KEEYASK GENERATION PROJECT STAGE IV STUDIES-PHYSICAL ENVIRONMENT GN-9.1.4- EXISTING AND PROJECT ENVIRONMENT VELOCITY REGIME EFFECTS ASSESSMENT

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KEEYASK GENERATION PROJECT

STAGE IV STUDIES - PHYSICAL ENVIRONMENT

EXISTING AND PROJECT ENVIRONMENT VELOCITY REGIME EFFECTS ASSESSMENT

REV 0

DELIVERABLE GN-9.1.4

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INTEROFFICE MEMORANDUM

FROM	J. Malenchak, Ph.D, P.Eng Section Head Sediment and Ice Studies Water Resource Engineering Department Power Planning Division	**TO**	M.E. St. Laurent, M.Sc., P.Eng. Section Head Nelson River Keeyask Project Hydro Power Planning Department Power Projects Development Division

DATE 2012 09 01

FILE 00195-11100-00139_01

SUBJECT **KEEYASK GENERATING STATION – PHYSICAL ENVIRONMENT STUDIES EXISTING & PROJECT ENVIRONMENT VELOCITY REGIME EFFECTS ASSESSMENT MEMORANDUM GN-9.1.4-REV 0**

Please find the attached report "Keeyask Generation Project Stage IV Studies - Physical Environment: Existing & Project Environment Velocity Regime Effects Assessment GN-9.1.4". This report documents the differences between existing environment and post-project velocity estimates, assuming base-loaded operation, 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 also 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.

Cc: Efrem Teklemarian, M.Sc., P.Eng.
Kevin Sydor, M.Sc., P.Eng.
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Will Dewit, M.Sc., P.Eng.

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1 INTRODUCTION

This report documents the procedures used to estimate **existing environment** and **post-project** open-water velocities under base-loaded 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 velocity information is summarized (in a format 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 INFLOWS FOR EXISTING AND POST-PROJECT ENVIRONMENT

The 5th, 50th, and 95th percentile open-water flow quantiles shown in Table 1 below were used to characterize the **existing environment** and **post-project** water regimes under a range of historical flow conditions. The velocity estimates are representative of flow conditions within a range of approximately ±1.5% of the flows shown in Table 1. The development of the project **inflows** shown in Table 1 is described in Deliverable GN-9.1.2 - "Sensitivity Analysis of Water Regime Products to Inflows" (Manitoba Hydro, 2012b). Based on a comparison of velocity estimates, a single set of results would be deemed to represent a range of flows that varies by 3%. However, since the change in flow under the 95th percentile existing environment conditions exceeds 3% when the updated data set (including data up to 2006) is considered, new results were generated for a flow condition of 4890 cms and supersede the velocities developed using the 2004 quantile of 4330 cms.

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) from Split Lake to Stephens Lake to characterize the water velocity patterns in detail. All of the runs were undertaken with 139.1 m (5th percentile level) and 141.1 m (full supply level) Stephens Lake level for a total of 20 runs. However, the velocity results for the additional runs are not shown in this memorandum but they were used as inputs in the mitigation and compensation studies.

Table 1 - Range of flows that water velocities represent

Quantile	Existing Environment Flow Range [cms]	Post Project Environment Flow Range [cms]
5%	2060 ± 1.5% = 2029 to 2091	2170 ± 1.5% = 2137 to 2203
50%	3030 ± 1.5% = 2985 to 3075	3030 ± 1.5% = 2985 to 3075
95%	*4890 ± 1.5% = 4817 to 4963	4430 ± 1.5% = 4364 to 4496

* Note: The 95 percentile velocity estimates are updated and supersede the 2004 flow estimate of 4330 cms when considering the existing environment conditions.

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 full gate + spill	4855

2.2 PLANT OUTFLOW FOR POST-PROJECT

The downstream velocity regime for the Keeyask Project depends on the operation of the plant. For the 5th percentile flow of 2170cms, the plant will operate in such a way that unit1, unit3 and unit7 have flows at a best gate of 550cms, and unit5 will have a flow of 520cms. For the 50th percentile flow of 3030 cms, unit1, unit2, unit3, unit5 and unit7 will have flows at a best gate of 550 cms. For the 95th percentile flow, the plant will operate at the full capacity of 4000cms, and the spillway will pass a flow of about 430 cms.

2.3 MODEL DESCRIPTION

MIKE 21, a two-dimensional hydraulic model developed by DHI Water & Environment (DHI 2004), was calibrated and used to estimate depth-averaged velocities within the Keeyask study reach for both **existing environment** and **post-project** conditions. Specifically, this two-dimensional depth-averaged finite volume hydraulic computational fluid dynamics (CFD) software program has applications in oceanographic, coastal, and overland flooding. The system is based on the numerical solution of the two-dimensional Reynolds Averaged Navier-Stokes equations, assuming hydrostatic pressure. The spatial domain is discretized by subdivision into non-overlapping elements. In this application, the computational meshes are generated using unstructured triangular elements, and the variables are associated to the cell centre. The model consists of continuity, momentum, temperature, salinity and density equations and is closed by a turbulent closure scheme. Turbulence is modeled using an eddy viscosity concept, where vertical and horizontal transport is described separately.

2.3.1 EXISTING ENVIRONMENT

The MIKE 21 hydraulic model for the existing environment was developed for the river reach between Clark Lake and Stephens Lake. A continuous digital terrain model (DTM) of the reach was developed based on cross sections and transects measured in grid patterns with spacing between 50 and 100 m. Details regarding development of the DTM are found in Deliverable GN-9.1.5 - “Existing and Project Environment Digital Terrain Models” (Manitoba Hydro, 2012c). The DTM was imported into MIKE 21, and initial bed roughness heights were applied and adjusted during calibration. The model was calibrated by adjusting the bed roughness and localized areas of **bathymetry** until simulated water levels matched rating curves based on measured water levels within a tolerance of approximately 0.2 m. Riverbed levels were adjusted in areas where limited information was available, usually in higher velocity zones where surveys could not be conducted safely. For verification, simulated velocities also compared well with measured velocity profiles collected at several specific locations along the reach.

A downstream boundary elevation of 140.2 m was used to model the **existing environment** velocities, representing the 50th percentile operating level of the Kettle GS **forebay** (Stephen’s Lake).

2.3.2 POST PROJECT ENVIRONMENT

For post project conditions, the MIKE 21 model was employed separately for the reach upstream of the project and downstream of the generating station. The upstream MIKE 21 model was developed by modifying the existing environment model to cover the entire forebay area and to incorporate the powerhouse intake channel and spillway approach channel. The reservoir full supply level of 159.0 m was used as the downstream model boundary for the reach upstream of the Keeyask GS.

The downstream MIKE 21 model from the generating station structure to Stephens Lake was developed in the same way as the existing environment model with the powerhouse tailrace channel and spillway tailrace channel also incorporated in the model. The outflow from the plant was applied as the upstream boundary condition and the average water level of Stephens Lake was applied as the downstream boundary condition.

Velocity grids (using 5 m x 5 m grid spacing) were developed in Environmental Systems Research Institute (ESRI) ArcGIS (Geographical Information System) format for each flow condition according to the following procedure:

1) Modeled velocities are imported into an ESRI ArcGIS map environment;
2) A triangulated irregular network (TIN) of the water velocities at the modeled node points is created and converted into a velocity grid using ArcGIS analysis tools;
3) The velocity grid is smoothed by applying a focal mean within a 5 m x 5 m grid window to correct for errors caused by the TIN version of the velocities.

No attempt was made to develop velocity grids representing the extent of the **forebay** beyond initial impoundment. Erosion of post-project shorelines will cause the velocity grids to change slightly over time. Therefore, the datasets presented in this report represent “Day 0” conditions.

3 RESULTS

Existing environment velocity grids developed for the 5th, 50th, and 95th percentile flows under steady-state conditions are presented in Figure 1 (Appendix B). **Post-project** velocity grids for the 5th, 50th, and 95th percentile flows under steady-state conditions are shown in Figure 2 (Appendix B). The velocities modeled are open water velocities and do not represent **existing environment** or **post-project** winter velocities.

4 EFFECTS ASSESSMENT

Estimated velocity changes due to the project are shown in Figure 3 (Appendix B). Changes resulting from the project are similar throughout the flow range used to characterize the **existing environment** and **post-project** water regimes. It is important to acknowledge that some of the changes in velocity will be due to the different flow values used and not only 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.

Velocities in Gull Rapids will be reduced by up to 6 m/s in the south channel, 4 m/s in the middle channel, and 2 m/s in the north channel. From Gull Lake to Gull Rapids, velocities will decrease between 0.1 to 0.5 m/s. Most of the reach between Portage Creek and Clark Lake will experience velocity decreases of up to 1.0 m/s, while effects within and above Clark Lake will be negligible. Velocities will increase by up to 0.3 m/s along some shorelines and within smaller embankments where **existing environment** flows are negligible, but will increase marginally under **post-project** impoundment.

Velocity just downstream of the spillway decreases about 2 m/s, while in some spots it decreases as much as 5 m/s since the flow that goes through spillway is less than the flow that passes through this area under existing environment conditions. In Stephens Lake, velocity increases in some areas by about 1 m/s and decreases by about 1 m/s in other areas.

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.

6 REFERENCES

DHI (2004). MIKE 21/3 Flow Model FM Hydrodynamic and Transport Module Scientific Documentation. DHI Water & Environment, Agern Alle 5, DK-2970 Horsholm, Denmark.

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 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.

APPENDIX A - ABBREVIATIONS

ABBREVIATIONS

CFD............................computational fluid dynamics

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

APPENDIX B - FIGURES

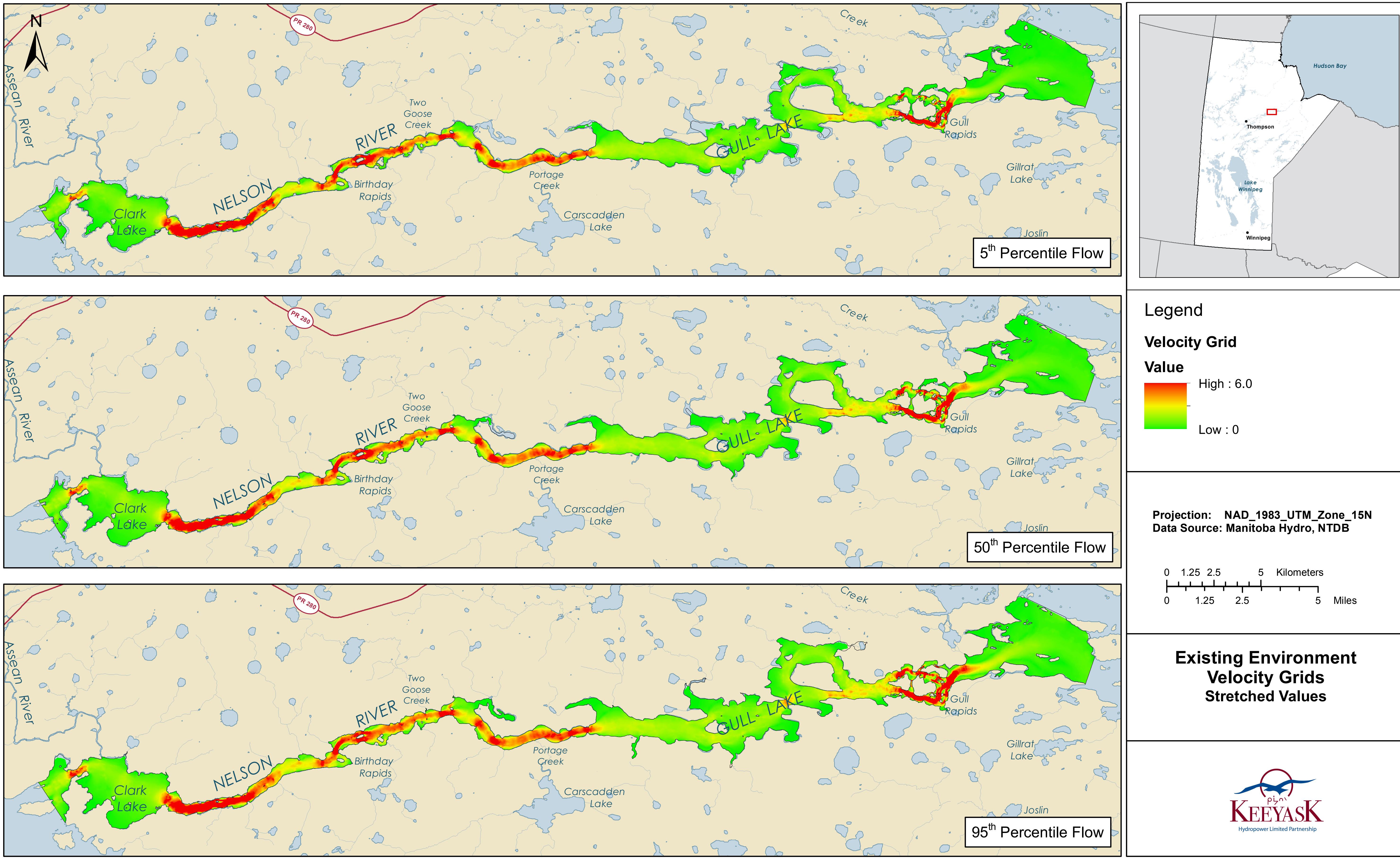

N
Assean River
PR 280
Creek
Two Goose Creek
NELSON RIVER
Clark Lake
Birthday Rapids
Portage Creek
Carscadden Lake
GULL LAKE
Gull Rapids
Gillrat Lake
Joslin
5th Percentile Flow
50th Percentile Flow
95th Percentile Flow
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Velocity Grid
Value
High : 6.0
Low : 0
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
Velocity Grids
Stretched Values
KEEYASK
Hydropower Limited Partnership

Figure 1

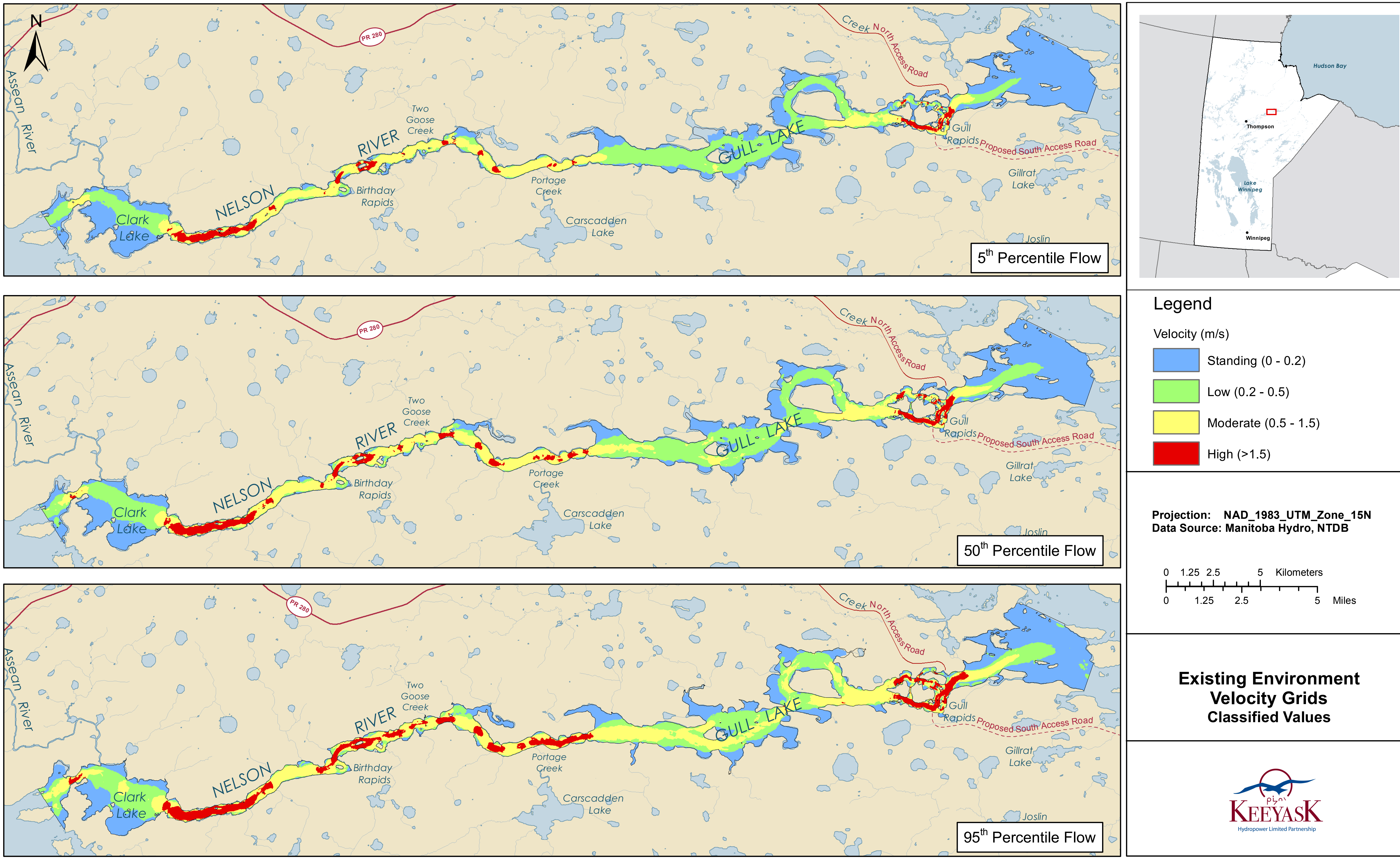

N
Assean River
PR 280
Creek
North Access Road
Two Goose Creek
RIVER
NELSON
Clark Lake
Birthday Rapids
Portage Creek
Carscadden Lake
GULL LAKE
Gull Rapids
Proposed South Access Road
Gillrat Lake
Joslin
5th Percentile Flow
50th Percentile Flow
95th Percentile Flow
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Velocity (m/s)
Standing (0 - 0.2)
Low (0.2 - 0.5)
Moderate (0.5 - 1.5)
High (>1.5)
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
Velocity Grids
Classified Values
KEEYASK
Hydropower Limited Partnership

Figure 2

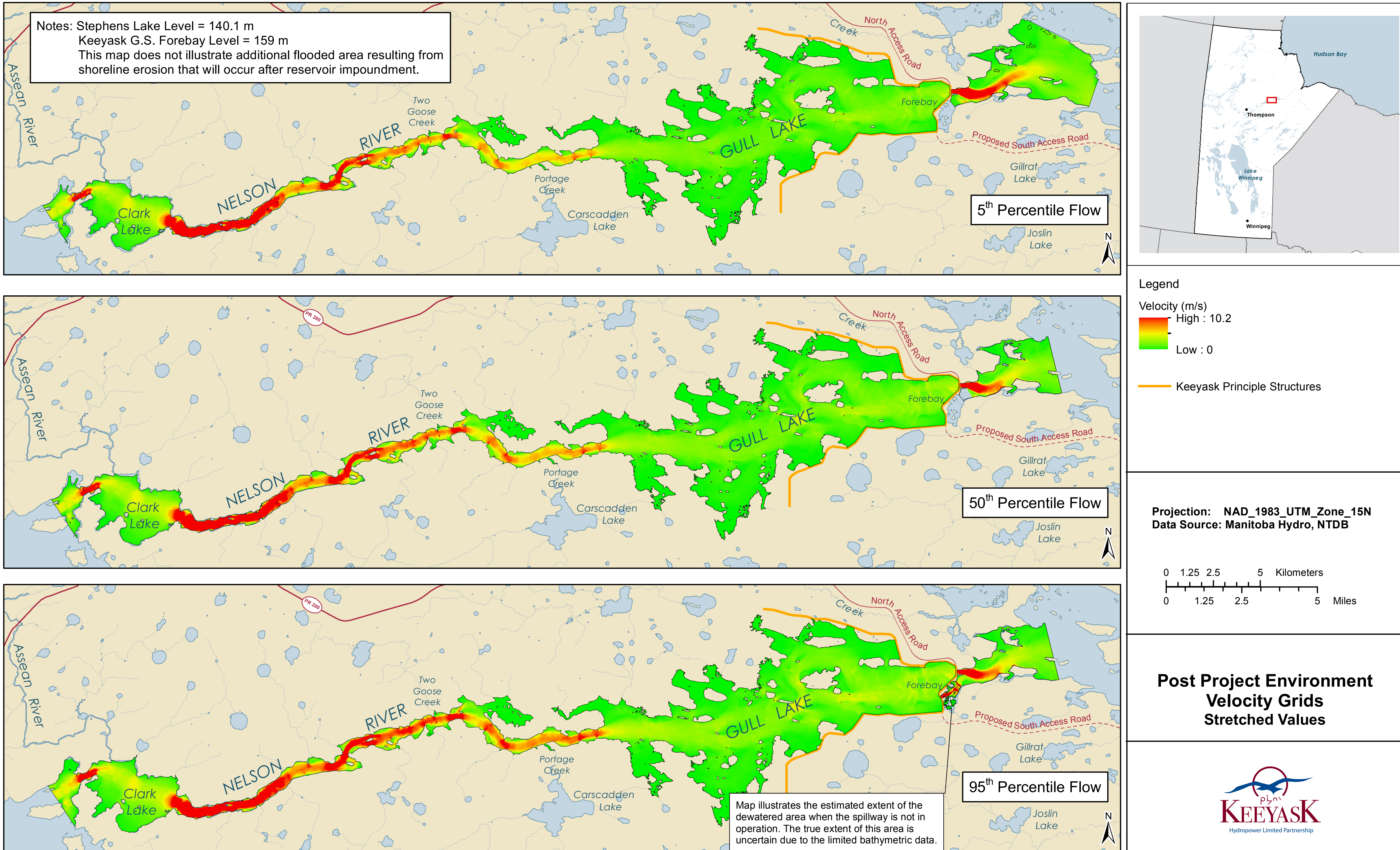
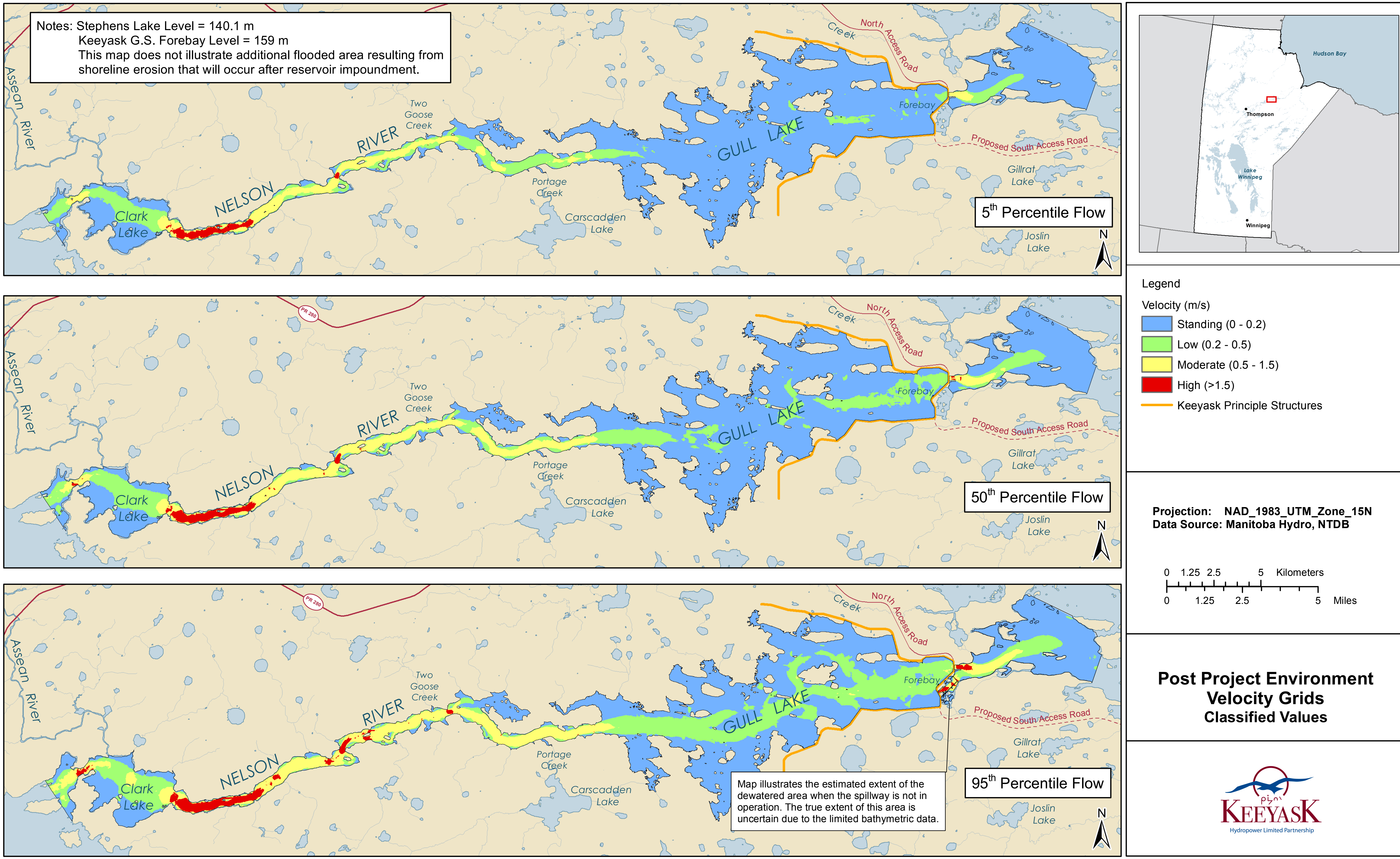

Notes: Stephens Lake Level = 140.1 m
Keeyask G.S. Forebay Level = 159 m
This map does not illustrate additional flooded area resulting from shoreline erosion that will occur after reservoir impoundment.
5th Percentile Flow
50th Percentile Flow
95th Percentile Flow
Map illustrates the estimated extent of the dewatered area when the spillway is not in operation. The true extent of this area is uncertain due to the limited bathymetric data.
Assean River
Clark Lake
NELSON RIVER
Two Goose Creek
Portage Creek
Carscadden Lake
GULL LAKE
Creek
North Access Road
Forebay
Proposed South Access Road
Gillrat Lake
Joslin Lake
PR 280
N
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Velocity (m/s)
High : 10.2
Low : 0
Keeyask Principle Structures
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
Velocity Grids
Stretched Values
KEEYASK
Hydropower Limited Partnership

Figure 3



Notes: Stephens Lake Level = 140.1 m
Keeyask G.S. Forebay Level = 159 m
This map does not illustrate additional flooded area resulting from shoreline erosion that will occur after reservoir impoundment.
5th Percentile Flow
50th Percentile Flow
95th Percentile Flow
Map illustrates the estimated extent of the dewatered area when the spillway is not in operation. The true extent of this area is uncertain due to the limited bathymetric data.
Assean River
Clark Lake
NELSON RIVER
Two Goose Creek
Portage Creek
Carscadden Lake
GULL LAKE
Forebay
North Access Road
Creek
Proposed South Access Road
Gillrat Lake
Joslin Lake
PR 280
N
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Velocity (m/s)
Standing (0 - 0.2)
Low (0.2 - 0.5)
Moderate (0.5 - 1.5)
High (>1.5)
Keeyask Principle Structures
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
Velocity Grids
Classified Values
KEEYASK
Hydropower Limited Partnership

Figure 4

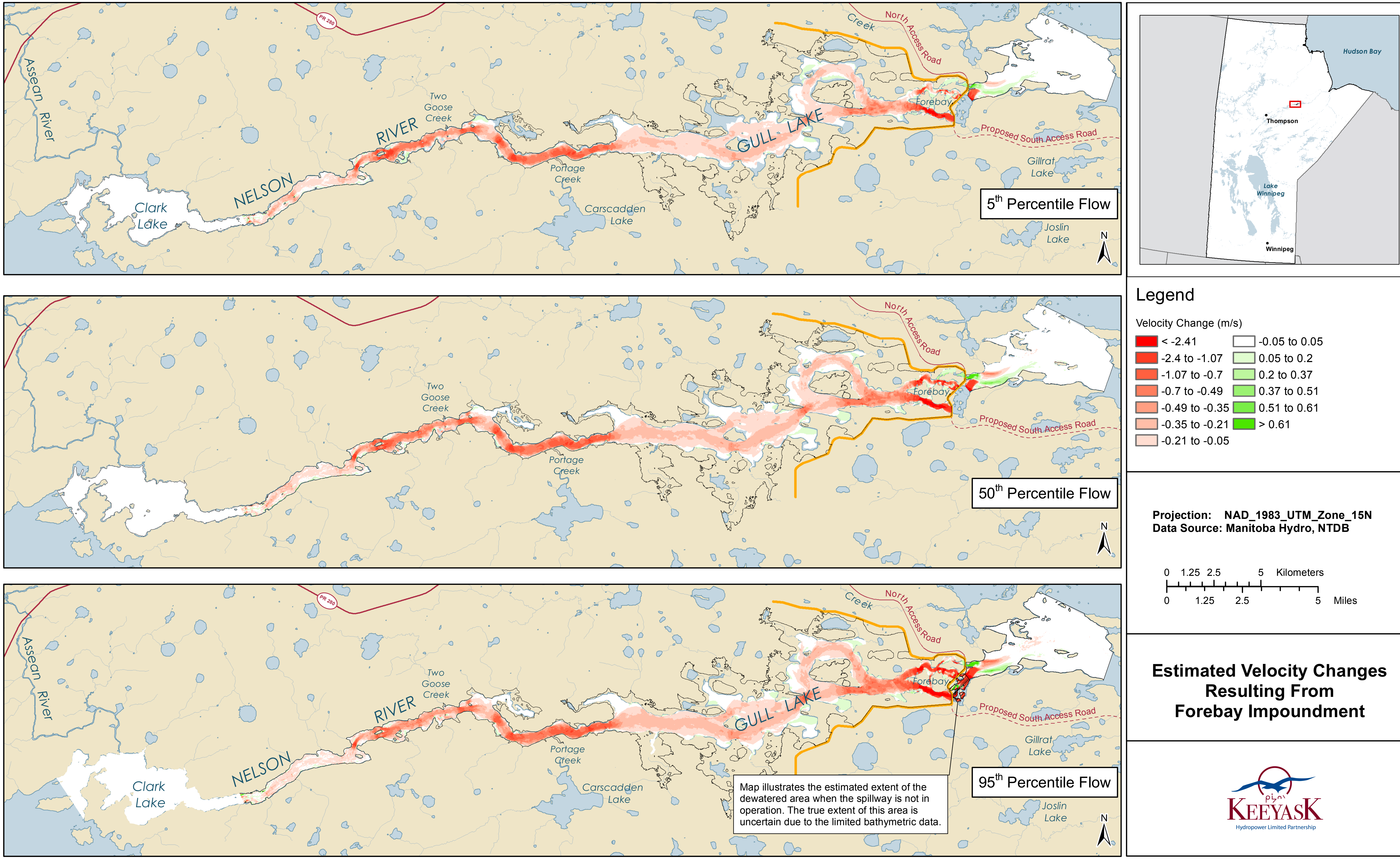

5th Percentile Flow
50th Percentile Flow
95th Percentile Flow
NELSON RIVER
GULL LAKE
Clark Lake
Two Goose Creek
Portage Creek
Carscadden Lake
Gillrat Lake
Joslin Lake
Assean River
Forebay
North Access Road
Proposed South Access Road
Creek
PR 280
N
Map illustrates the estimated extent of the dewatered area when the spillway is not in operation. The true extent of this area is uncertain due to the limited bathymetric data.
Hudson Bay
Thompson
Lake Winnipeg
Winnipeg
Legend
Velocity Change (m/s)
< -2.41
-2.4 to -1.07
-1.07 to -0.7
-0.7 to -0.49
-0.49 to -0.35
-0.35 to -0.21
-0.21 to -0.05
-0.05 to 0.05
0.05 to 0.2
0.2 to 0.37
0.37 to 0.51
0.51 to 0.61
> 0.61
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 Velocity Changes Resulting From Forebay Impoundment
KEEYASK
Hydropower Limited Partnership

Figure 5