



# Keeyask Generation Project Environmental Impact Statement

## Supporting Volume Physical Environment



June 2012

This page is intentionally left blank.

**KEYYASK GENERATION PROJECT  
ENVIRONMENTAL IMPACT STATEMENT  
RESPONSE TO EIS GUIDELINES**

**PHYSICAL ENVIRONMENT  
SUPPORTING VOLUME**

Prepared by

Keeyask Hydropower Limited Partnership  
Winnipeg, Manitoba

June 2012

Canadian Environmental Assessment  
Registry Reference Number: 11-03-64144

Manitoba Conservation and Water Stewardship  
Client File Number: 5550.00



This page is intentionally left blank.

# PREFACE

The Environmental Impact Statement (EIS) for the Keeyask Generation Project (the Project) is submitted to Canada and Manitoba by the Keeyask Hydropower Limited Partnership (the Partnership), which consists of Manitoba Hydro and four Cree Nations (referred to collectively as the Keeyask Cree Nations or KCNs): Tataskweyak Cree Nation (TCN) and War Lake First Nation (WLFN), acting collectively as the Cree Nation Partners (CNP), York Factory First Nation (YFFN), and Fox Lake Cree Nation (FLCN).

The Partners agreed early on that there would be a Keeyask Cree Nations evaluation process as well as the government regulatory environmental assessment process for the Project.

In the KCNs' process, each of the KCNs, assisted by Manitoba Hydro, evaluated the impact of the Project on their communities and Members in terms of their own worldview, values and experience with past hydroelectric development. This process supported conclusion of the Joint Keeyask Development Agreement by the Partners.

The Partnership's EIS response to the government regulatory environmental process was undertaken by Manitoba Hydro with the support of the KCNs. In summary, the EIS consists of:

- A video, *Keeyask: Our Story*, which presents the Keeyask Cree Nations' history and perspectives related to hydroelectric development. Presented through the prism of their holistic Cree worldview, it explains the journey taken by the KCNs as they evaluated their concerns about the Project, the nature of their participation as Partners, and the decisions they ultimately made to support the Project;
- An executive summary;
- A Response to EIS Guidelines issued by Canada March 30, 2012 in response to an application by the Partnership for environmental approvals under the government regulatory environmental assessment process. This response includes findings and conclusions<sup>1</sup>, with charts, diagrams, and maps to clarify information in the text, and a concordance table to cross reference requirements of the EIS Guidelines with information in the EIS; and
- The KCNs' Evaluation Reports providing each of the KCNs' own evaluation of the effects of the Project on their community and Members and including Aboriginal traditional knowledge (ATK) relevant to the Partnership's response to the EIS Guidelines.

---

<sup>1</sup> Technical supporting volumes are also provided, as developed by the Manitoba Hydro environmental team in consultation with the KCNs and their Members, to provide details on the Project Description and on the research and analysis of the following topics: Public Involvement Program, Physical Environment, Aquatic Environment, Terrestrial Environment, Socio-economic Environment, Resource Use, and Heritage Resources.

This page is intentionally left blank.

# ACKNOWLEDGEMENTS

The assessment of the effects of the Project on the physical environment was undertaken by a wide range of technical specialists from Manitoba Hydro and a number of consulting firms. The assessment was coordinated by a Keeyask Physical Environment Coordination Team.

## **Keeyask Physical Environment Coordination Team:**

Marc St. Laurent, M.Sc., P.Eng., Manitoba Hydro  
William DeWit, M.Sc., P.Eng., Manitoba Hydro  
George Rempel, M.Sc., P.Eng., Stantec  
Dave Morgan, Ph.D., P.Eng., Stantec  
Khizar Mahmood, M.Sc., P.Eng., Stantec

---

The physical environment assessment encompassed a broad spectrum of topics. Therefore, the coordination team relied upon a multidisciplinary group of specialists to assess the effects of the project on the physical environment and report on these effects. Key personnel involved in the physical environment studies and preparation of the Physical Environment Supporting Volume include:

## **Climate**

Kristina Koenig, M.Sc., P.Eng., Manitoba Hydro  
Bill Hamlin, P.Eng., Manitoba Hydro  
Bob Gill, M.N.R.M., EP, Manitoba Hydro

## **Air Quality and Noise / Effects of the Environment on the Project**

Roger Rempel, B.Sc., P.Eng., F.E.C., Stantec  
George Rempel, M.Sc., P.Eng., Stantec

## **Physiography**

Karen Mathers, B.Sc., M.Sc., P.Geo., Stantec  
James Ehnes, B.A.(Hon.), M.Phil, Ph.D., ECOSTEM Ltd.  
Ramli Halim, M.Eng., P.Eng., KGS-Acres  
Philippe Pantel, B.Sc, P.Eng, KGS-Acres  
Lynden Penner, M.Sc., P.Eng., P.Geo., JD Mollard and Associates (2010) Limited

## **Surface Water and Ice Regimes**

Jarrod Malenchak, Ph.D., P.Eng., Manitoba Hydro  
Andrew Baryla, M.Sc., P.Eng., KGS-Acres  
Marc St. Laurent, M.Sc., P.Eng., Manitoba Hydro  
Steven Wang, Ph.D., P.Eng.



### **Shoreline Erosion**

Lynden Penner, M.Sc., P.Eng., P.Geo., J.D. Mollard and Associates (2010) Limited  
James Ehnes, B.A.(Hon.), M.Phil., Ph.D., ECOSTEM Ltd.  
Habib Ahmari, Ph.D., P.Eng., Manitoba Hydro  
Philippe Pantel, B.Sc., P.Eng., KGS-Acres

### **Sedimentation**

Rajib Ahsan, M.A.Sc., M.Eng., P.Eng., KGS-Acres  
Ariel Lupu, B.Sc.  
Habib Ahmari, Ph.D., P. Eng., Manitoba Hydro  
William DeWit, M.Sc., P.Eng., Manitoba Hydro

### **Groundwater**

Karen Mathers, B.Sc., M.Sc., P.Geo., Stantec  
Mundzir Basri, Ph.D., P.Eng., Stantec  
Sitotaw Yirdaw-Zeleke, Ph.D., P.Eng., Stantec

### **Surface Water Temperature and Dissolved Oxygen**

Dave Morgan, Ph.D., P.Eng., Stantec  
William DeWit, M.Sc., P.Eng., Manitoba Hydro  
Khizar Mahmood, M.Sc., P.Eng., Stantec

### **Debris**

Marc St. Laurent, M.Sc., P.Eng., Manitoba Hydro  
William DeWit, M.Sc., P.Eng., Manitoba Hydro

---

The physical environment studies could not have been completed without the dedicated efforts of many other people providing specialist support in areas such as computer modeling, geographic information systems, technical analyses, data management, and field studies. Those who provided specialist support for the physical environment studies include:

### **Manitoba Hydro**

Jennifer Lidgett, H.B.Sc.F.  
Zsolt Zrinyi, Ph.D., P.Eng.  
Tariq Aziz, M.Eng., P.Eng.  
Greg Johnston, P.Eng.  
Marc Totte, B.Sc.  
Brent Bencharski, B.Sc.  
Ben Schmidt, B.A.  
Michael Kressock, B.A., C.E.T.  
Paul Chanel, M.Sc., P.Eng.

Danielle Kerr, B.A.  
John Crawford, B.Sc., P.Eng.  
Mike Viera, B.Sc., E.I.T.  
Mark Gervais, M.Sc., A.Sc.T.  
Rob Tkach, M.Sc., P.Eng.  
Nathan Lambkin, C.E.T.  
Tim Kirkham, M.Sc., P.Eng.  
Marcus Smith, M.Sc., P. Eng., EP  
Mike Stocki, P.Eng.  
Greg McNeill, B.Comm. (hons)



**ECOSTEM Ltd.**

Qiang Huang, B.Sc., M.Sc., Ph.D.  
Anthony Szumigalski, B.Sc., M.Sc., Ph.D.  
Pierre Tremblay, B.Sc., Natural Sciences Diploma  
Susanne Kames, B.Sc., M.Sc.  
Brock Epp, B.Sc., M.Sc.  
Alex Snitowski, B.Sc., Advanced Dipl. GIS (Hons.)

**North/South Consultants Inc.**

Megan Cooley, M.Sc.

**J.D. Mollard and Associates (2010) Limited**

Jason Cosford, Ph.D., P.Geo.  
Troy Zimmer, B.Sc., Hon. Dpl. (BioScience),  
MCRSS

**Stantec**

George Kroupa, RFT  
Joey Siemens, B.Sc.  
Scott Lobban, B.Env.Sc.  
Aaron Campigotto, B.A., A. Dip. GIS

**KGS Acres**

Ross Dewar, B.Sc., P. Eng.  
David Fuchs, M.Sc., P.Eng.  
Jim Smith, B.Sc., P.Eng.  
Ed Sikora, B.Sc., P.Eng.  
Shaun Kenny, B.Sc., P. Eng.  
Joe Groeneveld, M.Eng., P.Eng.  
Ruxandra Ditica, B.Sc.  
Elise Neufeld, B.Sc.

---

The specialists performing the physical environment assessments relied heavily upon data gathered in field studies performed in the project area over the last decade or more. Community Members from the Keeyask Cree Nations (Tataskweyak Cree Nation at Split Lake; York Factory First Nation at York Landing; War Lake First Nation (WLFN) at Ilford; and Fox Lake Cree Nation (FLCN) at Bird and Gillam) were involved in these field studies at various times for different durations over the years. The coordination team and study specialists would like to acknowledge the efforts of more than one hundred and thirty Members of the Keeyask Cree Nations who contributed significantly to the successful collection of data upon which physical environment studies are based.

In addition to the foregoing, the coordination team and study specialists also wish to acknowledge the contribution of the following people who contributed to the physical environment assessment:

Manitoba Hydro: Halina Zbigniewicz, Glen Cook, Ryan Penner, Dave Magnusson (retired), Agnieszka Kotula, Michael Morris, Kevin Sydor, Rob Gerry, Arch Csupak, Sarah Wach, David Hislop, Ted Lukasiewicz, Jose Pinzon, Justin Avery, Martin Hunt, Ryan Kustra, Nicholas Barnes, Maria Zbigniewicz, Jodine MacDuff, Russell Schmidt, Samantha McFarlane, Cecelia Baker, Cecil Embury, Russel Thiessen, Frank Sorenson, Matt Drew, Frances Michiels, Adam Sawchuk Rob Burch, Willi Coopman, Rod Oleksuk, Jeff Smuttell, Ron Ginter, Bob Raines, Richard Nickel, Martin Laing, Colin McLean, Kevin Klym, Jeff Chalmers, Karen Schultz, Michelle Rudnicki, Rachele Budge, Tim Christensen

Stantec: Crista Gladstone, Lorna Froese, Jocelyn Hiebert, Shirley Bartz

KGS Acres: Linda Hallow, Susan Altomare, Shiromi Amarakoon, Shaun Kenny, Nikou Jalayeri, Colin Rennie, Ed Sikora, Sharen Picca

ECOSTEM Ltd.: Alanna Sutton

Environnement Illimité Inc.:  
Stephane Lorrain, Dominique Fournier, Véronique Proulx, Roger Misson, Pierre-David Beaudry, Daniel Cloutier, Simon Roy, Sébastien Fortin, Lise Blais, Julie Korell



Finally, the coordination team and study specialists also acknowledges the valuable input provided by the Keeyask Cree Nations representatives, community Members, and advisors throughout the process of preparing the physical environment assessment. Your probing questions, insightful criticism, and gracious compliments have helped shape the assessment of the effects of the Keeyask Project on the physical environment reported in this supporting volume.

# TABLE OF CONTENTS

<b>1.0</b>	<b>INTRODUCTION .....</b>	<b>1-1</b>
1.1	OVERVIEW OF ASSESSMENT APPROACH .....	1-2
1.1.1	The Physical Environment in the Keeyask Study Area .....	1-2
1.1.2	Scope of the Physical Environment Assessment .....	1-4
1.1.2.1	Scope of the Project .....	1-4
1.1.2.2	Scope of the Assessment.....	1-5
1.1.2.3	Spatial Scope.....	1-6
1.1.2.4	Temporal Scope.....	1-6
1.1.3	Assessment Methodology .....	1-7
1.2	SOURCES OF INFORMATION .....	1-8
1.3	SUMMARY OF PROJECT COMPONENTS RELEVANT TO THE PHYSICAL ENVIRONMENT .....	1-10
1.4	STUDY INTEGRATION AND PEER-REVIEW PROCESS.....	1-10
1.5	REFERENCES .....	1-12
<b>2.0</b>	<b>CLIMATE .....</b>	<b>2-1</b>
2.1	INTRODUCTION .....	2-1
2.2	APPROACH AND METHODOLOGY.....	2-1
2.2.1	Overview.....	2-1
2.2.1.1	Existing Climate .....	2-2
2.2.1.2	Future Climate Change Scenarios .....	2-2
2.2.1.3	Life-Cycle Assessment.....	2-3
2.2.2	Study Areas.....	2-3
2.2.2.1	Keeyask Biophysical Study Area .....	2-3
2.2.2.2	Future Climate Change Scenarios .....	2-3
2.2.2.3	Life-Cycle Assessment.....	2-4
2.2.3	Data and Information Sources .....	2-4
2.2.3.1	Existing Climate .....	2-4
2.2.3.2	Future Climate Change Scenarios .....	2-4
2.2.3.3	Life-Cycle Assessment.....	2-4

2.2.4	Assumptions.....	2-8
2.2.4.1	Existing Climate Data .....	2-8
2.2.4.2	Future Climate Change Scenarios .....	2-8
2.2.4.3	Life-Cycle Assessment.....	2-8
2.2.5	Description of Models.....	2-10
2.2.5.1	Global Climate Models and Regional Climate Models .....	2-10
2.2.5.2	Life-Cycle Assessment.....	2-11
2.3	<b>ENVIRONMENTAL SETTING.....</b>	<b>2-12</b>
2.3.1	Existing Climate .....	2-12
2.3.1.1	Temperature .....	2-12
2.3.1.2	Growing Degree Days.....	2-12
2.3.1.3	Frost Free Days.....	2-12
2.3.1.4	Precipitation.....	2-13
2.3.1.5	Wind.....	2-14
2.3.2	Future Climate Change Scenarios .....	2-15
2.3.2.1	Temperature – Global Climate Model Ensemble.....	2-16
2.3.2.2	Precipitation – Global Climate Model Ensemble .....	2-16
2.3.2.3	Temperature, Precipitation and Evapotranspiration – Regional Climate Model.....	2-16
2.3.2.4	Wind and Extreme Events.....	2-17
2.4	<b>PROJECT EFFECTS, MITIGATION AND MONITORING .....</b>	<b>2-19</b>
2.4.1	Effect of the Project on Climate Change .....	2-19
2.4.1.1	Life-Cycle Assessment.....	2-19
2.4.1.2	Greenhouse Gas Displacement.....	2-21
2.4.2	Mitigation.....	2-22
2.4.2.1	Keeyask Project.....	2-22
2.4.2.2	Manitoba Hydro’s Climate Change Strategies .....	2-22
2.4.3	Summary of Residual Effects.....	2-23
2.4.4	Interaction with Future Projects.....	2-23
2.4.5	Monitoring and Follow-Up.....	2-24
2.5	<b>REFERENCES.....</b>	<b>2-25</b>

**3.0 AIR QUALITY AND NOISE .....3-1**

**3.1 INTRODUCTION .....3-1**

**3.2 APPROACH AND METHODOLOGY.....3-1**

**3.2.1 Overview to Approach.....3-1**

        3.2.1.1 Air Quality .....3-1

        3.2.1.2 Noise..... 3-2

**3.2.2 Data and Information Sources ..... 3-3**

        3.2.2.1 Air Quality ..... 3-3

        3.2.2.2 Noise..... 3-4

**3.2.3 Study Area ..... 3-4**

**3.2.4 Assumptions ..... 3-4**

**3.3 ENVIRONMENTAL SETTING ..... 3-4**

**3.3.1 Existing Environment: Air Quality..... 3-4**

**3.3.2 Existing Environment: Noise ..... 3-5**

**3.3.3 Future Conditions/Trends ..... 3-7**

        3.3.3.1 Local Air Quality ..... 3-7

        3.3.3.2 Local Noise..... 3-7

**3.4 PROJECT EFFECTS, MITIGATION AND MONITORING..... 3-7**

**3.4.1 Construction Period ..... 3-7**

        3.4.1.1 Air Quality Effects During Construction ..... 3-7

            3.4.1.1.1 Building Access Roads ..... 3-7

            3.4.1.1.2 Emissions from Highway/Road Transport of  
Equipment, Materials and Personnel ..... 3-8

            3.4.1.1.3 Site Clearing Activities ..... 3-9

            3.4.1.1.4 Construction of Keeyask Dam and Generation  
Facilities ..... 3-11

        3.4.1.2 Summary of Air Quality Effects During Construction .....3-12

        3.4.1.3 Local Noise Effects During Construction.....3-13

**3.4.2 Operating Period..... 3-17**

        3.4.2.1 Local Air Quality .....3-17

        3.4.2.2 Local Noise.....3-17



3.4.3	Mitigation.....	3-18
3.4.3.1	Local Air Quality.....	3-18
3.4.3.2	Noise.....	3-18
3.4.4	Summary of Residual Effects.....	3-18
3.4.5	Interactions with Future Projects .....	3-20
3.4.6	Environmental Monitoring and Follow Up.....	3-20
3.5	REFERENCES.....	3-21
4.0	<b>SURFACE WATER AND ICE REGIMES.....</b>	<b>4-1</b>
4.1	<b>INTRODUCTION .....</b>	<b>4-1</b>
4.1.1	Overview of Ice Processes .....	4-2
4.2	<b>APPROACH AND METHODOLOGY .....</b>	<b>4-5</b>
4.2.1	Overview to Approach.....	4-5
4.2.1.1	Open Water Conditions .....	4-6
4.2.1.2	Ice Conditions.....	4-8
4.2.2	Data and Information Sources.....	4-9
4.2.3	Study Area .....	4-11
4.2.4	Assumptions.....	4-11
4.2.5	Description of Numerical Models and Methods.....	4-12
4.2.5.1	Nelson River Existing Environment Inflows .....	4-13
4.2.5.2	Future Environment Inflows With and Without the Project .....	4-14
4.2.5.3	Water Levels and Fluctuations .....	4-15
4.2.5.4	Water Depths, Shorelines, and Water Surfaces.....	4-16
4.2.5.5	Water Velocities .....	4-17
4.2.5.6	Creek Hydrology and Hydraulics.....	4-17
4.3	<b>ENVIRONMENTAL SETTING.....</b>	<b>4-20</b>
4.3.1	<b>Nelson River Flow Conditions .....</b>	<b>4-21</b>
4.3.1.1	Open Water Conditions Upstream of Project Site.....	4-23
4.3.1.1.1	River Hydraulics .....	4-23
4.3.1.1.2	Water Levels and Fluctuations.....	4-29
4.3.1.1.3	Water Depths, Shorelines, and Water Surface Areas.....	4-33
4.3.1.1.4	Water Velocities.....	4-34

- 4.3.1.1.5 Open Water Mainstem Travel Time .....4-34
- 4.3.1.1.6 Creek Hydrology and Hydraulics .....4-35
- 4.3.1.2 Open Water Conditions Downstream of Project.....4-38
- 4.3.1.3 Winter Conditions Upstream of Project .....4-38
  - 4.3.1.3.1 Spring Break-Up on the Nelson River .....4-42
  - 4.3.1.3.2 Characterization of Existing Winter Water Levels .....4-43
- 4.3.1.4 Winter Conditions Downstream of Project .....4-44
- 4.3.2 Open Water Conditions/Trends.....4-49
- 4.3.3 Future Winter Conditions/Trends.....4-50
- 4.4 PROJECT EFFECTS, MITIGATION AND MONITORING.....4-50
  - 4.4.1 Construction Period .....4-50
    - 4.4.1.1 Overview .....4-50
    - 4.4.1.2 Construction Design Flows .....4-51
    - 4.4.1.3 Stage I Diversion .....4-51
      - 4.4.1.3.1 Winter Period .....4-56
    - 4.4.1.4 Stage II Diversion.....4-57
      - 4.4.1.4.1 River Closure.....4-57
      - 4.4.1.4.2 Construction of North, Central and South Dams .....4-57
      - 4.4.1.4.3 Construction of Final Spillway Rollways .....4-63
    - 4.4.1.5 Reservoir Impoundment.....4-66
    - 4.4.1.6 Summary of Water Level Staging .....4-66
  - 4.4.2 Operating Period.....4-69
    - 4.4.2.1 Nelson River Flow Conditions .....4-69
      - 4.4.2.1.1 Comparison of Existing Environment and Project Inflows.....4-69
    - 4.4.2.2 Open Water Conditions Upstream of Project.....4-71
      - 4.4.2.2.1 Peaking Mode of Operation.....4-72
      - 4.4.2.2.2 Base Loaded Mode of Operation.....4-73
      - 4.4.2.2.3 Water Levels and Fluctuations.....4-74
      - 4.4.2.2.4 Water Depths, Shorelines, and Water Surface Areas.....4-82
      - 4.4.2.2.5 Water Velocities .....4-84
      - 4.4.2.2.6 Upstream Open Water Mainstem Travel Time and Back-Bay Water Residence Time .....4-85
      - 4.4.2.2.7 Creek Hydraulics .....4-85





4.4.2.3	Open Water Conditions Downstream of Project .....	4-89
4.4.2.4	Winter Conditions Upstream of Project .....	4-90
4.4.2.4.1	Reservoir Reach .....	4-90
4.4.2.4.2	Birthday Rapids Reach .....	4-98
4.4.2.4.3	Clark Lake Reach .....	4-98
4.4.2.5	Winter Conditions Downstream of Project.....	4-99
4.4.2.6	Sensitivity of Winter Results to Modelling Assumptions .....	4-100
4.4.2.6.1	Peaking Mode of Operation.....	4-100
4.4.3	Mitigation.....	4-103
4.4.4	Summary of Residual Effects.....	4-103
4.4.5	Interactions With Future Projects .....	4-112
4.4.6	Monitoring and Follow-Up.....	4-113
4.5	REFERENCES .....	4-114
5.0	PHYSIOGRAPHY .....	5-1
5.1	INTRODUCTION .....	5-1
5.2	APPROACH AND METHODOLOGY .....	5-2
5.2.1	Overview to Approach.....	5-2
5.2.2	Study Area .....	5-2
5.2.3	Information and Data Sources.....	5-2
5.2.4	Assumptions.....	5-4
5.3	ENVIRONMENTAL SETTING .....	5-4
5.3.1	General Overview .....	5-4
5.3.1.1	Regional Study Area .....	5-4
5.3.1.2	Local Study Area .....	5-5
5.3.2	Bedrock and Surficial Geology .....	5-5
5.3.2.1	Regional Study Area .....	5-5
5.3.2.2	Local Study Area .....	5-7
5.3.2.3	Borrow Material Resources.....	5-9
5.3.3	Soils and Peatlands .....	5-9
5.3.3.1	Regional Study Area .....	5-9
5.3.3.2	Local Study Area .....	5-10

5.3.4	Permafrost .....	5-11
5.3.4.1	Regional Study Area .....	5-12
5.3.4.2	Local Study Area.....	5-12
5.3.4.2.1	Surface Permafrost .....	5-12
5.3.4.2.2	Deep Permafrost .....	5-13
5.3.5	Seismic Activity .....	5-14
5.3.5.1	Reservoir Triggered Seismic Activity .....	5-14
5.3.6	Post-Glacial Rebound .....	5-14
5.3.7	Future Conditions/Trends .....	5-15
5.3.7.1	Bedrock and Surficial Geology .....	5-15
5.3.7.1.1	Soils and Peatlands .....	5-15
5.3.7.1.2	Permafrost.....	5-15
5.4	<b>PROJECT EFFECTS, MITIGATION AND MONITORING.....</b>	<b>5-17</b>
5.4.1	Construction.....	5-17
5.4.1.1	Bedrock and Surficial Geology .....	5-19
5.4.1.1.1	Permanent Access Roads.....	5-19
5.4.1.1.2	Temporary Structures .....	5-20
5.4.1.1.3	Permanent Structures.....	5-20
5.4.1.1.4	Excavated Material Placement Areas .....	5-21
5.4.1.1.5	Local Borrow Material Resources.....	5-21
5.4.1.1.6	Assessing Environmental Sensitivity of Borrow and Quarry Rock Material .....	5-24
5.4.1.2	Soils and Peatlands .....	5-24
5.4.1.3	Permafrost.....	5-26
5.4.1.4	Seismic Activity .....	5-27
5.4.1.5	Post-Glacial Rebound.....	5-27
5.4.2	Operation.....	5-27
5.4.3	Decommissioning of Generating Station.....	5-27
5.4.3.1	Decommissioning of Construction Resources .....	5-27
5.4.3.2	Decommissioning of the Generating Station .....	5-27
5.4.4	Residual Effects .....	5-28
5.4.5	Interaction with Future Projects .....	5-29
5.4.5.1	Soils and Peatlands .....	5-30
5.4.5.2	Permafrost.....	5-30

5.4.6	Environmental Monitoring and Follow-Up.....	5-30
5.5	REFERENCES .....	5-31
<b>6.0</b>	<b>SHORELINE EROSION PROCESS.....</b>	<b>6-1</b>
6.1	INTRODUCTION .....	6-1
6.1.1	Overview of Peatland Disintegration Processes.....	6-2
6.1.2	Overview of Riverine Mineral Erosion Processes .....	6-6
6.1.3	Overview of Lakeshore Mineral Erosion Processes .....	6-7
6.2	APPROACH AND METHODOLOGY .....	6-9
6.2.1	Overview to Approach.....	6-9
6.2.1.1	Existing Environment .....	6-10
6.2.1.1.1	Historical Trends .....	6-11
6.2.1.1.2	Current Conditions.....	6-11
6.2.1.2	Construction Period.....	6-11
6.2.1.3	Prediction Periods for Future Conditions.....	6-12
6.2.1.4	Future Conditions/Trends .....	6-13
6.2.1.5	Future Environment With the Project .....	6-13
6.2.1.5.1	Proxy Areas.....	6-13
6.2.1.5.2	Peatland Disintegration Modelling.....	6-14
6.2.1.5.3	Mineral Shoreline Erosion Modelling.....	6-14
6.2.1.5.4	Integration of Mineral Shoreline Erosion and Peatland Disintegration .....	6-14
6.2.1.6	Project Effects.....	6-15
6.2.2	Study Area .....	6-16
6.2.2.1	Proxy Areas .....	6-16
6.2.3	Data and Information Sources.....	6-17
6.2.3.1	Peatland Disintegration and Mineral Erosion Data and Information Sources.....	6-17
6.2.3.2	Peatland Disintegration Data and Information Sources .....	6-18
6.2.3.3	Mineral Erosion Data and Information Sources .....	6-18
6.2.4	Assumptions.....	6-19
6.2.5	Description of Models.....	6-19
6.2.5.1	Future Conditions/Trends .....	6-19

6.2.5.2	Future With Project .....	6-19
6.2.5.2.1	Peatland Disintegration Modelling.....	6-19
6.2.5.2.2	Mineral Shoreline Erosion Modelling.....	6-20
<b>6.3</b>	<b>ENVIRONMENTAL SETTING .....</b>	<b>6-20</b>
<b>6.3.1</b>	<b>Existing Conditions .....</b>	<b>6-22</b>
6.3.1.1	General Overview.....	6-22
6.3.1.1.1	Peatlands and Peat Shorelines .....	6-22
6.3.1.1.2	Mineral Shorelines .....	6-23
6.3.1.2	Upstream of Project.....	6-23
6.3.1.2.1	Shoreline Attributes .....	6-23
6.3.1.2.2	Shoreline Condition and Erosion Process Descriptions by River Reach .....	6-24
6.3.1.2.3	Shoreline Recession .....	6-30
6.3.1.2.4	Sediment Loads.....	6-32
6.3.1.3	Downstream of Project .....	6-34
6.3.1.3.1	Shoreline Attributes .....	6-34
6.3.1.3.2	Shoreline Conditions and Erosion Process Descriptions .....	6-35
6.3.1.3.3	Shoreline Recession .....	6-36
6.3.1.3.4	Nelson River Water Surface Area.....	6-36
6.3.1.4	Future Conditions/Trends .....	6-37
6.3.1.4.1	Upstream of Project .....	6-37
6.3.1.4.2	Downstream of Project .....	6-42
<b>6.4</b>	<b>PROJECT EFFECTS, MITIGATION AND MONITORING.....</b>	<b>6-44</b>
<b>6.4.1</b>	<b>Construction Period .....</b>	<b>6-45</b>
6.4.1.1	Stage I Diversion .....	6-45
6.4.1.2	Stage II Diversion.....	6-45
6.4.1.3	Reservoir Impoundment.....	6-46
<b>6.4.2</b>	<b>Operating Period.....</b>	<b>6-46</b>
6.4.2.1	Upstream of Project.....	6-46
6.4.2.1.1	Shoreline Conditions, Shoreline Recession and Reservoir Expansion .....	6-46
6.4.2.1.2	Descriptions of Shoreline Erosion by River Reach.....	6-50
6.4.2.1.3	Comparison of Base Loaded and Peaking Modes of Operation .....	6-51

6.4.2.1.4	Nelson River Reservoir/Water Surface Area .....	6-54
6.4.2.1.5	Peat Resurfacing and Floating Peat Mat Mobility .....	6-56
6.4.2.1.6	Sediment Loads.....	6-57
6.4.2.1.7	Project Effects Beyond Year 30.....	6-65
6.4.2.2	Downstream of Project .....	6-66
6.4.2.2.1	Shoreline Conditions and Erosion Process Descriptions .....	6-66
6.4.2.2.2	Shoreline Recession .....	6-66
6.4.2.2.3	Nelson River Water Surface Area.....	6-67
6.4.2.2.4	Sediment Loads.....	6-67
6.4.3	Mitigation.....	6-67
6.4.4	Residual Effects .....	6-67
6.4.5	Interactions With Future Projects .....	6-72
6.4.6	Environmental Monitoring and Follow-Up.....	6-72
6.5	REFERENCES.....	6-73

7.0	SEDIMENTATION.....	7-1
7.1	INTRODUCTION .....	7-1
7.1.1	Overview of Sedimentation Processes .....	7-2
7.1.1.1	Mineral Sedimentation.....	7-2
7.1.1.2	Peat Sedimentation .....	7-2
7.2	APPROACH AND METHODOLOGY .....	7-3
7.2.1	Overview.....	7-3
7.2.1.1	Sedimentation During Construction Period.....	7-4
7.2.1.2	Mineral Sedimentation During Operating Period.....	7-5
7.2.1.3	Organic Sedimentation During Operating Period .....	7-6
7.2.2	Study Area .....	7-7
7.2.3	Data and Information Sources.....	7-7
7.2.3.1	Mineral Sedimentation.....	7-7
7.2.3.2	Peat Transport .....	7-8
7.2.3.3	Construction Period.....	7-8
7.2.4	Assumptions.....	7-9

7.2.5	Description of Models .....	7-9
7.2.5.1	Mineral Sedimentation .....	7-10
7.2.5.2	Peat Transport .....	7-11
7.3	<b>ENVIRONMENTAL SETTING .....</b>	<b>7-11</b>
7.3.1	<b>Existing Conditions .....</b>	<b>7-12</b>
7.3.1.1	<b>Mineral Sedimentation – Upstream of Project .....</b>	<b>7-13</b>
7.3.1.1.1	Mineral Sediment Concentration.....	7-13
7.3.1.1.2	Bedload and Bed Material .....	7-16
7.3.1.1.3	Total Mineral Sediment Load.....	7-17
7.3.1.1.4	Mineral Sediment Deposition .....	7-17
7.3.1.2	<b>Mineral Sedimentation – Downstream of Project .....</b>	<b>7-18</b>
7.3.1.2.1	Mineral Sediment Concentration.....	7-18
7.3.1.2.2	Bedload and Bed Material .....	7-18
7.3.1.2.3	Total Mineral Sediment Load.....	7-19
7.3.1.2.4	Mineral Sediment Deposition .....	7-19
7.3.1.3	<b>Peat Sedimentation – Upstream of Project .....</b>	<b>7-20</b>
7.3.1.3.1	Peat Transport .....	7-20
7.3.1.3.2	Organic Suspended Sediment Concentration.....	7-20
7.3.1.3.3	Organic Sediment Deposition .....	7-20
7.3.1.4	<b>Peat Sedimentation – Downstream of Project.....</b>	<b>7-20</b>
7.3.1.4.1	Peat Transport .....	7-20
7.3.1.4.2	Organic Suspended Sediment Concentration.....	7-20
7.3.1.4.3	Organic Sediment Deposition .....	7-21
7.3.2	<b>Future Conditions/Trends .....</b>	<b>7-21</b>
7.3.2.1	Mineral Sedimentation .....	7-21
7.3.2.2	Peat Sedimentation – Upstream and Downstream of Project.....	7-21
7.4	<b>PROJECT EFFECTS, MITIGATION AND MONITORING.....</b>	<b>7-22</b>
7.4.1	<b>Construction Period .....</b>	<b>7-22</b>
7.4.1.1	<b>Stage I Diversion .....</b>	<b>7-22</b>
7.4.1.1.1	Gull Rapids to Inlet of Stephens Lake .....	7-22
7.4.1.1.2	Stephens Lake.....	7-23

7.4.1.2	Stage II Diversion .....	7-23
7.4.1.2.1	Gull Rapids to Inlet of Stephens Lake .....	7-23
7.4.1.2.2	Effects on Stephens Lake .....	7-25
7.4.2	Operating Period.....	7-27
7.4.2.1	Mineral Sedimentation – Upstream of Project .....	7-27
7.4.2.1.1	Mineral Sediment Concentration .....	7-27
7.4.2.1.2	General Summary of Sediment Concentrations .....	7-27
7.4.2.1.3	Bedload and Bed Material.....	7-28
7.4.2.1.4	Total Sediment Load.....	7-28
7.4.2.1.5	Mineral Sediment Deposition .....	7-29
7.4.2.2	Mineral Sedimentation – Downstream of Project .....	7-34
7.4.2.2.1	Mineral Sediment Concentration .....	7-34
7.4.2.2.2	Bedload and Bed Material.....	7-34
7.4.2.2.3	Total Mineral Sediment Load .....	7-34
7.4.2.2.4	Mineral Sediment Deposition .....	7-35
7.4.2.3	Peat Sedimentation – Upstream of Project.....	7-35
7.4.2.3.1	Peat Transport.....	7-35
7.4.2.3.2	Organic Sediment Concentration .....	7-36
7.4.2.3.3	Organic Sediment Deposition.....	7-37
7.4.2.4	Peat Sedimentation – Downstream of Project.....	7-37
7.4.2.4.1	Peat Transport.....	7-37
7.4.2.4.2	Organic Sediment Concentration .....	7-38
7.4.2.4.3	Organic Sediment Deposition.....	7-38
7.4.3	Mitigation.....	7-38
7.4.4	Residual Effects .....	7-38
7.4.5	Interactions With Future Projects .....	7-43
7.4.6	Environmental Monitoring and Follow-Up.....	7-43
7.5	REFERENCES.....	7-44



**8.0 GROUNDWATER ..... 8-1**

**8.1 INTRODUCTION ..... 8-1**

**8.2 APPROACH AND METHODOLOGY ..... 8-2**

**8.2.1 Overview to Approach..... 8-2**

        8.2.1.1 Existing Environment ..... 8-2

        8.2.1.2 Future Environment Without the Project..... 8-3

        8.2.1.3 Future Environment With the Project..... 8-3

        8.2.1.4 Assessing Predicted Project Effects ..... 8-4

        8.2.1.5 Assessing Interactions With Future Projects ..... 8-4

**8.2.2 Study Area ..... 8-5**

**8.2.3 Data and Information Sources ..... 8-5**

        8.2.3.1 Physiographic Data and Information Sources ..... 8-5

        8.2.3.2 Surface Water and River Ice Data and Information Sources ..... 8-6

        8.2.3.3 Groundwater Data and Information Sources ..... 8-6

        8.2.3.4 Meteorological Data and Information Sources ..... 8-7

**8.2.4 Assumptions ..... 8-7**

**8.3 ENVIRONMENTAL SETTING ..... 8-8**

**8.3.1 Existing Conditions ..... 8-8**

        8.3.1.1 Existing Geological and Hydrological Setting..... 8-9

        8.3.1.2 Hydraulic Conductivity ..... 8-12

        8.3.1.3 Recharge..... 8-12

        8.3.1.4 Groundwater Levels..... 8-12

        8.3.1.5 Groundwater Flow Direction and Velocities ..... 8-13

        8.3.1.6 Depth-to-Groundwater ..... 8-14

        8.3.1.7 Groundwater Quality ..... 8-14

**8.3.2 Future Conditions/Trends ..... 8-15**

**8.4 PROJECT EFFECTS, MITIGATION AND MONITORING..... 8-15**

**8.4.1 Construction Period ..... 8-15**

**8.4.2 Operating Period..... 8-16**

        8.4.2.1 Project Features Impacting Groundwater Regime ..... 8-16

        8.4.2.2 Groundwater Levels..... 8-16

        8.4.2.3 Groundwater Flow Direction and Velocities ..... 8-17

        8.4.2.4 Depth-to-Groundwater ..... 8-18

8.4.2.5	Total Affected Area Predicted.....	8-19
8.4.2.5.1	Cross-Section D-D'.....	8-21
8.4.2.5.2	Cross-Section E-E' .....	8-21
8.4.2.5.3	Cross-Section A-A' .....	8-22
8.4.2.5.4	Cross-Section B-B' .....	8-23
8.4.2.5.5	Cross-Section C-C' .....	8-23
8.4.2.6	Groundwater Quality .....	8-23
8.4.3	Mitigation.....	8-29
8.4.4	Residual Effects .....	8-29
8.4.5	Interactions with Future Projects .....	8-30
8.4.6	Environmental Monitoring and Follow-Up.....	8-31
8.5	REFERENCES.....	8-32

9.0	<b>SURFACE WATER TEMPERATURE AND DISSOLVED OXYGEN .....</b>	<b>9-1</b>
9.1	<b>INTRODUCTION .....</b>	<b>9-1</b>
9.1.1	<b>Overview of Water Temperature and Dissolved Oxygen Processes .....</b>	<b>9-2</b>
9.1.1.1	Water Temperature .....	9-3
9.1.1.2	Dissolved Oxygen .....	9-5
9.2	<b>APPROACH AND METHODOLOGY .....</b>	<b>9-6</b>
9.2.1	<b>Overview to Approach.....</b>	<b>9-6</b>
9.2.1.1	Approach to Describing the Environmental Setting .....	9-6
9.2.1.2	Approach to Predicting Project Effects .....	9-6
9.2.1.2.1	River Flows.....	9-7
9.2.1.2.2	Weather Conditions.....	9-8
9.2.1.2.3	Modelling Scenarios.....	9-10
9.2.2	Study Area .....	9-10
9.2.3	Data and Information Sources.....	9-11
9.2.3.1	Climate.....	9-11
9.2.3.2	Water Regime .....	9-11
9.2.3.3	Peat Processes.....	9-11
9.2.3.4	Water Quality Data .....	9-12

9.2.3.5	Data Used to Estimate Rates and Spatial Variation of SOD .....	9-12
9.2.3.6	Additional Information.....	9-13
9.2.4	Assumptions .....	9-13
9.3	<b>ENVIRONMENTAL SETTING .....</b>	<b>9-13</b>
9.3.1	Existing Conditions .....	9-14
9.3.1.1	Upstream of Project.....	9-15
9.3.1.1.1	Water Temperature - Open Water Period.....	9-15
9.3.1.1.2	Dissolved Oxygen Concentration – Open Water Period .....	9-15
9.3.1.1.3	Water Temperature – Winter Period.....	9-15
9.3.1.1.4	Dissolved Oxygen Concentration – Winter Period.....	9-15
9.3.1.1.5	Water Temperature – Open Water Period .....	9-17
9.3.1.2	Downstream of Project .....	9-19
9.3.1.2.1	Dissolved Oxygen Concentration – Open Water Period .....	9-19
9.3.1.2.2	Water Temperature – Winter Period.....	9-20
9.3.1.2.3	Dissolved oxygen Concentration – Winter Period.....	9-21
9.3.1.3	Total Dissolved Gas Pressure .....	9-21
9.3.2	Future Conditions/Trends .....	9-21
9.4	<b>PROJECT EFFECTS, MITIGATION AND MONITORING.....</b>	<b>9-22</b>
9.4.1	Construction Period .....	9-22
9.4.1.1	Stage I Diversion and Early Stage II Diversion .....	9-22
9.4.1.2	Late Stage II Diversion.....	9-22
9.4.2	Operating Period.....	9-23
9.4.2.1	Upstream of Project.....	9-23
9.4.2.1.1	Water Temperature – Open Water Period .....	9-23
9.4.2.1.2	Dissolved Oxygen Concentration - Open Water Period .....	9-23
9.4.2.1.3	Water Temperature - Winter Periods.....	9-30
9.4.2.1.4	Dissolved Oxygen Concentration – Winter Periods .....	9-31
9.4.2.2	Downstream of Project .....	9-34
9.4.2.2.1	Water Temperature – Open Water Period .....	9-34
9.4.2.2.2	Water Temperature – Winter .....	9-34

9.4.2.2.3	Dissolved Oxygen Concentration – Open Water and Winter Period .....	9-34
9.4.2.2.4	Total Dissolved Gas Pressure .....	9-34
9.4.4	Mitigation.....	9-35
9.4.5	Residual Effects .....	9-35
9.4.6	Interactions With Future Projects .....	9-38
9.4.7	Environmental Monitoring and Follow-Up.....	9-39
9.5	REFERENCES.....	9-40
10.0	DEBRIS.....	10-1
10.1	INTRODUCTION .....	10-1
10.2	APPROACH AND METHODOLOGY .....	10-1
10.2.1	Overview to Approach.....	10-1
10.2.2	Woody Debris Classification.....	10-2
10.2.3	Study Area .....	10-6
10.2.4	Assumptions.....	10-6
10.3	ENVIRONMENTAL SETTING.....	10-6
10.3.1	Current Conditions .....	10-7
10.3.1.1	Factors Contributing to Debris Generation.....	10-7
10.3.1.1.1	Shoreline Recession .....	10-7
10.3.1.1.2	Ice Processes .....	10-8
10.3.1.1.3	River Flows and Water Levels.....	10-12
10.3.1.1.4	Forest Fires.....	10-12
10.3.1.2	Factors Contributing to Debris Movement .....	10-13
10.3.1.3	Woody Debris Mapping.....	10-13
10.3.1.4	Peat Debris.....	10-15
10.3.3	Future Conditions/Trends .....	10-16
10.4	PROJECT EFFECTS, MITIGATION AND MONITORING.....	10-16
10.4.1	Construction Period .....	10-17
10.4.1.1	Reservoir Clearing.....	10-17
10.4.1.2	Stage I and Stage II Diversion.....	10-17
10.4.1.3	Reservoir Impoundment.....	10-18
10.4.2	Operating Period.....	10-19

10.4.2.1	Debris Due to Reservoir Expansion.....	10-19
10.4.2.2	Debris Due to Ice Processes.....	10-21
10.4.3	Mitigation.....	10-21
10.4.3.1	Reservoir Clearing Plan .....	10-22
10.4.3.1.1	Reservoir Clearing Plan Objectives and Activities .....	10-22
10.4.3.1.2	Pre-Flooding Reservoir Clearing .....	10-23
10.4.3.1.3	Post-Flooding Reservoir Clearing.....	10-24
10.4.3.2	Waterways Management Program .....	10-24
10.4.3.2.1	Phase One – Pre-Flooding.....	10-25
10.4.3.2.2	Phase Two – Post Flooding .....	10-25
10.4.4	Residual Effects .....	10-26
10.4.5	Interaction with Future Projects .....	10-28
10.4.6	Environmental Monitoring and Follow-Up.....	10-28
10.5	REFERENCES .....	10-29
11.0	<b>SENSITIVITY OF EFFECTS ASSESSMENT TO CLIMATE CHANGE .....</b>	<b>11-1</b>
11.1	INTRODUCTION .....	11-1
11.2	APPROACH AND METHODOLOGY.....	11-1
11.3	SURFACE WATER AND ICE REGIME .....	11-2
11.4	SHORELINE EROSION PROCESSES .....	11-4
11.5	SEDIMENTATION .....	11-5
11.6	GROUNDWATER.....	11-6
11.7	SURFACE WATER TEMPERATURE AND DISSOLVED OXYGEN.....	11-6
11.8	PHYSIOGRAPHY.....	11-7
11.9	AIR QUALITY AND NOISE.....	11-8
11.10	DEBRIS .....	11-8
11.11	SUMMARY/CONCLUSIONS .....	11-8
11.12	REFERENCES .....	11-9

**12.0 EFFECTS OF THE ENVIRONMENT ON THE PROJECT ..... 12-1**

12.1 INTRODUCTION ..... 12-1

12.2 PLANNING AND DESIGN ..... 12-1

12.3 KEY CLIMATE FACTORS/HAZARDS ..... 12-1

    12.3.1 Hydrology ..... 12-1

    12.3.2 Construction Phase ..... 12-2

    12.3.3 Operations Phase ..... 12-2

    12.3.4 Severe Wind Events ..... 12-4

    12.3.5 Seismic Activity ..... 12-4

    12.3.6 Lightning ..... 12-5

12.4 CLIMATE CHANGE ..... 12-5

    12.4.1 Change in Nelson River Flow ..... 12-5

    12.4.2 Warmer Temperatures ..... 12-6

    12.4.3 Wind and Extreme Events ..... 12-6

    12.4.4 Conclusions ..... 12-6

12.5 REFERENCES ..... 12-7

# APPENDICES

APPENDIX 1A:	LIST OF PHYSICAL ENVIRONMENT TECHNICAL MEMORANDA
APPENDIX 2A:	RESERVOIR GREENHOUSE GAS SCIENCE AND QUANTIFICATION
APPENDIX 2B:	MANITOBA HYDRO'S CLIMATE CHANGE STRATEGIES
APPENDIX 4A:	SURFACE WATER AND ICE REGIME TABLES
APPENDIX 4B:	DESCRIPTION OF NUMERICAL MODELS AND METHODS
APPENDIX 6A:	DESCRIPTION OF MODELS
APPENDIX 6B:	RESULTS TABLES
APPENDIX 6C:	PREDICTION UNCERTAINTY
APPENDIX 6D:	DETAILED TABLES OF PREDICTED SHORELINE RECESSION AND EROSION VOLUMES
APPENDIX 7A:	MODEL DESCRIPTIONS
APPENDIX 7B:	DETAILED DESCRIPTION OF THE ENVIRONMENTAL SETTING FOR MINERAL SEDIMENTATION
APPENDIX 7C:	FIELD MAPS (OPEN WATER)
APPENDIX 7D:	MONITORING LOCATIONS (WINTER)
APPENDIX 7E:	SEDIMENTATION FIELD DATA 2005 TO 2007
APPENDIX 7F:	EROSION DURING CONSTRUCTION – GENERAL SITE CONDITIONS
APPENDIX 8A:	MODEL DESCRIPTION
APPENDIX 8B:	ADDITIONAL GROUNDWATER MAPS
APPENDIX 9A:	DESCRIPTION OF MODELS AND ANALYSIS
APPENDIX 9B:	POST-PROJECT DISSOLVED OXYGEN CONCENTRATIONS IN THE SURFACE AND BOTTOM MODEL LAYERS



This page is intentionally left blank.

# LIST OF FIGURES

	<b>Page</b>
Figure 1.1-1: Physical Environment Studies and How They Interact.....	1-3
Figure 2.2-1: High Level Life-Cycle Model .....	2-11
Figure 2.3-1: Temperature Normals (1971-2000).....	2-13
Figure 2.3-2: Precipitation Normals (1971-2000) .....	2-14
Figure 2.3-3: Wind Rose for Hourly Wind Speed .....	2-15
Figure 2.3-4: Monthly Average Temperature Climate Scenarios from Global Climate Model Ensemble .....	2-16
Figure 2.3-5: Monthly Average Precipitation Climate Scenarios from Global Climate Model Ensemble .....	2-17
Figure 2.3-6: Annual Temperature and Precipitation Change Scenarios for Keeyask from Canadian Regional Climate Change Model .....	2-18
Figure 2.4-1: Breakdown of GHG Emissions per Primary Activity .....	2-21
Figure 2.4-2: Generation Life-Cycle Comparison .....	2-22
Figure 3.4-1: Construction Equipment Noise Levels .....	3-14
Figure 3.4-2: Common Indoor and Outdoor Noise Levels.....	3-15
Figure 4.1-1: Typical River Ice Processes (after Ashton, 1986) .....	4-2
Figure 4.1-2: Typical Hanging Ice Dam (after Ashton, 1986).....	4-3
Figure 4.1-3: Typical Mechanically Thickened Ice Cover (after Ashton, 1986) .....	4-4
Figure 4.1-4: Typical Border Ice Growth (after Ashton, 1986).....	4-4
Figure 4.1-5: Typical Anchor Ice Accumulation (after Ashton, 1986).....	4-5
Figure 4.2-1: Historical River Flows at the Split Lake Outlet (1977 to 2006).....	4-14
Figure 4.2-2: Creek Sub-Basins in the Keeyask GS Study Region.....	4-18
Figure 4.2-3: Plan view of Nap Creek HEC-RAS Cross-Sections.....	4-20
Figure 4.3-1: Keeyask GS Calculated Daily Inflow Hydrograph (1977 to 2006) .....	4-22
Figure 4.3-2: Keeyask GS Calculated Monthly Average Duration Curves.....	4-22
Figure 4.3-3: Gull Lake Water Level Elevation Spaghetti Hydrographs .....	4-31
Figure 4.3-4: Mean Monthly Hydrograph for Nap Creek.....	4-35
Figure 4.3-5: Mean Monthly Hydrograph for Portage Creek .....	4-36
Figure 4.3-6: Mean Monthly Hydrograph for Two Goose Creek .....	4-36
Figure 4.3-7: Mean Monthly Hydrograph for Rabbit (Broken Boat) Creek .....	4-37
Figure 4.3-8: Existing Environment Winter Water Surface Profile - Low Flow Year (2003/04) .....	4-45
Figure 4.3-9: Existing Environment Winter Water Surface Profile - Average Flow Year (1999/2000).....	4-46
Figure 4.3-10: Existing Environment Winter Water Surface Profile - High Flow Year (2005/06) .....	4-47
Figure 4.4-1: Estimated Water Surface Profile During Stage I Diversion (All Flow Through South Channel) Annual 1:20 Year Flood (6,358 m <sup>3</sup> /s) .....	4-53

Figure 4.4-2: Estimated Average Velocity Profile During Stage I Diversion (All Flow Through South Channel) Annual 1:20 Year Flood (6,358 m<sup>3</sup>/s) .....4-54

Figure 4.4-3: Estimated Velocity Distribution around Stage I Spillway Cofferdam Annual 1:20 Year Flood (6,358 m<sup>3</sup>/s) .....4-55

Figure 4.4-4: Estimated Velocity Distribution Under Existing Conditions in Vicinity of Stage I Spillway Cofferdam – Annual 1:20 Year Flood (6,358 m<sup>3</sup>/s).....4-55

Figure 4.4-5: Estimated Winter Water Surface Profile During Stage I Diversion – Mean Monthly 1:20 Year High Flows, Average Air Temperatures .....4-58

Figure 4.4-6: Estimated Winter Water Surface Profile During Stage I Diversion – Mean Monthly 1:20 Year Low Flows, Average Air Temperatures .....4-59

Figure 4.4-7: Estimated Water Surface Profile During Stage II Diversion – Annual 1:20 Year Flood (6,358 m<sup>3</sup>/s).....4-60

Figure 4.4-8: Estimated Average Velocity Profile During Stage II Diversion – Annual 1:20 Year Flood (6,358 m<sup>3</sup>/s).....4-61

Figure 4.4-9: Estimated Velocity Distribution at Spillway During Stage II Diversion Annual 1:20 Year Flood (6,358 m<sup>3</sup>/s) .....4-62

Figure 4.4-10: Estimated Water Surface Profiles During Initial Phase of Rollway Construction Mean Monthly 1:20 Year Flow .....4-64

Figure 4.4-11: Estimated Average Velocity Profiles During Initial Phase of Rollway Construction Mean Monthly 1:20 Year Flow .....4-65

Figure 4.4-12: Future Environment Inflow Hydrograph (1912-2006) .....4-70

Figure 4.4-13: Existing and Future Environment all-Season Inflow Duration Curves .....4-70

Figure 4.4-14: Existing and Future Environment All-Season Inflow Duration Curves (1977 to 2006) .....4-71

Figure 4.4-15: Plant Outflow Hydrograph (Open Water Peaking Mode).....4-73

Figure 4.4-16: Plant Outflow Hydrograph (Open-Water Base Loaded Mode).....4-74

Figure 4.4-17: Stage Hydrograph at Key Sites for 50th Percentile Inflow (Open Water Peaking Mode).....4-76

Figure 4.4-18: Stage Hydrograph at Key Sites for 50th Percentile Inflow (Open Water Base Loaded Mode).....4-76

Figure 4.4-19: Water Surface Level Duration Curves at Keeyask Reservoir (Base Loaded and Peaking Modes).....4-77

Figure 4.4-20: Water Surface Level Variation Duration Curves at Keeyask Reservoir (Base Loaded and Peaking Modes) .....4-77

Figure 4.4-21: 95th Percentile WSL Variation Decay Curves (Peaking Mode of Operation).....4-78

Figure 4.4-22: 95th Percentile WSL Variation Decay Curves (Base Load Mode of Operation).....4-78

Figure 4.4-23: Nap Creek Water Surface Profiles (95th Percentile Creek Inflow) .....4-87

Figure 4.4-24: Portage Creek Water Surface Profiles (95th Percentile Creek Inflow) .....4-87

Figure 4.4-25: Two Goose Creek Water Surface Profiles (95th Percentile Creek Inflow).....4-88

Figure 4.4-26: Rabbit Creek Water Surface Profiles (95th Percentile Creek Inflow) .....4-88

Figure 4.4-27: Modelled Winter Water Surface Profiles, 5th Percentile Flow, Average Temperature Conditions.....4-92

Figure 4.4-28: Modelled Winter Water Surface Profiles, 50th Percentile Flow, Average Temperature Conditions ..... 4-93

Figure 4.4-29: Modelled Winter Water Surface Profiles, 95th Percentile Flow, Average Temperature Conditions ..... 4-94

Figure 4.4-30: Modelled Winter Stage Hydrographs, 50th Percentile Flow, Future Environment Without Project, Average Temperature Conditions..... 4-96

Figure 4.4-31: Modelled Winter Stage Hydrographs, 50th Percentile Flow, Base Loaded Operation, Average Temperature Conditions ..... 4-97

Figure 4.4-32: Modelled Winter Stage Hydrographs, 50th Percentile Flow, Peaking Operation, Average Temperature Conditions ..... 4-102

Figure 5.3-1: Emergence Curves for North Eastern Manitoba and other Parts of Hudson Bay (after Dredge and Nixon 1992)..... 5-16

Figure 6.1-1: Shoreline Profile Illustrating Peatland Disintegration Processes..... 6-3

Figure 6.1-2: Shoreline Profile Illustrating Processes of Nearshore Downcutting and Toe-of-Bank Erosion..... 6-8

Figure 6.1-3: Schematic Illustrating Erosion of Mineral Material Over Bedrock Under High and Low Water Levels..... 6-9

Figure 6.2-1: Mineral Erosion Leading to Disintegration of Peat Along the Shoreline..... 6-10

Figure 6.3-1: Historical Average Annual Top-of-Bank Recession Rates Measured from Air Photos..... 6-31

Figure 6.3-2: Estimated Average Annual Mineral and Organic Sediment by Shoreline Reach Upstream of the Project for Existing Conditions in Tonnes/y..... 6-33

Figure 6.3-3: Estimated Average Annual Mineral and Organic Sediment Load by Shoreline Reach Upstream of the Project Under Existing Conditions in m<sup>3</sup>/y ..... 6-34

Figure 6.4-1: Histogram Showing the Length of each Shoreline Type and Total Shoreline Length for each Model Interval. Eroding Mineral Shorelines..... 6-47

Figure 6.4-2: Project Future Annual Rate (km<sup>2</sup>/Y) of Reservoir Expansion Related to Peatland Disintegration and Mineral Erosion for Peaking and Base Loaded Modes of Operation..... 6-49

Figure 6.4-3: Comparison of Projected Bank Recession Distance With and Without the Keeyask Project Over the 30 Year Modelling Period ..... 6-53

Figure 6.4-4: Change in Total Water Surface Area With and Without the Project..... 6-55

Figure 6.4-5: Cumulative Total Peat Resurfacing Area for With and Without Project Conditions..... 6-56

Figure 6.4-6: Comparison of Projected Average Annual Organic Sediment Loads in m<sup>3</sup> by Reach With and Without the Project..... 6-57

Figure 6.4-7: Comparison of Projected Average Annual Organic Sediment Loads in Tonnes by Reach With and Without the Project..... 6-58

Figure 6.4-8: Comparison of Projected Average Annual Mineral and Organic Sediment Loads Generated by Peatland Disintegration and Erosion of Mineral Banks With Overlying Peat With and Without the Project..... 6-59

Figure 6.4-9: Comparison of Projected Average Annual Mineral Sediment Loads by Shoreline Reach With and Without the Project..... 6-61

Figure 6.4-10: Comparison of the With and Without Project Mean Annual Mineral Sediment Loads in the Keeyask Reservoir Over the First 30 Years of Operation.....6-62

Figure 7.1-1: A Conceptual Diagram of Major Sediment Transport Processes.....7-3

Figure 7.4-1: Temporal Variation of Suspended Sediment Concentrations at Site K-Tu-2 During Construction for 20-Year Flood Flow of 6,358 m<sup>3</sup>/s.....7-24

Figure 7.4-2: Longitudinal Description of Suspended Sediment Concentrations During Construction Within Stephens Lake for 95th Percentile Flow of 4,855 m<sup>3</sup>/s.....7-26

Figure 7.4-3: Longitudinal Distribution of Suspended Sediment Concentrations During Construction Within Stephens Lake for 1:20 Year Flood Flow of 6,352 m<sup>3</sup>/s.....7-26

Figure 7.4-4: Mineral Deposition Along North Nearshore (Base Loaded) .....7-32

Figure 7.4-5: Mineral Deposition Along South Nearshore (Base Loaded).....7-32

Figure 7.4-6: Mineral Deposition Along North Nearshore (Peaking).....7-33

Figure 7.4-7: Mineral Deposition Along South Nearshore (Peaking).....7-33

Figure 7.4-8: Total Organic Material for Year 1, Years 2 to 5, and Years 6 to 15.....7-36

Figure 8.1-1: Groundwater and Surface Water Flow Systems .....8-1

Figure 8.3-1a: Lake-Water Levels in the Nelson River (HOBO 05UF620), Lake 617 (HOBO 05UF617), Lake 616 (HOBO 05UF616) and Lake 615 (HOBO 05UF615) .....8-11

Figure 8.3-1b: Lake-Water Levels in Lake 619 (HOBO 05UF619) and Lake 618 (HOBO 05UF618) .....8-11

Figure 8.3-2a: Water Levels in Groundwater Wells Recorded by DIVERs G 0561 and G 0547.....8-12

Figure 8.3-2b: Water Levels in Groundwater Wells Recorded by DIVERs 03-045, 03 042, G-0359, G-0348A and G-5086 .....8-12

Figure 8.4-1: Curve Illustrating the Predicted Total Affected Area and Increased Groundwater Levels (Typical Year, 50th Percentile Meteorological and River-Flow Conditions).....8-22

Figure 8.4-2: Curve Illustrating the Predicted Total Affected Area and Decreased Depth-to-Groundwater (Typical Year, 50th Percentile Meteorological and River-Flow Conditions) .....8-23

Figure 8.4-3a: Cross-Sectional Profile of Groundwater Level With and Without the Project for Typical Year (50th Percentile) in Conjunction With Topographic Elevation at Cross-Section D-D’.....8-25

Figure 8.4-3b: Cross-Sectional Profile of Groundwater Level With and Without the Project for Typical Year (50th Percentile) in Conjunction With Topographic Elevation at Cross-Section E-E’ .....8-26

Figure 8.4-3c: Cross-Sectional Profile of Groundwater Level With and Without the Project for Typical Year (50th Percentile) in Conjunction With Topographic Elevation at Cross-Section A-A’ .....8-27

Figure 8.4-3d: Cross-Sectional Profile of Groundwater Level With and Without the Project for Typical Year (50th Percentile) in Conjunction With Topographic Elevation at Cross-Section B-B’ .....8-28

Figure 8.4-3e: Cross-Sectional Profile of Groundwater Level With and Without the Project for Typical Year (50th Percentile) in Conjunction With Topographic Elevation at Cross-Section C-C’ .....8-29

Figure 9.1-1: Physical Environment Studies and how they Interact ..... 9-1

Figure 9.1-2: Schematic Representation of Water Temperature and DO Processes..... 9-4

Figure 9.3-1: Gull Lake Daily Water and Air Temperature in Summer 2004 and 2006..... 9-16

Figure 9.3-2: Gull Lake Site K-DT-C-01 – 2008 Continuous Water Temperature and Dissolved Oxygen Data ..... 9-17

Figure 9.3-3: Gull Lake Site K-DT-C-01 - 2008 Discrete Depth Profiles of Water Temperature and Dissolved Oxygen ..... 9-18

Figure 9.3-4: Gull Lake Site K-DT-C-01 – 2009 Continuous Water Temperature and Dissolved Oxygen Data ..... 9-18

Figure 9.3-5: Stephens Lake Site K-DT-C-02 – 2008 Continuous Water Temperature and Dissolved Oxygen Data ..... 9-19

Figure 9.3-6: Stephens Lake Site K-DT-C-02 – 2009 Continuous Water Temperature and Dissolved Oxygen Data ..... 9-20

Figure 9.4-1: Keeyask Summer Water Temperature (Map 9.4-1, Cross-Section A-A) Summer Scenarios ..... 9-25

Figure 9.4-2: Keeyask Summer Water Temperature (Map 9.4-1, Cross-Section B-B) ..... 9-26

Figure 9.4-3: Year 1, Mid-Depth Reservoir Dissolved Oxygen, Expected Summer Scenarios ..... 9-27

Figure 9.4-4: Vertical Dissolved Oxygen Profiles at Six Reservoir Locations, Year 1 Critical Week (Model Hour 47)..... 9-28

Figure 9.4-5: Year 1 and Year 5, Mid-Depth Reservoir Dissolved Oxygen, Critical Summer Week..... 9-30

Figure 9.4-6: Year 1, Mid-Depth Reservoir Dissolved Oxygen, Expected Winter Scenarios..... 9-33

Figure 9.4-7: Three-Week Variability of Dissolved Oxygen at Seven Reservoir Locations (Map 9.4-7), Year 1 Winter Peaking Mode of Operation ..... 9-33

This page is intentionally left blank.



# LIST OF TABLES

	<b>Page</b>
Table 1.1-1: Factors Considered in Assessment of Residual Environmental Effects.....	1-9
Table 1.4-1: List of Independent Peer Reviewers Used to Review the Physical Environment Technical Work Developed by the Physical Environment Team.....	1-11
Table 2.2-1: Ensemble of Global Climate Models.....	2-5
Table 2.4-1: Summary Results - Keeyask Life-Cycle Analysis .....	2-20
Table 2.4-2: Summary of Climate Residual Effects .....	2-23
Table 3.3-1: Outdoor Sound Levels Measured at Various Locations.....	3-6
Table 3.4-1: Equipment, Materials and Personnel Road Transport: Trip Summary Estimates .....	3-8
Table 3.4-2: Equipment, Materials and Personnel Road Transport: Emission Estimates .....	3-9
Table 3.4-3: Emission Estimates for Keeyask Site Clearing Compared to Emission Estimates for Winnipeg Bus Diesel Use (2006) .....	3-11
Table 3.4-4: Emission Estimates for Keeyask Dam and Generation Facilities Construction Compared to Emission Estimates for Winnipeg Bus Diesel Use (2006).....	3-12
Table 3.4-5: Summary of Air Quality and Noise Residual Effects.....	3-19
Table 4.3-1: Existing Environment Inflows .....	4-23
Table 4.3-2: Existing Environment Water Levels at Key Sites.....	4-32
Table 4.3-3: Existing Environment 1 Day Water Level Variations at Key Sites.....	4-32
Table 4.3-4: Existing Environment 7 Day Water Level Variations at Key Sites.....	4-33
Table 4.3-5: Depth Areas (by Category) - 50th Percentile Flow.....	4-34
Table 4.3-6: Velocity Areas (by Category) - 50th Percentile Flow .....	4-34
Table 4.3-7: Estimated Daily Percentile Flows for the Four Ungauged Creeks .....	4-37
Table 4.4-1: Estimated Water Level Staging During Construction Period (4,379 m <sup>3</sup> /s).....	4-68
Table 4.4-2: 95th Percentile Future Environment Water Levels.....	4-80
Table 4.4-3: 95th Percentile Future Environment 1 day Water Level Variations.....	4-81
Table 4.4-4: 95th Percentile Future Environment 7 day Water Level Variations.....	4-82
Table 4.4-5: Summary of Reservoir Depth by Area - 50th Percentile Flow.....	4-83
Table 4.4-6: Summary of Velocity by Area - 50th Percentile Flow.....	4-85
Table 4.4-7: Summary of Surface Water Regime and Ice Processes Residual Effects.....	4-104
Table 5.3-1: Surface Material Deposition Mode in the Study Area and Northern Manitoba as a Percentage of Total Area* .....	5-6
Table 5.3-2: Soil Parent Material in the Study Areas and Northern Manitoba as a Percentage of Total Land Area.....	5-8
Table 5.3-3: Coarse Ecosite Composition in the local study area as a Percentage of Land Area .....	5-11
Table 5.3-4: Surface Permafrost Composition in the Local Study Area by Continuity Type as a Percentage of Total Land Area .....	5-13
Table 5.4-1: Summary of Lands (Area) Required for the Project and as a Percentage of the Project Footprint.....	5-18

Table 5.4-2:	Summary of Material Excavation and Placement Altering the Physiography .....	5-19
Table 5.4-3:	Estimated Borrow and Quarry Area Utilization.....	5-22
Table 5.4-4:	Preliminary Borrow and Quarry Material Utilization Plan.....	5-23
Table 5.4-5:	Coarse Ecosite Composition of the Project Footprint as a Percentage of Land Area .....	5-25
Table 5.4-6:	Permafrost Distribution in the Project Footprint as a Percentage of Land Area .....	5-26
Table 5.4-7:	Summary of Physiography Residual Effects .....	5-28
Table 6.3-1:	Shoreline Bank Material Composition by Material Type in the Upstream Reaches.....	6-23
Table 6.3-2:	Bank Heights Around the Existing Keeyask Study Area Shoreline Upstream of the Project Site.....	6-24
Table 6.3-3:	Shore Material Composition (%) by Existing Environment Study Area Reach.....	6-25
Table 6.3-4:	Estimated Average Annual Mineral and Peat Volume being Eroded from the Study Area Shoreline Upstream of the Project Under Existing Conditions .....	6-32
Table 6.3-5:	Estimated Average Annual Mineral and Peat Mass being Eroded from the Study Area Shoreline Upstream of the Project Under Existing Conditions .....	6-33
Table 6.3-6:	Shoreline Bank Material Composition by Material Type in the Downstream Reach.....	6-35
Table 6.3-7:	Bank Heights Around the Existing Keeyask Study Area Shoreline Downstream of the Project Site .....	6-35
Table 6.3-8:	Historical Average Annual Top-of-Bank Recession Rates Measured from 1986 – 2006 Air Photos Downstream of Project .....	6-36
Table 6.3-9:	Shoreline Classification for Existing Environment and for the Future Without the Project, Upstream of the Project.....	6-37
Table 6.3-10:	Average Recession Rate of Mineral Banks Without the Project Upstream of the Project.....	6-39
Table 6.3-11:	Projected Mineral and Peat Erosion Volumes Without the Project.....	6-39
Table 6.3-12:	Project Mineral Erosion Mass Without the Project Upstream of the Project.....	6-40
Table 6.3-13:	Project Peat Erosion Mass Without the Project Upstream of the Project.....	6-41
Table 6.3-14:	Projected Total Mineral and Peat Erosion Mass Without the Project Upstream of the Project.....	6-41
Table 6.3 15:	Average Recession Rate of Mineral Banks Without the Project Along Shorelines Downstream of the Project Site .....	6-43
Table 6.3-16:	Mineral and Peat Volumes Predicted to Erode from the Downstream of the Project Site Without the Project .....	6-43
Table 6.3-17:	Mineral Mass Predicted to Eroded Downstream of the Project Without the Project .....	6-43
Table 6.4-1:	Average Annual Recession Rate of Mineral Banks1 With the Project for Peaking and Base Loaded Modes of Operation (see Footnote) .....	6-52
Table 6.4-2:	Comparison of Totals With (Base Loaded Mode of Operation) and Without the Keeyask Project.....	6-63
Table 6.4-3:	Comparison of Average Annual Amounts With (Base Loaded Mode of Operation) and Without the Keeyask Project.....	6-64
Table 6.4-4:	Summary of Shoreline Erosion Residual Effects .....	6-68

Table 7.3–1: Range of Suspended Sediment Concentration Measurements for 2005, 2006 and 2007 (Openwater)..... 7-14

Table 7.3–2: Average Suspended Sediment Concentrations in Stephens Lake (Based on all Available 2005-2007 Samples for Each Station in Stephens Lake)..... 7-19

Table 7.4-1: Range of North Nearshore Mineral Deposition Thickness in Modelling Reaches (for Base Loaded Scenario) ..... 7-29

Table 7.4-2: Range of South Nearshore Mineral Deposition Thickness in Modelling Reaches (for Base Loaded Scenario) ..... 7-30

Table 7.4-3: Range of North Nearshore Mineral Deposition Thickness in Modelling Reaches (for Peaking Scenario) ..... 7-30

Table 7.4-4: Range of South Nearshore Mineral Deposition Thickness in Modelling Reaches (for Peaking Scenario) ..... 7-31

Table 7.4-5: Predicted Peak Organic Suspended Sediment Concentration Increases..... 7-37

Table 7.4-6: Summary of Sedimentation Residual Effects ..... 7-39

Table 8.3-1: Soil and Bedrock Properties: Keeyask GS Area..... 8-12

Table 8.3-2: Average Groundwater Level Rise due to Variations in Seasonal Atmospheric Conditions ..... 8-13

Table 8.4 1: Predicted Total Area Groundwater Levels During a Typical Year (50th Percentile Meteorological and River-Flow Conditions) ..... 8-20

Table 8.4 2: Predicted Total Area with Decreased Depth-to-Groundwater Level During a Typical Year (50th Percentile Meteorological and River-Flow Conditions)..... 8-20

Table 8.4 3: Summary of Groundwater Residual Effects..... 8-29

Table 9.4-1: Areas of Reservoir With Predicted Dissolved Oxygen Concentration Within Given Concentration Ranges - Year 1 Summer..... 9-24

Table 9.4-2: Areas of Reservoir With Predicted Dissolved Oxygen Concentration Within Given Concentration Ranges Year 5 Summer ..... 9-29

Table 9.4-3: Areas of Reservoir With Predicted Dissolved Oxygen Concentration Within Given Concentration Ranges – Year 1 Winter..... 9-32

Table 9.4-4: Summary of Surface Water Temperature and DO Residual Effects..... 9-36

Table 10.3-1: Mobilized Debris Removed From Study Area by Manitoba Hydro Waterways Management Program ..... 10-15

Table 10.4-1: Summary of Debris Residual Effects..... 10-26

This page is intentionally left blank.

# LIST OF MAPS

	<b>Page</b>
Map 1.1-1: Physical Environment Study Area.....	1-13
Map 1.1-2: Project Footprint During Construction Phase – Site Level.....	1-14
Map 1.1-3: Project Footprint During Operations Phase – Site Level.....	1-15
Map 1.1-4: Project Footprint Overview – Construction and Operation Phase.....	1-16
Map 2.2-1: Existing Climate Study Area.....	2-27
Map 2.2-2: Canadian Global Climate Model 3.1 Study Area.....	2-28
Map 2.2-3: Canadian Regional Climate Model 4.2.3 Study Area.....	2-29
Map 2.4-1: Keeyask Area – Upstream and Downstream Pre-Project Greenhouse Gas Sampling Locations.....	2-30
Map 2.4-2: Split Lake Area Pre-Project Greenhouse Gas Sampling Locations.....	2-31
Map 4.2-1: Water Regime Study Area.....	4-115
Map 4.2-2: Topographic and Bathymetric Data Sources.....	4-116
Map 4.2-3: Existing Environment Digital Elevation Model (DEM).....	4-117
Map 4.2-4: Post Project Environment Digital Elevation Model.....	4-118
Map 4.2-5: Area for Keeyask GS Inflow Calculation.....	4-119
Map 4.3-1: Watershed Area Contributing to the Lower Nelson River.....	4-120
Map 4.3-2: Typical Existing Environment Open Water Surface Profile.....	4-121
Map 4.3-3: Existing Environment Water Depth Grids.....	4-122
Map 4.3-4: Existing Environment and Post Project Environment Shoreline Polygons.....	4-123
Map 4.3-5: Existing Environment Velocity Grids (Classified Scale).....	4-124
Map 4.3-6: Existing Environment Velocity Grids (Stretched Scale).....	4-125
Map 4.3-7: Overview of Existing Environment Ice Processes at Key Locations in the Keeyask GS Study Area.....	4-126
Map 4.4-1: General Arrangement Drawings Stage I and Stage II Diversion.....	4-127
Map 4.4-2: Stage I Shoreline Polygons (95th Percentile).....	4-128
Map 4.4-3: Stage II Shoreline Polygons (95th Percentile).....	4-129
Map 4.4-4: Water Surface Profiles 50th Percentile, Open Water Flow Existing Environment and Post Project Environment.....	4-130
Map 4.4-5: Post Project Environment Water Depth Grids.....	4-131
Map 4.4-6: Estimated Water Depth Changes Resulting from Reservoir Impoundment.....	4-132
Map 4.4-7: Intermittently Exposed Post Project Shoreline 50th Percentile Flow.....	4-133
Map 4.4-8: Post Project Environment Velocity Grids (Classified Scale).....	4-134
Map 4.4-9: Post Project Environment Velocity Grids (Stretched Scale).....	4-135
Map 4.4-10: Estimated Velocity Changes Resulting From Reservoir Impoundment.....	4-136
Map 4.4-11: 95th Percentile Shoreline Locations Downstream of Project Site.....	4-137
Map 5.2-1: Local and Regional Physiography Study Areas.....	5-34
Map 5.3-1: Surface Material Deposition Mode.....	5-35

Map 5.3-2:	Surface Deposits in the Physiography Study Area .....	5-36
Map 5.3-3:	Borrow Material Deposits .....	5-37
Map 5.3-4:	Soil Great Groups in the Physiography Study Area.....	5-38
Map 5.3-5:	Soil Type in the Local Study Area.....	5-39
Map 5.3-6:	Coarse Ecosite Types in the Local Study Area.....	5-40
Map 5.3-7:	Permafrost Thickness and Distribution in Manitoba .....	5-41
Map 5.3-8:	Surface Permafrost Distribution in the Local Study Area .....	5-42
Map 5.3-9:	Depth to Bottom of Permafrost as Observed from Field Drilling Investigations .....	5-43
Map 5.3-10:	Earthquakes In or Near Canada, 1627 to 2007.....	5-44
Map 5.3-11:	Earthquakes Within 600 km of Thompson, Manitoba, 1965 to 2007 .....	5-45
Map 5.3-12:	Model Predicted Glacial Isostatic Rebound Rates (Lambert 1996).....	5-46
Map 5.4-1:	Project Footprint During Construction Phase – Site Level.....	5-47
Map 5.4-2:	Project Footprint During Operations Phase – Site Level.....	5-48
Map 5.4-3:	Project Footprint Overview – Construction and Operation Phase .....	5-49
Map 6.2-1:	Shoreline Erosion Study Area and Zones.....	6-75
Map 6.2-2:	Shoreline Erosion and Aquatic Reaches .....	6-76
Map 6.3-1:	Shore Bank Material Type and Shore Segments With High Banks in Western Upstream Reaches .....	6-77
Map 6.3-2:	Shore Bank Material Type and Shore Segments With High Banks in Eastern Upstream Reaches .....	6-78
Map 6.3-3:	Shoreline Recession in Western Upstream Area Years 1 to 30 Without Project (Existing Conditions Only) .....	6-79
Map 6.3-4:	Shoreline Recession in Eastern Upstream Area Years 1 to 30 Without Project (Existing Conditions Only) .....	6-80
Map 6.3-5:	Shoreline Recession in Eastern Area Downstream of the Keeyask Project Years 1 to 30 Without Project (Existing Conditions Only) .....	6-81
Map 6.4-1:	Potential Locations of Shoreline Erosion During the Construction Phase.....	6-82
Map 6.4-2:	Shoreline Material at Day 1 in Western Upstream Reaches .....	6-83
Map 6.4-3:	Shoreline Material at Day 1 in Eastern Upstream Reaches.....	6-84
Map 6.4-4:	Shoreline Material in Western Upstream Reaches at Year 30 .....	6-85
Map 6.4-5:	Shoreline Material in Eastern Upstream Reaches at Year 30 .....	6-86
Map 6.4-6:	Reservoir Expansion in Western Upstream Reaches – Peatland Disintegration and Mineral Bank Erosion During First 30 Year of Operation.....	6-87
Map 6.4-7:	Reservoir Expansion in Eastern Upstream Reaches – Peatland Disintegration and Mineral Bank Erosion During First 30 Years of Operation.....	6-88
Map 6.4-8:	Ecosite Composition Along Year 30 Shoreline in Western Upstream Reaches .....	6-89
Map 6.4-9:	Ecosite Composition Along Year 30 Shoreline in Eastern Upstream Reaches .....	6-90
Map 6.4-10:	Downstream Areas Defined for Discussion of Project Effects.....	6-91
Map 7.2-1:	Monitoring Locations in Stephens Lake .....	7-47
Map 7.2-2:	Keeyask Sedimentation General Study Area.....	7-48
Map 7.2-3:	Peat Modelling Zones .....	7-49
Map 7.2-4:	Modelling Reaches.....	7-50

Map 7.3-1: Spatial Distribution of Depth Averaged Sediment Concentration - Existing Environment - 50th Percentile Flow ..... 7-51

Map 7.3-2: Spatial Distribution of Depth Averaged Sediment Concentration - Existing Environment - 95th Percentile Flow ..... 7-52

Map 7.4-1: Deposition in Stephens Lake During Construction ..... 7-53

Map 7.4-2: Deposition Potential – Stage I Construction, 50th Percentile Flow, Stephens Lake Level – 141.1 m ..... 7-54

Map 7.4-3: Deposition Potential – Stage II Construction, 50th Percentile Flow, Stephens Lake Level = 141.1 m..... 7-55

Map 7.4-4: Spatial Distribution of Depth Averaged Sediment Concentration – Year 1 After Impoundment - 50th Percentile Flow (Base Loaded)..... 7-56

Map 7.4-5: Spatial Distribution of Depth Averaged Sediment Concentration – Year 5 After Impoundment - 50th Percentile Flow (Base Loaded)..... 7-57

Map 7.4-6: Spatial Distribution of Depth Averaged Sediment Concentration – Year 15 After Impoundment - 50th Percentile Flow(Base Loaded)..... 7-58

Map 7.4-7: Spatial Distribution of Depth Averaged Sediment Concentration – Year 30 After Impoundment - 50th Percentile Flow (Base Loaded)..... 7-59

Map 7.4-8: Spatial Distribution of Depth Averaged Sediment Concentration – Year 1 After Impoundment - 95th Percentile Flow (Base Loaded)..... 7-60

Map 7.4-9: Spatial Distribution of Depth Averaged Sediment Concentration – Year 5 After Impoundment - 95th Percentile Flow (Base Loaded)..... 7-61

Map 7.4-10: Spatial Distribution of Depth Averaged Sediment Concentration – Year 1 After Impoundment – 50th Percentile Flow (Peaking)..... 7-62

Map 7.4-11: Spatial Distribution of Depth Averaged Sediment Concentration – Year 5 After Impoundment – 50th Percentile Flow (Peaking)..... 7-63

Map 7.4-12: Spatial Distribution of Depth Averaged Sediment Concentration – Year 1 After Impoundment – 95th Percentile Flow (Peaking)..... 7-64

Map 7.4-13: Spatial Distribution of Depth Averaged Sediment Concentration – Year 5 After Impoundment – 95th Percentile Flow (Peaking)..... 7-65

Map 7.4-14: Changes in Depth Averaged Sediment Concentration – Year 1 to 5 After Impoundment – 50th Percentile Flow (Base Loaded)..... 7-66

Map 7.4-15: Changes in Depth Averaged Sediment Concentration – Year 5 to 15 After Impoundment – 50th Percentile Flow (Base Loaded)..... 7-67

Map 7.4-16: Changes in Depth Averaged Sediment Concentration – Year 15 to 30 After Impoundment – 50th Percentile Flow (Base Loaded)..... 7-68

Map 7.4-17: Mineral Sediment Deposition – Year 1 After Impoundment (Base Loaded) ..... 7-69

Map 7.4-18: Nearshore Mineral Sediment Deposition – Year 1 After Impoundment (Base Loaded) ..... 7-70

Map 7.4-19: Nearshore Mineral Sediment Deposition – Year 5 After Impoundment (Base Loaded) ..... 7-71

Map 7.4-20: Nearshore Mineral Sediment Deposition – Year 15 After Impoundment (Base Loaded) ..... 7-72



Map 7.4-21: Nearshore Mineral Sediment Deposition – Year 30 After Impoundment (Base Loaded).....7-73

Map 7.4-22: Nearshore Mineral Sediment Deposition – Year 1 After Impoundment (Peaking).....7-74

Map 7.4-23: Nearshore Mineral Sediment Deposition – Year 5 After Impoundment (Peaking).....7-75

Map 7.4-24: Nearshore Mineral Sediment Deposition – Year 15 After Impoundment (Peaking).....7-76

Map 7.4-25: Nearshore Mineral Sediment Deposition – Year 30 After Impoundment (Peaking).....7-77

Map 7.4-26: Deposition Potential – Post-Project Environment, All 7 Units Best Gate, Stephens Lake Level = 141.1 m .....7-78

Map 7.4-27: Total Mobile Organic Material in Each Zone – Year 1 After Impoundment.....7-79

Map 7.4-28: Peat Transport by Wind Driven Current – Year 1 After Impoundment, May to July.....7-80

Map 7.4-29: Peat Transport by Wind Drive Current – Year 1 After Impoundment, August to October .....7-81

Map 8.2-1: Selected Assessment Area .....8-33

Map 8.2-2: Data Used in Study Area .....8-34

Map 8.3-1: Simulated Groundwater Level Without Project (typical Year, 50th percentile).....8-35

Map 8.3-2: Simulated Groundwater Depths Without Project (typical year, 50th percentile).....8-36

Map 8.3-3: Simulated Groundwater Depths Without Project (high river flows and wet year, 50th percentile).....8-37

Map 8.3-4: Simulated Groundwater Depths Without Project (low river flows and dry year, 50th percentile).....8-38

Map 8.4-1: Simulated Groundwater Level With Project (typical year, 50th percentile) .....8-39

Map 8.4-2a: Simulated Groundwater Depths With Project (typical year, 50th percentile).....8-40

Map 8.4-2b: Simulated Groundwater Depths With Project (typical year, 50th percentile).....8-41

Map 8.4-3a: Simulated Groundwater Depths With Project (high river flows and wet year, 50th percentile).....8-42

Map 8.4-3b: Simulated Groundwater Depths With Project (high river flows and wet year, 50th percentile).....8-43

Map 8.4-4a: Simulated Groundwater Depths With Project (low river flows and dry year, 50th percentile).....8-44

Map 8.4-4b: Simulated Groundwater Depths With Project (low river flows and dry year, 50th percentile).....8-45

Map 8.4-5: Predicted Future Change in Groundwater Regime (Typical Year, 50th Percentile).....8-46

Map 8.4-6: Predicted Future Change in Groundwater Regime (High River Flows and Wet Year, 50th Percentile) .....8-47

Map 8.4-7: Predicted Future Change in Groundwater Regime Upstream of Gull Lake (Typical Year, 50th Percentile).....8-48

Map 8.4-8: Predicted Future Change in Groundwater Regime Gull Lake and Downstream (Typical Year, 50th Percentile) .....8-49

Map 9.2-1: Study Area.....9-41

Map 9.2-2: Data Collection Sites .....9-42

Map 9.4-1: Depth Averaged Water Temperature, Worst Case – Year 1 Summer .....9-43

Map 9.4-2: Depth Averaged DO, Expected Year 1, Average Typical Week.....9-44



Map 9.4-3: Depth Averaged DO, Expected Year 1, Critical Week ..... 9-45

Map 9.4-4: Depth Averaged DO, Expected Year 1 Critical Week, Peaking Mode of Operation ..... 9-46

Map 9.4-5: Depth Averaged DO, Expected Year 5, Critical Week ..... 9-47

Map 9.4-6: Depth Averaged DO, Expected Year 1 Winter ..... 9-48

Map 9.4-7: Depth Averaged DO, Year 1 Winter, Peaking Mode of Operation ..... 9-49

Map 10.2-1: Keeyask Study Area ..... 10-30

Map 10.3-1: Shoreline Debris Map – Summer 2003, Reach 1: Clark Lake to Gull Lake ..... 10-31

Map 10.3-2: Shoreline Debris Map – Summer 2003, Reach 2: Gull Lake to Stephens Lake ..... 10-32

Map 10.3-3: Shoreline Debris Map – September 1, 2008 ..... 10-33

Map 10.4-1: Keeyask Reservoir Clearing Plan – Pre-Flooding Phase ..... 10-34

Map 10.4-2: Keeyask Reservoir Clearing Plan – Post-Flooding Phase ..... 10-35



This page is intentionally left blank.

# LIST OF PHOTOS

	<b>Page</b>
Photo 4.2-1: Outlet of Portage Creek (left) and Rabbit (Broken Boat) Creek (right).....	4-19
Photo 4.3-1: Outlet of Split Lake.....	4-24
Photo 4.3-2: Turbulent Reach Between Clark Lake and Birthday Rapids .....	4-25
Photo 4.3-3: Birthday Rapids.....	4-25
Photo 4.3-4: Gull Lake .....	4-26
Photo 4.3-5: Nelson River Flow Split Around Caribou Island.....	4-27
Photo 4.3-6: Nelson River Flow Splits Through Gull Rapids .....	4-28
Photo 4.3-7: Gull Rapids During Open Water Conditions.....	4-29
Photo 4.3-8: Typical Ice Pan Density, Upstream Of Gull Rapids (Looking Downstream) .....	4-40
Photo 4.3-9: Typical Ice Bridging Point Near Gull Lake (Looking Downstream).....	4-40
Photo 4.3-10: Remnants of Pack Ice on the Shore.....	4-43
Photo 4.3-11: Typical Hanging Dam Downstream of Gull Rapids (Looking Upstream).....	4-49
Photo 6.1-1: Peat Shoreline on the Nelson River that is Formed by Inland Peatlands.....	6-4
Photo 6.1-2: Example of Shoreline Peatlands in Off-System Lakes and Streams.....	6-5
Photo 6.1-3: Example of Flooded Peatlands and Peat Resurfacing.....	6-6
Photo 6.3-1: Common Peatland and Mineral Ecosite Types in the Keeyask Reservoir Area .....	6-22
Photo 7.3-1: An Example of High Suspended Sediment Concentration in Nearshore Areas .....	7-16
Photo 10.2-1: Example of Densely Distributed Beached Woody Debris Found on the South Shore of Gull Lake .....	10-3
Photo 10.2-2: Beached Debris that is of Light Density and Sparsely Distributed.....	10-4
Photo 10.2-3: Medium Density Floating as well as Light Submerged Debris can be seen here on the North Shore of Gull Lake.....	10-4
Photo 10.2-4: Leaning Trees of Medium Density on the North Shore of Gull Lake.....	10-5
Photo 10.2-5: Medium Density Standing Dead Trees in an Inlet on the North Side of the Nelson River .....	10-5
Photo 10.3-1: Eroding Mineral Soil Bank Between Clark Lake and Birthday Rapids. Photo Taken 19 September 2007.....	10-8
Photo 10.3-2: High Banks, South Side of Caribou Island, in Gull Lake Upstream from Gull Rapids .....	10-9
Photo 10.3-3: Localized Slope Failure in Mineral Soil Bank Between Clark Lake and Birthday Rapids. Photo Taken 19 September 2007 .....	10-9
Photo 10.3-4: Example of Low Eroding Mineral Soil Bank and Ice-Scour Zone Below Trees in River Reach Between Birthday Rapids and Gull Lake .....	10-10
Photo 10.3-5: Example of River Ice Bull Dozing Trees Along Shoreline .....	10-11
Photo 10.3-6: Example of Border Ice Collapsing Onto Shore Zone Where Woody Debris is Pulled into the River by the Ice.....	10-11

This page is intentionally left blank.

# ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	
AE SV	Aquatic Environment Supporting Volume
asl	Above sea level
ATK	Aboriginal traditional knowledge
ATV	All terrain vehicles
BC	British Columbia
BOD	Biochemical oxygen demand
CCME	Canadian Council of Ministers of the Environment
CEAA	Canadian Environmental Assessment Agency
CNP	Cree Nation Partners (Tataskweyak Cree Nation (TCN), War Lake First Nation (WLFN))
CO	Carbon monoxide
CO <sub>2</sub>	Carbon dioxide
CRCM	Canadian Regional Climate Model
CRD	Churchill River Diversion
dB	Decibel (noise power)
dBa	Decibel- a weighted
DO	Dissolved oxygen
<i>e.g.</i>	Example
EA	Environmental assessment
EC	Environment Canada
EIA	Environmental impact assessment
EIS	Environmental impact statement
EMPA	Excavated Material Placement Area
EnvPP	Environmental protection plan
EPA	Environmental Protection Agency
<i>et al.</i>	and others
FLCN	Fox Lake Cree Nation
FSL	Full Supply Level
GHG	Greenhouse gas
GIS	Geographic Information System
GPS	Global positioning system
GS	Generating Station
HVDC	High Voltage Direct Current
HZI	Hydraulic Zone of Influence
<i>i.e.</i>	in other words
IEZ	Intermittently exposed zone
IPCC	Intergovernmental Panel on Climate Change
JKDA	Joint Keeyask Development Agreement
KCN	Keeyask Cree Nations communities including Tataskweyak Cree Nation (TCN), War Lake First Nation (WLFN), York Factory First Nation (YFFN), and Fox Lake Cree Nation (FLCN).
KIP	Keeyask Infrastructure Project
LCA	Life Cycle Assessment
LWR	Lake Winnipeg Regulation

<b>Acronym / Abbreviation</b>	
MB	Manitoba
MH	Manitoba Hydro
MIT	Manitoba Infrastructure and Transportation
MOL	Minimum operating level
MWQSOG	Manitoba Water Quality Standards, Objectives, and Guidelines
NO <sub>x</sub>	Nitrogen oxides ( <i>e.g.</i> , NO <sub>2</sub> , NO <sub>3</sub> )
NPRI	National Pollutant Release Inventory
PD SV	Project Description Supporting Volume
PE SV	Physical Environment Supporting Volume
PEMP	Physical Environment Monitoring Program
PI SV	Public Involvement Supporting Volume
PM	Particulate Matter
PR	Provincial Road
PTH	Provincial Trunk Highway
QA/QC	Quality assurance/quality control
RCM	Regional Climate Model
SE SV	Socio-Economic Environment, Resource Use and Heritage Resources Supporting Volume
SO <sub>2</sub>	Sulphur dioxide
SOD	Sediment Oxygen Demand
SV	Supporting Volume
TCN	Tataskweyak Cree Nation
TDS	Total Dissolved Solids
TE SV	Terrestrial Environment Supporting Volume
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
VEC	Valued Environmental Component
VOC	Volatile organic compounds

# LIST OF UNITS

<b>List of Units</b>	
<b>Unit</b>	<b>Abbreviation</b>
centimetre	cm
cubic centimetre	cm <sup>3</sup>
cubic metre	m <sup>3</sup>
cubic metre per second	m <sup>3</sup> /s
day	d
days per week	d/wk
days per year	d/y
degrees Celsius	°C
gigajoule	GJ
gigawatt	GW
gigawatt-hours	GWh
gram	g
grams per litre	g/L
grams per square metre	g/m <sup>2</sup>
grams per tonne	g/t
greater than	>
greater than or equal to	≥
hectare (10,000 m <sup>2</sup> )	ha
hertz	Hz
hour	h
hours per day	h/d
hours per week	h/wk
hours per year	h/y
inch	"
joule	J
kilogram	kg
kilograms per cubic metre	kg/m <sup>3</sup>
kilograms per hour	kg/h
kilograms per square metre	kg/m <sup>2</sup>
kilojoule	kJ
kilometre	km
kilometres per hour	km/h
kilopascal	kPa
kilovolt	kV
kilowatt	kW
Kilowatt-hour	kWh
less than	<
less than or equal to	≤
litre	L
megawatt	MW
megawatt-hour	MWh
metre	m
metres per second	m/s

<b>List of Units</b>	
<b>Unit</b>	<b>Abbreviation</b>
metric ton (tonne)	t
milligram	mg
milligrams per litre	mg/L
millimetre	mm
million	M
percent	%
second (time)	s
square centimetre	cm <sup>2</sup>
square kilometre	km <sup>2</sup>
square metre	m <sup>2</sup>
tonne (metric ton)	t
week	wk
year	y