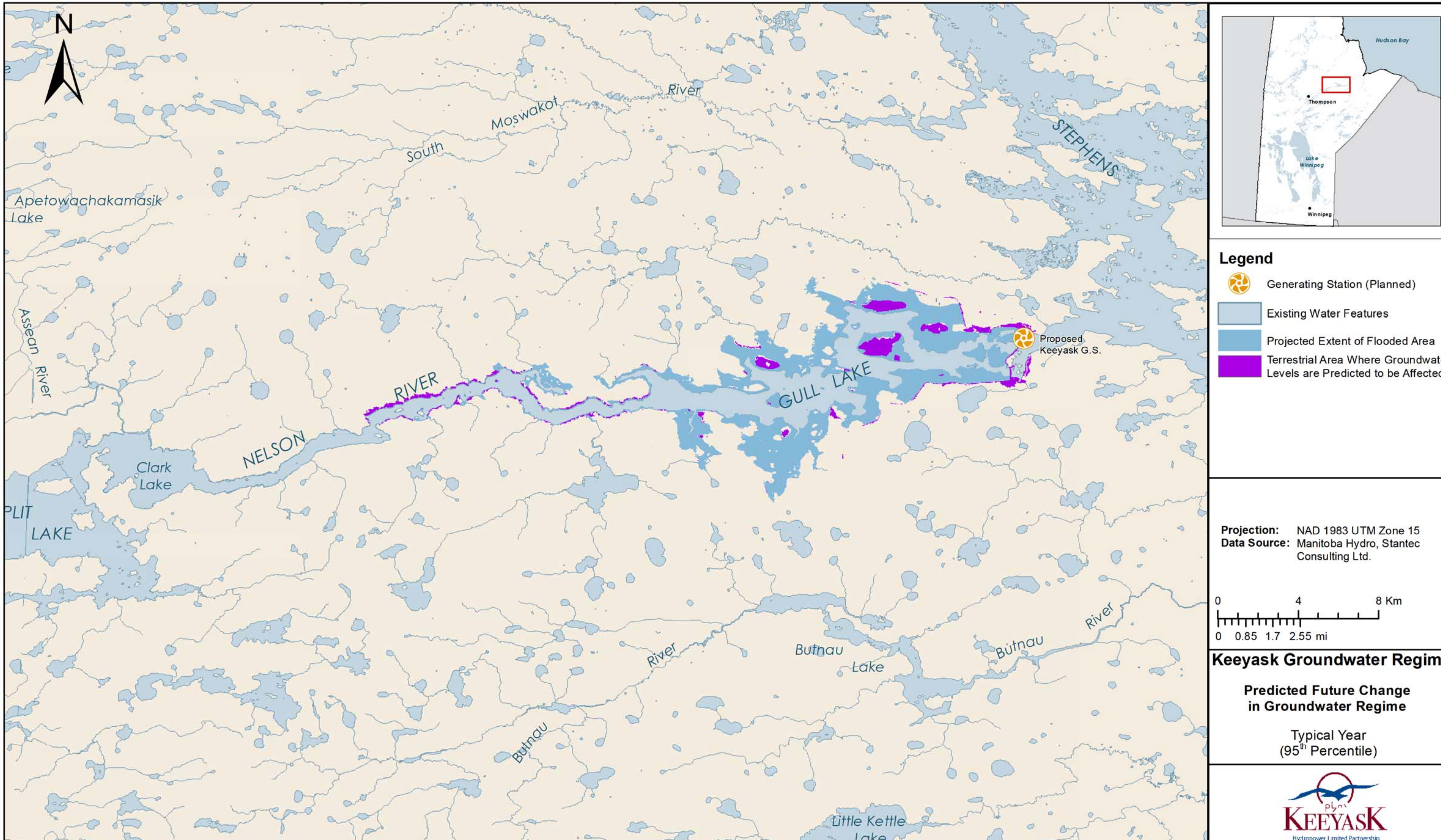
Apetowachakamasik Lake
South
Moswakot
River
STEPHENS
Looking
Back
Creek
Assean River
NELSON
RIVER
Birthday Rapids
Clark Lake
SPLIT LAKE
Carscadden Lake
GULL LAKE
Gull Rapids
Proposed Keeyask G.S.
Gillrat Lake
Joslin Lake
River
Butnau Lake
Butnau
River
Wapikopaw Lake
Butnau
Little Kettle Lake
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Groundwater Elevation (m)
< 140
140 - 146
146 - 152
152 - 158
158 - 164
164 - 170
170 - 176
176 - 182
182 - 188
> 188
Groundwater Flow Direction
Projection: NAD 1983 UTM Zone 15
Data Source: Manitoba Hydro, Stantec Consulting Ltd.
0 5 10 Km
0 2.5 5 Miles
Keeyask Groundwater Regime
Simulated Groundwater Level (Post Project)
Dry Year (50th Percentile)
KEEYASK
Hydropower Limited Partnership

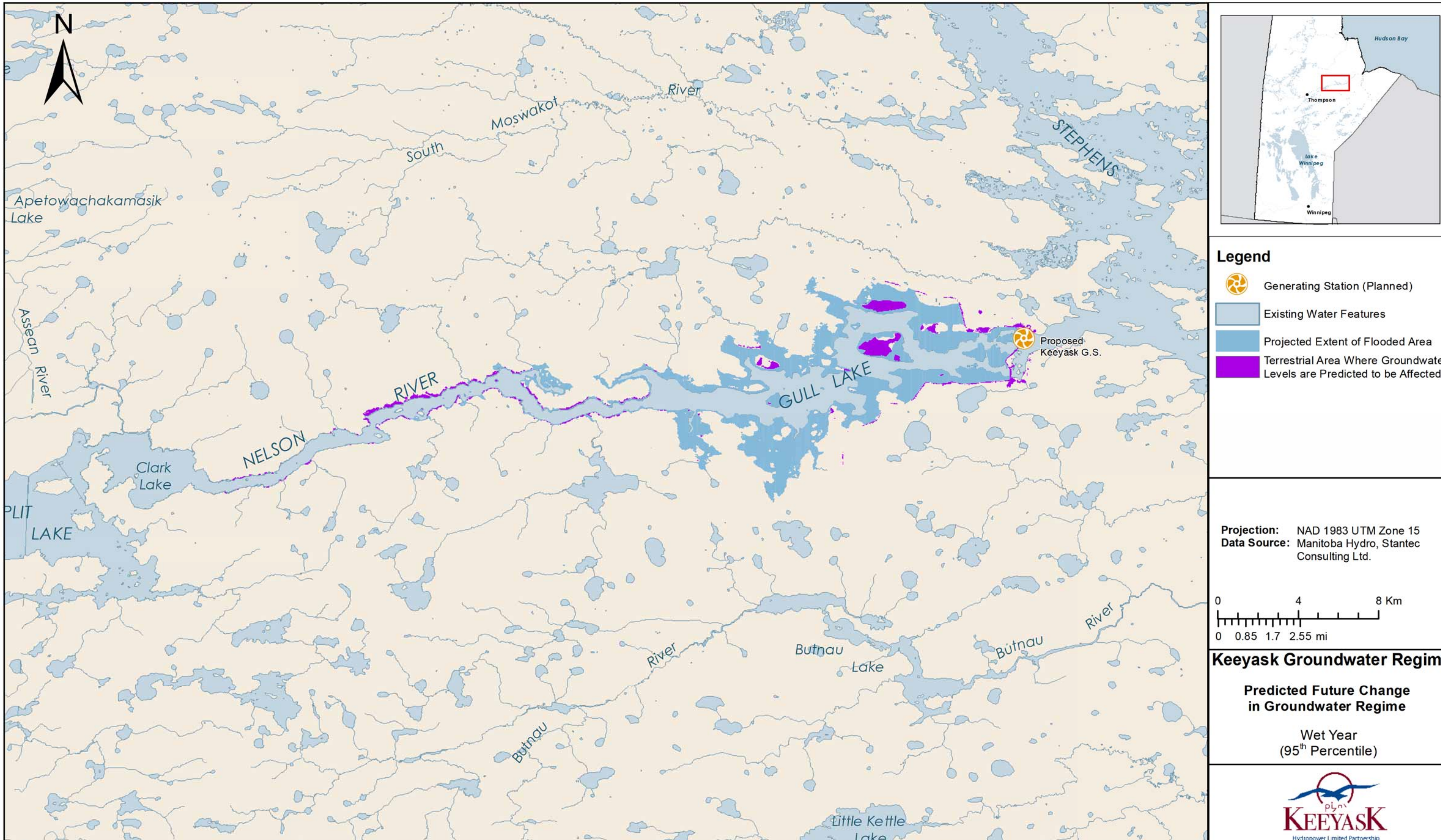
Map 8.B-4


N
South
Moswakot
STEPHENS
RIVER
GULL LAKE
Proposed
Keeyask G.S.
Butnau
Lake
Butnau
River
River
Hudson Bay
Thompson
Lake
Winnipeg
Winnipeg
Legend
Generating Station (Planned)
Existing Water Features
Projected Extent of Flooded Area
Terrestrial Area Where Groundwater Levels are Predicted to be Affected
Projection: NAD 1983 UTM Zone 15
Data Source: Manitoba Hydro, Stantec Consulting Ltd.
0
6 Km
0 0.7 1.4 2.1 mi
Keeyask Groundwater Regime
Predicted Future Change in Groundwater Regime
Dry Year
(50th Percentile)
KEEYASK
Hydropower Limited Partnership

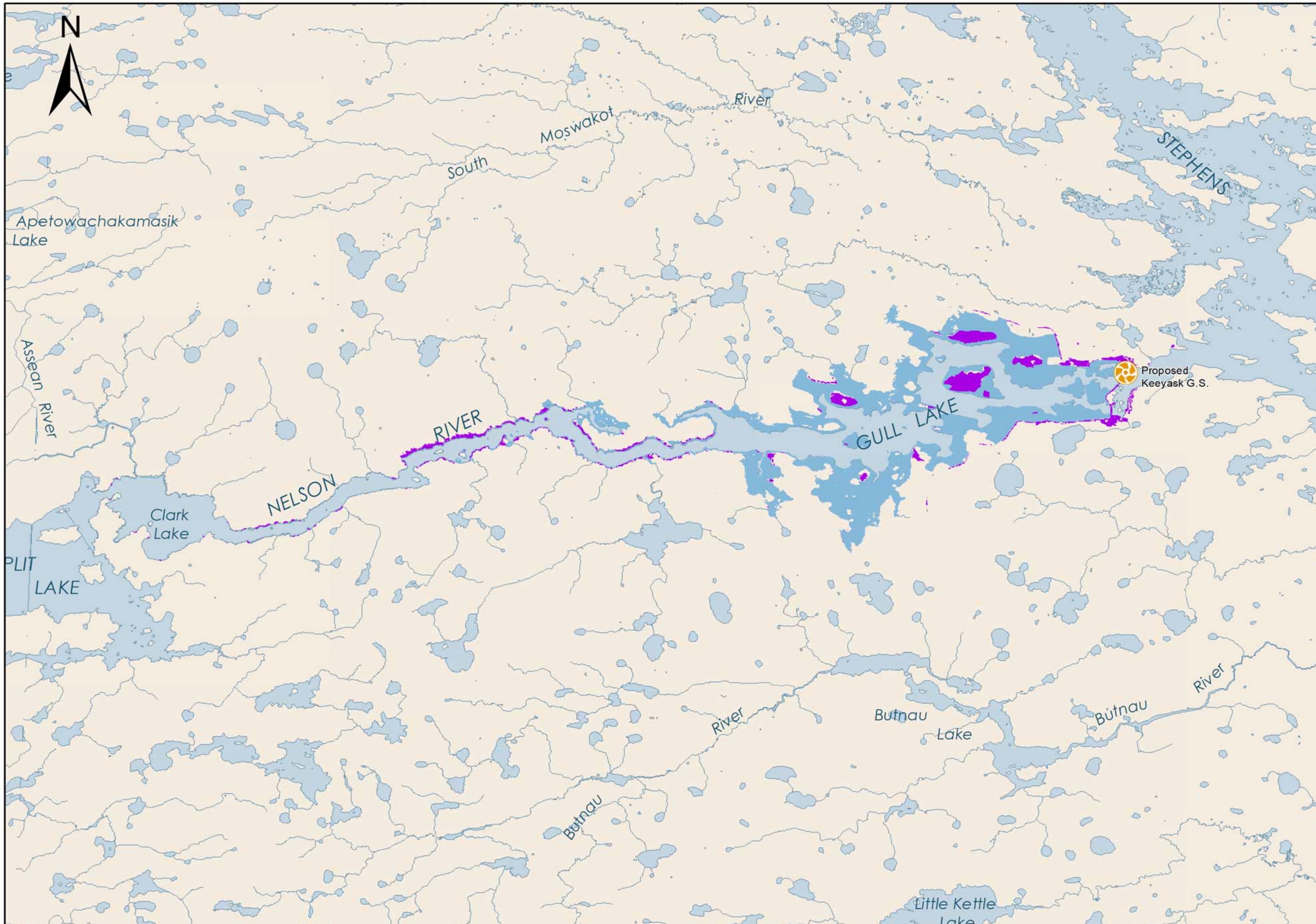
Map 8.B-5


N
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
River
Moswakot
South
STEPHENS
Apetowachakamasik
Lake
Assean
River
RIVER
NELSON
Clark
Lake
PLIT
LAKE
GULL LAKE
Proposed
Keeyask G.S.
Butnau
Lake
Butnau
River
River
Butnau
Little Kettle
Lake
Legend
Generating Station (Planned)
Existing Water Features
Projected Extent of Flooded Area
Terrestrial Area Where Groundwater Levels are Predicted to be Affected
Projection: NAD 1983 UTM Zone 15
Data Source: Manitoba Hydro, Stantec Consulting Ltd.
0 4 8 Km
0 0.85 1.7 2.55 mi
Keeyask Groundwater Regime
Predicted Future Change in Groundwater Regime
Typical Year
(95th Percentile)
KEEYASK
Hydropower Limited Partnership

Map 8.B-6


N
Apetowachakamasik Lake
South Moswakot River
STEPHENS
Assean River
NELSON RIVER
Clark Lake
PLIT LAKE
GULL LAKE
Proposed Keeyask G.S.
Butnau River
Butnau Lake
Butnau
Little Kettle Lake
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Generating Station (Planned)
Existing Water Features
Projected Extent of Flooded Area
Terrestrial Area Where Groundwater Levels are Predicted to be Affected
Projection: NAD 1983 UTM Zone 15
Data Source: Manitoba Hydro, Stantec Consulting Ltd.
0 4 8 Km
0 0.85 1.7 2.55 mi
Keeyask Groundwater Regime
Predicted Future Change in Groundwater Regime
Wet Year (95th Percentile)
KEEYASK
Hydropower Limited Partnership

Map 8.B-7



Legend

- Generating Station (Planned)
- Existing Water Features
- Projected Extent of Flooded Area
- Terrestrial Area Where Groundwater Levels are Predicted to be Affected

Projection: NAD 1983 UTM Zone 15
Data Source: Manitoba Hydro, Stantec Consulting Ltd.

0 4 8 Km
0 0.85 1.7 2.55 mi

Keeyask Groundwater Regime

Predicted Future Change in Groundwater Regime

Dry Year
(95th Percentile)

KEEYASK
Hydropower Limited Partnership

Map 8.B-8