Keeyask Generation Project

Physical Environment Monitoring Plan

Physical Environment Monitoring Report

PEMP-2015-01

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KEEYASK GENERATION PROJECT

PHYSICAL ENVIRONMENT MONITORING PLAN

REPORT #PEMP–2015–01

2014 – 2015 Physical Environment Monitoring Report: Year 1 Construction

Prepared for

Manitoba Hydro

By

Water Resources Engineering Department and

Environmental Licensing & Protection Department

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SUMMARY

BACKGROUND

The Keeyask Generation Project (the Project) involves the construction and operation of the Keeyask Generating Station (GS) at Gull Rapids. In order to obtain a license to construct the GS and before construction began in July 2014, the Keeyask Hydropower Limited Partnership (KHLP) prepared a plan to monitor the effects of the Project on the physical environment. Monitoring results will help the KHLP, government regulators, members of local First Nation communities, and the general public understand how GS construction and operation affects the physical environment. Monitoring will help determine if the actual effects are consistent with predicted effects reported in the Project's environmental impact statement.

The Keeyask Physical Environment Monitoring Plan (PEMP) discusses planned monitoring during the Project's first year of construction, which include monitoring of water and ice regimes, shoreline erosion and reservoir expansion, sedimentation, debris and greenhouse gases. This report describes the 2014/15 physical environment monitoring activities and results.

WATER AND ICE REGIME

The water and ice regime monitoring parameters include water levels, water depth / river and lake-bottom elevation, water velocity, and ice cover, however velocity and depth/elevation monitoring is not planned until after the reservoir is filled.

After receiving approval for the project in the summer of 2014, six automated, continuous water level gauges were installed on the Nelson River between Clark Lake and Gull Rapids to monitor water levels during the construction of the Project.

The river discharge between July 2014 and March 2015 was above average and ranged from approximately 3,500 m^3/s (cubic metres per second) to 6,000 m^3/s (124,000 to 212,000 cubic feet per second). This is the equivalent of 1.4 to 2.4 Olympic sized swimming pools every second. Although the Project does not affect the amount of water flowing in the Nelson River, knowing the amount of water flowing in the river helps to understand water level changes and if they are due to changes in flow or because of the Project.

River diversion measures were implemented to divert water from construction areas in Gull Rapids. Construction of the north channel rock groin near the head of Gull Rapids diverted most of the flow to the south channel of Gull Rapids and caused an increase in upstream water levels. The water level in Gull Lake at the gauge at Caribou Island increased by approximately 1.3 metres (m) (4.3 feet). The amount of water level change due to this groin diminished in the upstream direction and caused no change in water levels at the gauge just downstream of Birthday Rapids and thus had no effects on levels further upstream. The observed water level increases were consistent with the predicted increases due to the north channel rock groin.

North channel rock groin under construction, August 2015

In winter, water levels at the gauge site at the upstream end of Gull Lake experienced maximum increases of almost 5 m (16.4') and about 4 m (13') at Birthday Rapids due to ice. The increases diminished upstream. Based on observed water level conditions, neither Clark Lake nor Split Lake water levels were affected as a result of the Project. The observed increases were consistent with those anticipated without the Keeyask Project during a high flow winter in which an ice bridge forms on Gull Lake and an upstream ice cover develops.

It was anticipated that each winter during construction an ice cover would develop between the head of Gull Rapids to at least Birthday Rapids due to the installation of an ice-boom across the river just upstream of Gull Rapids. Satellite imagery was used to monitor the extents of ice cover development over the winter. An ice cover did not develop upstream of the boom early in the winter as planned because the ice boom partially failed. As a result, a rough, thick ice cover developed downstream at the entrance to Stephens Lake and grew in an upstream direction to the base of Gull Rapids similar to conditions that have occurred under high flow conditions without the Project.

SHORELINE EROSION AND RESERVOIR EXPANSION

The largest changes in shoreline erosion rates are predicted to occur within the Gull Lake area of the reservoir during the initial impoundment and in the first year of operation. The rate of reservoir expansion due to erosion is predicted decrease over time after the reservoir is impounded.

High resolution satellite imagery was collected to mark the location of the shoreline/top of bank at the start of the construction period. It is planned to collect this information in future years after the creation of the reservoir to monitor the shoreline erosion and reservoir expansion.

SEDIMENTATION

Sedimentation monitoring includes monitoring the transport and deposition of sediment in the water. Sediment transport monitoring is done through the collection of river/lake water samples to measure the amount of sediment in the water (done in a laboratory), continuous turbidity monitoring and monitoring of sediment moving along the river bed. Sediment traps are used to monitor deposition.

Turbidity monitoring is done with a turbidity sensor that is placed into the water that measures the murkiness of the water. It is a convenient parameter to monitor as the data can be collected on an automated, continuous basis without collecting samples for laboratory analysis.

Placing a turbidity sensor at a monitoring site

A sediment trap generally consists of open-ended plastic tubes that sit on the lake bed with the tube standing vertically. Sediment settling through the water column enters the open end of the tube and is retained in it until the tube is recovered.

Between Clark Lake and the Kettle GS, continuous turbidity meters were installed at five locations in summer and three locations in winter. Sediment traps were also placed at two locations to monitor deposition in the waterway while two additional sites were monitored to obtain samples of sediment moving along the bottom of the river. No effects on sediment transport were observed in the summer period of 2014.

Continuous turbidity monitoring site – turbidity sensors suspended below catamaran that supports solar power panel and electronics housing

DEBRIS

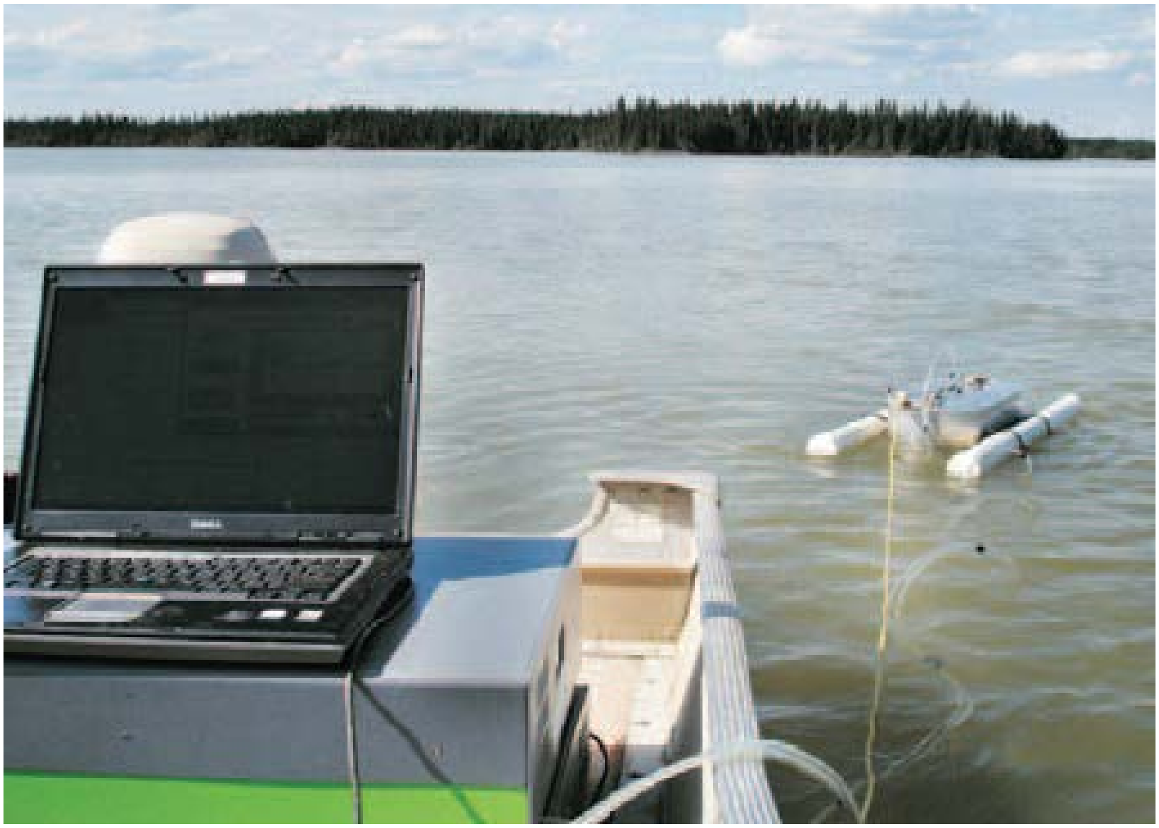
Manitoba Hydro operates waterway management programs that are implemented locally on various water bodies to monitor and remove debris. Debris such as floating logs and branches are monitored and removed where it poses a safety hazard to navigation along the waterway in the Project area.

With the start of the project there is an increased focus on managing debris in the project area between Clark Lake and Stephens Lake. The amount of debris removed by the waterways management team in 2014 was within the range of debris amounts recorded in previous years.

GREENHOUSE GAS

Studies indicate that greenhouse gas emissions from boreal hydroelectric reservoirs, such as the Keeyask reservoir, will increase shortly after flooding and return towards levels similar to those of natural water bodies within a period of approximately 10 years following impoundment.

Emission of greenhouse gases, primarily carbon dioxide and methane, were monitored in the waterway to confirm the amount of greenhouse gas emissions from the water prior to flooding. Monitoring results showed that emissions levels in 2014/15 were similar to emissions observed in previous years.



Measuring greenhouse gas emissions

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1.0 INTRODUCTION

Construction of the Keeyask Generation Project (the Project), a 695 megawatt hydroelectric generating station (GS) and associated facilities, began in July 2014. The Project is located at Gull Rapids on the lower Nelson River in northern Manitoba where Gull Lake flows into Stephens Lake, 35 km upstream of the existing Kettle GS.

The *Keeyask Generation Project: Response to EIS Guidelines* (EIS), completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the physical environment and a summary of proposed monitoring and follow-up programs are provided in the *Keeyask Generation Project Environmental Impact Statement: Physical Environment Supporting Volume* (PE SV). As part of the licensing process for the Project, a Physical Effects Monitoring Plan (PEMP) was developed detailing the monitoring activities of various components of the physical environment.

This report describes the physical environment monitoring completed from July 2014 to March 2015, the first year of construction monitoring. The monitoring was completed as per the preliminary Keeyask Physical Environment Monitoring Plan (PEMP) (KHLP, 2013). The PEMP is expected to be finalized in 2015 based on regulatory reviews, which may result in modifications to some of the monitoring requirements.

The physical environment is defined as the physical and chemical make-up of an ecosystem and describes the area where things live and includes the air, water and land within the ecosystem. The PEMP provides details on monitoring and follow-up related to the physical environment based on the assessment and feedback received through the regulatory process. Monitoring and follow-up activities focus on effects to key components of the physical environment to:

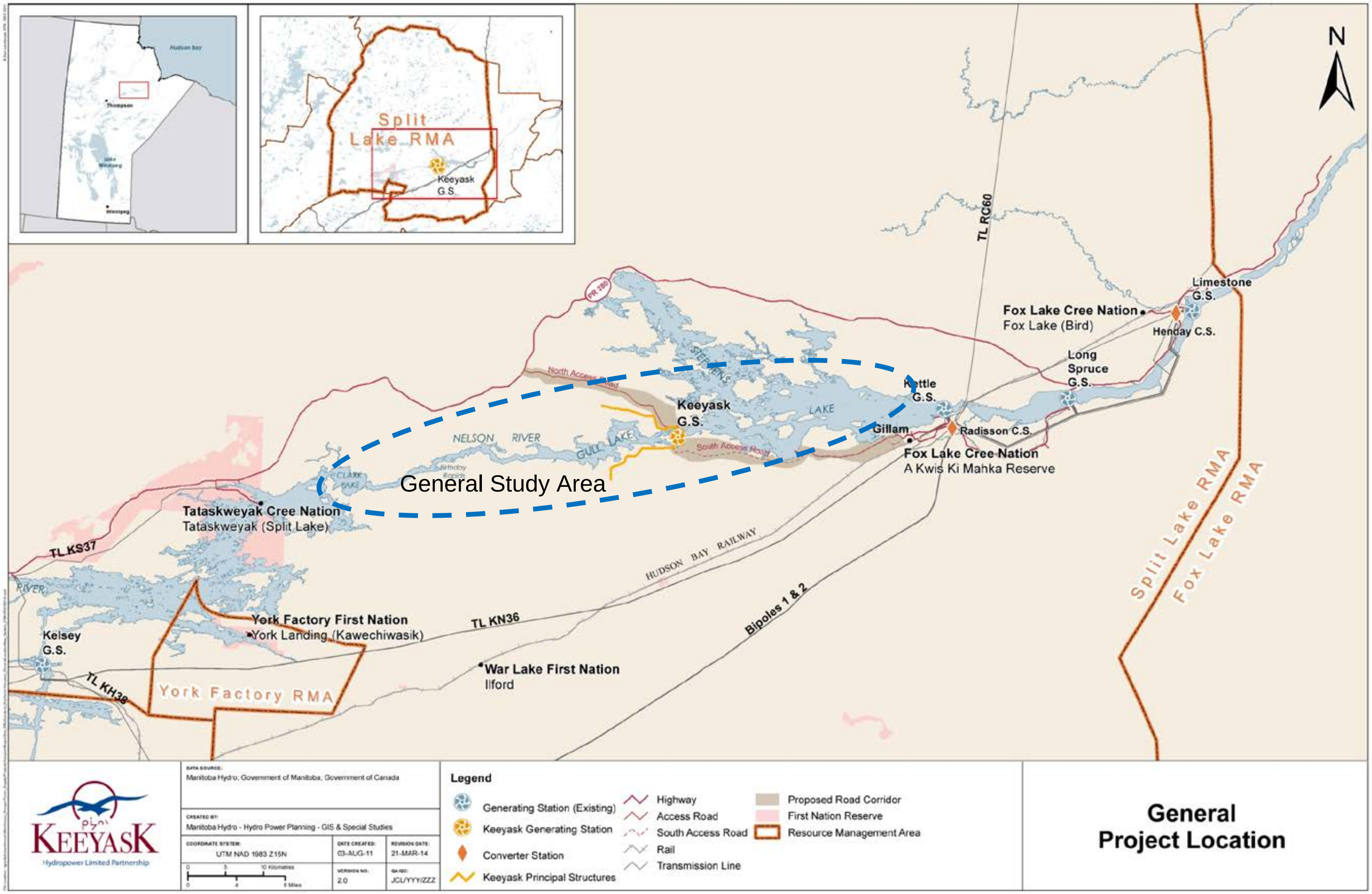
- Determine if EIS predictions of Project effects on the physical environment are correct and to identify unanticipated effects.
- Support other monitoring programs (e.g., aquatic and terrestrial) that will monitor Project effects and determine the effectiveness of mitigation/offsetting measures.

The environmental components that will be monitored under the PEMP include the following:

- surface water (level/depth) and ice-regimes,
- shoreline erosion and reservoir expansion,
- sedimentation (related to water quality, sediment transport and deposition),
- greenhouse gas,
- woody debris,
- surface water temperature and dissolved oxygen (related to water quality and aquatic habitat), and

- total dissolved gas pressure.

In 2014/15 physical environment monitoring included surface water and ice regime, shoreline, sedimentation, greenhouse gas and woody debris monitoring. Monitoring for surface water temperature and dissolved oxygen, and total dissolved gas pressure will begin after the reservoir is impounded. The PEMP provides a schedule of the physical environment monitoring activities planned during the construction and operation periods of the Keeyask Generation Project. The study area extends generally from Clark Lake into Stephens Lake near the Kettle Generating Station as shown in Map 1.



Map 1: **General Project Location and Study Area**

2.0 SURFACE WATER AND ICE REGIMES

The water regime and ice parameters include water levels, water depth / river and lake-bottom elevation, water velocity, and ice cover. The largest changes to water and ice regimes are expected to occur once the reservoir has been impounded and include increases in water levels, reduction of velocities and development of a smoother ice cover. During the construction period, water levels are expected to increase from the construction of cofferdams used to isolate construction areas and an ice cover is expected to develop earlier from the installation of an ice boom.

The objectives of the water and ice regime monitoring include:

- determining water level regime and verifying expected changes in water levels resulting from the Project;
- confirming that there are no unanticipated Project effects on Split Lake water levels;
- determining water depth/bottom elevation and velocity information to support monitoring being performed under the AEMP;
- measuring ice conditions to support understanding of winter water levels, which may be affected by ice processes; and
- confirming that future ice conditions during operation are consistent with predicted effects reported in the EIS.

2.1 NELSON RIVER FLOW CONDITIONS

River discharge (flow) is represented by the outflow from Split Lake. Small streams that flow into the monitoring area between Clark Lake and Gull Lake typically contribute less than 3% of the total flow and are not included in the total flow. River flow rates are correlated to water levels (i.e. high flow rates result in high water levels); however water levels are also influenced by ice conditions in the study reach and the relationship between flow and water levels changes in winter months. The Project will not affect the amount of water flowing in the Nelson River.

The historical daily flow records have been analyzed to characterize flow conditions since September 1, 1977 and represent regulated flow conditions since Lake Winnipeg Regulation and Churchill River Diversion began operating.

Flow in the Nelson River has generally been high since the start of construction in mid July, 2014 (Figure 1). River discharge between July 2014 and March 2015 was above average and ranged from approximately 3,500 m^3/s (cubic metres per second) to 6,000 m^3/s (124,000 to

212,000 cubic feet per second). This is the equivalent of 1.4 to 2.4 Olympic sized swimming pools every second (an Olympic Pool holds 2,500 m^3 of water).

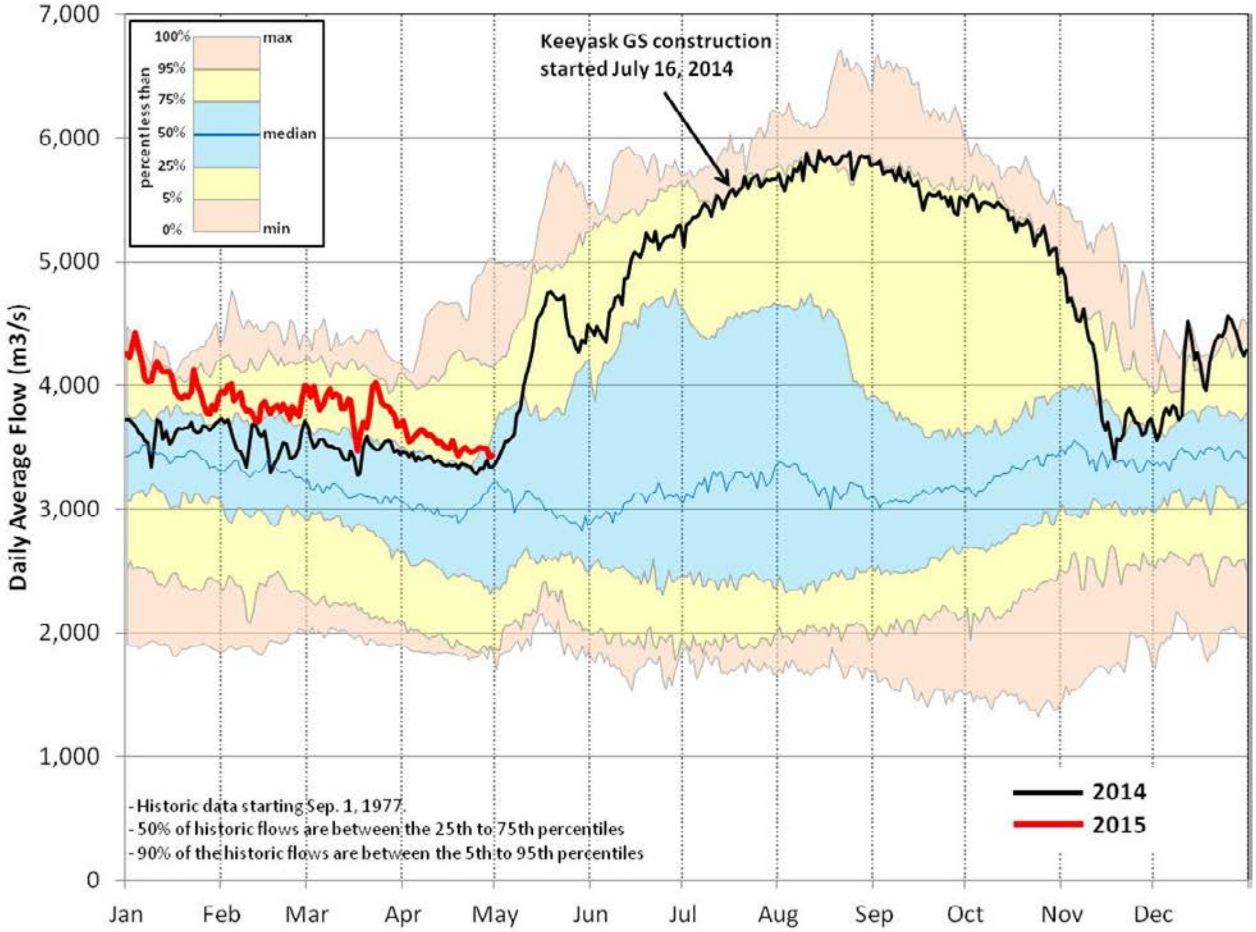
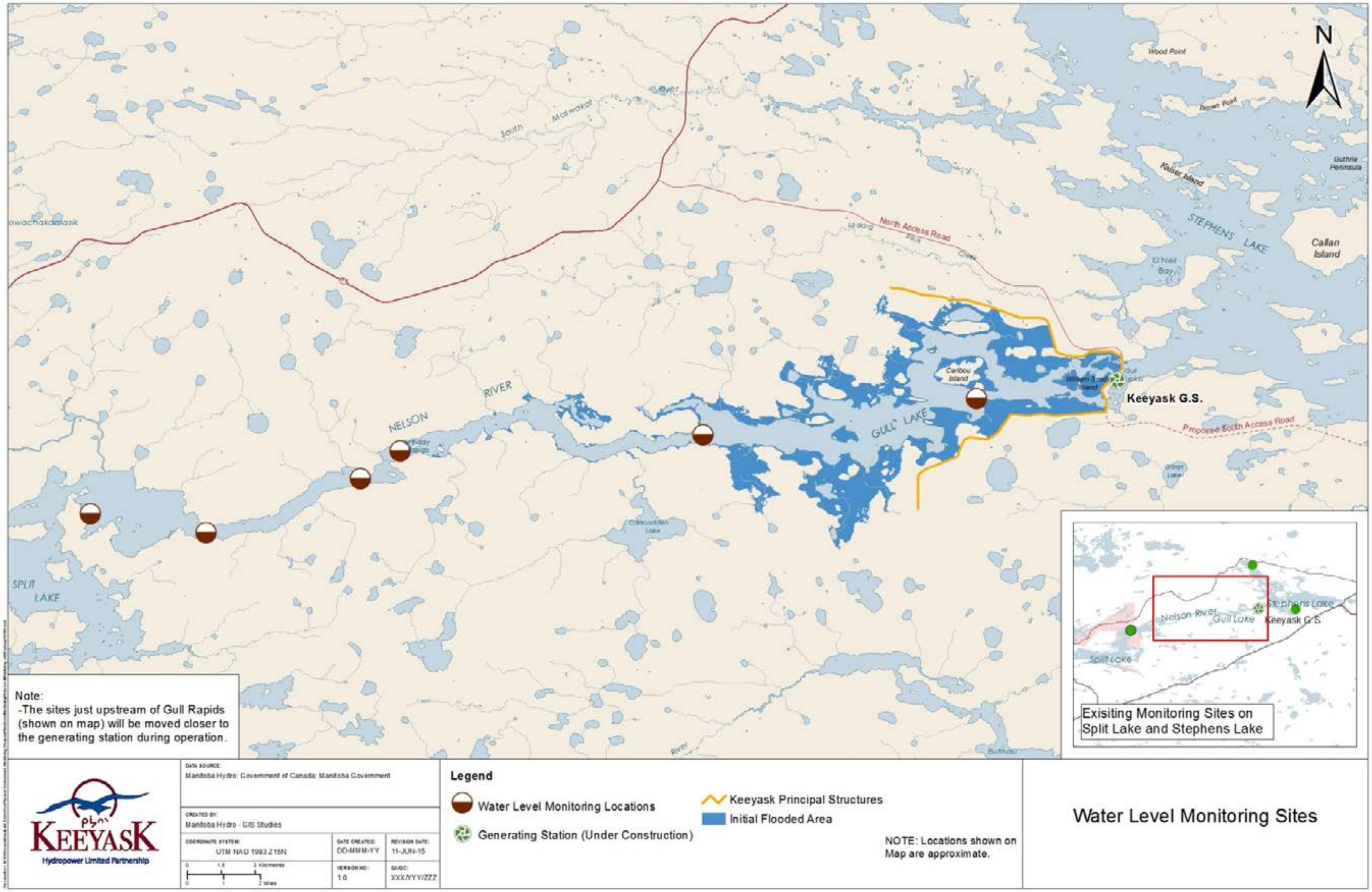


Figure 1: Split Lake 2014/15 Daily Average Outflow and Historical Statistics

2.2 WATER LEVELS

Water levels have been monitored at six sites in the study area from Clark Lake to Gull Rapids (Table 1, Map 2). A typical water level gauge is shown in Photo 1. The two Clark Lake sites have been monitored regularly since 2003, while the Gull Lake gauge was installed at the start of construction in mid July. The other three sites were installed once the necessary permits and heritage surveys were complete, which were applied for and done after the environment act licence was received in early July.

The 2014/15 water level records at each PEMP monitoring site are shown in Figure 2. The site upstream of Birthday Rapids has some data gaps and irregular readings during the winter due to interference from ice crystals. The water level data may be subject to further review and revision.



Map 2: PEMP Water Level Monitoring Sites

Table 1: List of Water Level Monitoring Sites

Site ID	Name	Start of Record	Notes
05UF766	Clark Lake	Oct. 2003	4 km above outlet
05UF759	downstream of Clark Lake	Dec. 2003	1.9 km below outlet
05UF770	upstream of Birthday Rapids	Oct. 2014	1.1 km above rapids
05UF771	downstream of Birthday Rapids	Oct. 2014	2.1 km below rapids
05UF749	upstream Gull Lake	Oct. 2014	0.26 km above lake
05UF596	Gull Lake	Jul. 2014	7 km above Gull Rapids
05UF701	Split Lake at Split Lake Community	Oct. 1997	existing site

Photo 1: Water Level Gauge Station in Winter

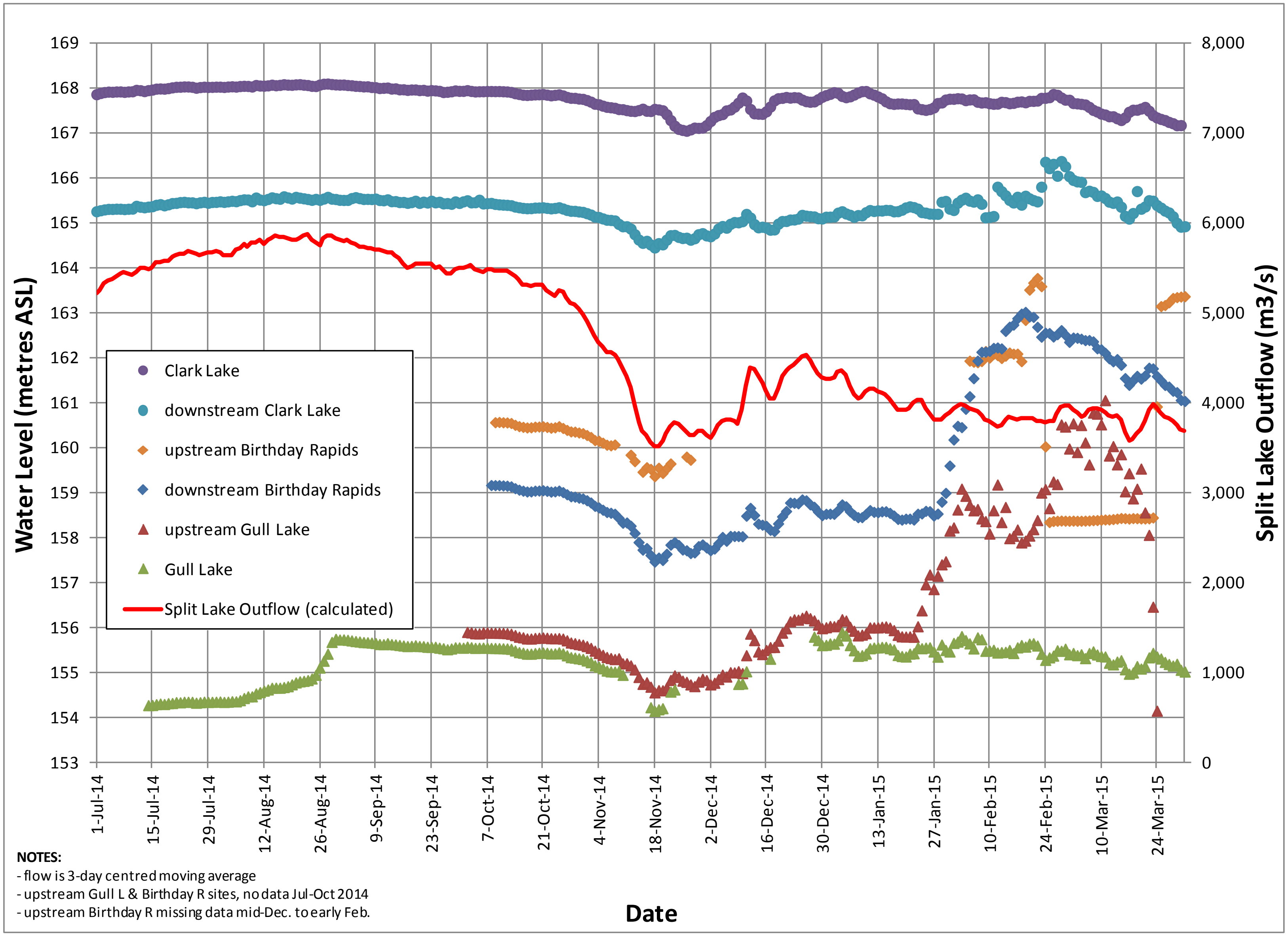


Figure 2: Observed Water Levels at PEMP Monitoring Sites in 2014/15

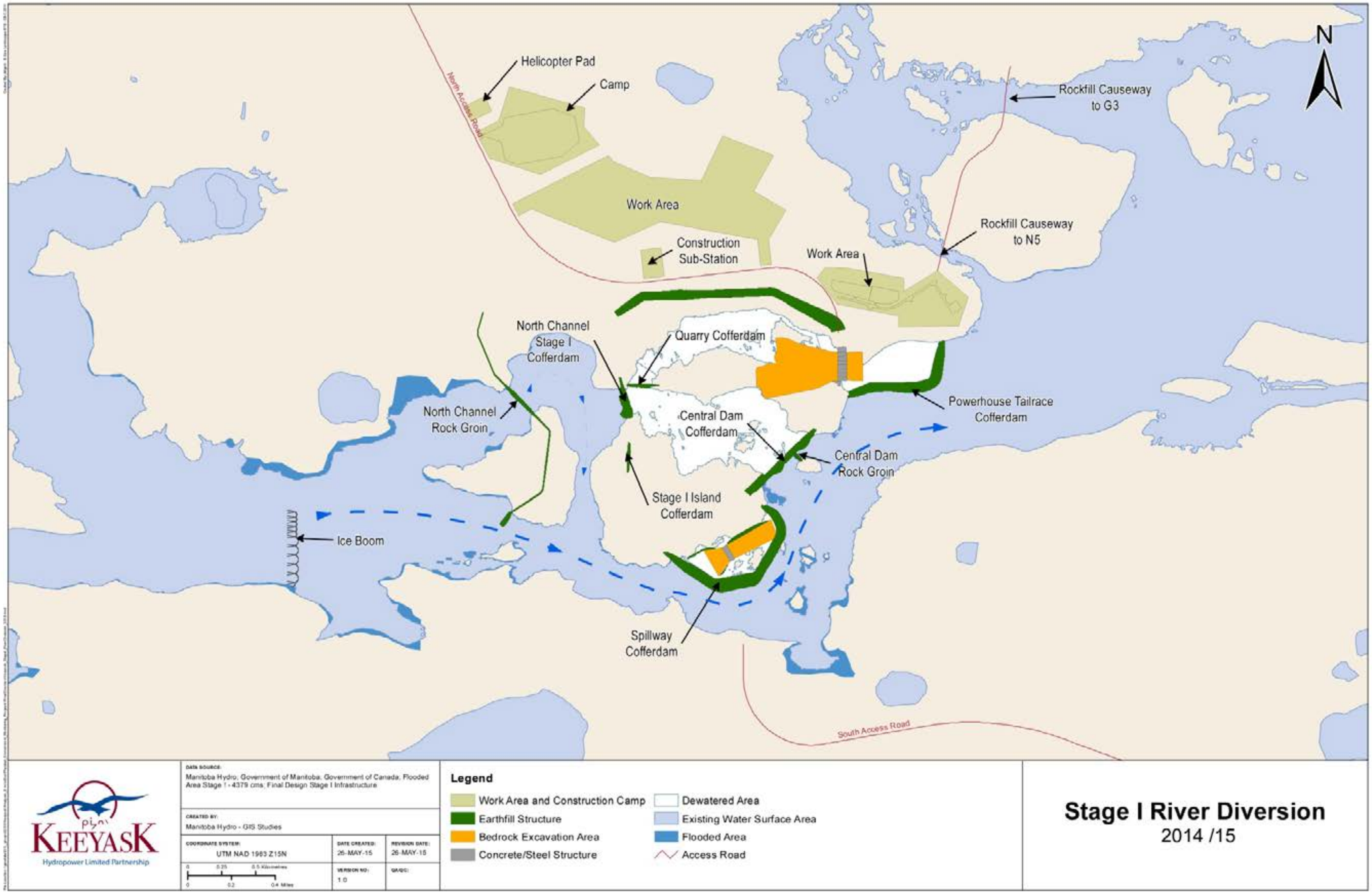
Water levels changed with variations in the flow (Figure 2) and were also affected by in-stream construction and ice processes in winter, as discussed below. Due to the high flows the water level at all sites have been generally well above average since the start of construction based on the seasonal and annual water level percentiles that were reported in the EIS (KHLP, 2012) which are summarized in Appendix A.

2.2.1 OBSERVED EFFECT OF NORTH CHANNEL ROCK GROIN ON WATER LEVELS AT PEMP MONITORING SITES

Map 3 shows the structures constructed as a part of the Stage I river diversion. The quarry cofferdam was the first structure constructed in the river and was completed in a few days. This structure dewatered the downstream portion of the north channel of Gull Rapids and altered flow in the rapids but did not affect levels upstream of Gull Rapids. Rock excavated from the dewatered area was used to construct the north channel rock groin across the north channel further upstream near the head of Gull Rapids. This structure was designed to raise upstream water levels on Gull Lake to create more favourable conditions for winter ice formation.

Construction of the north channel rock groin began on August 5 by placing rock in the river and by August 29 rock had been placed across the channel to the north shore of the central island (Photo 2). This rock groin caused most of the flow to be diverted to the south channel of Gull Rapids. Some water seeps through the groin because it is not designed to be sealed.

Photo 2: Construction of the North Channel Rock Groin



Map 3: Constructed In-Stream Structures 2014/15

Gull Lake levels gradually increased from about August 5-18 with increasing flow and in-stream rock placement (Figure 3). From about August 18-23 levels continued to rise due to rock placement while flows are steady. From about August 24-29 there is a steeper increase in Gull Lake level as the rock groin neared the opposite shore and finally closed the channel. Water level increased approximately 1.5 m from August 5-29 due to the flow increase and groin construction (Figure 3). The Gull Lake water level at a flow of about 5,400 m^3/s on October 5 is approximately 1.3 m higher than the level before construction on July 14 at roughly the same flow. The observed water level increases were consistent with the predicted increases.

Observed open water levels in October at the upstream Gull Lake and downstream Birthday Rapids sites were compared with modeled historic levels near the monitoring site. The comparisons indicate that the rock groin caused higher levels by about 0.4 m just upstream of Gull Lake but did not affect levels at the monitoring site located just downstream of Birthday Rapids for similar flows. It was predicted in the EIS (KHLP, 2012) that effects of the north channel rock groin on open water levels would diminish upstream of Gull Lake and would not affect levels at Birthday Rapids and further upstream, which is consistent with the observations. Map 4 shows the approximate extents of the peak water level increases resulting from the construction of the north channel rock groin.

2.2.2 OBSERVED EFFECTS OF WINTER STAGING ON WATER LEVELS AT PEMP MONITORING SITES

An ice boom was installed upstream of Gull Rapids to force the formation of an ice cover early in the winter upstream of the main construction site and to minimize winter water level increases at the foot of Gull Rapids adjacent to the construction area. A loss of a part of the ice boom, which is discussed further in Section 2.3, resulted in there being open water along the river from Clark Lake to Stephens Lake. This condition persisted until January 23 when ice bridged across the river at a location in Gull Lake.

Formation of the ice bridge and subsequent growth of the upstream ice cover had an immediate impact on water levels at the site upstream of Gull Lake. Prior to January 23 the levels at this site were consistently higher than Gull Lake by about 0.3-0.4 m (Figure 4). After the ice bridge formed, the water level at this site increased by 3 m within two weeks (Figure 4). Levels at this site remained elevated but variable through to the end of March with maximum staging in mid-March when the level is about 5 m higher than the levels observed prior to January 23.

About a week after the ice bridge formed the water levels downstream of Birthday Rapids also started to increase as the ice cover moved upstream. This increase is due to ice accumulation that restricts flow capacity in the river channel. The level at this site steadily increased until mid February when it was 4.5 m higher, after which it gradually declined by about 2 m to the end of March. While readings for the site upstream of Gull Rapids showed irregularities during this period due to the effects of ice particles on the monitoring equipment, the data does suggest

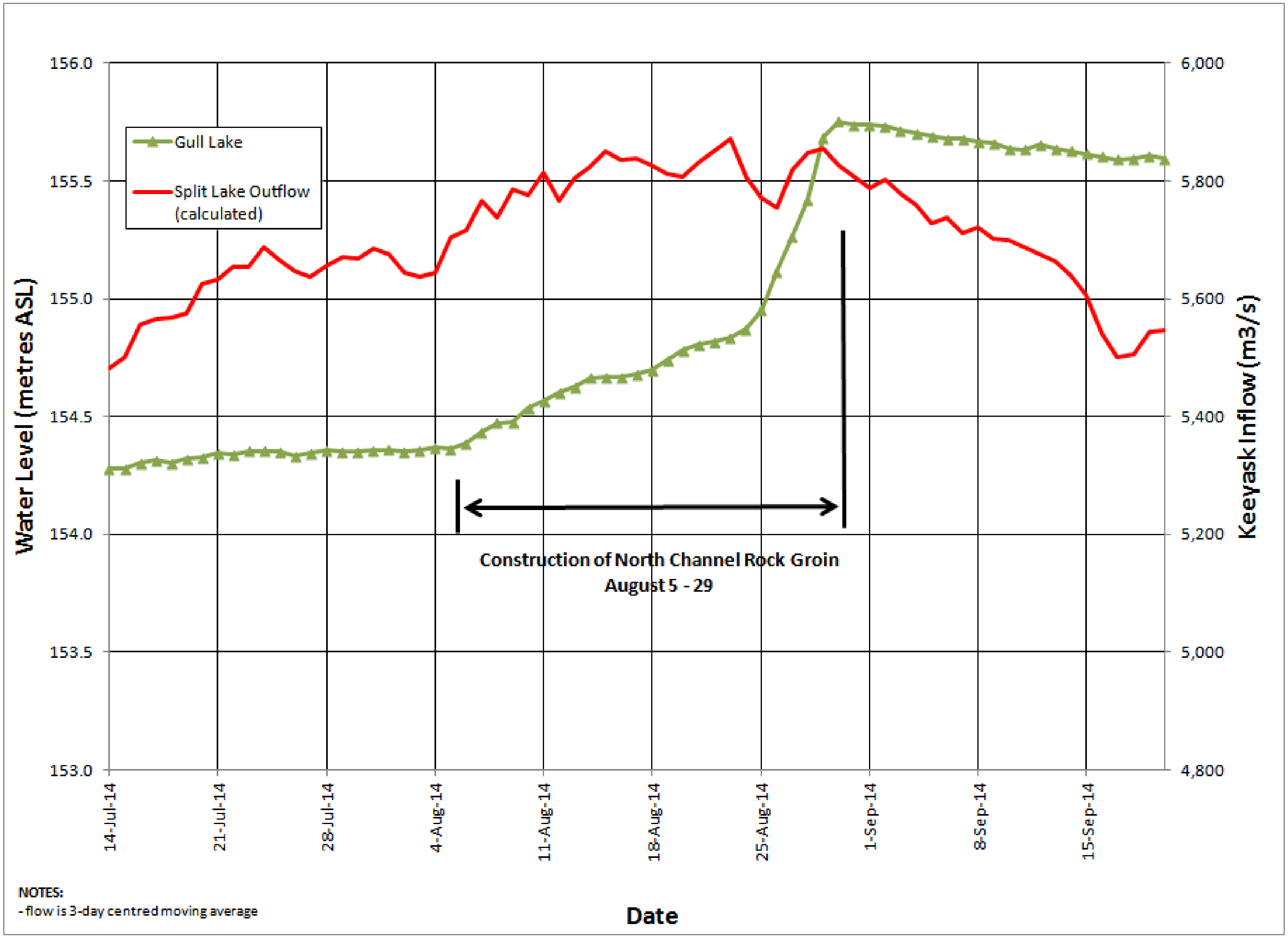
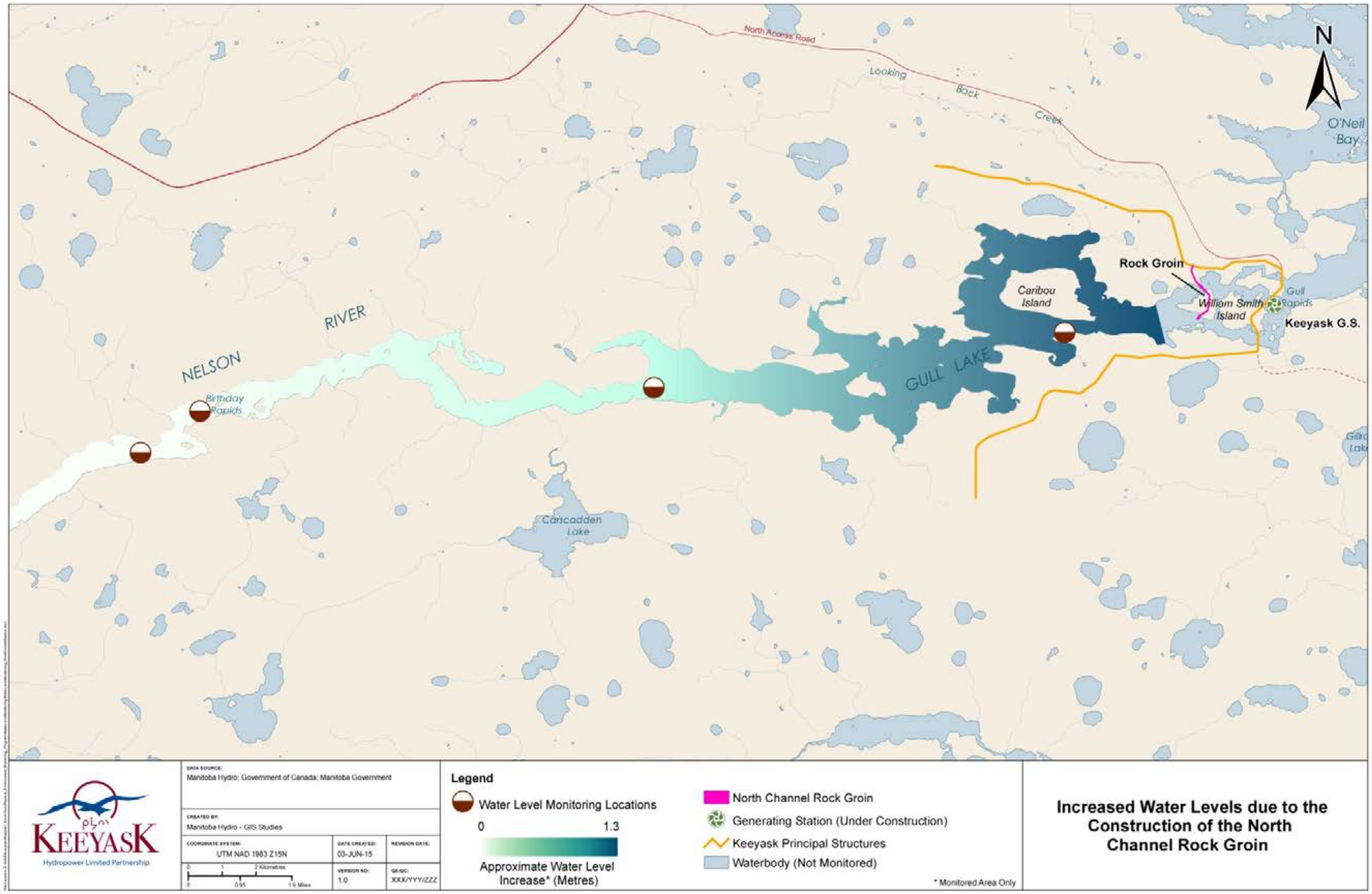


Figure 3: Gull Lake Water Level Increase during Construction of North Channel Rock Groin



NOTE: Locations shown on Map are approximate.

Map 4: Approximate Water Level Increases due to Construction of North Channel Rock Groin

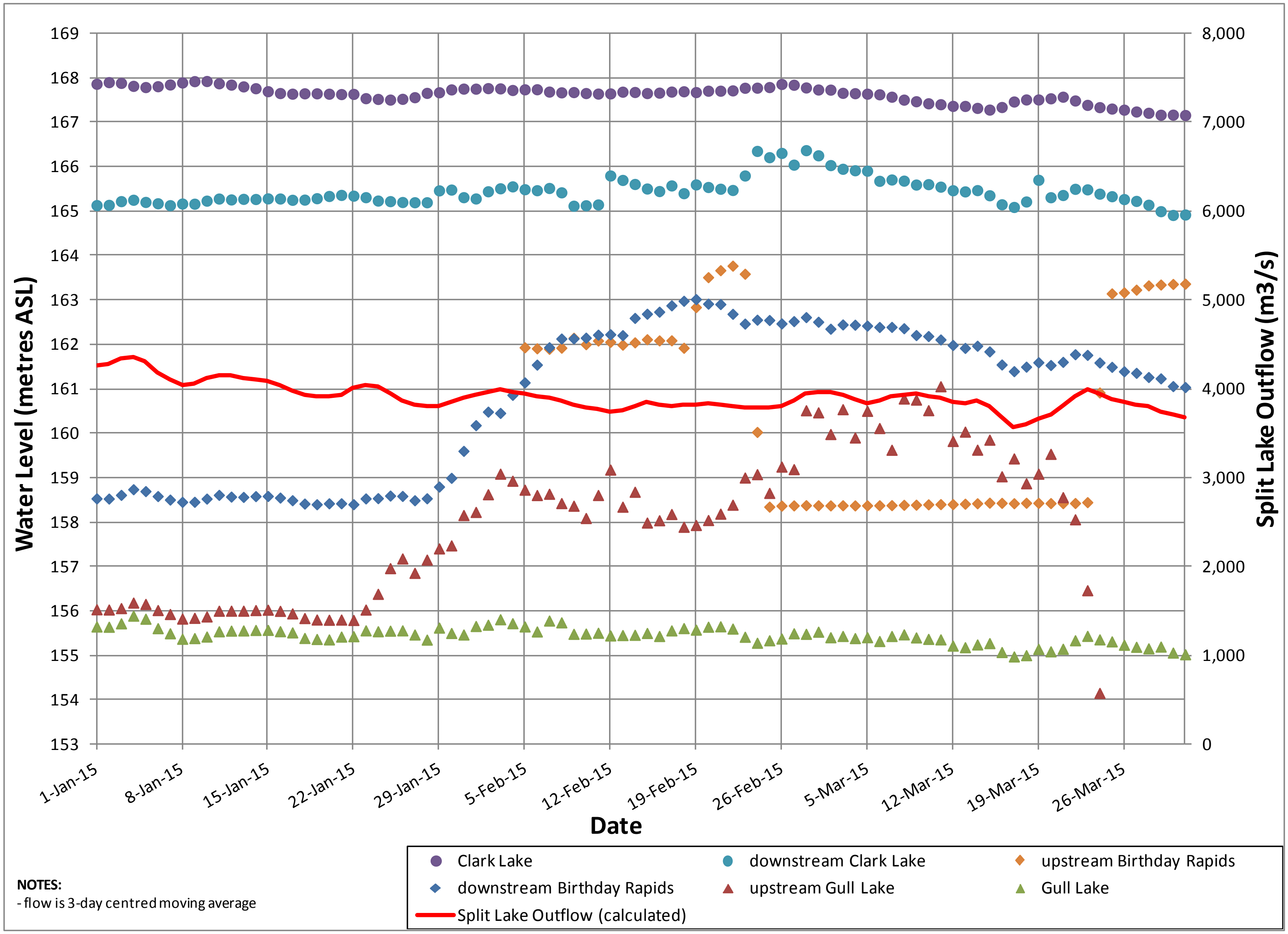


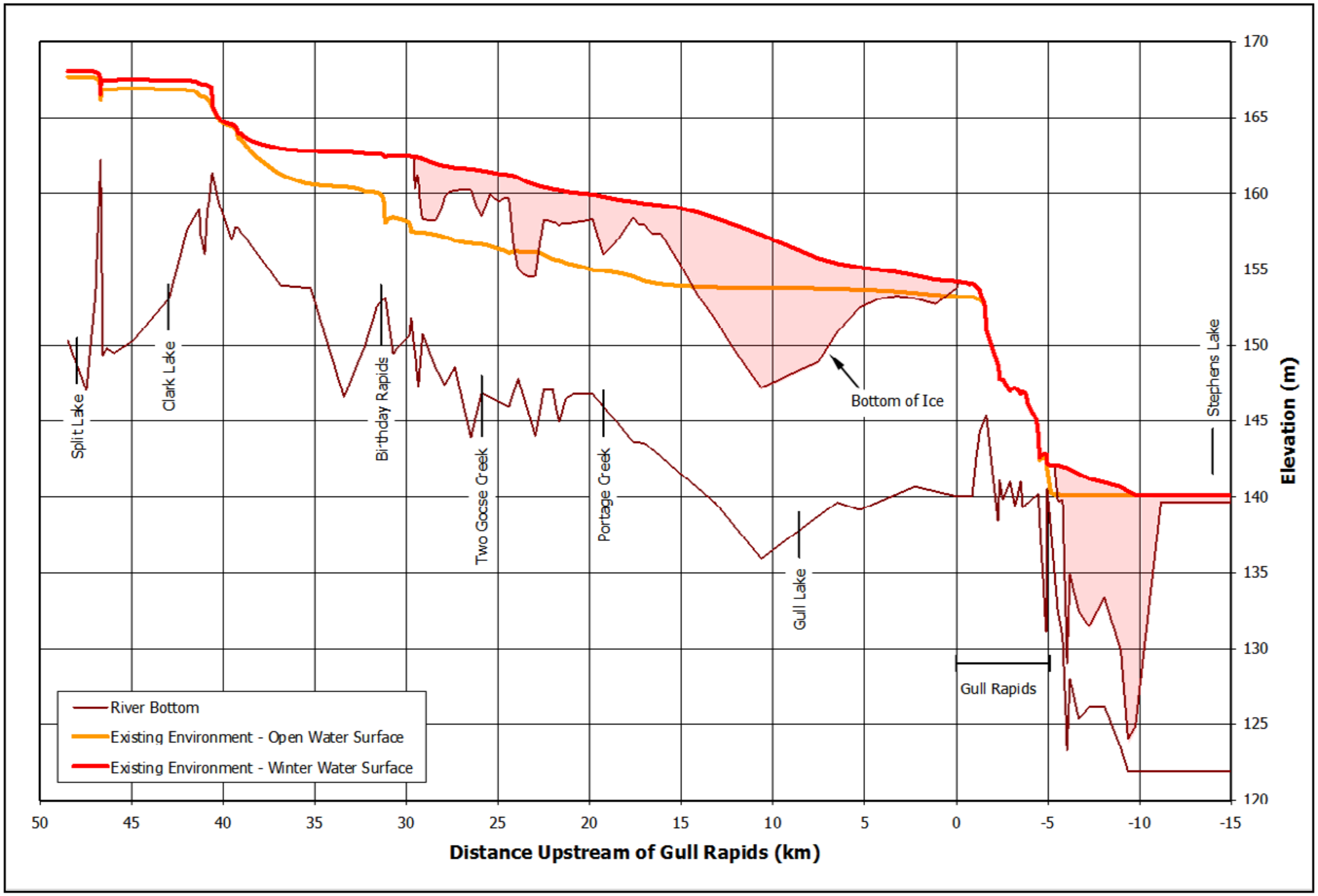
Figure 4: Observed Water Levels, January to March, 2015

staging of about 2-4 m may have occurred at this location. The site downstream of Clark Lake showed an increase of about 1 m between mid-January and mid-February that may also have resulted from downstream ice development. Levels on Clark Lake were comparatively steady during this period and did not show any obvious staging as a result of downstream ice cover development.

The observed staging was consistent with effects that would be anticipated without the Keeyask Project during a high flow winter in which an ice bridge and upstream ice cover are formed. Simulated winter levels for a high flow year showed staging of about 5 m at the upstream end of Gull Lake with a diminishing amount of staging in the upstream direction through Birthday Rapids to just downstream of Clark Lake (Figure 5).

2.2.3 CLARK LAKE AND SPLIT LAKE WATER LEVELS

Split Lake water level data from the existing Split Lake Community gauging station (Site ID: 05UF701) were obtained and plotted along with the levels for the PEMP site on Clark Lake (Figure 6). The levels on these two lakes show the same pattern of variation, differing by about 0.3-0.7 m with an average difference of approximately 0.5 m. Both show a clear correlation to variations in flow. As noted above, upstream staging due to the north channel rock groin did not affect water levels at or upstream of Birthday Rapids. Similarly, there was no apparent staging on either Clark Lake or Split Lake when water levels increased upstream of the ice bridge that formed on Gull Lake in the latter part of January. Based on observed water level conditions, neither Clark Lake nor Split Lake water levels were affected as a result of the Project.



(source: Keeyask EIS, PE SV Figure 4.3-10)

Figure 5: Existing Environment Winter Water Surface Profile – High Flow Year (2005/06)

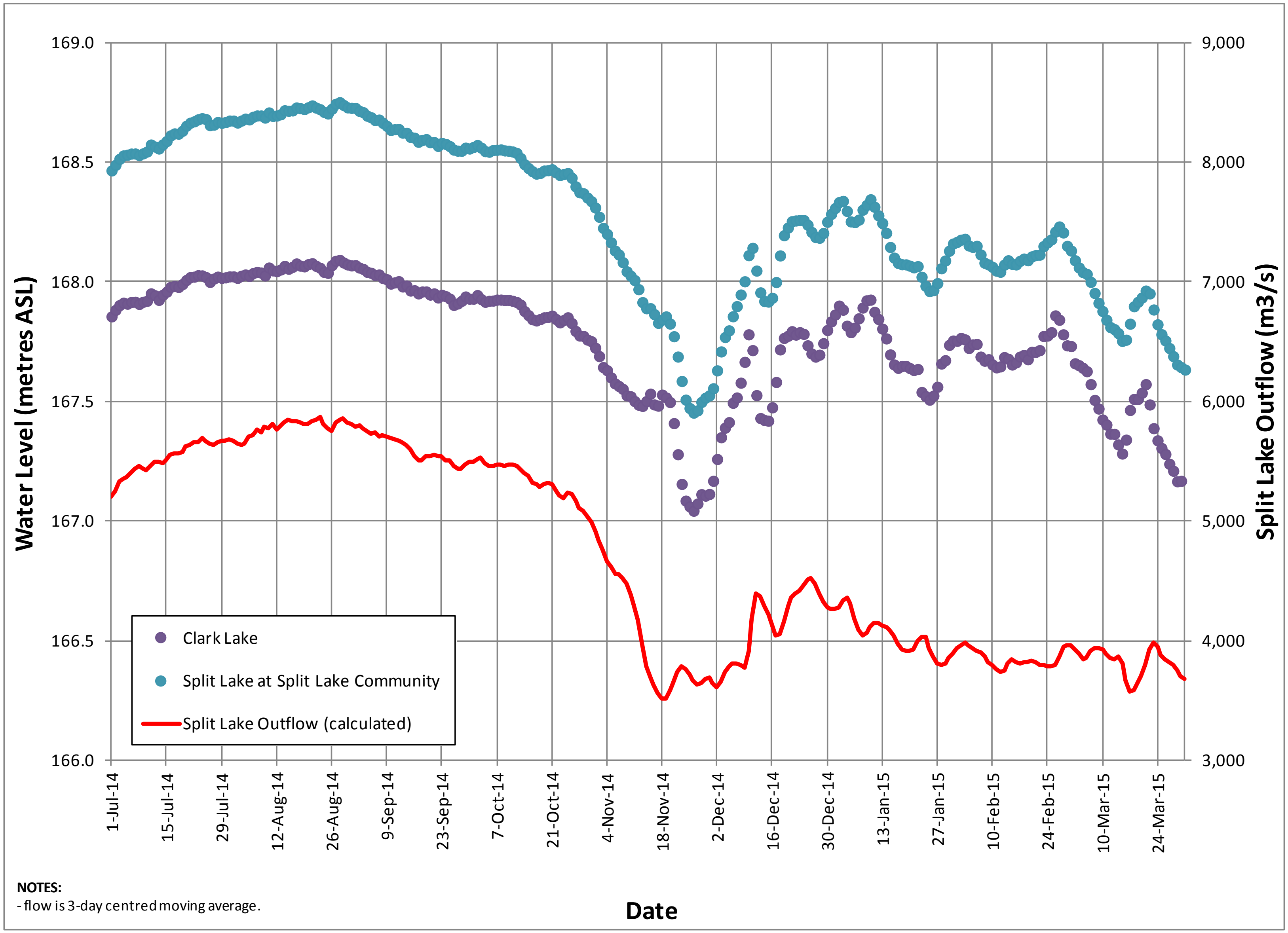


Figure 6: Observed Water Levels at Clark Lake and Split Lake in 2014/15

2.3 ICE REGIME

The PE SV (Section 4) discusses ice processes and the pre-Project ice regime in the vicinity of the Project. In the pre-Project environment, a complete ice cover forms most years (approximately 2 out of 3 years) on Gull Lake and the Nelson River up to Birthday Rapids, although the timing and extents varies with flow and climate conditions. A combination of higher flow and/or warmer conditions may prevent a bridge from forming in some years. In years when bridging does form, the date when it occurs may be as early as November at lower flows to as late as January at higher flows.

An ice cover develops in an upstream direction once larger ice pans jam up and form an ice bridge across the central open water channel between the border ice on opposite shorelines (Photo 3). It was anticipated that each winter during construction an ice cover would develop between the head of Gull Rapids to at least Birthday Rapids due to the installation of an ice-boom across the river just upstream of Gull Rapids. The ice boom was designed to create an ice bridge early in the winter that would force an upstream ice cover to develop even at high flows. A full ice cover is shown in Photo 4.

Photo 3: Ice Pans Flowing Down the Nelson River

Photo 4: Full Ice Cover on the Nelson River

During the construction period the spatial extents of the ice cover was monitored using satellite imagery. Ice conditions have been characterized based on imagery from the Landsat 8 satellite that captures images of this area approximately every eight days. The images can have interferences, such as excess cloud cover, reducing the number of images in which ice cover may be seen.

Around the start of November ice was observed forming. By November 9, border ice was forming and ice had bridged behind the ice boom as expected (Figure 7). On that same day a portion of the boom failed so that, although part of the boom remained, an open channel on the north side was observed (Photo 5, Figure 8). As a result, a channel of open water remained in place between Split Lake and Stephens Lake, including north and south of Caribou Island, until mid-January.

On January 23, 2015, an ice bridge formed on Gull Lake approximately 10 km upstream of the ice-boom (Figure 9). Once this bridge formed, an ice cover proceeded to develop in the upstream direction, reaching the foot of Birthday Rapids about a month later. The ice cover stalled at the foot of the rapids and did not advance any further, which is typical in the existing environment without the Project.

In mid-December the north channel rock groin was extended into the south channel of Gull Rapids off the centre island immediately downstream of the ice boom in order to raise Gull Lake water levels and reduce flow velocity in an attempt to create more favourable conditions for a natural ice bridge to form. It is uncertain if this lead to the bridge forming in January since bridging can be delayed to as late as January under high flow conditions like those observed in 2014/15.

Photo 5: Ice Flowing Past the Failed Ice Boom

Early initiation of ice cover development by an ice boom was designed to reduce ice build up at the entrance to Stephens Lake and associated water level increases in the area near the base of Gull Rapids. Because the ice boom failed, a rough, thick ice cover developed at the entrance to Stephens Lake similar to that which has occurred under high flow conditions without the Project.

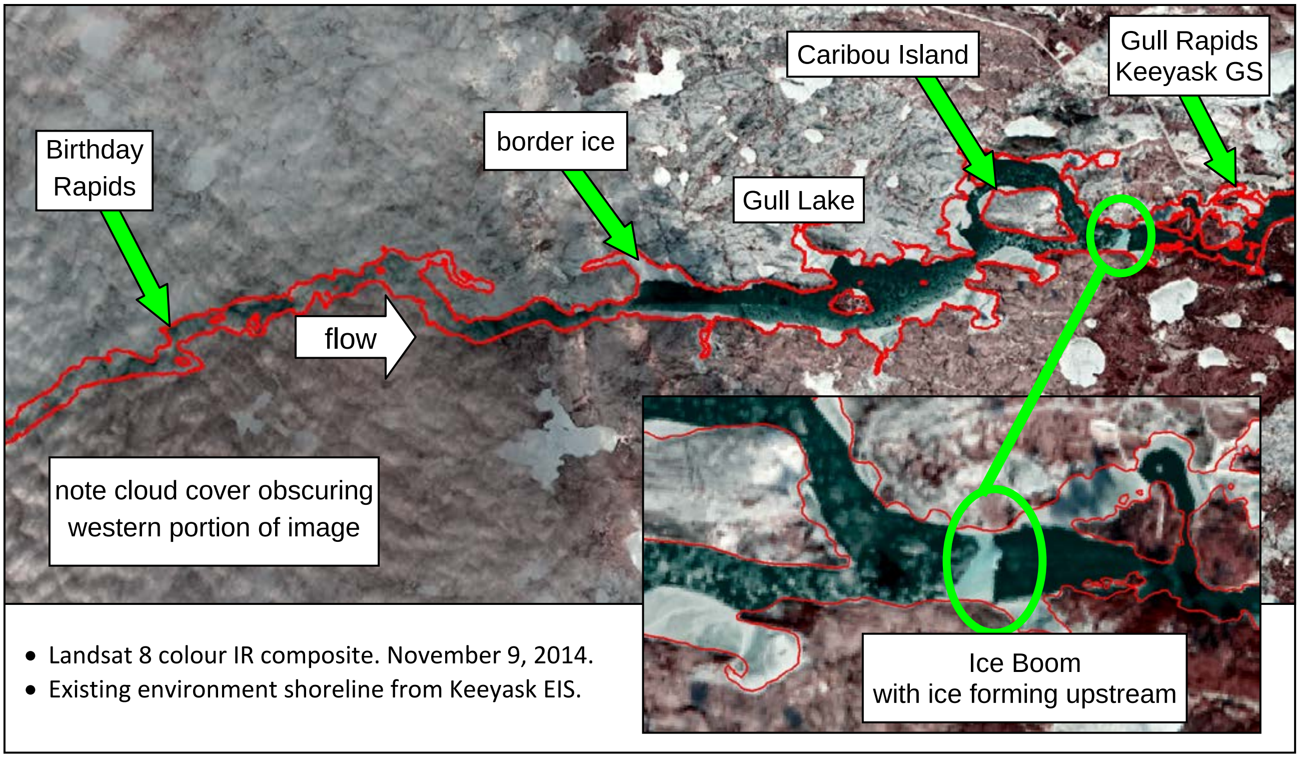


Figure 7: Ice Conditions – November 9, 2014

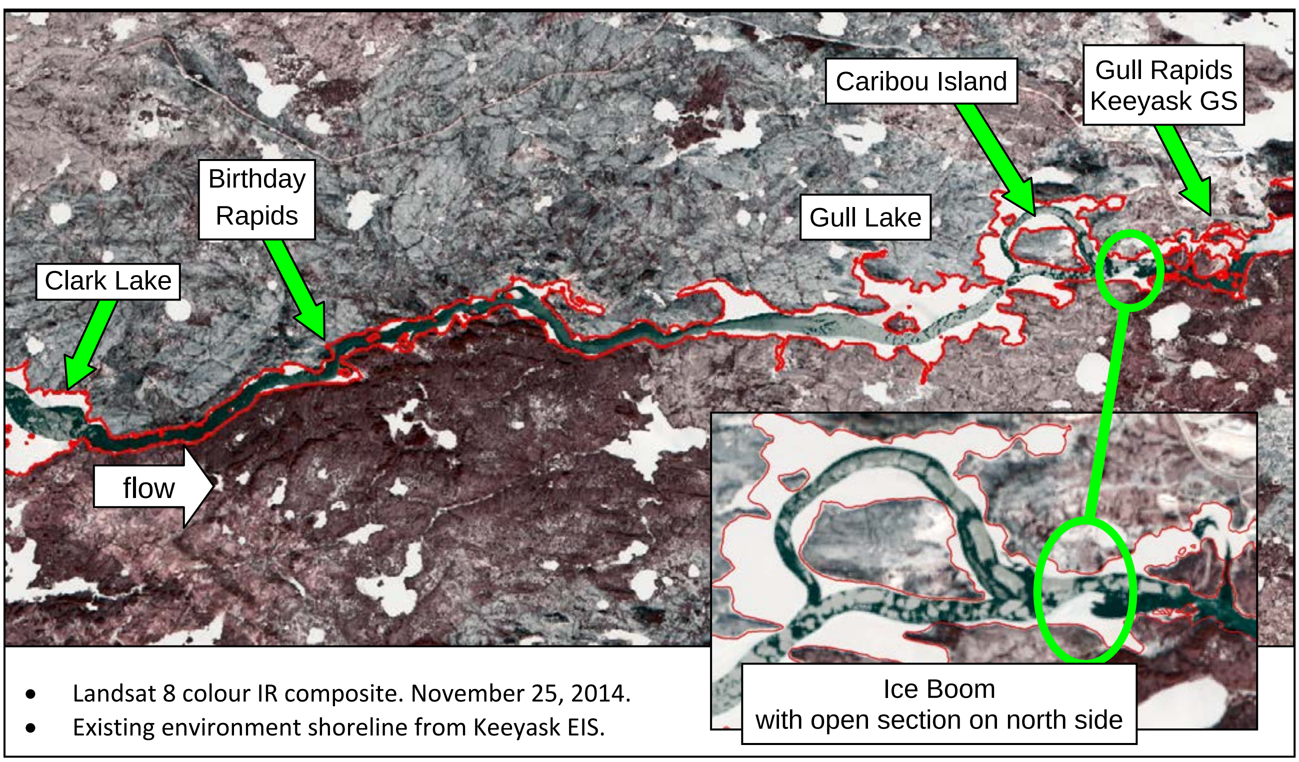
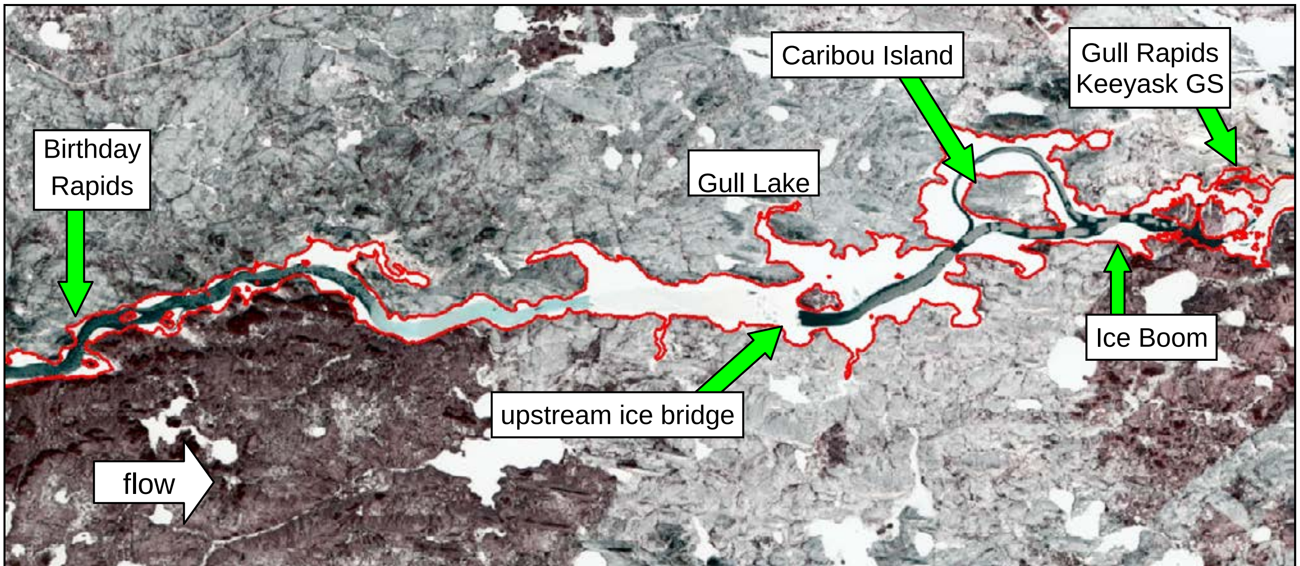


Figure 8: Ice Conditions – November 25, 2014



- Landsat 8 colour IR composite: February 6, 2015 (top) and April 2, 2015 (bottom).
- Existing environment shoreline from Keeyask EIS.

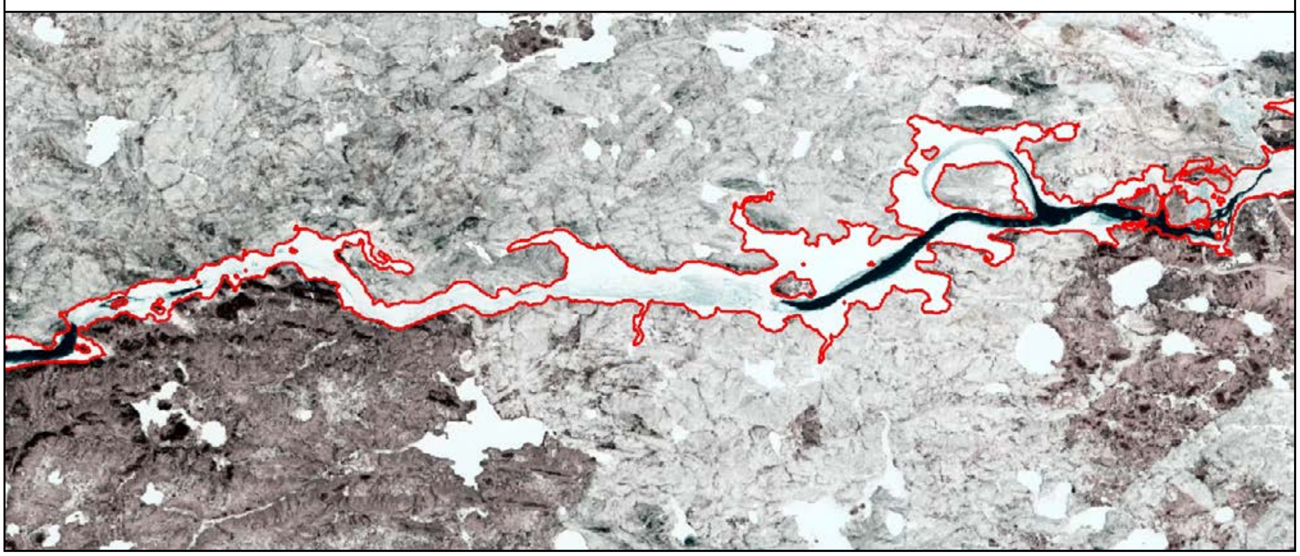


Figure 9: Ice Conditions – February 6 and April 2, 2015

3.0 SHORELINE EROSION

Shoreline erosion monitoring during construction consists of mapping the shoreline position (edge of peat for peat shorelines, top-of-bluff for mineral banks) prior to the start of construction and before full impoundment of the reservoir.

In 2014, high resolution satellite imagery was collected at the start of the construction period. It is planned to collect this information in future years immediately before and after the creation of the reservoir to monitor the shoreline erosion and reservoir expansion.

4.0 SEDIMENTATION

Sedimentation monitoring includes monitoring the transport and deposition of sediment, the objectives of the sedimentation monitoring include:

- confirming sediment transport and deposition predictions; and
- supporting water quality and aquatic habitat monitoring components of the AEMP.

The largest overall effects of the Project on sedimentation are predicted to occur after impoundment of the reservoir with the highest total sediment loading predicted to occur in the first year after impoundment. During the construction period prior to reservoir impoundment the PEMP sedimentation monitoring is generally done to collect data that will support conclusions of the effects of the Project on sediment transport and deposition after impoundment. Sediment monitoring under the Sediment Management Plan (SMP) for In-stream Construction (KHLP 2014) is designed to specifically monitor sediment releases due to in-stream construction activities. A separate annual report discusses the results of monitoring performed in the implementation of the SMP (MH 2015).

4.1 SEDIMENT TRANSPORT

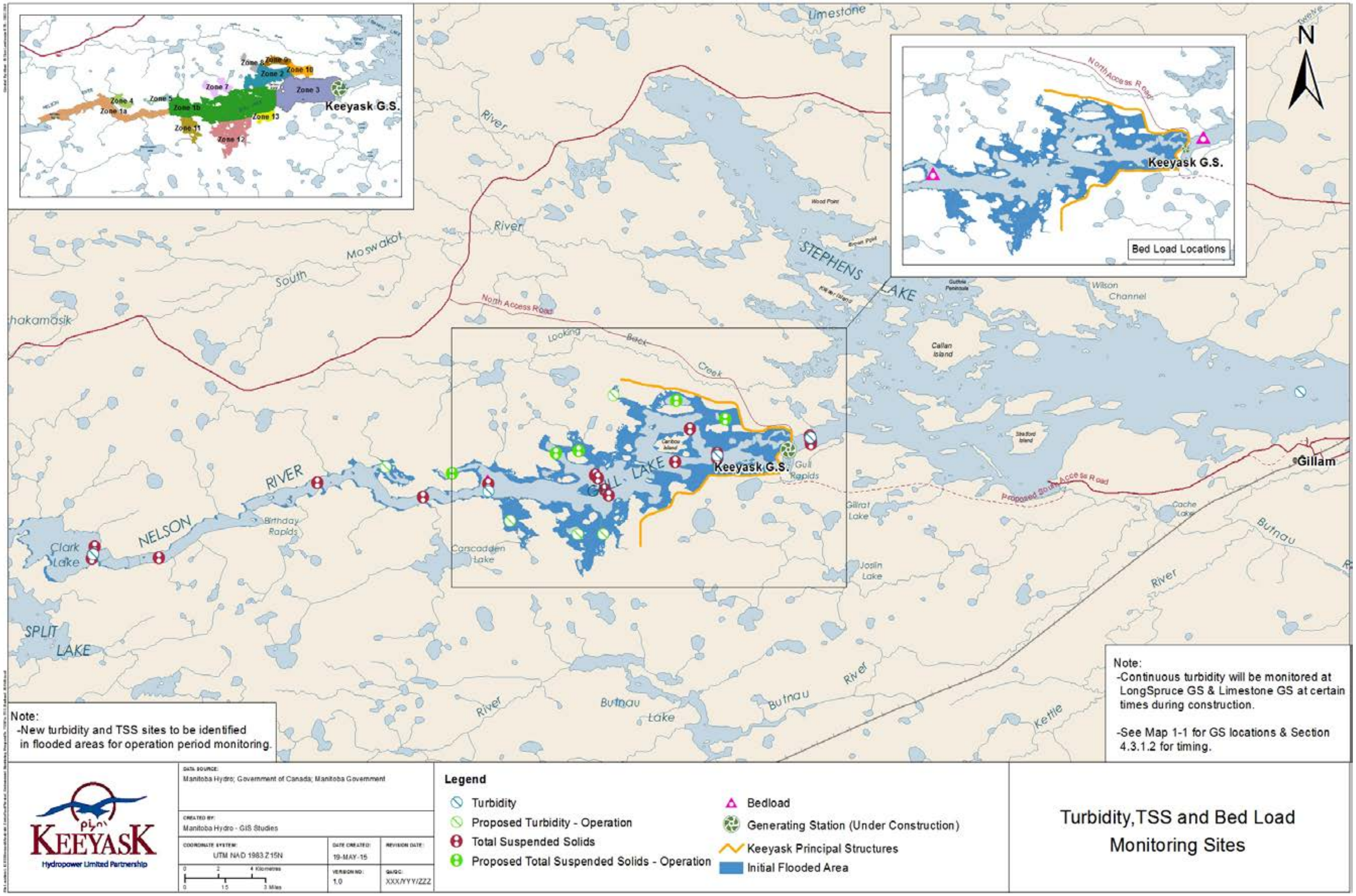
Sediment transport monitoring was done through collection of discrete water samples, bed load samples and continuous turbidity monitoring at locations shown in Map 5 (detailed site maps are provided in Appendix B). Discrete sampling involves the collection of samples by field personnel at certain times (e.g., monthly) while continuous turbidity monitoring involves the installation of automated equipment (Photo 6) that remains in place to take readings much more frequently. The discrete water samples were tested for total suspended sediment (TSS) concentrations and sediment grain size distribution.

Figure 10 shows the TSS data collected in the 2014 summer period and in years prior to construction along the length of the study area.TSS concentrations were measured between 7 and 27 mg/L and were observed to be within the historical concentration levels at all locations. Lab data on suspended sediment concentrations, sediment grain size and bed load was not available in time for its inclusion in this annual report: therefore, this data and analysis will be included in next annual report.

Continuous turbidity is monitored at five locations from the exit of Clark Lake into Stephens Lake near the Kettle Generating Station in summer. In winter, the monitoring is limited to the sites at the Clark Lake exit, Gull Lake entrance and Stephens Lake entrance, which locations where there is safe ice to work on. Turbidity data collected from sites at the exit of Gull Lake and entrance to Stephens Lake is shared between the SMP and PEMP programs.

Turbidity is a general measure of water clarity (or how murky the water is) and increases in turbidity can be correlated to increases in suspended sediment. It is a convenient parameter to monitor as the data can be collected on a continuous basis without collecting samples for laboratory analysis.

Photo 6: Installing Turbidity Monitoring Equipment and a Station after Installation



Map 5: Turbidity, Total Suspended Solids and Bed Load Monitoring Sites

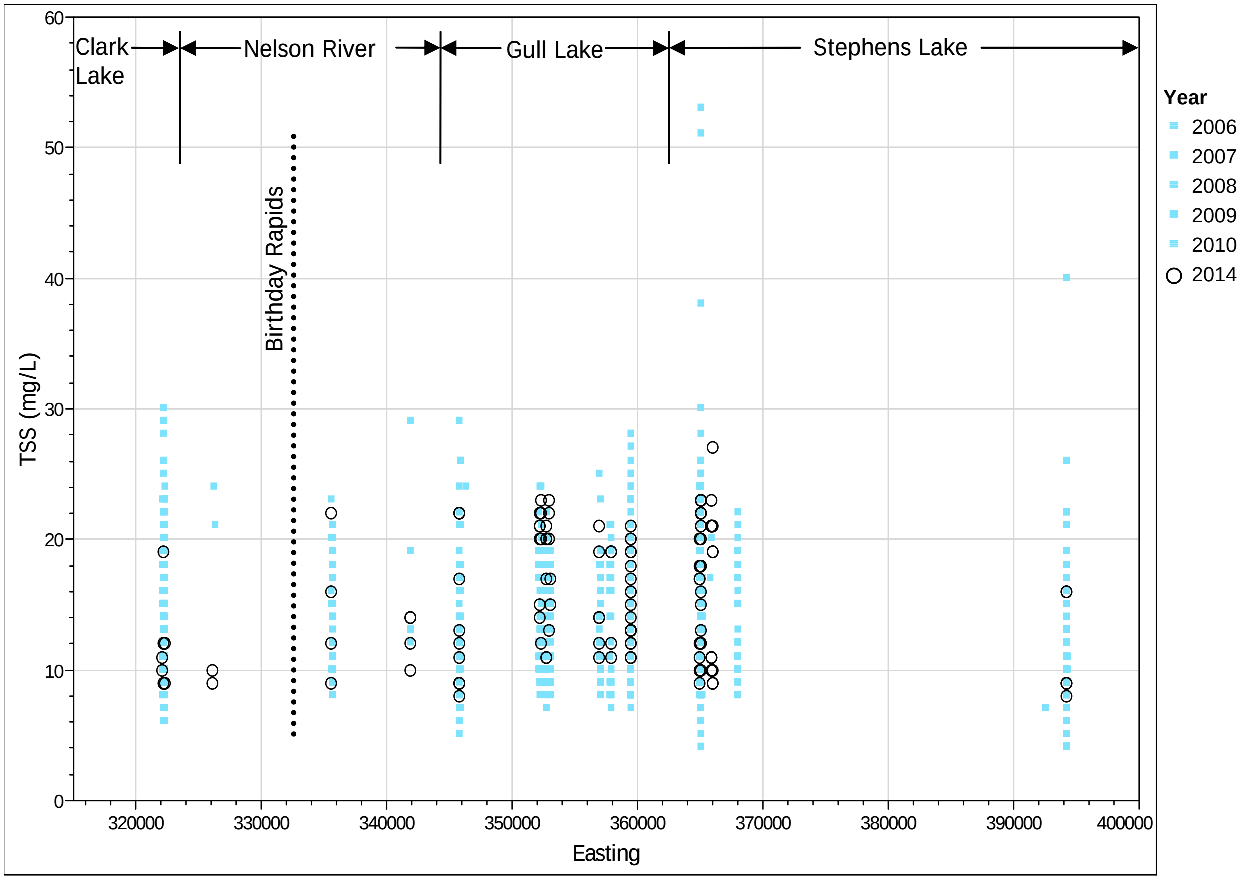
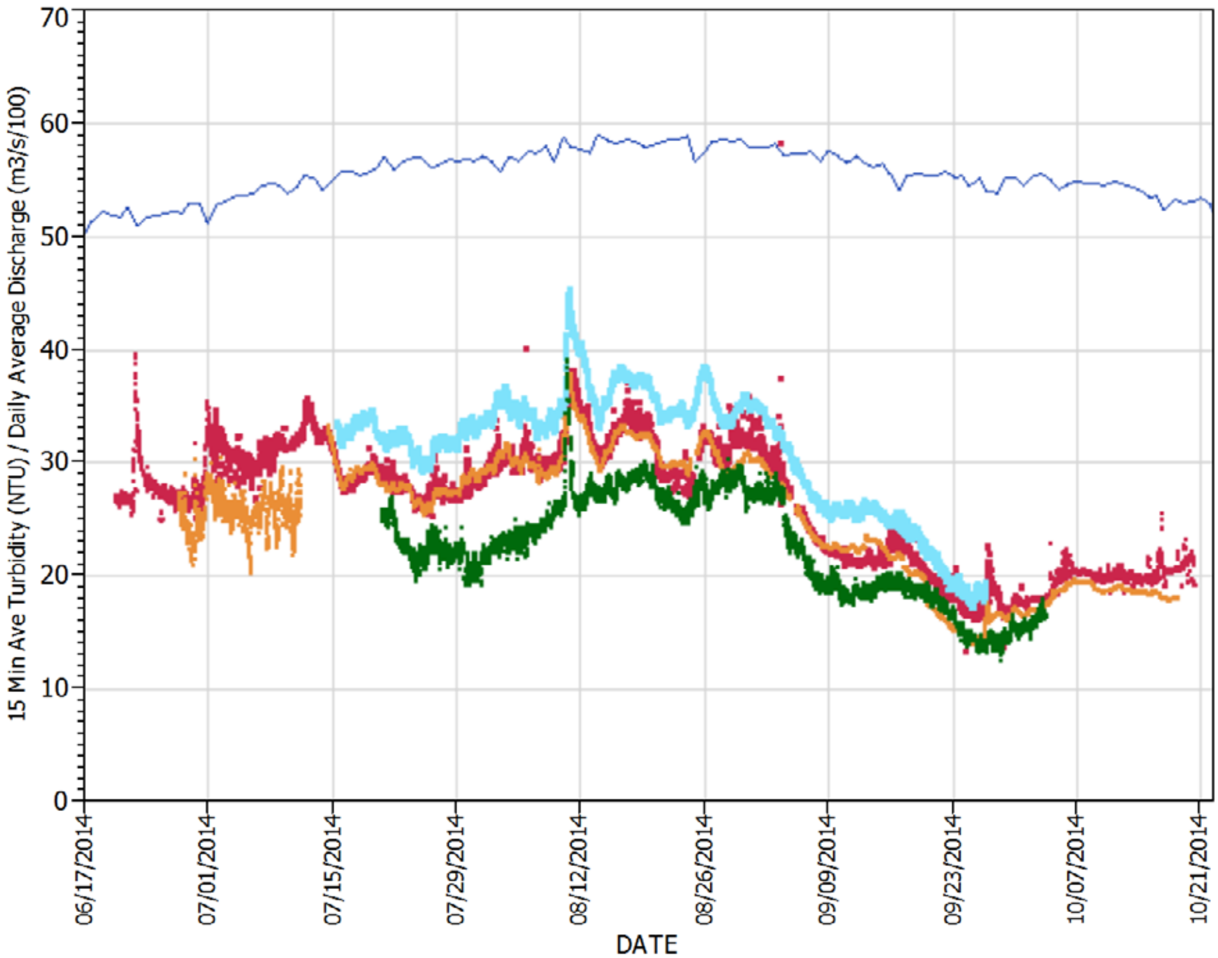


Figure 10: Total Suspended Sediment Concentration

Figure 11 shows the continuous turbidity data collected in the 2014 summer period along with the daily discharge. The logger located at the exit of Clark Lake malfunctioned during the summer and no data is available for that period. The winter data from each site is still under review as equipment was only removed near the end of the winter and will therefore be reported in the next annual report.

Data from all four available monitoring stations follow a very similar pattern. Turbidity levels are fairly steady throughout the summer and decline in September. There are some brief peaks and increases observed due to periods of sustained high winds, with the most notable wind event occurring around August 10-12.

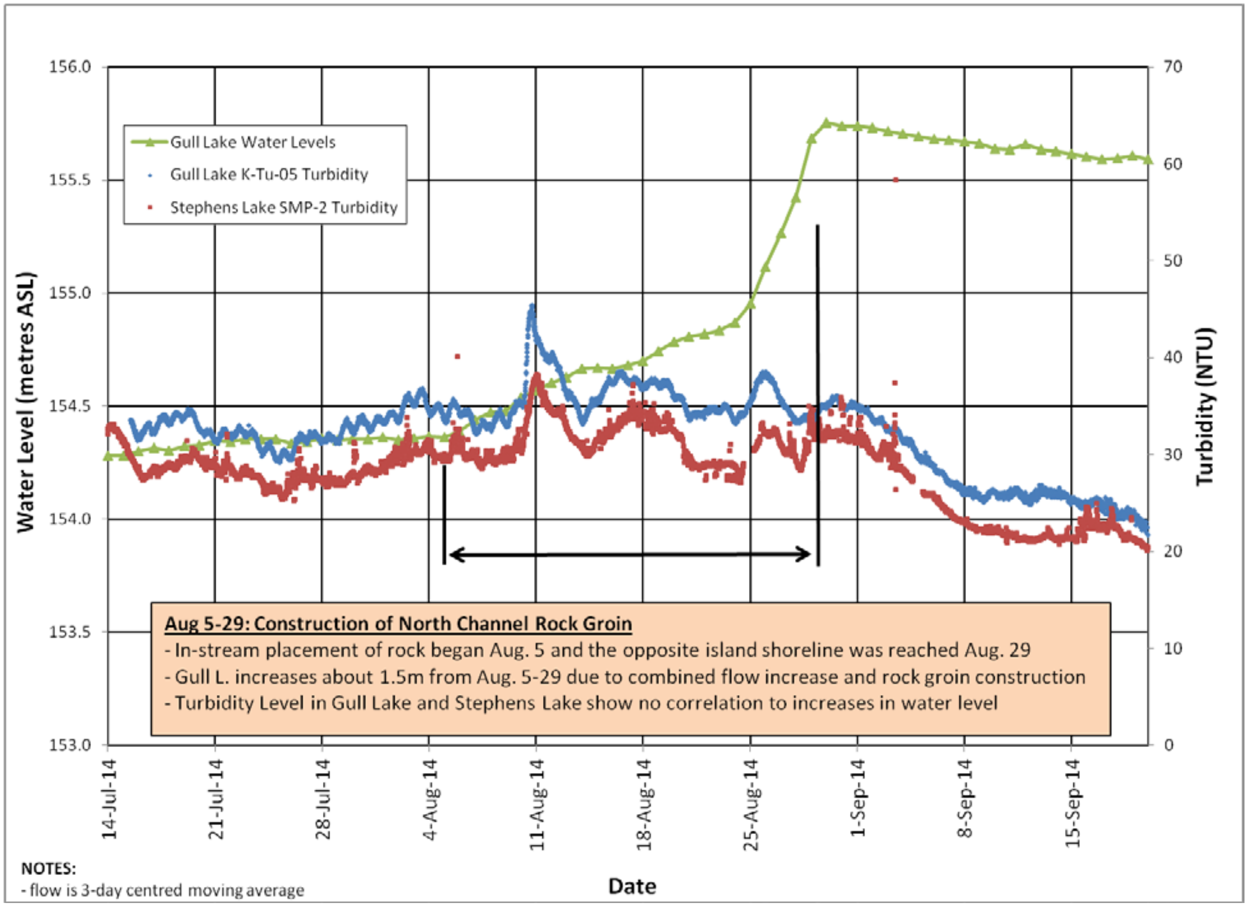


Colour legend:
- Daily Discharge; - Entrance to Gull Lake (K-Tu-05); - Gull Lake (SMP-1);
- Stephens Lake (SMP-2 – average of 4 sensors); - Stephens Lake near Kettle GS (K-Tu-04)

Figure 11: Continuous Turbidity and Water Levels

Figure 12 shows the turbidity levels near the entrance to Gull Lake and downstream of the Keeyask GS in Stephens Lake during the time that Gull Lake water levels increased due to the construction of the north channel rock groin. Turbidity levels did not show any signs of increasing due to the increase in water levels, the increase that occurred around Aug 10-11 was likely due to high winds that occurred at the time. No effects on sediment transport were observed in the summer period of 2014.

The data collected in 2014 along with data collected from previous years (not included in this report) will provide suitable baseline data to compare against post-impoundment turbidity levels.



Colour legend:
- Water Level; - Turbidity at Entrance to Gull Lake (K-Tu-05);
- Turbidity in Stephens Lake (SMP-2 – average of 4 sensors)

Figure 12: Continuous Turbidity and Water Levels

4.2 DEPOSITION

Sediment traps were also placed at two locations to monitor deposition in the waterway (Map 5).The sediment traps were installed in the fall and are planned to be retrieved after the ice has melted in the spring of 2015.

5.0 DEBRIS

Manitoba Hydro operates waterway management programs that are implemented locally on various water bodies to monitor and remove debris. Debris such as floating logs and branches was monitored and removed where it posed a safety hazard to navigation along the waterway in the Project area (see Map 1).

The amount of debris removed by the waterways management team in 2014 was within the range of debris amounts recorded in previous years for when data is available (Table 2). The debris is classified by size as either large or small, and by type as either new (green woody material), old or beaver (showing signs of beaver activity).

The Split Lake waterways management area covers portions of the Nelson and Burntwood rivers upstream of Split Lake and extends downstream to head of Gull Rapids, which encompasses the Project area from Clark Lake to Gull Rapids. As has been done in previous years, the waterways management crews for the Split Lake management area performed debris removal work between Clark Lake and Gull Rapids on about one out of five days. Therefore, as was done in the EIS (PE SV, Section 10), it is assumed that 20% of the total amount of debris removed from the overall Split Lake debris management area was found in the Project area from Clark Lake to Gull Rapids.

Table 2: Debris Removed from the Waterway

Year	Small (<1 m)	Large (> 1m)			
		New	Old	Beaver	Total
2003	3	4	7	0	11
2004	36	1	140	0	141
2005	2	6	103	0	109
2006	11	1	65	0	66
2007	0	3	81	0	84
2008	1	0	49	1	49
2012	0	1	30	1	32
2014	2	1	59	0	60

6.0 RESERVOIR GREENHOUSE GAS

The purpose of Manitoba Hydro's Keeyask Reservoir Greenhouse Gas Monitoring Program is to enable the comparison of aquatic greenhouse gas (GHG) concentrations and emissions before and after flooding and reservoir creation. Studies indicate that GHG emissions from boreal hydroelectric reservoirs, such as the future Keeyask reservoir, will increase shortly after flooding and return towards levels similar to those of natural water bodies within a period of approximately 10 years following impoundment.

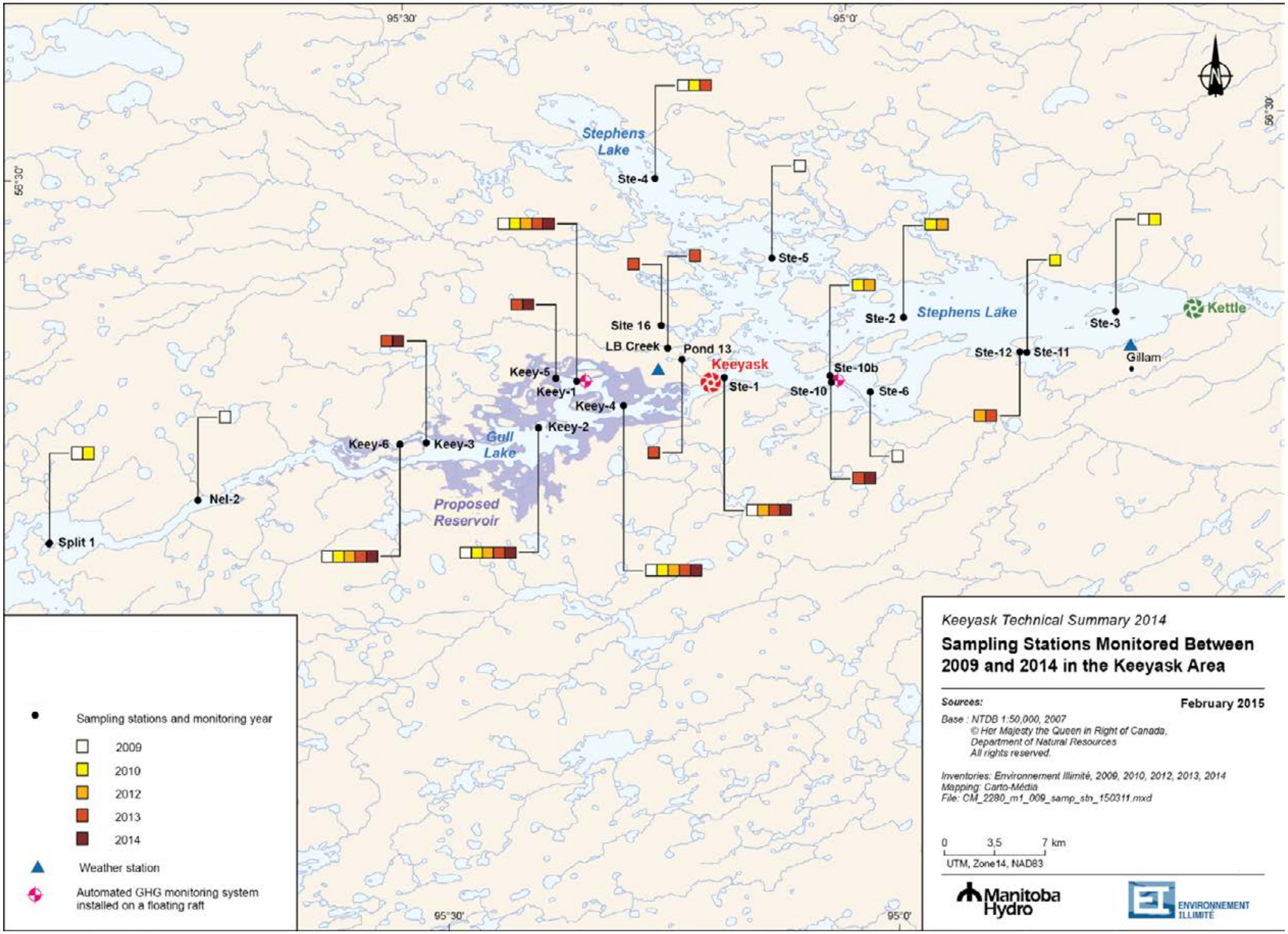
Measurement of aquatic GHG concentrations was conducted upstream, within and downstream of the planned Keeyask reservoir area (Map 6). GHG concentrations were measured by discrete sampling (point-in-time measurements) and by continuous monitoring. Discrete sampling was conducted during the open water season and under the winter ice at various locations throughout the waterway to determine if aquatic GHG concentrations vary spatially. Continuous monitoring of Carbon Dioxide (CO_2) and Methane (CH_4) concentrations was conducted during the open water season at fixed locations to record seasonal and annual trends in aquatic GHG concentrations.

6.1 GULL LAKE

6.1.1 MAIN CHANNEL: CO_2 & CH_4 AQUATIC CONCENTRATIONS

Concentrations of carbon dioxide (pCO_2) measured on a continuous basis from June 25 to October 3, 2014 in the main channel of Gull Lake ranged from 398 parts-per-million (ppm) to 724 ppm. These values are within the minimum and maximum values measured during the pre-Project period from 2009 to 2013 (Figure 13).

The mean 2014 CO_2 concentration was calculated to be 549 ppm, which is slightly above the mean of 507 ppm for the pre-project period of 2009-2013, and is nearly identical to the 2009 mean of 543 ppm. Pre-Project and construction period CO_2 concentrations are similar to those measured at other locations on Manitoba Hydro's hydraulic system and at reference lakes during the pre-project monitoring period. Slightly elevated 2014 CO_2 concentrations were measured from June to mid September. The peak levels pre-dated the construction of the north channel rock groin and the subsequent gradual increase in Gull Lake levels, which commenced on August 5, 2015 (see Section 2.2 for water level discussion).



Map 6: Greenhouse Gas Monitoring Sites

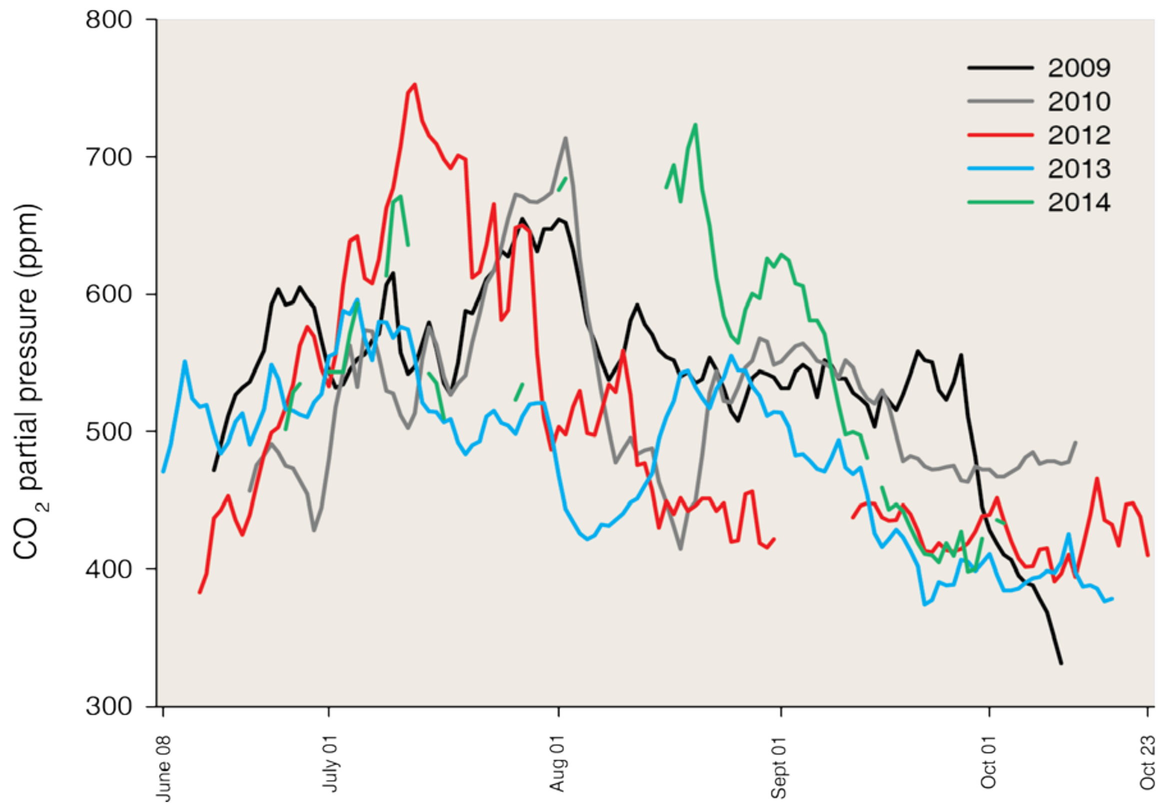


Figure 13: Gull Lake Continuous Monitoring of CO_2 Concentrations

Minimum, maximum and mean concentrations of methane (pCH_4) measured on a continuous basis from June 25 to October 2, 2014 in the main channel of Gull Lake were 4 ppm, 27 ppm and 16 ppm, respectively. These results are within the range of minimum, maximum and mean values measured during the pre-Project period of 2009 to 2013 (Figure 14).

Discrete measurements of pCO_2 ranged from 661 ppm to 691 ppm during 2014.These values were within the range measured during the pre-project period of 2009 to 2013 (Figure 15). Discrete measurements of pCH_4 ranged from 19 ppm to 28 ppm during 2014, which were within the range measured during the pre-project period (Figure 15).

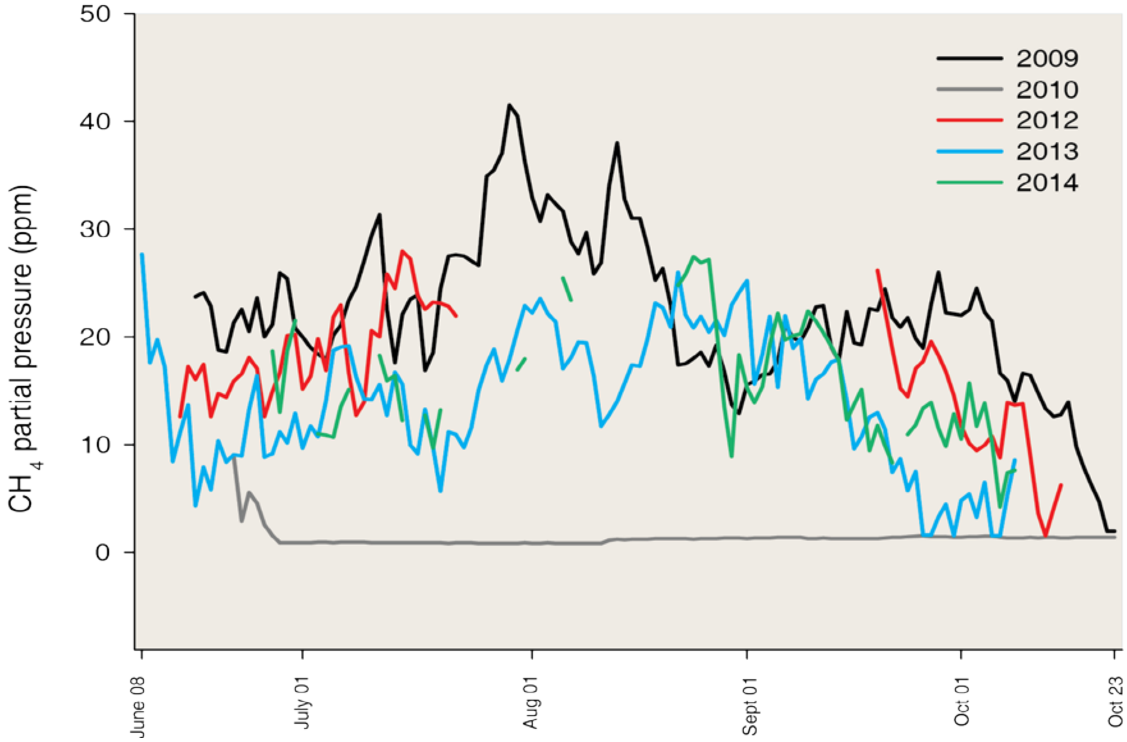


Figure 14: Gull Lake Continuous Monitoring of CH4 Concentrations

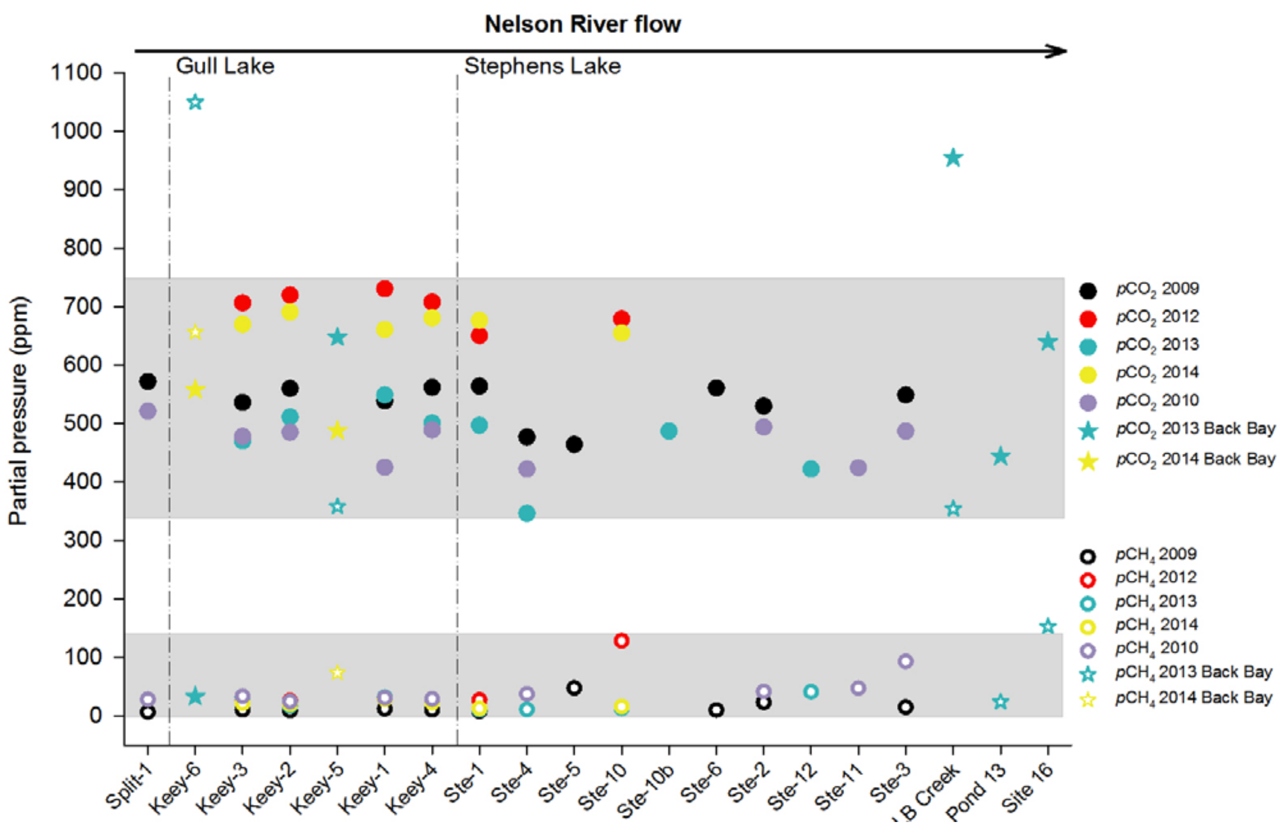


Figure 15: Gull Lake and Stephens Lake Spatial Monitoring of CO_2 and CH_4 Concentrations

6.1.2 MAIN CHANNEL: CO_2 & CH_4 FLUXES TO ATMOSPHERE

Minimum and maximum CO_2 fluxes based on continuous measurements of CO_2 concentrations from June 25 to October 3, 2014 were calculated to be -3 and 1,650 mg CO_2 m^{-2} d^{-1} (milligrams of CO_2 per square metre per day) respectively. These values are within the range measured during the pre-Project period of 2009 to 2013 (Table 3).

The mean 2014 CO_2 flux was calculated to be 732 mg CO_2 m^{-2} d^{-1}. This value is slightly higher than the mean of 479 mg CO_2 m^{-2} d^{-1} for the pre-project period, is similar to the 2009 mean of 693 mg CO_2 m^{-2} d^{-1}, and is within the range of mean annual fluxes measured elsewhere along the Nelson River during the pre-project period.

Minimum, maximum and mean CH_4 fluxes based on continuous measurements of CH_4 concentrations from June 25 to October 2, 2014 were calculated to be 0 mg CH_4 m^{-2} d^{-1}, 2 CH_4 m^{-2} d^{-1} and 1 mg CH_4 m^{-2} d^{-1}, respectively. These results are within the mean ranges calculated during the pre-project period (Table 3).

6.1.3 BACK BAY AREAS

For the Gull Lake back bay areas, discrete measurements were obtained for the aquatic concentrations of CO_2 and CH_4. Discrete measurements of pCO_2 ranged from 488 ppm to 674 ppm during 2014.These values were within the range measured during the Pre-project period of 2009 to 2013, as illustrated in Figure 15. Discrete measurements of pCH_4 ranged from 73 ppm to 657 ppm during 2014, which compared to the range of 358 ppm to 1050 ppm measured during the Pre-project period of 2009 to 2013 (Figure 15).

6.2 STEPHENS LAKE

6.2.1 MAIN CHANNEL: CO_2 & CH_4 AQUATIC CONCENTRATIONS

Concentrations of carbon dioxide (pCO_2) measured on a continuous basis from June 25 to October 18, 2014 in the main channel of Stephens Lake ranged from 391 ppm to 734 ppm. These values are similar to the minimum and maximum values measured during the pre-Project period of 2009 to 2013 (Figure 16). The mean 2014 CO_2 concentration was calculated to be 530 ppm, which is similar to the annual mean CO_2 concentration of 479 ppm measured during the pre-Project period.

Minimum, maximum and mean concentrations of methane (pCH_4) measured on a continuous basis from June 25 to October 18, 2014 in the main channel of Stephens Lake were 2 ppm, 41 ppm and 12 ppm, respectively. These results are comparable to the minimum, maximum and mean of 2 ppm,25 ppm, and 8 ppm measured during the pre-Project year of 2013 (Figure 17).

Discrete measurements of pCO_2 ranged from 655 ppm to 677 ppm during 2014.These values were within the range measured during the pre-Project period of 2009 to 2013 (Figure 15). Discrete measurements of pCH_4 ranged from 13 ppm to 16 ppm during 2014, which were within the range measured during the pre-Project period (Figure 15).

6.2.2 MAIN CHANNEL: CO_2 & CH_4 FLUXES TO ATMOSPHERE

Minimum and maximum CO_2 fluxes based on continuous measurements of CO_2 concentrations from June 25 to October 18, 2014 were calculated to be -36 mg CO_2 m^{-2} d^{-1} and 2,484 mg CO_2 m^{-2} d^{-1}, respectively. These values compare to the minimum and maximum values of -1 and 1,474 mg CO_2 m^{-2} d^{-1} respectively, for the pre-Project period of 2009 to 2013 (Table 3).

The mean 2014 CO_2 flux was calculated to be 724 mg CO_2 m^{-2} d^{-1}. This value is slightly higher than the mean of 491 mg CO_2 m^{-2} d^{-1} for the pre-Project period but is within the range of mean annual fluxes measured elsewhere along the Nelson River during the pre-Project period.

Minimum, maximum and mean CH_4 fluxes based on continuous measurements of CH_4 concentrations from June 25 to October 18, 2014 were calculated to be 0 mg CH_4 m^{-2} d^{-1}, 3 mg CH_4 m^{-2} d^{-1} and 1 mg CH_4 m^{-2} d^{-1}, respectively. These results are similar to the mean ranges calculated during the pre-Project period of 2009 to 2013 (Table 3).

6.2.3 BACK BAY AREAS

For the Stephens Lake back bay areas, discrete measurements were obtained for the aquatic concentrations of CO_2 and CH_4. Discrete measurements of pCO_2 ranged from 444 ppm to 955 ppm during 2013 (Figure 15). Discrete measurements of pCH_4 ranged from 24 ppm to 354 ppm during 2013.

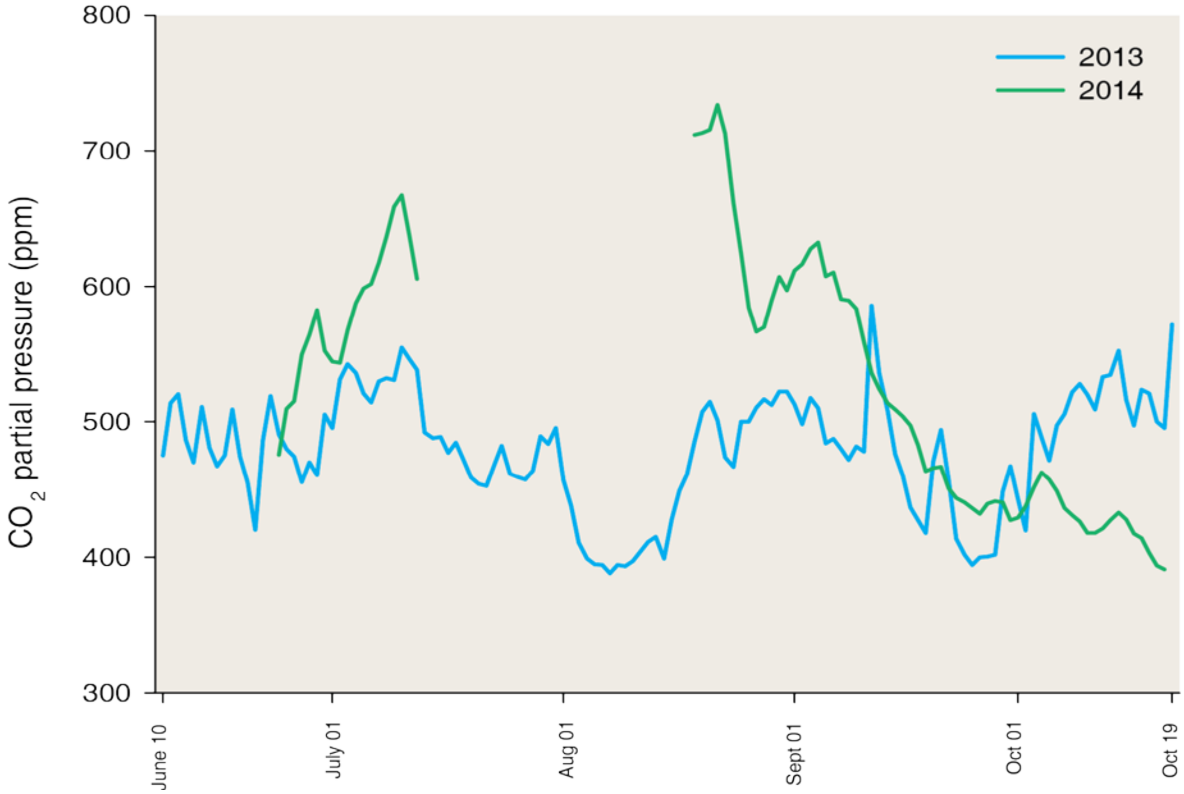


Figure 16: Stephens Lake Continuous Monitoring of CO_2 Concentrations

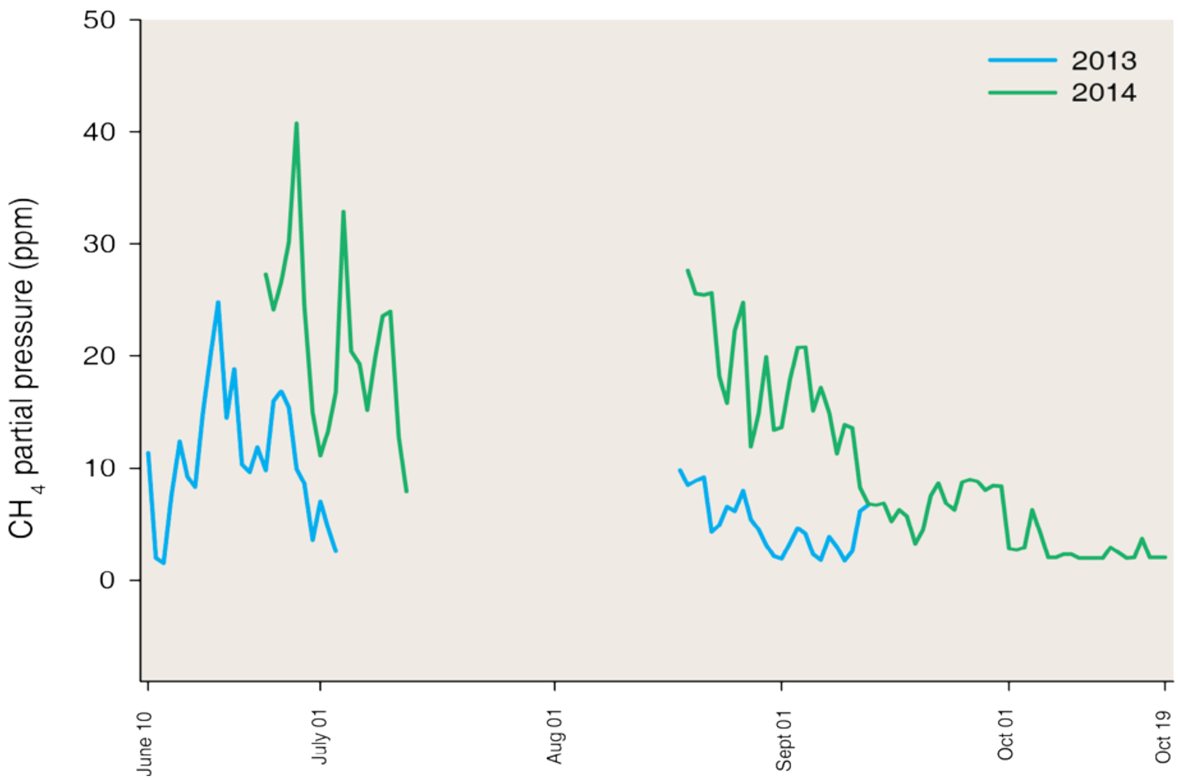


Figure 17: Stephens Lake Continuous Monitoring of CH_4 Concentrations

6.3 SUMMARY

In 2014, construction activities did not affect GHG aquatic concentrations or emissions and the data collected in 2014 along with data collected in the pre-Project period from 2009-2013 will provide suitable baseline data to compare against post-impoundment GHG concentrations and emissions.

Table 3: Summary of Gull Lake and Stephens Lake Continuous Monitoring Results for GHG partial pressures and diffusive fluxes during 2009, 2010, 2012-2014 ice-free periods

Parameter	Descriptive Statistics	Gull Lake Pre-Project Monitoring Period 2009 - 2013					Gull Lake Construction Monitoring Period 2014	Stephens Lake Pre-Project Monitoring Period 2009 - 2013			Stephens Lake Construction Monitoring Period 2014
		Automated System					Automated System	Automated System			Automated System
		Main Channel					Main Channel	Main Channel			Main Channel
		2009	2010	2012	2013	2009-2013	2014	2010	2013	2010-2013	2014
pCH_4 (µatm)	n	121	116	62	115	298	69	14	50	50	81
	Min.	2	1	2	2	2	4	11	2	2	2
	Max.	42	9	28	28	42	27	67	25	25	41
	Median	22	1	17	14	18	15	39	7	7	9
	Mean	22	1	17	14	18	16	37	8	8	12
	CV	33%	70%	35%	44%	42%	35%	45%	68%	68%	74%
pCO_2 (µatm)	n	119	116	123	133	559	69	13	132	132	81
	Min.	331	414	383	374	253	398	445	388	388	391
	Max.	655	714	753	596	753	724	492	586	586	734
	Median	545	521	452	493	515	551	465	484	484	524
	Mean	543	526	501	480	507	549	469	479	479	530
	CV	12%	12%	19%	12%	16%	16%	3%	9%	9%	17%
CH_4 flux (mg CH_4 m^{-2} d^{-1})	n	119	116	60	115	410	69	13	50	50	81
	Min.	0	0	0	0	0	0	0	0	0	0
	Max.	3	0	2	2	3	2	4	2	2	3
	Median	1	0	1	1	1	1	3	0	0	1
	Mean	1	0	1	1	1	1	2	0	0	1
	CV	43%	-222%	45%	54%	86%	47%	45%	99%	99%	96%
CO_2 flux (mg CO_2 m^{-2} d^{-1})	n	119	116**	105**	133	501	69	13	132	145	81
	Min.	-296	162**	-35**	-100	-818	-3	218	-1	-1	-36
	Max.	2,075	2,031**	2,044**	922	2,044	1,650	706	1,474	1,474	2,484
	Median	640	567**	340**	310	431	714	456	483	480	642
	Mean	693	644**	484**	293	479	732	439	497	491	724
	CV	61%	55%**	89%**	83%	87%	63%	32%	57%	55%	80%

(See notes on following page)

Table 3 Notes:
Black italicized data are incomplete and should be judged based on their valid periods of monitoring
Red italicized data are offset, low ranges measured with Panterra sensors are considered invalid
Green data represents calculated flux
* Data from August to October only
** Water temperature data is partly estimated from the following power correlation: y=4.4539 (x+5) 0.4507 where = water temperature in Gull Lake and x = air temperature at Gillam meteorological station calculated fluxes are presented in the table if measured fluxes are unavailable for field campaigns

7.0 LITERATURE CITED

Keeyask Hydropower Limited Partnership (KHLP), 2012. Keeyask Generation Project: Physical Environment Supporting Volume. June 2012. Winnipeg, Manitoba

Keeyask Hydropower Limited Partnership (KHLP), 2012a. Keeyask Generation Project: Response to EIS Guidelines. June 2012. Winnipeg, Manitoba.

Keeyask Hydropower Limited Partnership (KHLP), 2013. Keeyask Generation Project: Preliminary Physical Environment Monitoring Plan. April 2013. Winnipeg, Manitoba.

Keeyask Hydropower Limited Partnership (KHLP), 2014, Keeyask Generation Project: Sediment Management Plan for In-stream Construction. July 2014. Winnipeg, Manitoba.

Manitoba Hydro 2015, Sediment Management Plan Annual Report July 2014 – April 2015. May 2015. Winnipeg, Manitoba.

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APPENDIX A - Water Level Percentiles

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- Water level statistics are copied from the Keeyask EIS, PESV (Sec. 4, App. 4A).
- Levels were simulated at key sites for conditions without the Keeyask GS for the 1977-2006 period and statistics shown were obtained from that derived data set.
- Six of the Key sites are the same as or correspond closely with the six PEMP water level monitoring sites.

Clark Lake				**Percentile**				
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		165.11	165.60	166.02	166.49	167.07	167.46	167.86
Seasonal	Open Water	165.15	165.49	165.82	166.07	166.41	167.29	167.86
	Winter	165.11	166.04	166.59	166.97	167.24	167.51	167.75
D/S Clark Lake				**Percentile**				
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		162.41	163.02	163.50	163.83	164.12	164.57	165.17
Seasonal	Open Water	162.51	162.91	163.28	163.58	163.93	164.67	165.17
	Winter	162.41	163.46	163.79	163.98	164.17	164.44	164.76
U/S Birthday Rapids				**Percentile**				
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		157.41	158.39	159.16	159.73	161.17	162.69	164.00
Seasonal	Open Water	157.41	158.17	158.82	159.30	159.84	160.92	161.54
	Winter	157.81	159.11	159.65	161.00	162.20	162.91	164.00
D/S Birthday Rapids				**Percentile**				
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		155.63	156.53	157.22	157.92	160.34	162.36	163.70
Seasonal	Open Water	155.84	156.37	156.89	157.34	157.94	159.14	159.92
	Winter	155.63	157.21	157.92	160.36	161.84	162.56	163.70
Portage Creek (upstream end of Gull Lake)				**Percentile**				
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		152.05	152.83	153.60	154.53	156.05	158.37	159.86
Seasonal	Open Water	152.05	152.64	153.19	153.66	154.26	155.52	156.28
	Winter	152.08	153.77	154.69	155.97	157.43	158.85	159.86
Gull Lake				**Percentile**				
Type of Data		**Min**	**5**	**25**	**50**	**75**	**95**	**Max**
All Data		151.43	152.01	152.54	153.16	153.94	154.84	156.67
Seasonal	Open Water	151.43	151.86	152.28	152.61	153.08	154.18	154.94
	Winter	151.66	152.59	153.23	153.71	154.25	155.23	156.67

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APPENDIX B – TSS and Turbidity Monitoring Sites

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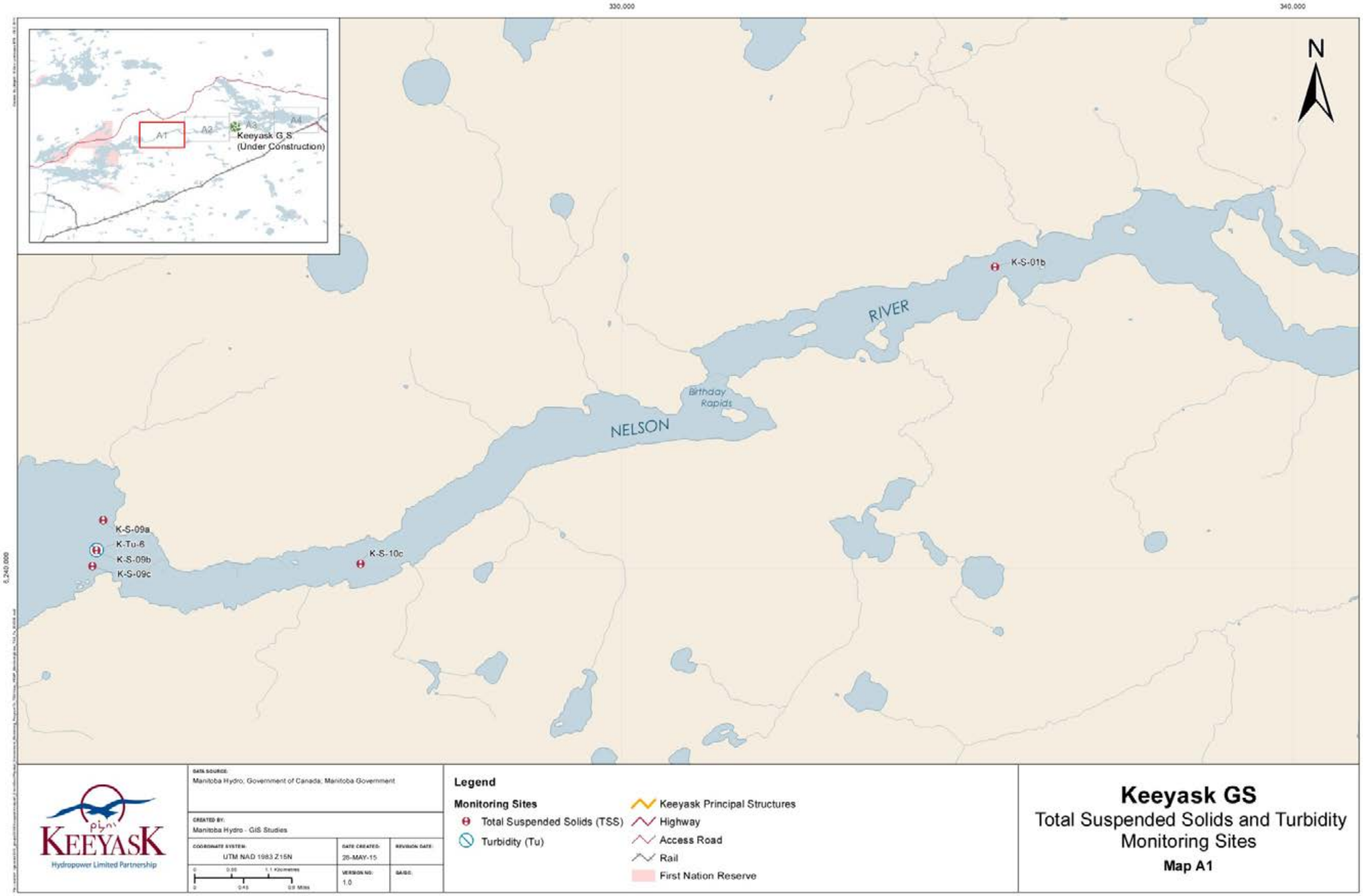

330,000
340,000
N
A1
A2
A3
A4
Keeyask G.S.
(Under Construction)
K-S-01b
RIVER
Birthday
Rapids
NELSON
K-S-09a
K-Tu-6
K-S-09b
K-S-09c
K-S-10c
DATA SOURCE:
Manitoba Hydro; Government of Canada; Manitoba Government
CREATED BY:
Manitoba Hydro - GIS Studies
COORDINATE SYSTEM:
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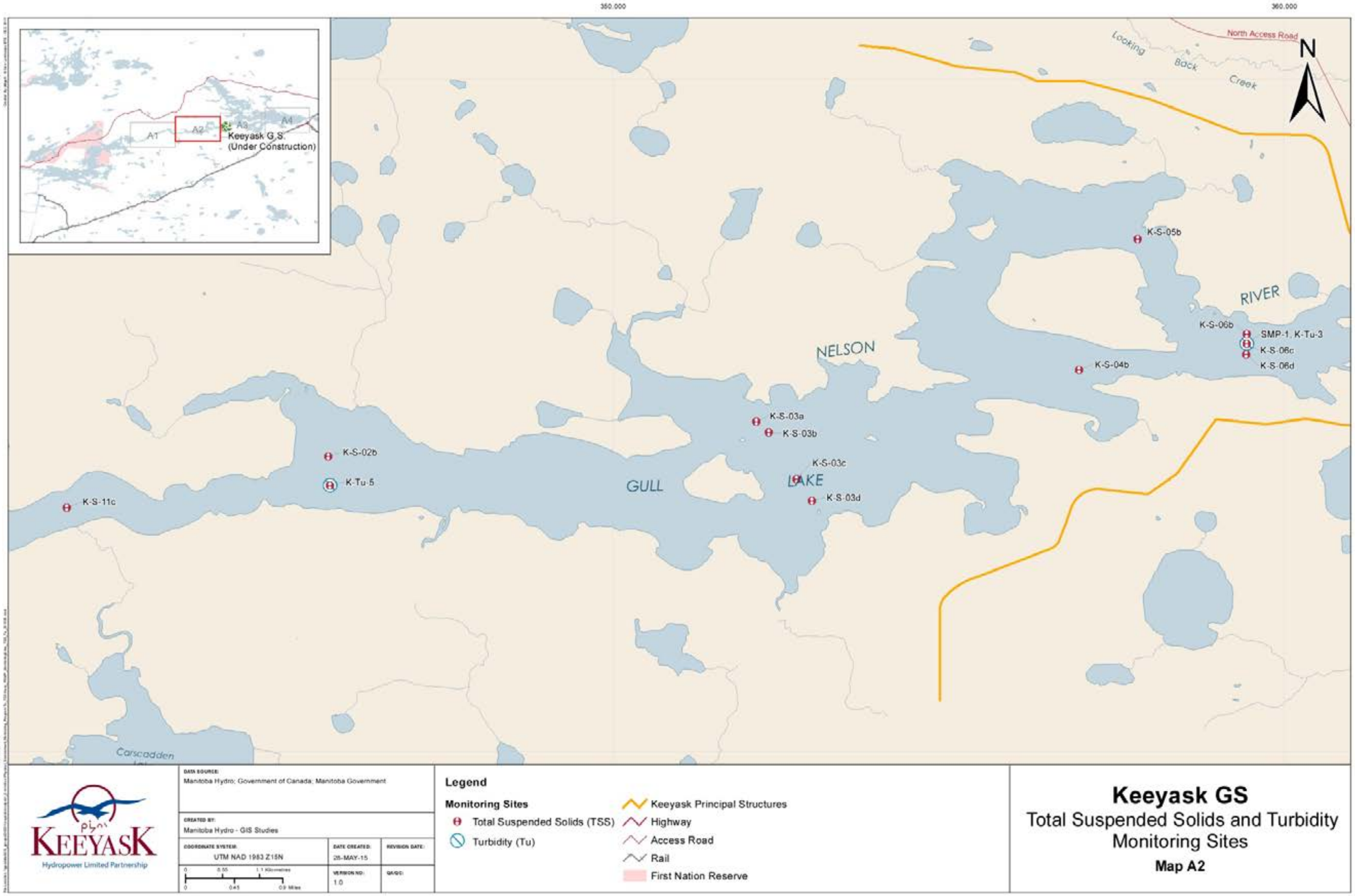
DATE CREATED:
26-MAY-15
REVISION DATE:
VERSION NO:
1.0
QA/QC:
Legend
Monitoring Sites
Total Suspended Solids (TSS)
Turbidity (Tu)
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
Total Suspended Solids and Turbidity
Monitoring Sites
Map A1


Keeyask G.S. (Under Construction)
A1
A2
A3
A4
North Access Road
Looking Back Creek
N
NELSON
RIVER
GULL
LAKE
Cascadden
K-S-05b
K-S-06b
SMP-1, K-Tu-3
K-S-06c
K-S-06d
K-S-04b
K-S-03a
K-S-03b
K-S-03c
K-S-03d
K-S-02b
K-Tu-5
K-S-11c
DATA SOURCE:
Manitoba Hydro; Government of Canada; Manitoba Government
CREATED BY:
Manitoba Hydro - GIS Studies
COORDINATE SYSTEM:
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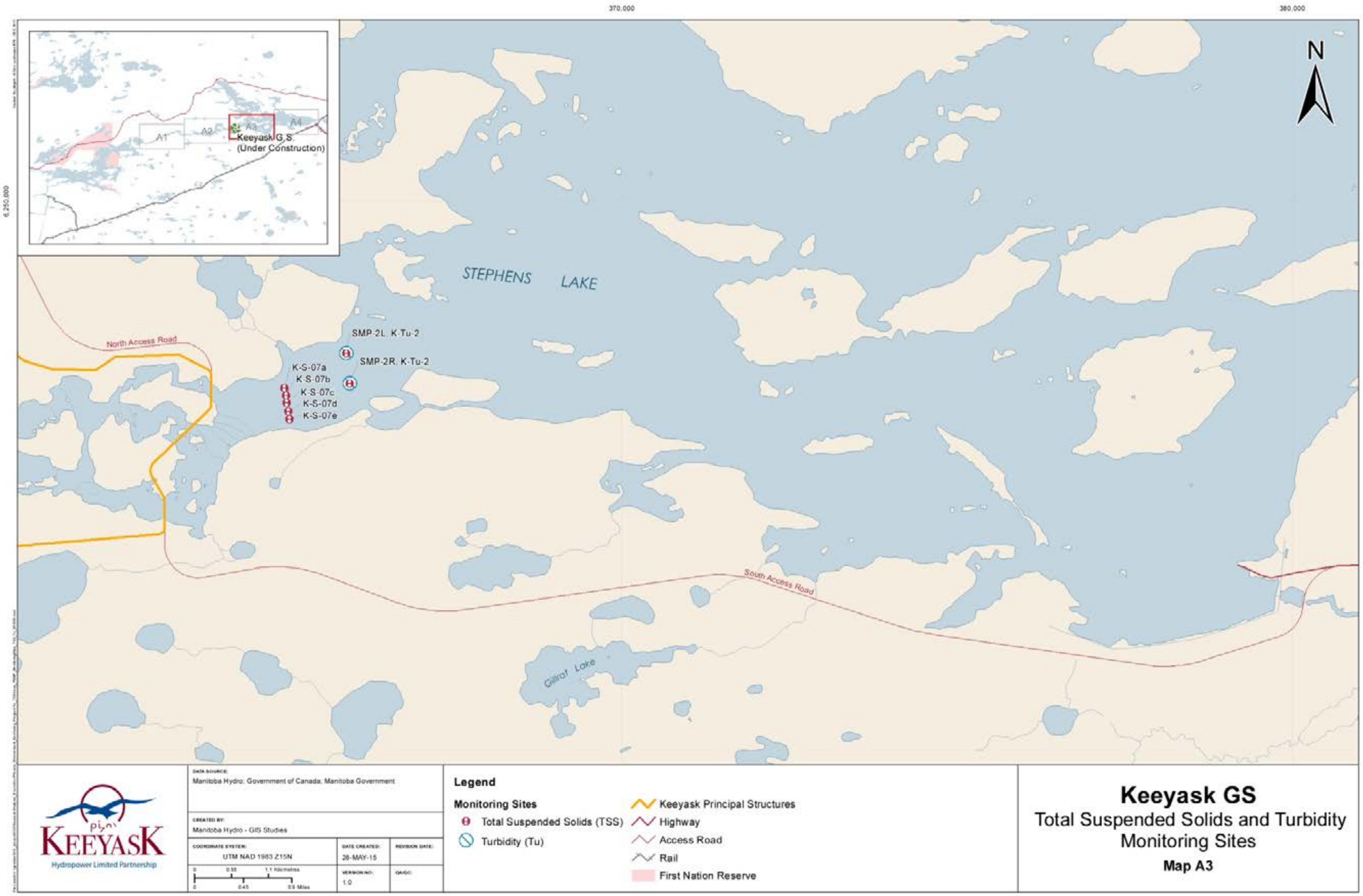
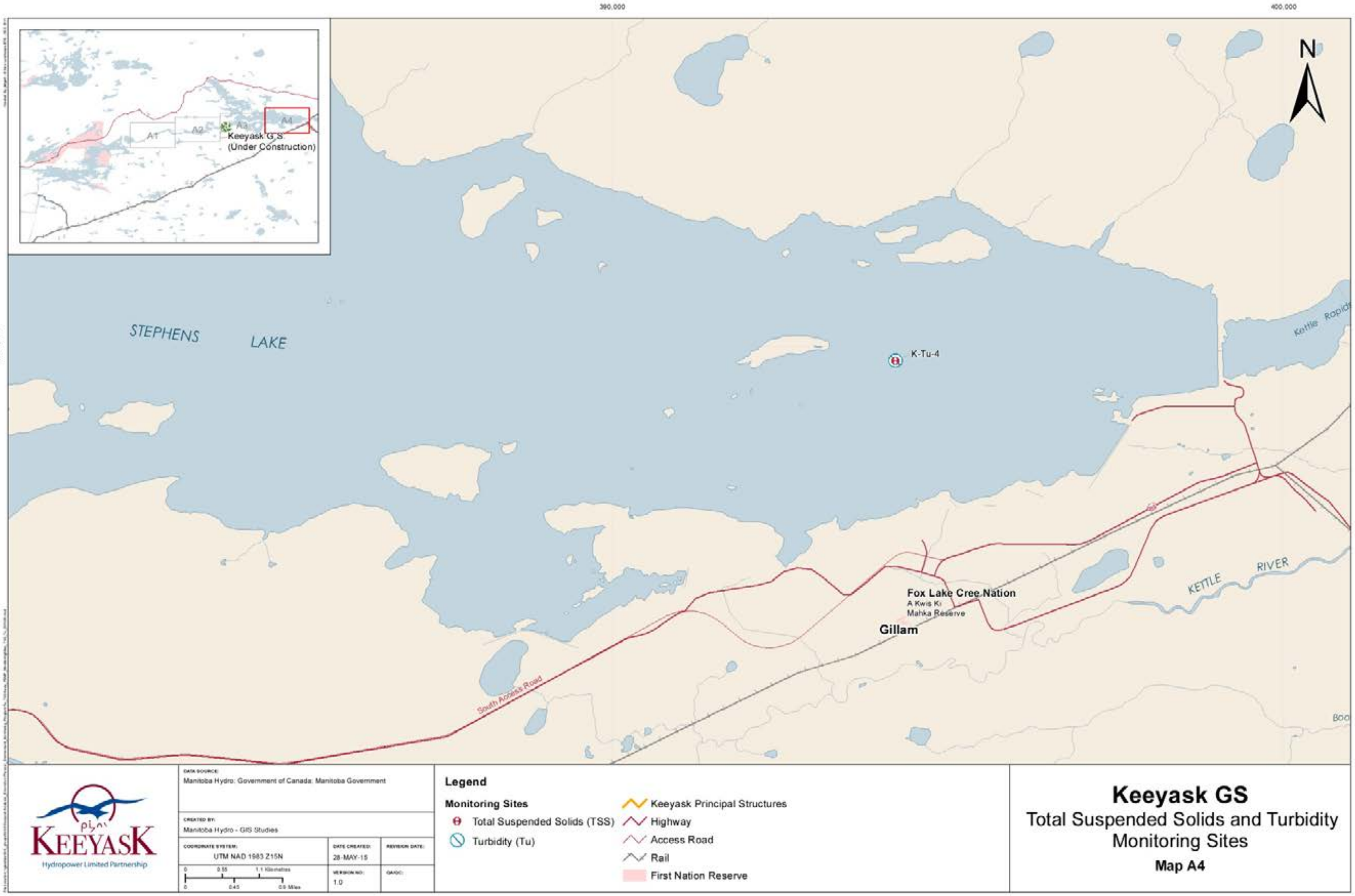
DATE CREATED:
28-MAY-15
REVISION DATE:
VERSION NO:
1.0
QA/QC:
Legend
Monitoring Sites
Total Suspended Solids (TSS)
Turbidity (Tu)
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
Total Suspended Solids and Turbidity Monitoring Sites
Map A2


370,000
380,000
6,250,000
N
Keeyask G.S.
(Under Construction)
A1
A2
A3
A4
STEPHENS LAKE
North Access Road
South Access Road
Gillrat Lake
SMP-2L, K-Tu-2
SMP-2R, K-Tu-2
K-S-07a
K-S-07b
K-S-07c
K-S-07d
K-S-07e
KEEYASK
Hydropower Limited Partnership
DATA SOURCE:
Manitoba Hydro; Government of Canada; Manitoba Government
CREATED BY:
Manitoba Hydro - GIS Studies
COORDINATE SYSTEM:
UTM NAD 1983 Z15N
DATE CREATED:
28-MAY-15
REVISION DATE:
VERSION NO:
1.0
QA/QC:
Legend
Monitoring Sites
Total Suspended Solids (TSS)
Turbidity (Tu)
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
Total Suspended Solids and Turbidity
Monitoring Sites
Map A3


STEPHENS LAKE
K-Tu-4
Kettle Rapids
Fox Lake Cree Nation
A Kwis Ki Mahka Reserve
Gillam
KETTLE RIVER
South Access Road
Keeyask G.S. (Under Construction)
A1
A2
A3
A4
N
390,000
400,000
6,250,000
DATA SOURCE: Manitoba Hydro; Government of Canada; Manitoba Government
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KEEYASK
Hydropower Limited Partnership
Legend
Monitoring Sites
Total Suspended Solids (TSS)
Turbidity (Tu)
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
Total Suspended Solids and Turbidity Monitoring Sites
Map A4