KEEYASK GENERATION PROJECT STAGE IV STUDIES-PHYSICAL ENVIRONMENT GN-9.1.3- EXISTING & PROJECT ENVIRONMENT SHORELINE AND DEPTH EFFECTS ASSESSMENT

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Manitoba Hydro

CONFIDENTIAL

KEEYASK GENERATION PROJECT

STAGE IV STUDIES - PHYSICAL ENVIRONMENT

EXISTING & PROJECT ENVIRONMENT SHORELINE AND DEPTH EFFECTS ASSESSMENT

DELIVERABLE GN-9.1.3

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INTEROFFICE MEMORANDUM

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DATE 2012 09 01

FILE 00195-11100-00138_01

SUBJECT **KEEYASK GENERATING STATION – PHYSICAL ENVIRONMENT STUDIES EXISTING & PROJECT ENVIRONMENT SHORELINE AND DEPTH EFFECTS ASSESSMENT MEMORANDUM GN-9.1.3 - REV 0**

Please find the attached report "Keeyask Generation Project Stage IV Studies - Physical Environment: Existing & Project Environment Shoreline and Depth Effects Assessment GN-9.1.3". This report documents the differences between existing and post-project shoreline and depth estimates under steady-state conditions, as used in the Keeyask Generating Station Stage IV Engineering and Physical Environment Environmental Impact Statement studies. In this memo, post-project results and effects assessments are provided for the reach upstream of the project, which covers the most significant project-related effects. Post-project effects downstream of the project site are included where applicable.

This technical memorandum is to be used in support of the Keeyask Generating Station Environmental Impact Statement. In order to provide appropriate interpretation and guidance, please consult the Water Resource Engineering Department prior to external distribution.

Please contact me at (204) 360-5028 or JMalenchak@hydro.mb.ca if you have any questions or concerns.

Sincerely,

J. Malenchak, Ph.D, P. Eng.

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1 INTRODUCTION

This report documents the procedures used to estimate **existing environment** and **post-project** shorelines and water depths under steady-state conditions, as used in the Keeyask Generating Station (GS) Stage IV Engineering and Physical Environment Environmental Impact Statement (EIS) studies.

The proposed Keeyask GS project is located within the study reach on the Lower Nelson River approximately 56 km downstream of Split Lake and approximately 4 km upstream of Stephens Lake (see Figure 1 - Appendix B). Once built, the project will alter various characteristics of the existing water regime within the project's **hydraulic zone of influence**, as described in Deliverable GN-9.1.13 "Existing and Project Environment Water Surface Profiles Effects Assessment" (Manitoba Hydro, 2012d). The shoreline and depth information is summarized (in formats as prescribed by the engineering and physical environment study teams) to assist in illustrating how the **existing environment** could change due to the proposed Keeyask GS project, under a range of flow conditions.

All elevations are referenced to the National Geodetic Vertical Datum 1929 adjustment (NGVD 29), unless otherwise stated.

2 DATA AND METHODOLOGY

2.1 PROJECT INFLOWS

The 5th, 50th, and 95th percentile all-season flow quantiles shown in Table 1 were used to characterize the **existing environment** and **post-project** water regimes under a range of flow conditions. The shoreline and depth estimates are representative of flow conditions within a range of approximately 5% (± 2.5%) of the flows shown in Table 1. The development and update of the project **inflows** shown in Table 1 is described in Deliverable GN-9.1.1 - "Existing Environment and Post-Project Flow Files" (Manitoba Hydro, 2012a) and Deliverable GN-9.1.2 - "Sensitivity Analysis of Water Regime Products to Inflows" (Manitoba Hydro, 2012b).

In order to support various mitigation and compensation studies, additional runs as listed in Table 2 were conducted with an extended numerical model (Mike 21, see GN-9.1.4) from Split Lake to Stephens Lake to characterize the water depth and shoreline. All of the runs were undertaken with a 139.1 m (5th percentile level) and 141.1 m (full supply level) Stephens Lake level for a total of 20 runs. However, the depth and shoreline results

for these additional runs are not shown in this memorandum but were used as inputs to the mitigation and compensation studies.

Table 1 - Range of flows that water surface profiles and shoreline polygons represent

Quantile	Existing Environment Flow Range [cms]	Post-Project Environment Flow Range [cms]
5%	2060 ± 2.5% = 2009 to 2112	2170 ± 2.5% = 2116 to 2224
50%	3030 ± 2.5% = 2954 to 3106	3030 ± 2.5% = 2954 to 3106
95%	4330 ± 2.5% = 4222 to 4438	4430 ± 2.5% = 4319 to 4541

Table 2 Additional runs conducted in support of mitigation and compensation studies

Existing Environment		Post-Project Environment	
Quantile	Flow (cms)	Scenario	Flow (cms)
25%	2579	2 unit best gate (UBG)	1100
75%	3525	3 UBG	1650
-	-	4 UBG	2200
-	-	5 UBG	2750
-	-	6 UBG	3300
-	-	7 UBG	3850
-	-	7 unit full gate (UFG)	4000
-	-	7 unit + spill	4855

2.2 SHORELINES AND WATER DEPTHS

A calibrated one-dimensional steady-state backwater model was developed using the US Army Corps of Engineers' HEC-RAS and HEC-GeoRAS software programs (USACE 1999 & 2002). The model was then used to estimate water levels along the Keeyask study reach under the **existing environment** and **post-project** flow conditions. The model, using the **inflows** defined in Table 1, was developed as described in Deliverable GN-9.1.13 "Water Surface Profiles Effects Assessment" (Manitoba Hydro, 2012d). In short, cross sections were extracted from the digital terrain model (DTM) using the HEC-GeoRAS tool, and then imported into the HEC-RAS hydraulic modeling software. Details regarding development of the DTM are found in Deliverable GN-9.1.5 "Existing and Project Environment Digital Terrain Model" (Manitoba Hydro, 2012c). The model was then calibrated by adjusting the hydraulic roughness, ineffective flow areas, and localized areas of **bathymetry** so that modeled water levels matched rating curves that were based on measured water levels. Overall, the modeled water levels were calibrated

to within ± 0.10 m - 0.30 m, while the majority of the reach was calibrated to ± 0.10 m - 0.15 m. The model is less accurate within Gull Rapids due to complex hydraulic conditions that are present within the rapids, as well as the general lack of real bathymetric data. Once the **existing environment** model was calibrated, it was modified to simulate the hydraulic conditions for the **post-project** environment.

A downstream boundary elevation of 140.2 m was used for the **existing environment** model, representing the 50th percentile operating level of the Kettle GS **forebay** (Stephen's Lake). For the **post-project** hydraulic model, the Keeyask reservoir full supply level of 159.0 m was used as the downstream model boundary in the reach upstream of the Keeyask GS.

No attempt was made to develop **shoreline polygons** and depth grids to represent the extent of the **forebay** beyond initial impoundment. Erosion of shorelines will cause the **shoreline polygons** and depth grids to change. Therefore, the datasets presented in this report represent "Day 0" conditions.

The HEC-GeoRAS software, an extension developed for use within the Environmental Systems Research Institute (ESRI) ArcGIS (Geographical Information System) software, was used to develop the **shoreline polygons** and depth grids presented in this report. **Shoreline polygons** and depth grids (using 5 m x 5 m grid spacing) in ESRI ArcGIS format were developed for each flow condition according to the following procedure:

1) HEC-GeoRAS is used to import modeled water surface profiles to develop a water level triangulated irregular network (TIN) for each profile.
2) HEC-GeoRAS intersects the water level TIN with the DTM of the study area (also a TIN) in ESRI ArcGIS to create **shoreline polygons**.
3) The water level TIN is converted into a water level grid and clipped using the **shoreline polygon**.
4) HEC-GeoRAS creates a grid version of the study area DTM.
5) HEC-GeoRAS develops a water depth grid by subtracting the DTM grid from the water level grid.
6) **Shoreline polygons** are visually inspected and manually cleaned to ensure:
    a) shorelines for different flow conditions do not cross each other (which can occur as a by-product of shoreline smoothing);
    b) the extents of GeoRAS shorelines agree well with digital air photos of the study area;
    c) the extents of GeoRAS shorelines agree well with the contour data set established for the study area;
    d) there are no extraneous polygons; and

e) the **shoreline polygons** meet the accuracy requirements of the Aquatics Study Team.

3 RESULTS

Existing environment depth grids developed for 5th, 50th, and 95th percentile flows under steady-state conditions are presented in Figure 1 (Appendix B). **Post-project** depth grids are shown in Figure 2. Depth changes resulting from **forebay** impoundment are shown in Figure 3. **Existing environment** and **post-project shoreline polygons** are shown in Figure 4. These figures do not illustrate additional flooded areas which would result from shoreline erosion occurring after reservoir impoundment, they represent "Day 0" conditions. Also, when comparing existing environment and post-project conditions, it is important to acknowledge that some of the changes will be due to the different flow values used and not to the project itself. See Deliverable GN-9.1.1 "Existing and Project Environment Flow Files" (Manitoba Hydro, 2012a) for a description of how these flow values were obtained.

4 EFFECTS ASSESSMENT

Water levels upstream of the Keeyask project will be raised above natural levels, creating a **forebay** that extends approximately 40 km upstream. Water depths in the river reach downstream of Clark Lake will increase and newly flooded areas, mostly around Gull Lake and Gull Rapids, will be created. Estimated changes to the water depth occurring within the river and the newly flooded areas due to impoundment of the Keeyask **forebay** are shown in Figure 3. Changes resulting from the project are similar throughout the flow range used to characterize the **existing environment** and **post-project** water regimes.

The creation of the reservoir will drown out Gull Rapids by increasing water levels 10 to 15 m above **existing environment** conditions in this area. However, the greatest depths of approximately 31 m will occur in an excavated channel leading to the new powerhouse located in the vicinity of the north channel of the existing rapids. Gull Lake will be approximately 6 m deeper, and the reach between Birthday Rapids and Portage Creek will be about 3 to 5 m deeper under **post-project** conditions, thereby drowning out the rapids in this reach also. Depths within the reach between Birthday Rapids and Clark Lake will vary up to 1 m deeper, with the greatest change found just upstream of the rapids, and negligible change near the outlet of Clark Lake. Newly flooded areas will generally experience depths less than 5 m, and some of this flooding will be contained

within dykes constructed around portions of the **forebay**. The effects of impoundment on water depths are negligible within and above Clark Lake.

Shorelines within the newly flooded areas will extend further inland from their current location to contain the increased water levels within the reservoir. The greatest change will occur on the south shore of Gull Lake, where the new shoreline will extend approximately 4 km from the existing waters' edge due to lower vertical relief in this area. Most of the **forebay** within approximately 10 km upstream of the new station will be contained by dykes. The larger islands upstream of Gull Rapids will be smaller, while other islands within Gull Rapids and Gull Lake will be submerged. Several smaller islands will be created within the newly flooded areas.

Between the Full supply Level (159 m) and the Minimum Operating Level (158 m) there will exist some areas along the shoreline that will be intermittently wetted and dried as the reservoir is drawn down and reponded. These areas will be underwater at 159 m and dry at 158 m. These areas represent conditions immediately following reservoir impoundment and do not include the effects of shoreline erosion, peatland disintegration or peatland resurfacing that is expected to occur following reservoir impoundment and in the future. For 5th, 50th and 95th percentile flow conditions, the total intermittently exposed areas are 10.76 km^2, 10.75 km^2 and 10.74 km^2 respectively as shown in Figure 5, 6 and 7. The majority of these areas are located at the edges of the newly formed back-bays surrounding Gull Lake. As well, some intermittently exposed areas exist around both the existing and newly formed islands in the **forebay** area. There will be no intermittently exposed shorelines due to the Project on Clark Lake or Split Lake which will be outside of the open water **hydraulic zone of influence.**

5 GLOSSARY

bathymetry	Data resulting from the measurement of the depth or elevation of the bottom of a body of water.
existing environment	Refers to the environment in which a proposed generating station is to be built, under the conditions that exist prior to it actually being built.
forebay	A reservoir feeding the intake of a hydroelectric power plant.
hydraulic zone of influence	The upstream and downstream extent of the influence of the project during operation
post-project	Refers to the environment in which a proposed generating station is to be built, under the conditions that exist after it has been built.
shoreline polygon	Refers to delineating a shoreline area by means of a clustered supervised classification that creates a continuous area represented by a polygon. Shoreline polygons are analyzed using image analysis techniques.

6 REFERENCES

Manitoba Hydro (2012a). Keeyask Generation Project Stage IV Studies - Physical Environment: Existing and Project Environment Flow Files. GN-9.1.1, Rev 0.

Manitoba Hydro (2012b). Keeyask Generation Project Stage IV Studies - Physical Environment: Sensitivity Analysis of Water Regime Products to Inflows. GN-9.1.2, Rev 0.

Manitoba Hydro (2012c). Keeyask Generation Project Stage IV Studies - Physical Environment: Existing and Project Environment Digital Terrain Models. GN-9.1.5, Rev 0.

Manitoba Hydro (2012d). Keeyask Generation Project Stage IV Studies - Physical Environment: Existing and Project Environment Water Surface Profiles Effects Assessment. GN-9.1.13, Rev 0.

USACE (1999). US Army Corps of Engineers HEC-GeoRAS Users Manual Version 1. CPD-75. USACE Hydrologic Engineering Center (HEC) 609 Second Street Davis, CA 95616-4687
http://www.hec.usace.army.mil/publications/pub_download.html

USACE (2002). US Army Corps of Engineers HEC-RAS River Analysis System Hydraulic Reference Manual Version 3.1. CPD-69. USACE Hydrologic Engineering Center (HEC) 609 Second Street Davis, CA 95616-4687
http://www.hec.usace.army.mil/publications/pub_download.html

7 APPENDIX A - ABBREVIATIONS

ABBREVIATIONS

cm.....centimetres

cms .....cubic metres per second

DTM.....digital terrain model

EIS.....environmental impact statement

ESRI.....Environmental Systems Research Institute

GIS .....Geographical Information System

GS .....generating station

km .....kilometre

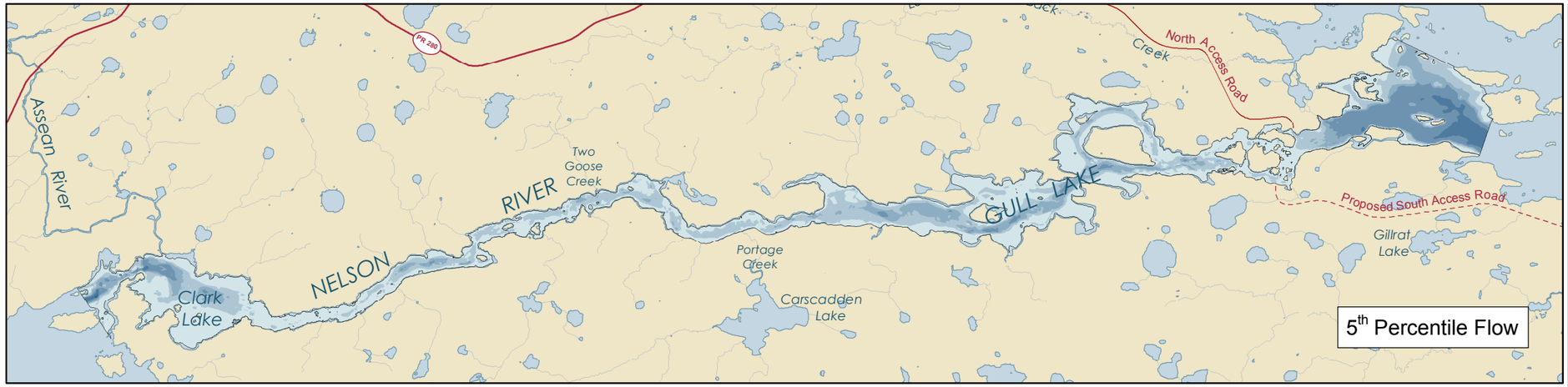
m .....metre

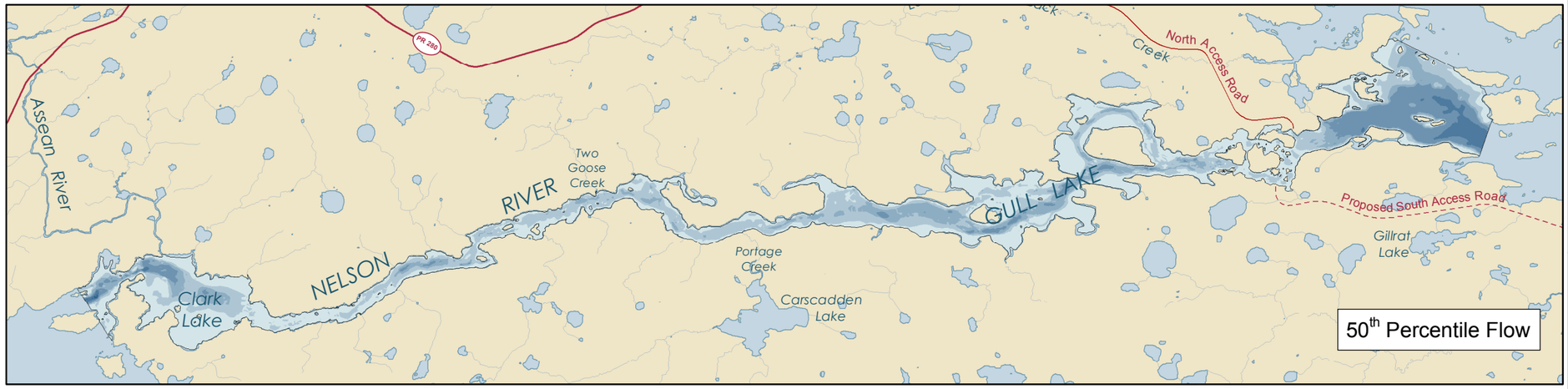
m/s.....metres per second

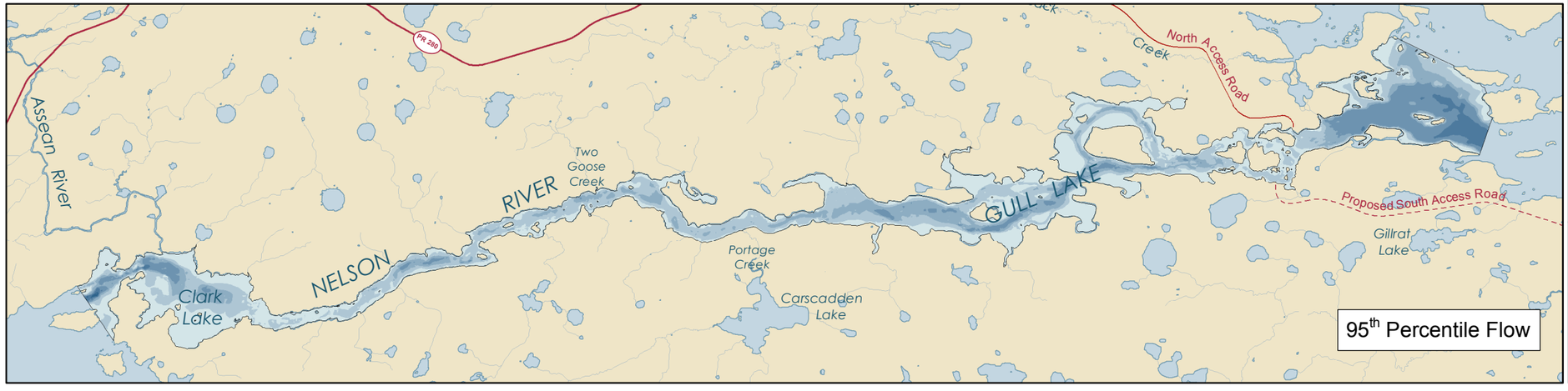
NGVD.....National Geodetic Vertical Datum

TIN.....triangulated irregular network

8 APPENDIX B - TABLES AND FIGURES







Legend

Depth (m)

- 0 - 4
- 4 - 8
- 8 - 12
- 12 - 18
- 18 - 23
- 23 - 31

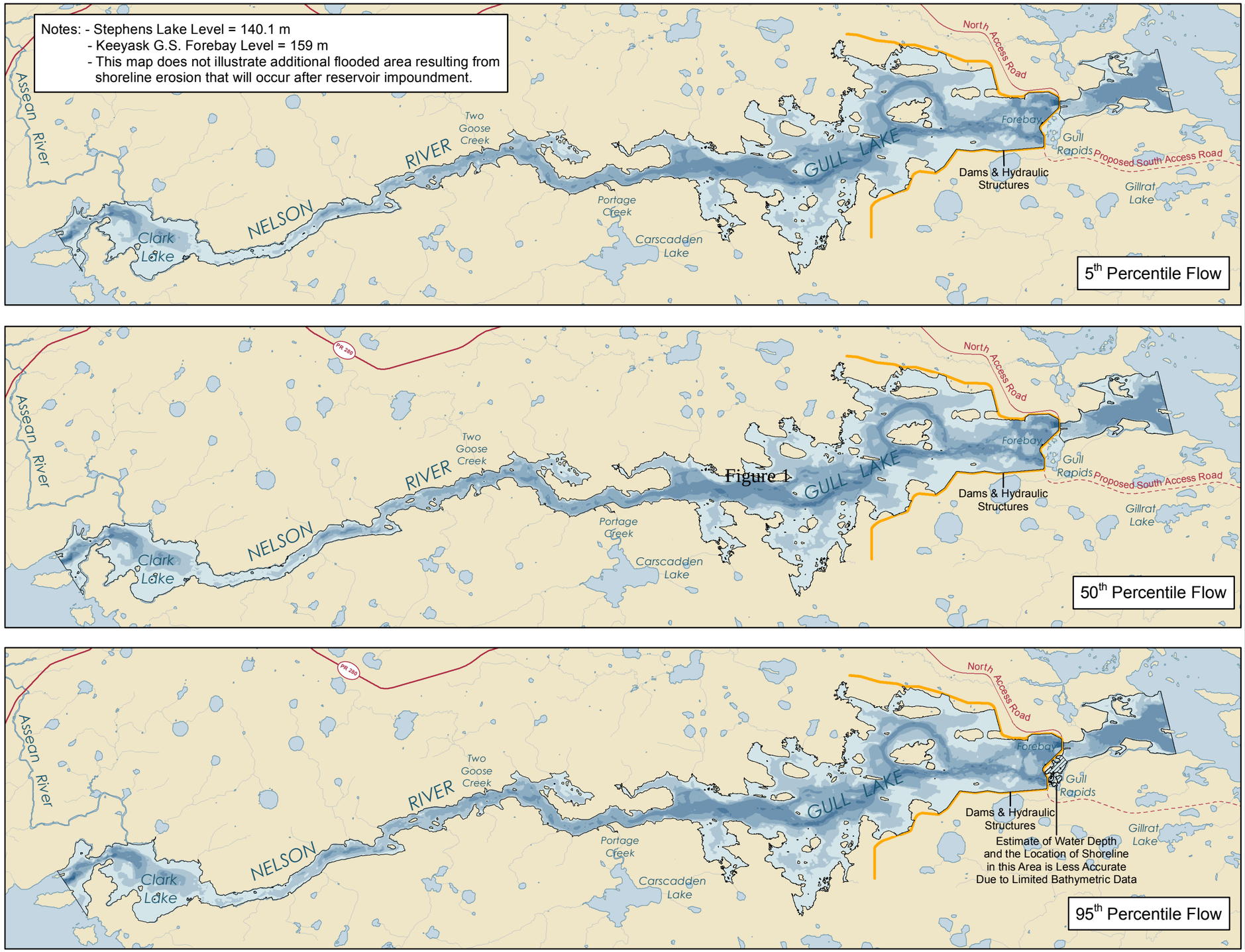
Projection: NAD_1983_UTM_Zone_15N
Data Source: Manitoba Hydro, NTDB

0 1.25 2.5 5 Kilometers
0 1.25 2.5 5 Miles

Water Depth Grid
Existing Environment

KEEYASK Hydropower Limited Partnership

Figure 1



Legend

- 0 - 4
- 4 - 8
- 8 - 12
- 12 - 18
- 18 - 23
- 23 - 31

Projection: NAD_1983_UTM_Zone_15N
Data Source: Manitoba Hydro, NTDB

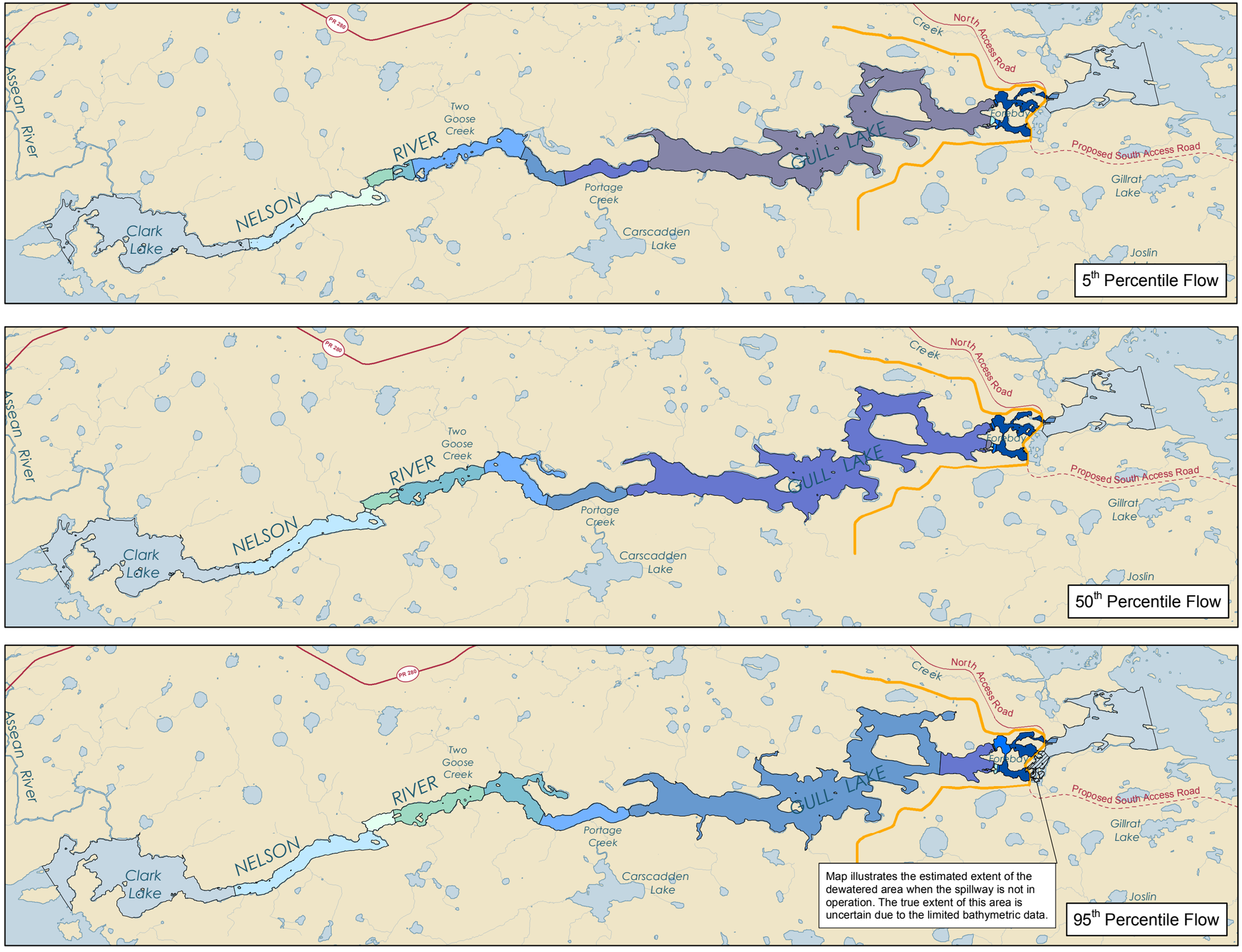
0 1.25 2.5 5 Kilometers
0 1.25 2.5 5 Miles

Post Project Environment Water Depth Grids

KEEYASK Hydropower Limited Partnership

Figure 1

Figure 2



Legend

Depth Change (m)

- Keeyask Principle Structures
- 0
- 0 to 1
- 1 to 2
- 2 to 3
- 3 to 4
- 4 to 5
- 5 to 6
- 6 to 7
- 7 to 8
- 8 to 9
- 9 to 10
- >10

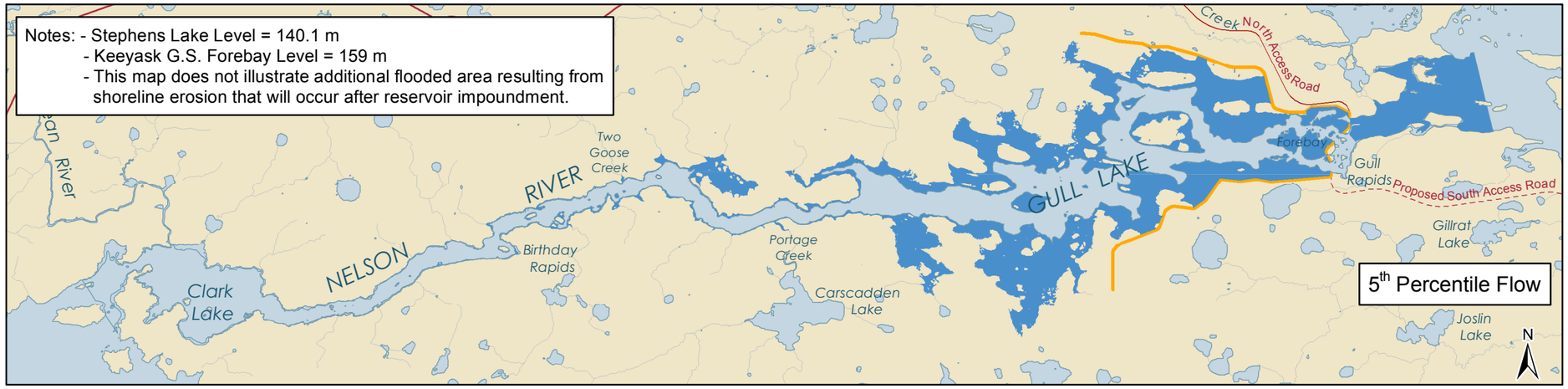
Projection: NAD_1983_UTM_Zone_15N
Data Source: Manitoba Hydro, NTDB

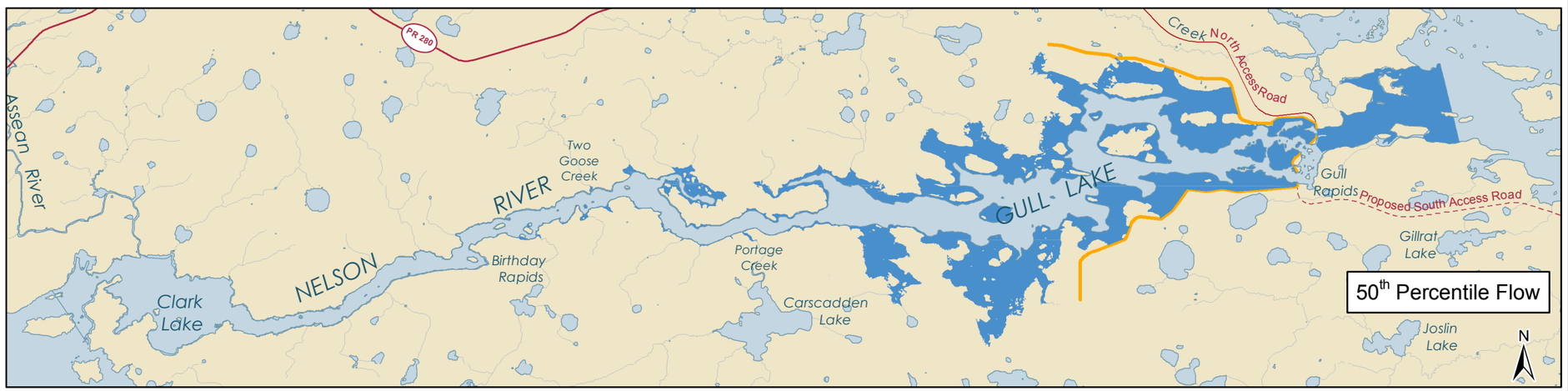
0 1.25 2.5 5 Kilometers
0 1.25 2.5 5 Miles

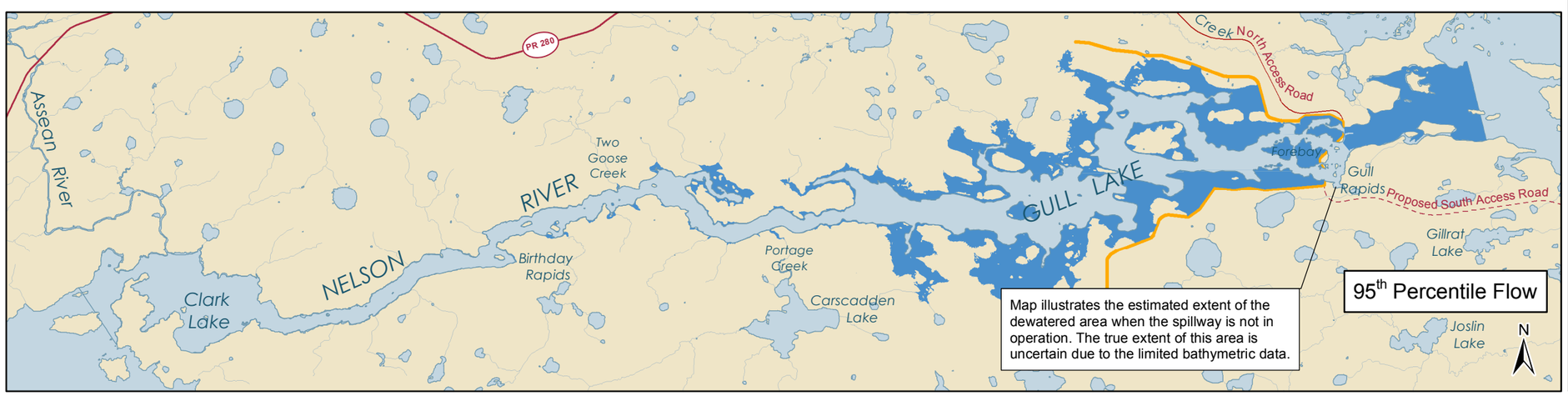
Estimated Water Depth Changes Resulting from Forebay Impoundment

KEEYASK Hydropower Limited Partnership

Figure 3







Legend

Shoreline Polygons

- Existing Environment Flow
- Post Project Environment Flow
- Keeyask Principal Infrastructure Axis

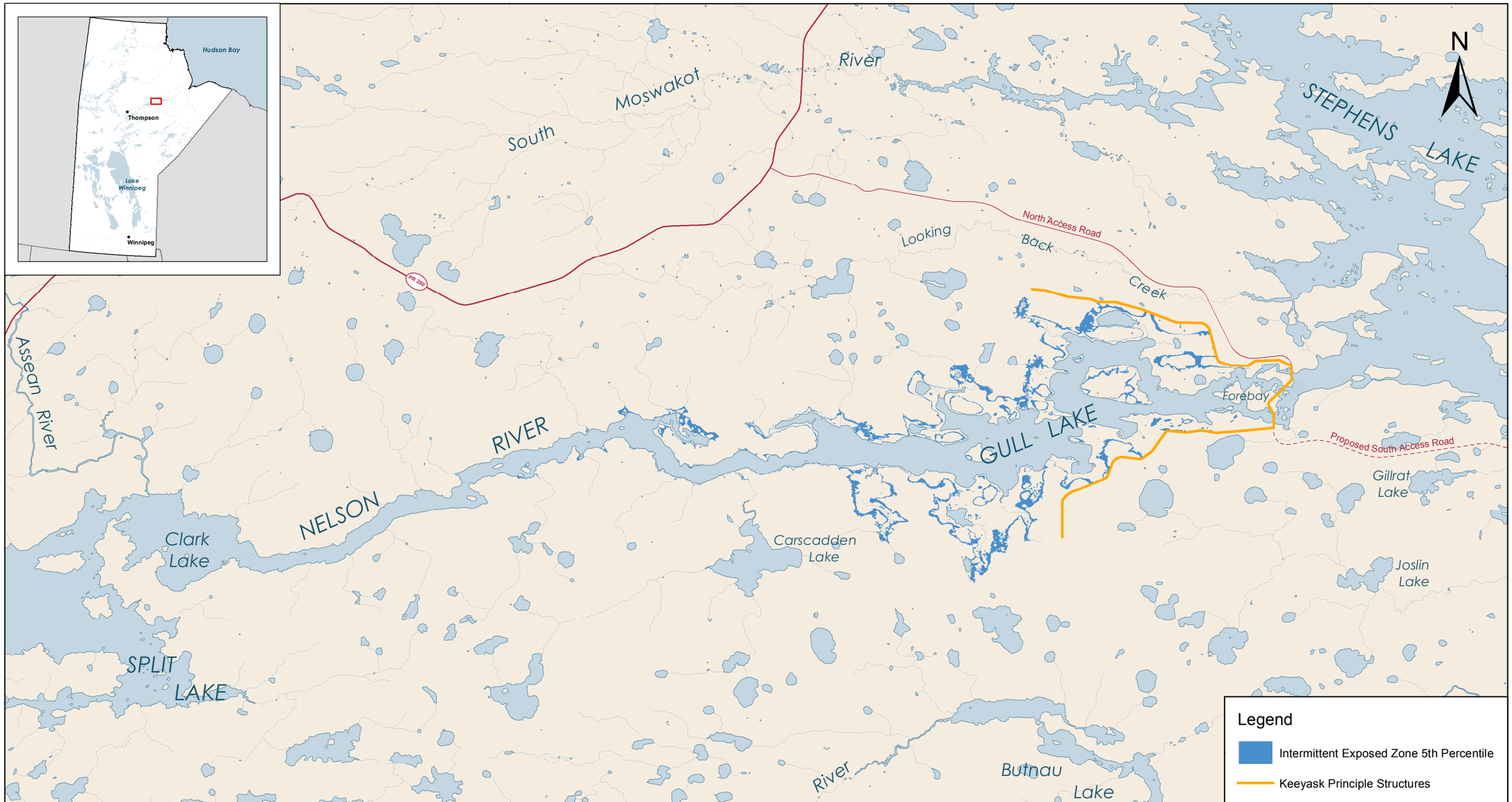
Projection: NAD_1983_UTM_Zone_15N
Data Source: Manitoba Hydro, NTDB

0 1.25 2.5 5 Kilometers
0 1.25 2.5 5 Miles

Existing Environment and Post Project Environment Shoreline Polygons

KEEYASK Hydropower Limited Partnership

Figure 4



KEEYASK Hydropower Limited Partnership

0 1.25 2.5 5 Kilometers
0 1.25 2.5 5 Miles

Projection: NAD_1983_UTM_Zone_15N
Data Source: Manitoba Hydro, NTDB

Intermittently Exposed Post Project Shoreline
5th Percentile Flow

Figure 5

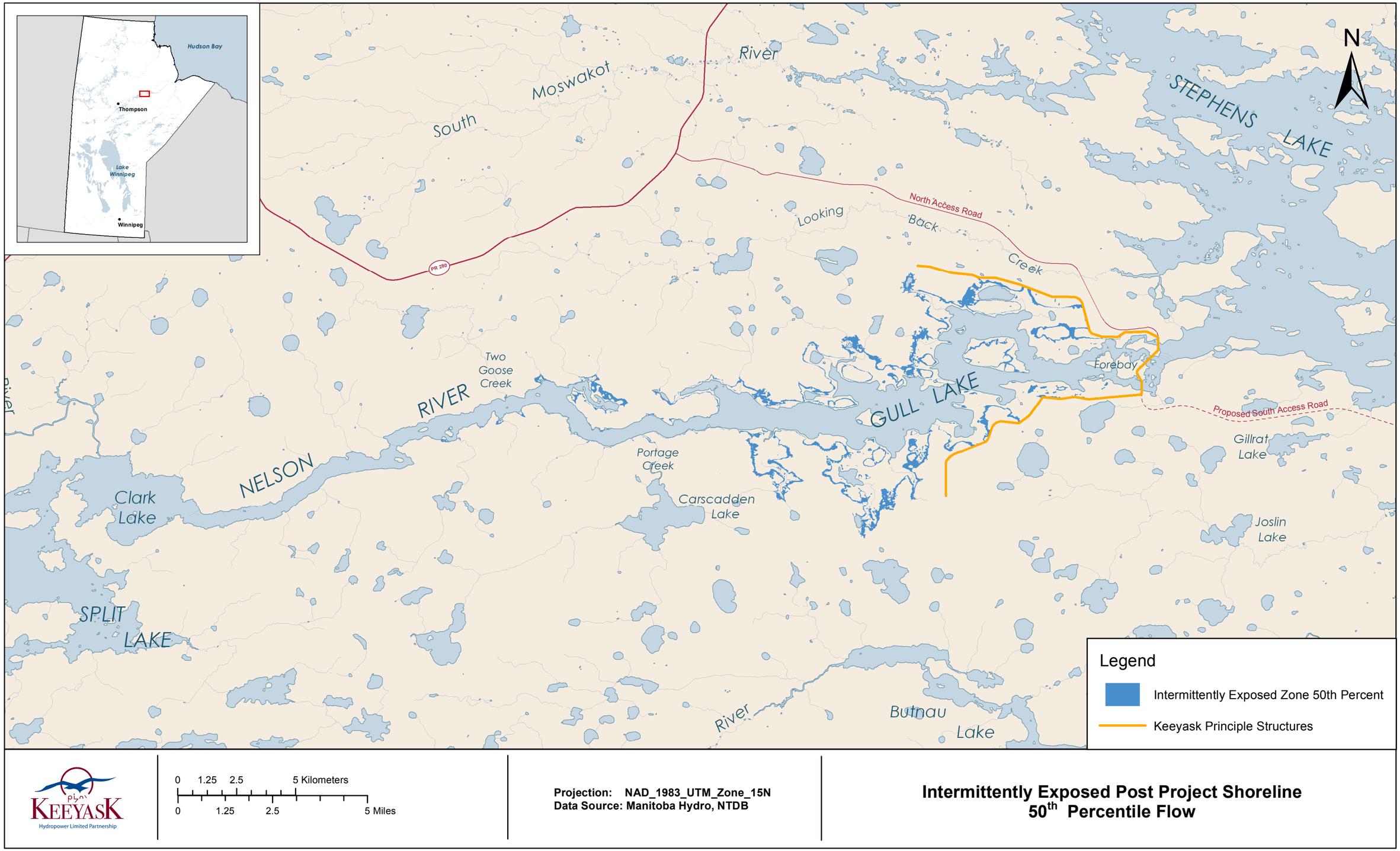
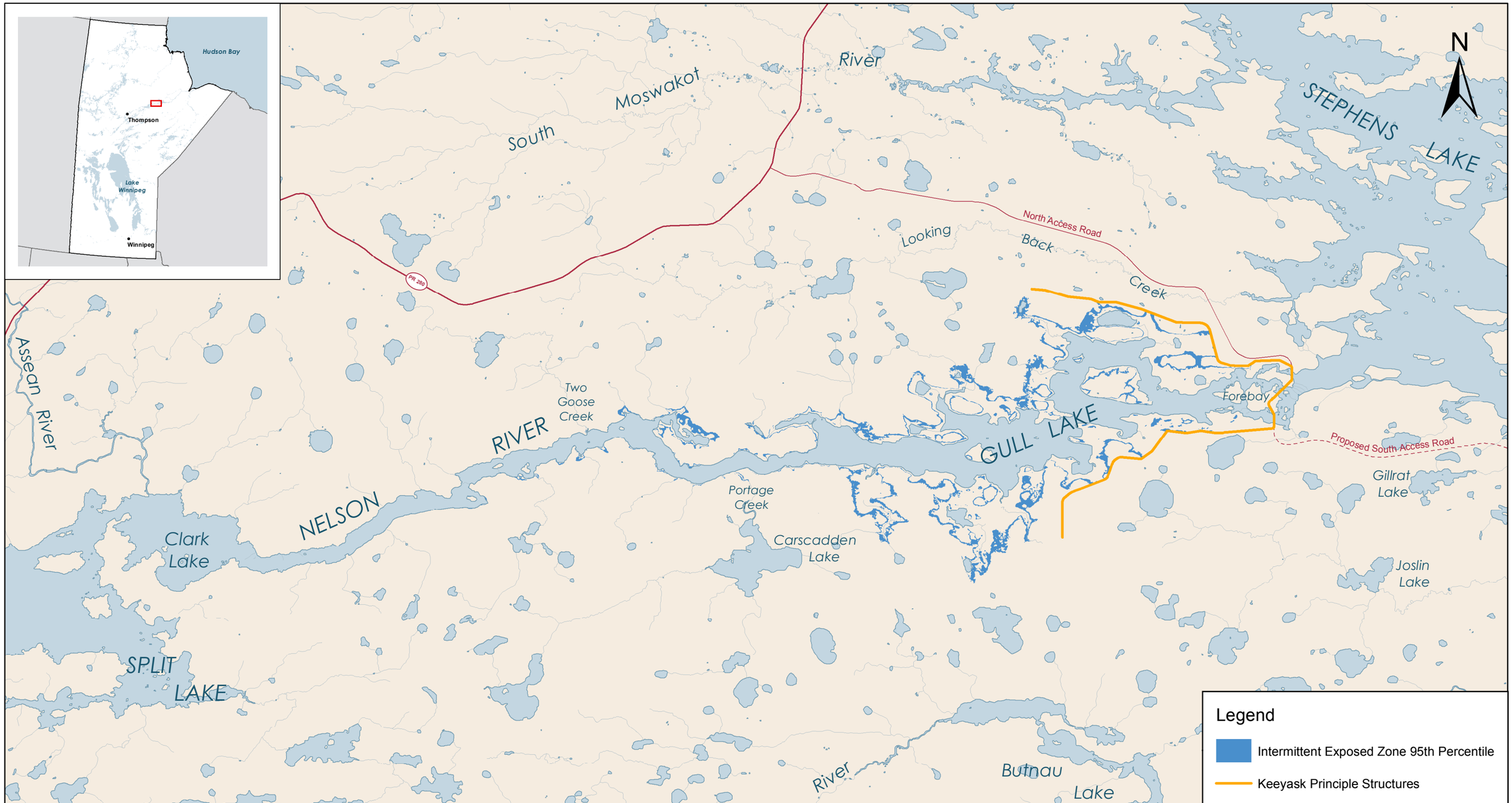

Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
N
South Moswakot River
STEPHENS LAKE
North Access Road
Looking Back Creek
PR 280
Two Goose Creek
RIVER
NELSON
GULL LAKE
Forebay
Proposed South Access Road
Gillrat Lake
Portage Creek
Carscadden Lake
Clark Lake
Joslin Lake
SPLIT LAKE
River
Butnau Lake
Legend
Intermittently Exposed Zone 50th Percent
Keeyask Principle Structures
0 1.25 2.5 5 Kilometers
0 1.25 2.5 5 Miles
Projection: NAD_1983_UTM_Zone_15N
Data Source: Manitoba Hydro, NTDB
Intermittently Exposed Post Project Shoreline
50th Percentile Flow

Figure 6



KEEYASK Hydropower Limited Partnership

0 1.25 2.5 5 Kilometers
0 1.25 2.5 5 Miles

Projection: NAD_1983_UTM_Zone_15N
Data Source: Manitoba Hydro, NTDB

Intermittently Exposed Post Project Shoreline
95th Percentile Flow

Figure 7