Keeyask Generation Project

Physical Environment Monitoring Plan

Physical Environment Monitoring Report

PEMP-2016-01

KEEYASK

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KEEYASK GENERATION PROJECT

PHYSICAL ENVIRONMENT MONITORING PLAN

REPORT #PEMP–2016–01

PHYSICAL ENVIRONMENT MONITORING REPORT

YEAR 2 CONSTRUCTION

Prepared By

Manitoba Hydro

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SUMMARY

BACKGROUND

The Keeyask Generation Project (the Project) involves the construction, which began in July 2014, and operation of the Keeyask Generating Station (GS) at Gull Rapids. As part of the Project the Keeyask Hydropower Limited Partnership (KHLP) was required to prepare 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 construction of the Project, which includes monitoring of water and ice regimes, shoreline erosion, sedimentation, debris and greenhouse gases. This report describes the 2015/16 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; the velocity and depth/elevation monitoring is planned for 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 April 2015 and March 2016 was above the historical average most of the time. While it ranged from approximately 3,200 m^3/s (cubic metres per second) to 4,300 m^3/s (113,000 to 152,000 cubic feet per second), it generally remained within a relatively narrow range from about 3,500 m^3/s to 4,000 m^3/s (124,000 to 141,000 cubic feet per 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.

Construction activities that have influenced the water regime include river diversion measures 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 about 0.9 m (3 feet) due to the rock groin. 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.

Rough Ice Due to Shoving and Piling Up at the Entrance to Gull Lake (Jan. 21, 2016)

In winter, water levels at the gauge site at the upstream end of Gull Lake experienced maximum increases of almost 3 m (10') and about 5.5 m (18') at Birthday Rapids due to ice accumulation at the entrance to Gull Lake and upstream. The increases diminished upstream. Based on observed water level conditions, neither Clark Lake nor Split Lake water levels were affected due to the Project. While the ice cover likely formed sooner due to the Project ice boom, the observed water level increases are still consistent with those that could be anticipated without the Keeyask Project when an ice bridge forms on Gull Lake and an upstream ice cover develops.

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 riverbed. Sediment traps are used to monitor deposition.

Turbidity monitoring is done with a turbidity probe placed into the water that uses an optical sensor 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. 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. There were no apparent effects of the Project on sediment transport during the 2015/16 reporting period.

Probe used for continuous turbidity monitoring can be equipped with multiple sensors to measure additional parameters if needed

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. During the monitoring period, sediment traps placed at the upstream end of Gull Lake were not recovered due to unsuitable site conditions. In keeping with the monitoring plan, traps will no longer be placed at that site but the substrate (bottom material) will continue to be sampled. Sediment collected in the trap at the entrance to Stephens Lake was almost entirely fine inorganic material (silt and clay). Substrate material at both monitoring sites was found to be comprised of coarse rock material. The results indicate that while fine sediment is present in the water, this fine material is not being deposited in the area where the traps are located but instead is being transported downstream.

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

DEBRIS

Manitoba Hydro operates waterway management programs on various water bodies to monitor and remove debris. In 2015, an additional crew began operating that was dedicated to monitoring the waterway from Clark Lake to Gull Rapids. Previously, a crew from Split Lake checked the area about once per week (i.e., 20% of the time). Debris such as floating logs and branches are monitored and removed where it poses a safety hazard to navigation. In addition, the crew marks hazards and engages with other waterway users within the river reach. Despite now having a dedicated crew, the amount of woody debris removed was much lower than reported in previous years when it was estimated that 20% of material collected by the Split Lake waterway management crew was recovered between Clark Lake and Gull Rapids. The results suggest that the previous debris removal quantities were likely overestimated.

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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 (KHLP, 2012a). 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; KHLP, 2012b). 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 April 2015 to March 2016, the second year of construction monitoring. The monitoring was completed according to the Keeyask Physical Environment Monitoring Plan (PEMP), which was finalized in 2015 following regulatory review and approval (KHLP, 2015).

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:

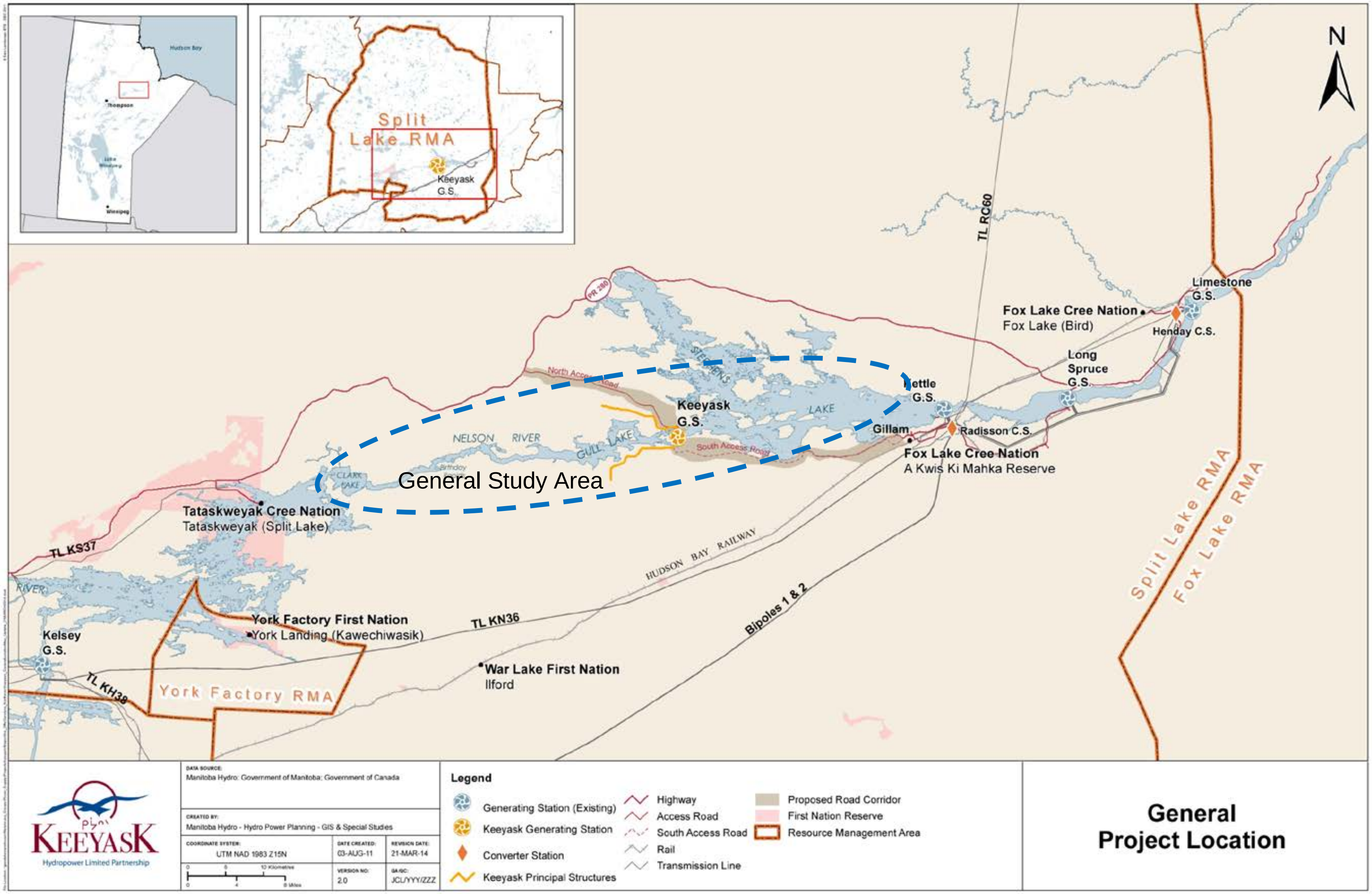
- Determine if EIS predictions of Project effects on the physical environment are correct and to identify unanticipated effects.
- Support other monitoring programs (e.g., aquatic and terrestrial) that will monitor Project effects and determine the effectiveness of mitigation/offsetting measures.

The environmental components that will be monitored under the PEMP include the following although, according to the plan, some components are not scheduled for monitoring each year:

- 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 2015/16 physical environment monitoring included surface water and ice regime, shoreline, sedimentation, 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 (detailed site maps are provided in Appendix A).



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 and is not affected by the Keeyask Project. 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 directly correlated to water levels under open water conditions (i.e;. high flow rates result in high water levels). In winter, the levels are also influenced by ice conditions so the relationship between flow and water level is not consistent between summer and winter months.

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 in the current reporting period has been generally lower than the high flows experienced during about the first 6 months of construction when they peaked near 6,000 m^3/s (cubic metres per second). With a few exceptions, river discharge between April

2015 and March 2016 has been above the historical daily median flows. While the flow has ranged from approximately 3,200 m^3/s to 4,300 m^3/s (113,000 to 152,000 cubic feet per second), it has generally remained within a relatively narrow range from about 3,500 m^3/s to 4,000 m^3/s (124,000 to 141,000 cubic feet per second).

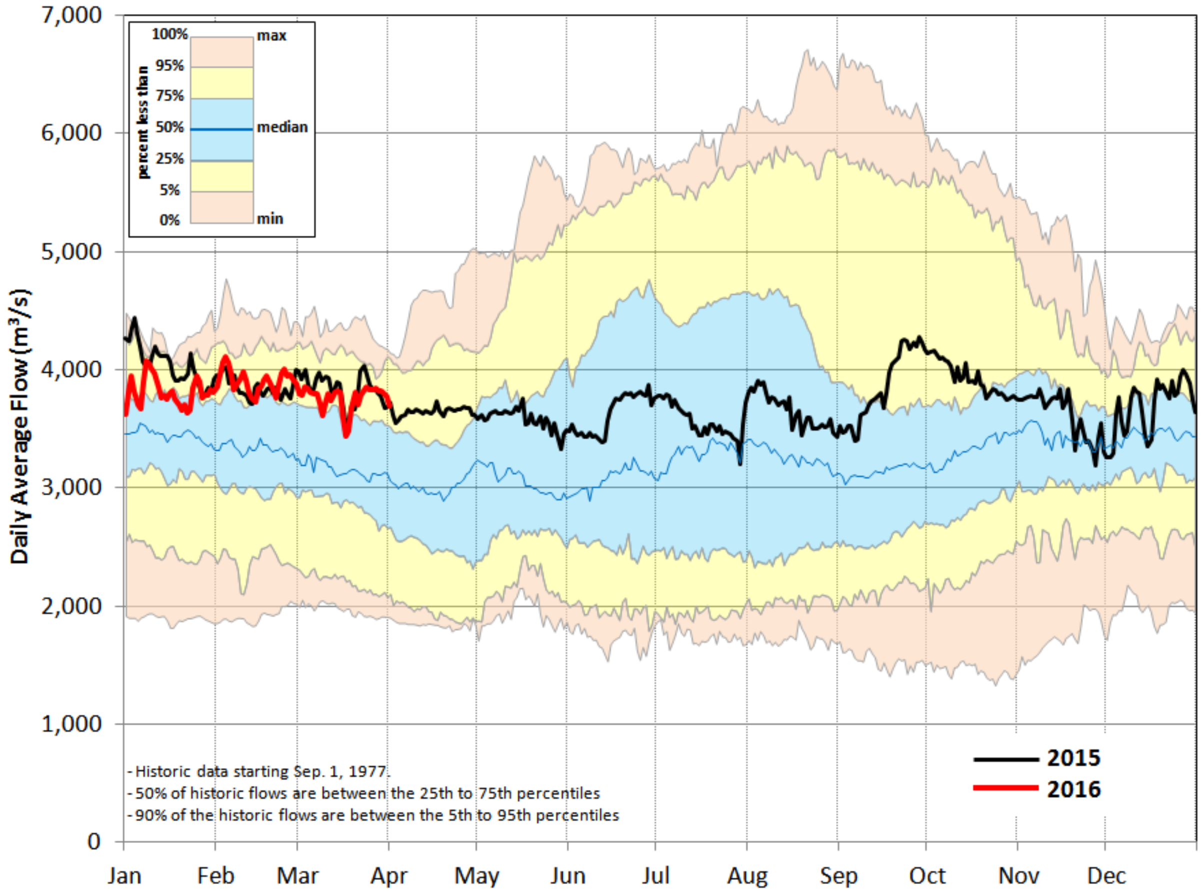
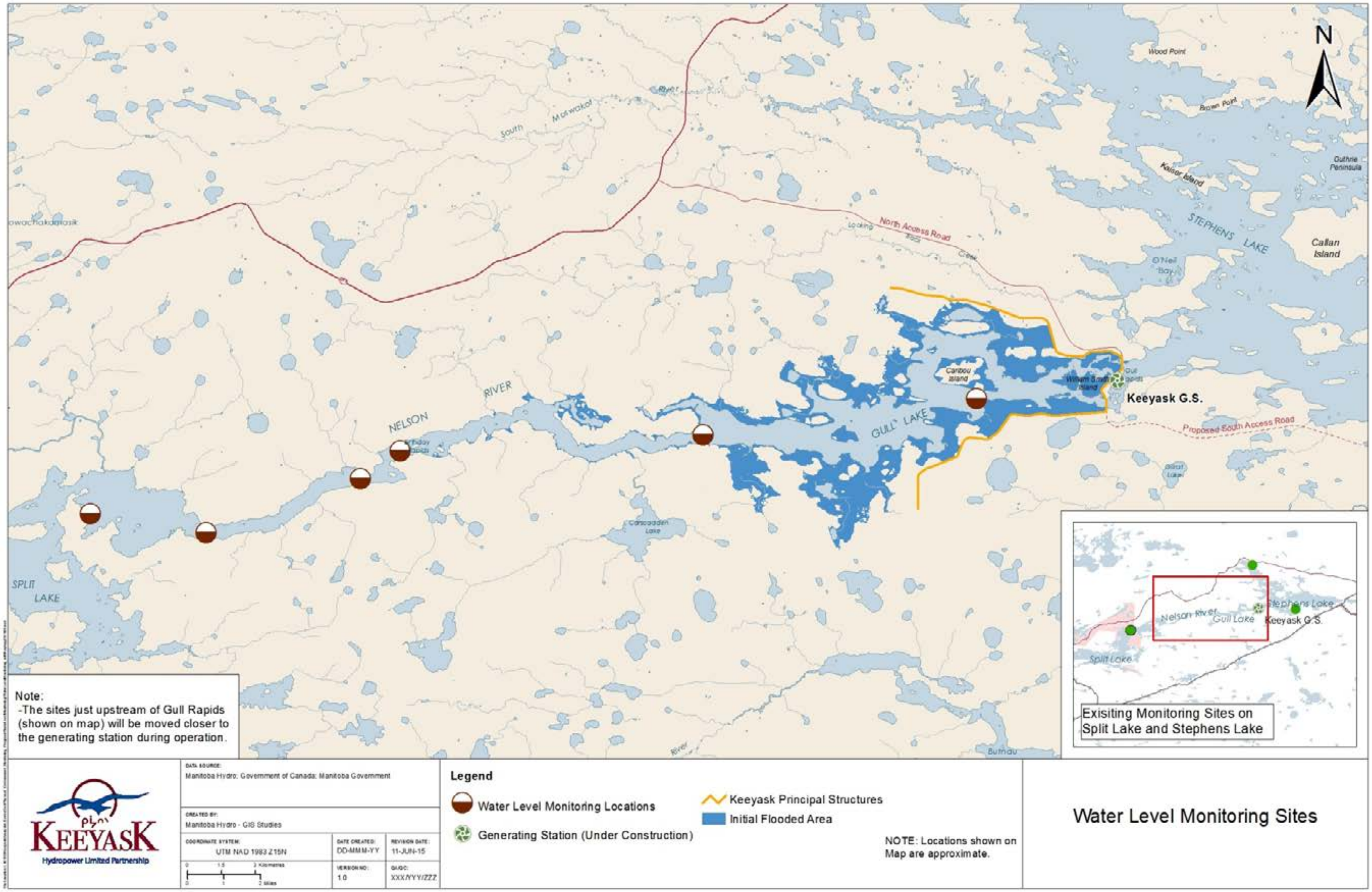


Figure 1: Split Lake 2015-2016 Daily Average Outflow and Historical Statistics

2.2 WATER LEVELS

2.2.1 OBSERVED WATER LEVELS – SUMMER AND WINTER

Water levels have been monitored at six sites 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, 2014. The other three sites were installed after construction started, 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. In addition to data from the PEMP gauges, data was also obtained for the existing Split Lake gauge at the community of Split Lake.



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

The 2015/16 water level records at each PEMP monitoring site are shown in Figure 2. There are some data gaps and somewhat irregular readings during the winter due to ice effects and the data may be subject to further quality review and revision.

In January, 2015, water levels had increased due to ice conditions as previously reported in the 2014/15 annual PEMP report (Manitoba Hydro 2015). By April 2015, the start of the current reporting period, water levels were starting to drop from their winter peak (Figure 2). This was partly due to gradually declining flow and typical changes in ice conditions towards the end of winter (e.g., bottom of ice gets smoother and less resistant to flow).

By about the end of May the water levels once again reflect open water conditions where levels are only dependent upon flow without any ice effects. During the open water period up to about the third week of November, the water levels vary directly with flow changes (Figure 2). Depending on location, summer water levels were generally about 1-1.5 m lower than in 2014 due to lower flows. The North Channel Rock Groin continues to affect open water levels upsptream as reported in the 2014/15 annual PEMP report (Manitoba Hydro 2015) (Map 3) on upstream water levels. For the Gull Lake site at Caribou Island, the water level was about 0.9 m higher compared with pre-construction conditions at a flow of about 3,500 m^3/s. The effect on level diminishes further upstream such that there is no impact on levels at and upstream of the monitoring site below Gull Rapids (Map 4). The observed effect is consistent with predicted effects within the range of model accuracy.

Two new ice booms were installed in 2015 to replace the boom at the head of Gull Rapids, which failed in 2014. The new booms, Boom A and Boom B, are located east and south of Caribou Island while a remnant of the original ice boom remains in place at the head of Gull Rapids (Map 3). The booms are designed to trap ice and force the early formation of an ice cover upstream of the main construction site, which minimizes winter water level increases at the foot of Gull Rapids adjacent to the construction area.

At the beginning of November, flows and water levels were steady in the study area as open water conditions prevailed (Figure 3). Starting November 19, air temperatures dropped sharply and, correspondingly, water levels at all of the monitoring sites began to increase as ice formation increased. On November 19, the ice booms trapped sufficient ice to cause the ice to bridge across the width of the river and an ice cover formed rapidly upstream on Gull Lake.

At each site the levels generally increased up to a peak around mid February, when the flow was similar to the flow just before ice formation started in November. At the Gull Lake monitoring site, water level staging (i.e., higher level at same flow) of about 1 m occurred between November and February. Respectively, staging of about 0.8 m and 1.4 m occurred for the Clark Lake site and the site just downstream. On Split Lake, staging of about 0.7 m occurred between November and February, which is typical for Split Lake (KHLP 2012b, Sec. 4.3.1.3).

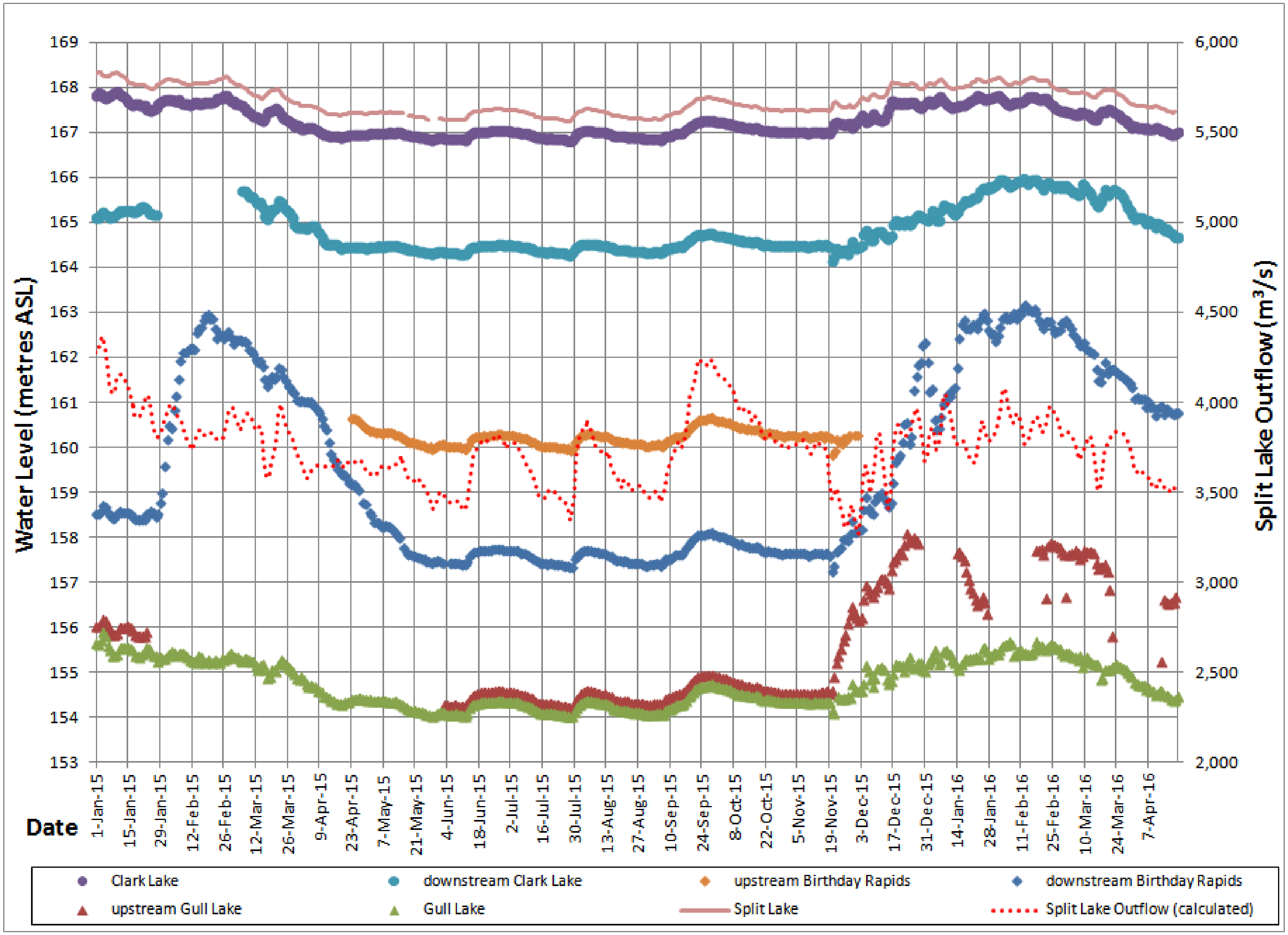
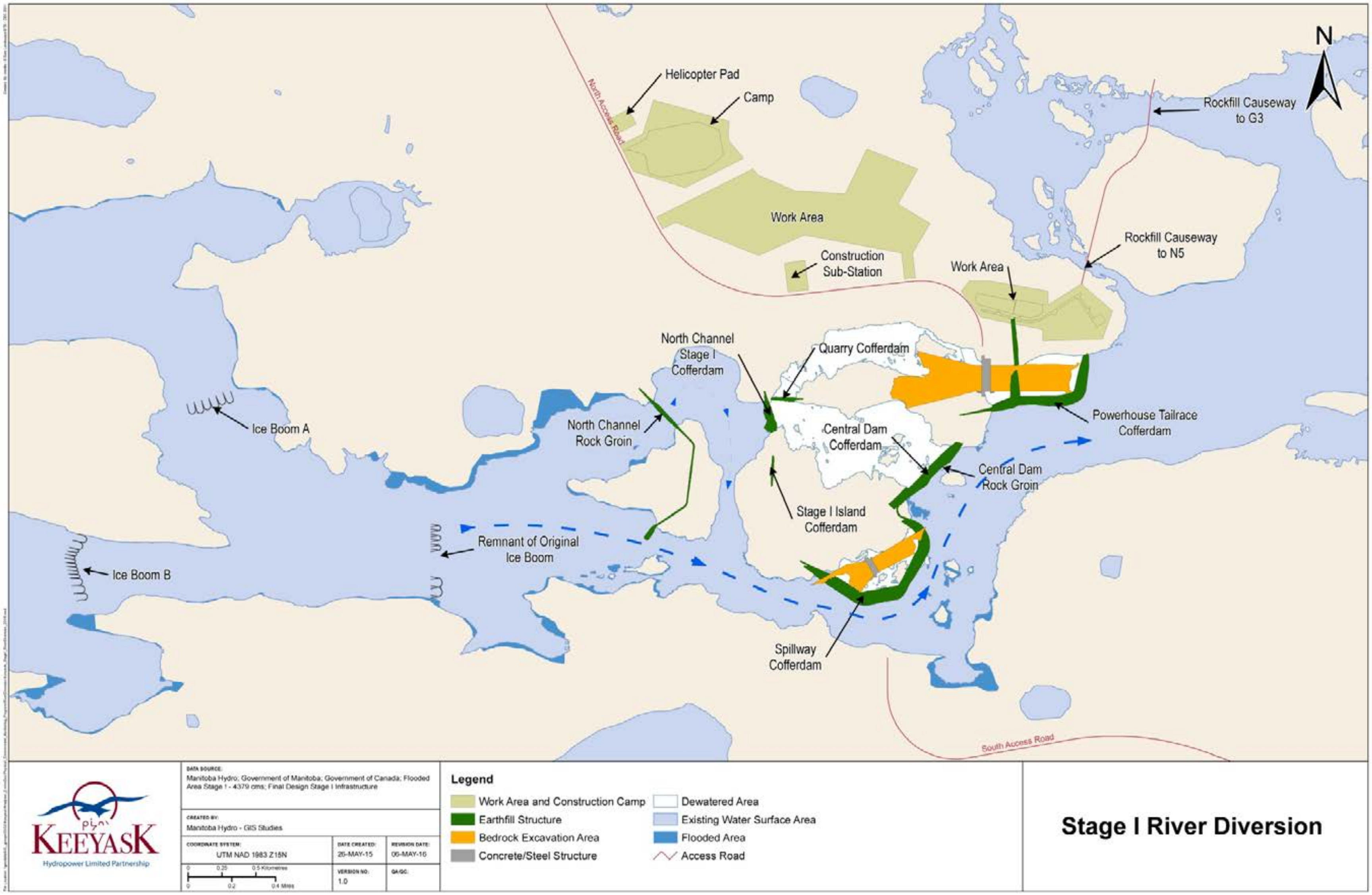
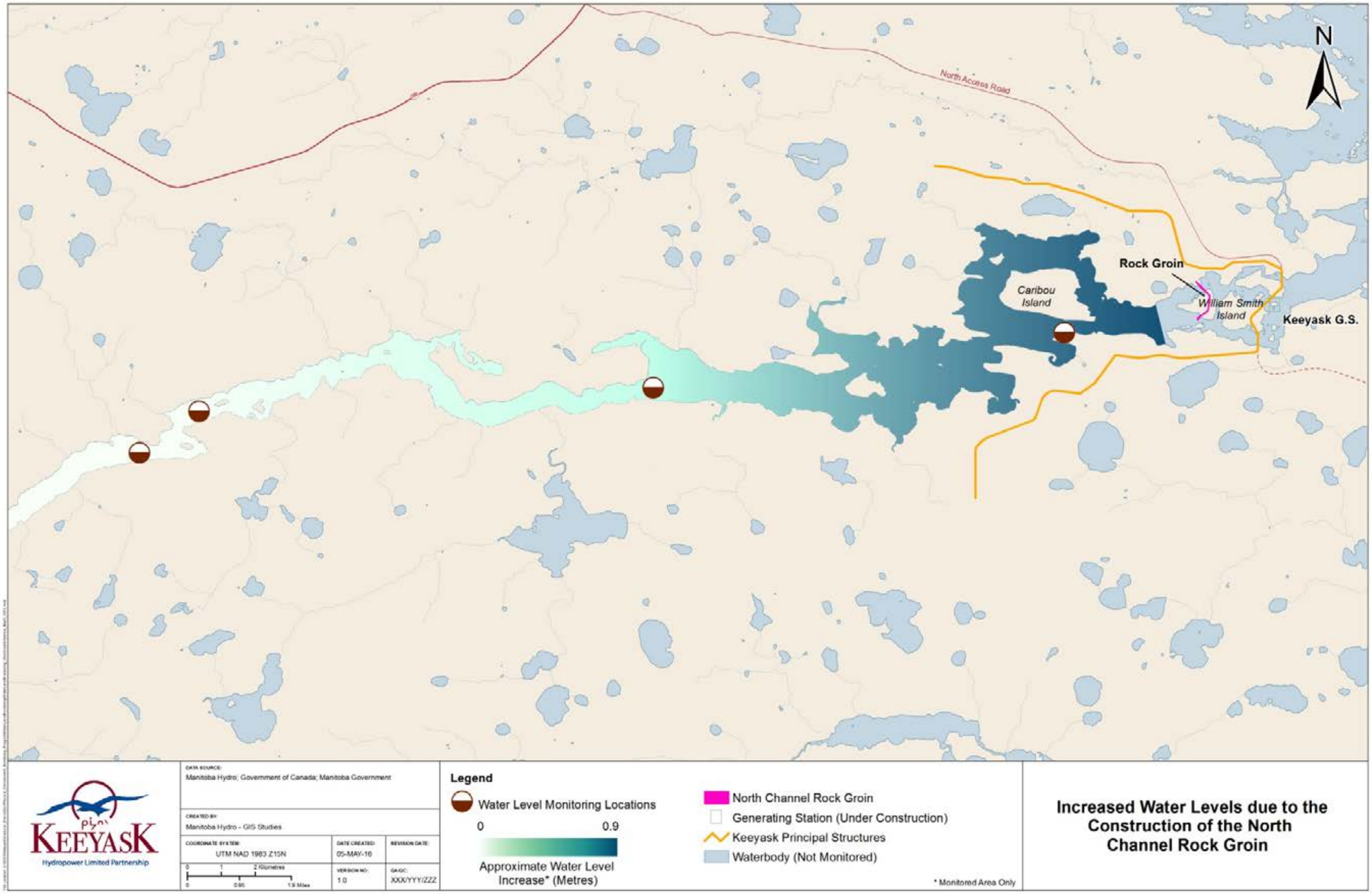


Figure 2: Observed Water Levels at PEMP Monitoring Sites in 2015-2016



Map 3: Constructed In-Stream Structures



NOTE: Locations shown on Map are approximate.

Map 4: Approximate 2015 Water Level Increases due to the North Channel Rock Groin (Open Water Conditions)

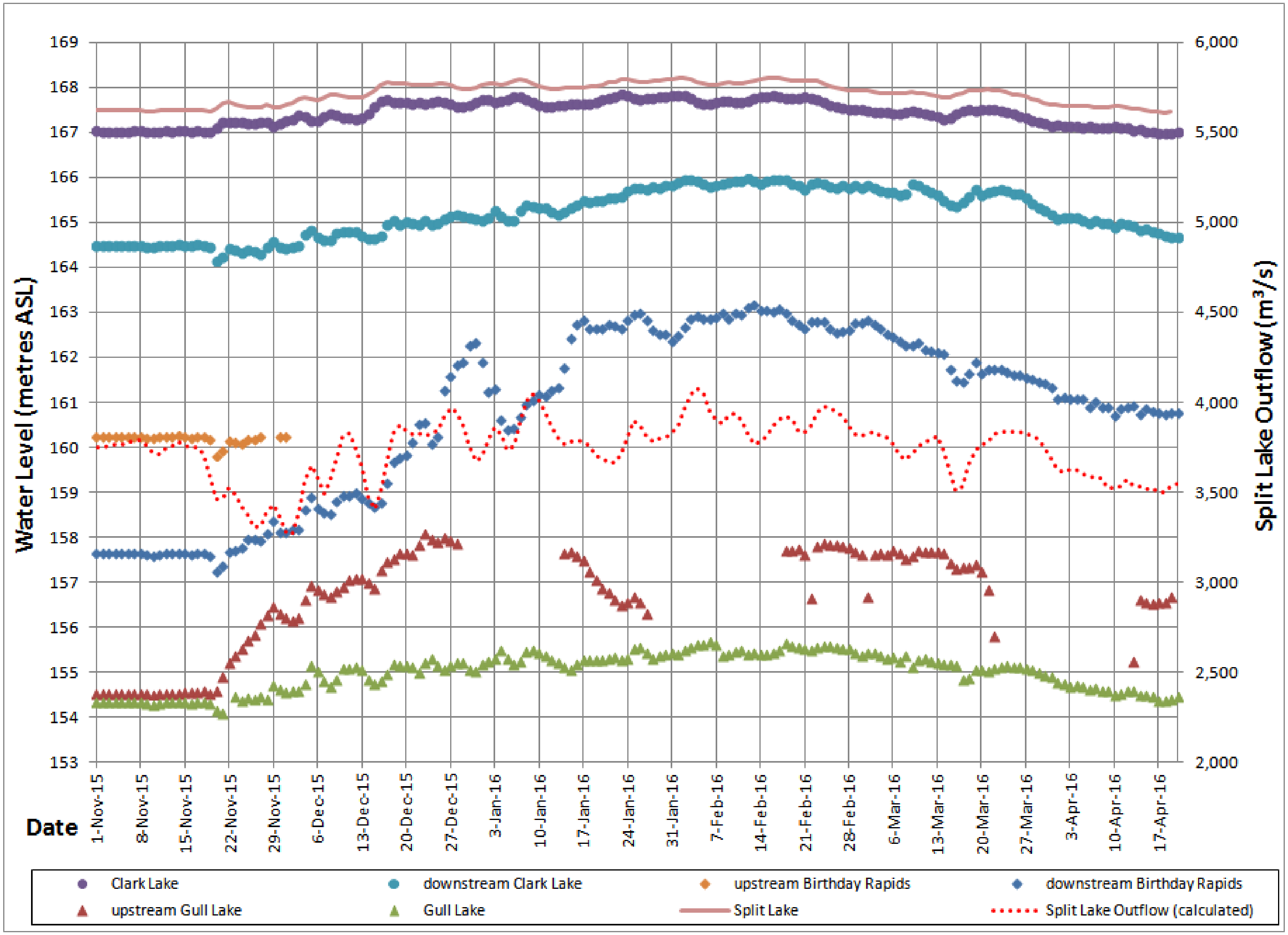


Figure 3: Observed Water Levels, November 2015 to April 2016

As in winter 2014/15, larger staging occurs just upstream of Gull Lake and the greatest amount of staging occurred below Birthday Rapids. Just upstream of Gull Lake, an increase of about 3 m (10') occurs from mid November to the end of December and similarly high levels are indicated later in the winter. Data gaps occur due to challenging ice conditions that affect monitoring in this area. At the site below Birthday Rapids, the water levels increase almost 5.5 m (about 18') because of ice effects, similar to the increase observed in 2014/15. Staging will have occurred at the site above Birthday Rapids, however the influence of ice on this gauge resulted in poor quality data.

2.2.2 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 4). 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, in winter, the water level variations correspond well with flows while staging is occurring due to ice, and results do not suggest an influence on Clark Lake water levels due to downstream water level staging. As noted above, the observed winter staging of about 0.7 m on Split Lake is typical for this lake. The PE SV noted that winter staging on Split Lake in the pre-project environment could range from 0.3 m to 1.2 m, and averaged about 0.6 m (KHLP 2012b, Section 4.3). Based the observed water level conditions, neither Clark Lake nor Split Lake water levels were affected as a result of the Project.

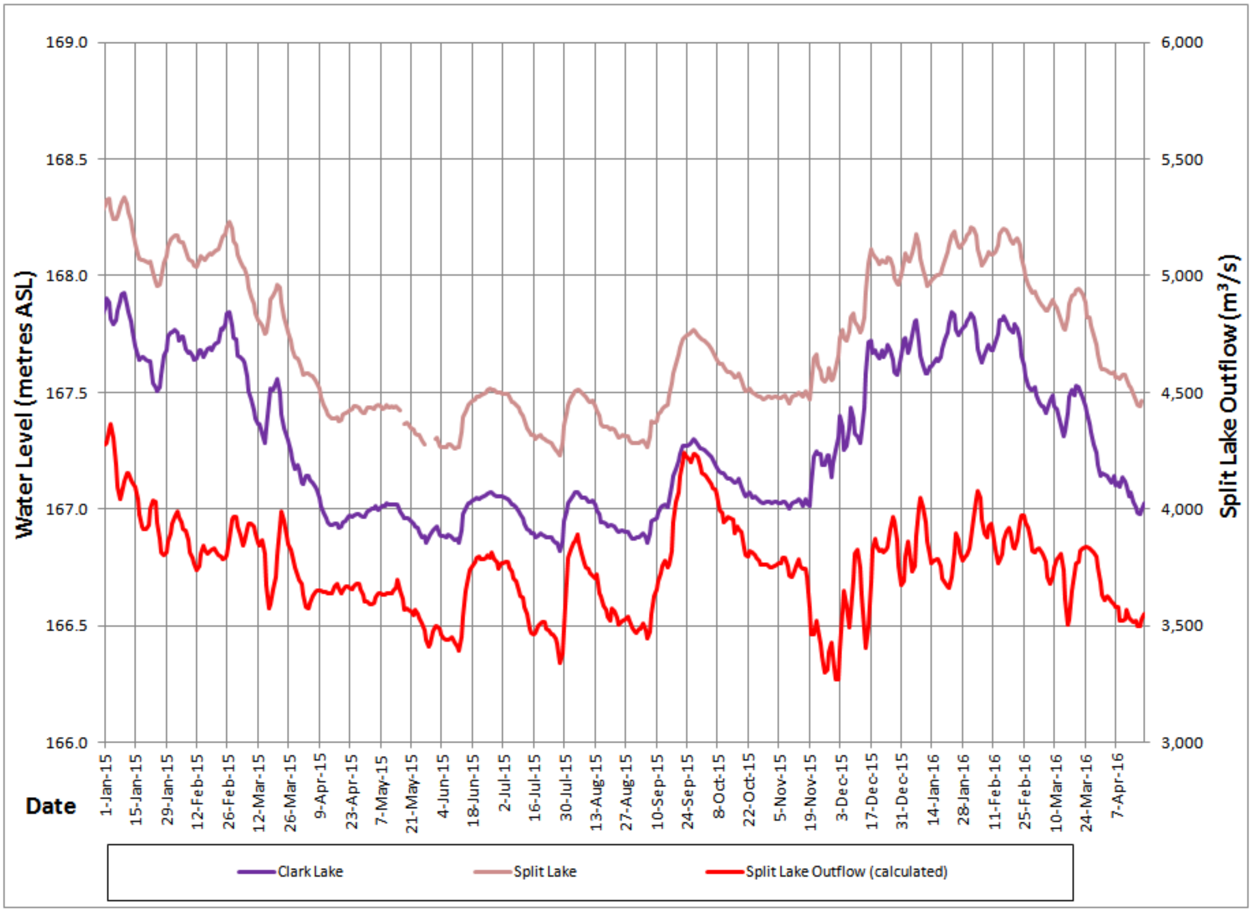


Figure 4: Observed Water Levels at Clark Lake and Split Lake in 2014/15

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 so that open water may persist in the central channel from the exit of Split Lake to the entrance of Stephens Lake. In years when bridging does occur the date when it occurs may be as early as November at lower flows to as late as January at higher flows.

Open water conditions persisted until about November 19 when air temperatures dropped sharply and ice formation increased, as evidenced by increasing water levels at all sites, as noted above. The best available satellite image prior to November 19 is a Landsat 7 image six days earlier, which shows open water from Split Lake to below Gull Rapids with some border ice (Figure 5). On November 19, the ice booms caused the ice to bridge across the width of the river and an ice cover rapidly formed upstream on Gull Lake. Field staff obtained photos from a helicopter in the area of Ice Boom B south of Caribou Island that show open water upstream of the boom on November 18 before ice formation began, and then again on November 21, about one or two days after it started (Photo 2) . These images show that the ice booms functioned as intended, having trapped ice sheets coming downstream and causing ice to accumulate quite rapidly upstream.

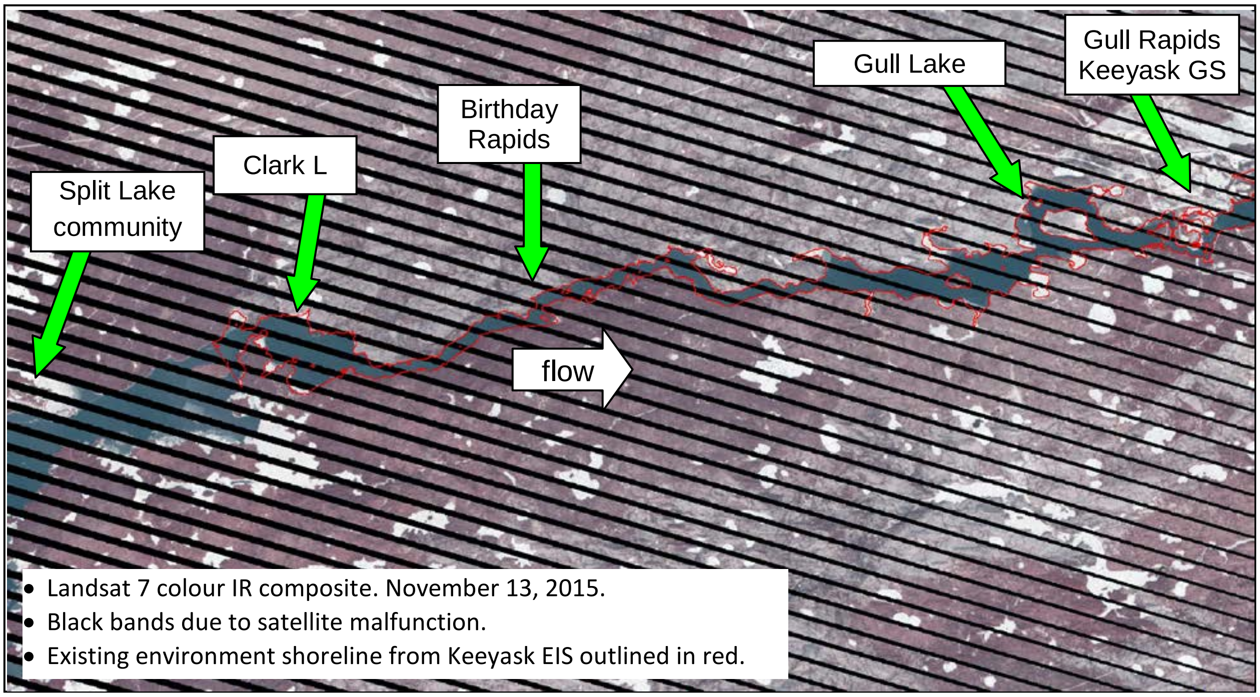


Figure 5: Ice Conditions – November 13, 2015

The next best available satellite image is from December 30, 2015, which shows that the ice cover had grown from the ice booms at Caribou Island to the leading edge of the ice front about 5 km upstream of Gull Lake (Figure 6). The image shows that an ice cover has developed on Split Lake while open water persists from the outlet of the lake to the leading edge of the ice cover just above Gull Lake. Additional border ice growth is also apparent, as is open water between the ice booms at Caribou Island to below Gull Rapids. The upstream advance of the ice front reaches Birthday Rapids by January 31, 2016 (Figure 6). By March 3, 2016, the ice front is still just below Birthday Rapids, having stalled at this location due to the fast flow through rapids. However, by March 12, the ice front has just started to advance above Birthday Rapids and by March 21 it has advanced to about 4 km above Birthday Rapids. This is the limit that the ice front progresses upstream, remaining in this location until at least April 13, 2016 (after the current reporting period). By April 20, 2016, the extent of the ice cover is already beginning to decrease, the early stages of the spring breakup.

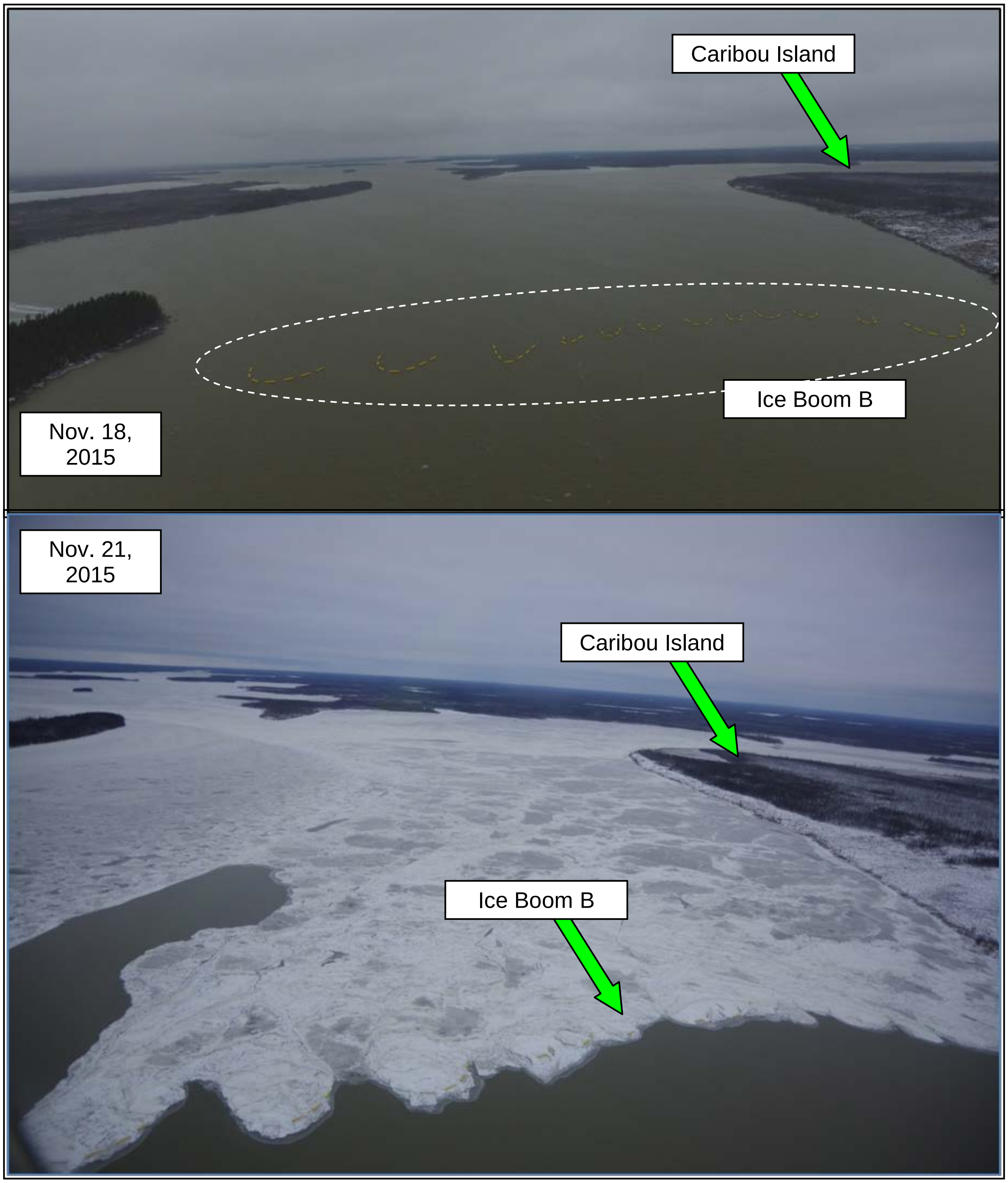


Photo 2: Nelson River Conditions on November 18 and 21, 2015

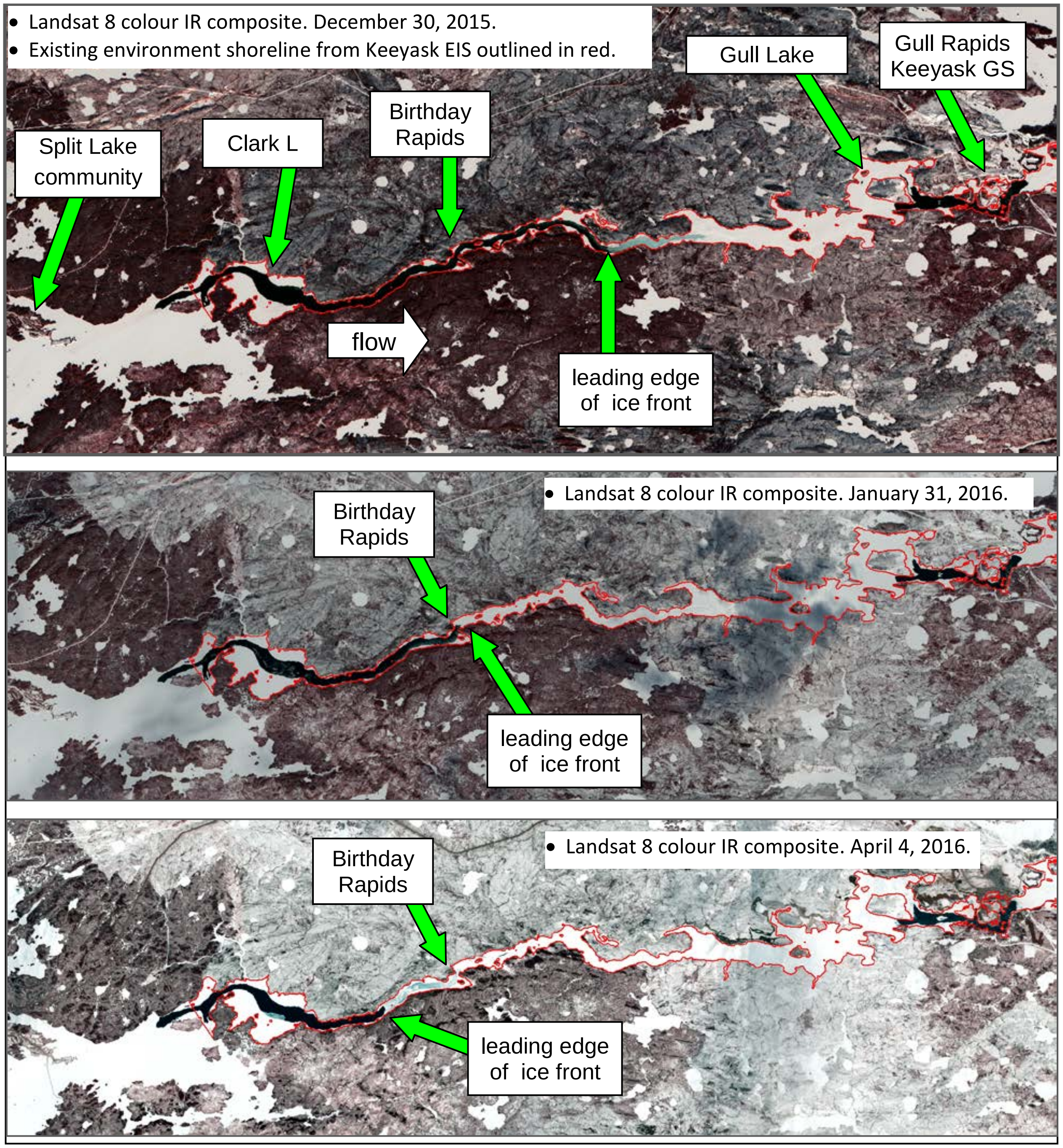


Figure 6: Ice Conditions – Dec. 30, 2015; Jan. 31, 2016; and Apr. 4, 2016.

During the winter, field crews periodically obtained photographs of ice conditions from Clark Lake to Gull Rapids. The photos show a variety of ice conditions in different areas over time. A photo just upstream of Birthday Rapids on November 30, 2015 shows border ice along the shore and areas of less current (Photo 3). A photo a few months later, after the ice front has advanced past the rapids, shows how slush and ice pans progressively build up against the ice front causing it to advance upstream (Photo 3).

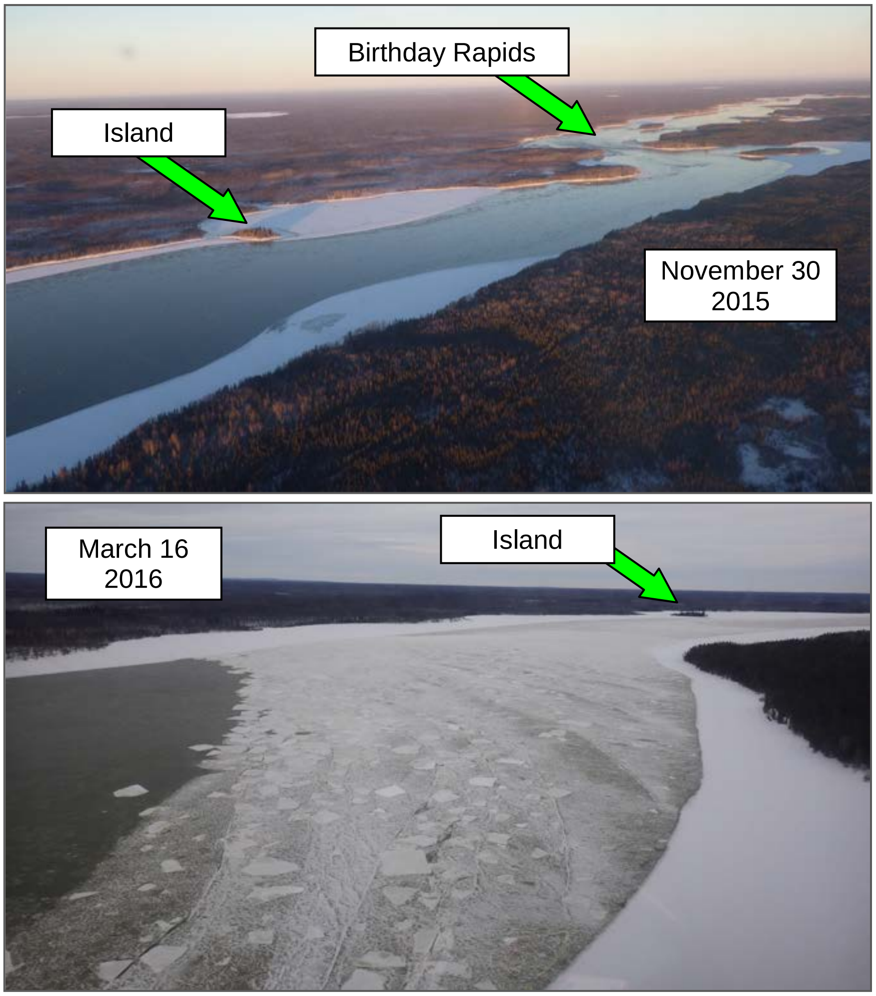


Photo 3: Ice Conditions Above Birthday Rapids – Nov. 30, 2015 and Mar. 16, 2016

Previously it was noted that data were missing from some water level sites due to the effects of ice on the gauging stations. Challenging ice conditions occur in the river section where the gauge site upstream of Gull Lake is situated. Slush ice and ice pans moving downstream tend to build up in this reach, creating a very rough ice cover that shifts and shoves over time. This is demonstrated in a photo from January 21, 2016, which shows heavily jumbled ice with ridges that may be a couple metres more in height (Photo 4). As the ice piles up, it shoves along the shore which can remove sensors placed in the water while increased water levels and ice pushed onto shore can destroy equipment placed there.

Photo 4: Rough Ice Cover Upstream of Gull Lake

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 the future immediately before the creation of the reservoir. The shorelines at the start and end of construction will be compared to see if any substantive shoreline erosion occurred during construction. Images collected after impoundment will be used to determine the actual extent of flooding and reservoir expansion over time.

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.

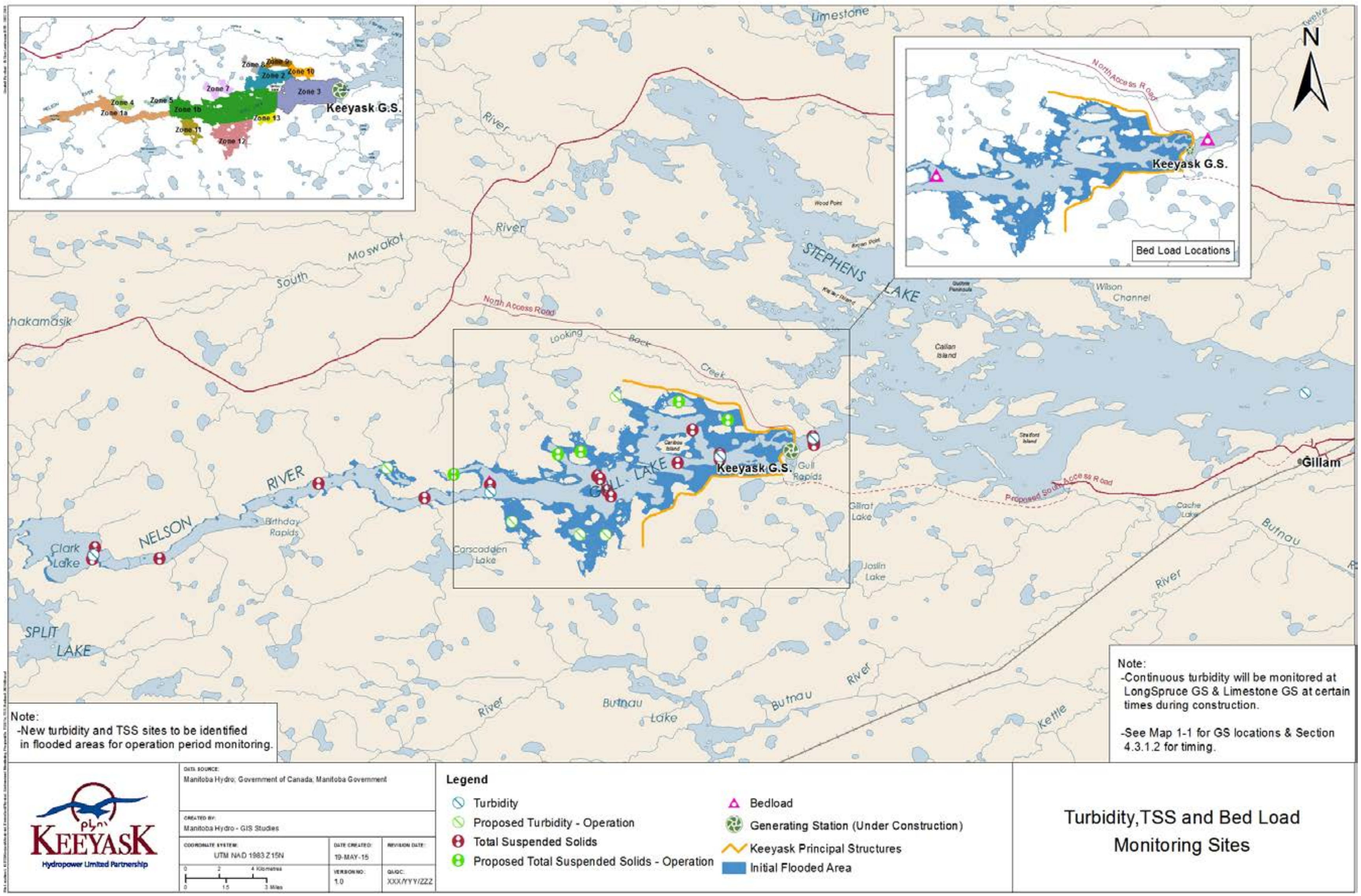
The largest overall effects of the Project on sedimentation are predicted to occur after impoundment of the reservoir with the highest total sediment loading predicted to occur in the first year after impoundment. During the construction period prior to reservoir impoundment the PEMP sedimentation monitoring 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 2016).

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 A). 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 that remains in place to take readings much more frequently. The continuous turbidity sites are periodically visited for maintenance checks, typically at the same time that discrete monitoring is performed. The discrete water samples were tested for total suspended sediment (TSS) concentrations and sediment grain size distribution.

4.2 WINTER 2014-2015

Winter monitoring conducted in the 2014/15 reporting period was not previously presented because removal of equipment at the end of winter does not allow time for the data to be reviewed before the reporting deadline. Continuous turbidity probes were deployed at three locations in January 2015: K-Tu-06 in Clark Lake; K-Tu-03 above Gull Rapids (site SMP-01 in KHLP 2014); and SMP-03 (see KHLP 2014) downstream of Gull Rapids (Photo 5). The SMP-03 site is further downstream from Gull Rapids than the K-Tu-02 PEMP site at the entrance to Stephens Lake; however SMP-03 data were used because adverse ice conditions (thick ice) prevented a probe from being placed closer to K-Tu-02



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

Photo 5: Winter Installation of Turbidity Monitoring Equipment (site SMP-03)

Figure 7 shows turbidity data collected in the January to April period. Monitoring during the winter is particularly challenging due to the effects of ice on the equipment. While several probes were placed earlier in January, the results are shown after January 21 because of poor data quality earlier in the month due to ice. Similarly, records show data gaps and end before April because of poor quality data due to ice. The best continuous record is for site K-Tu-06 at Clark Lake, which has a relatively complete data set from its installation on January 29 to its removal at the end of April. From a peak of about 20 NTU at installation, the turbidity gradually declines from about 15 NTU to 8 NTU in April. At the outlet of a large lake like Split Lake, this pattern of turbidity decline over winter would be anticipated as there are no upstream processes likely to contribute sediment to the water during winter. Though the record is shortened due to ice effects on the data, the results for site K-Tu-03 are similar to those upstream at K-Tu-06, which may be expected as significant additional sediment entrainment would not generally be expected between the two locations, although open water upstream could create slush ice that could influence the K-Tu-03 location.

The downstream SMP3 turbidity results are roughly 10-15 NTU higher for both the left (SMP3L) and right (SMP3R) locations. This is likely due in part to ice effects as significant slush ice can be transported into this area from upstream, which caused data issues earlier in January. Some additional sediment may also be entrained because the upstream hanging ice dam at the entrance to Stephens Lake can redirect the river flow and increase flow velocities over erodible materials under the ice.

Limited discrete sampling was performed during the winter monitoring period. Manual turbidity readings were generally lower than the corresponding turbidity readings from the continuous sensors, ranging from about 7 to 13 NTU (Figure 7). Corresponding TSS concentrations were low and ranged from about 3 to 20 mg/L (Table 2).

Overall, the observed turbidity upstream of Gull Rapids (K-Tu-06, K-Tu-03) from January to April was generally lower than observed in preceding summer (2014) while the results from SMP3 were of a similar magnitude.

Table 2: January – Arpil Discrete Monitoring Results

Site ID	Date	Turbidity (NTU)	TSS (mg/L)
K-Tu-06	Jan 29	12	7
K-Tu-06	Feb 19	9	6
K-Tu-06	Mar 24	7	3
K-Tu-06	Apr 24	12	7
K-Tu-03	Jan 30	13	8
K-Tu-03	Feb 17	9	
SMP3R	Feb 18	11	20

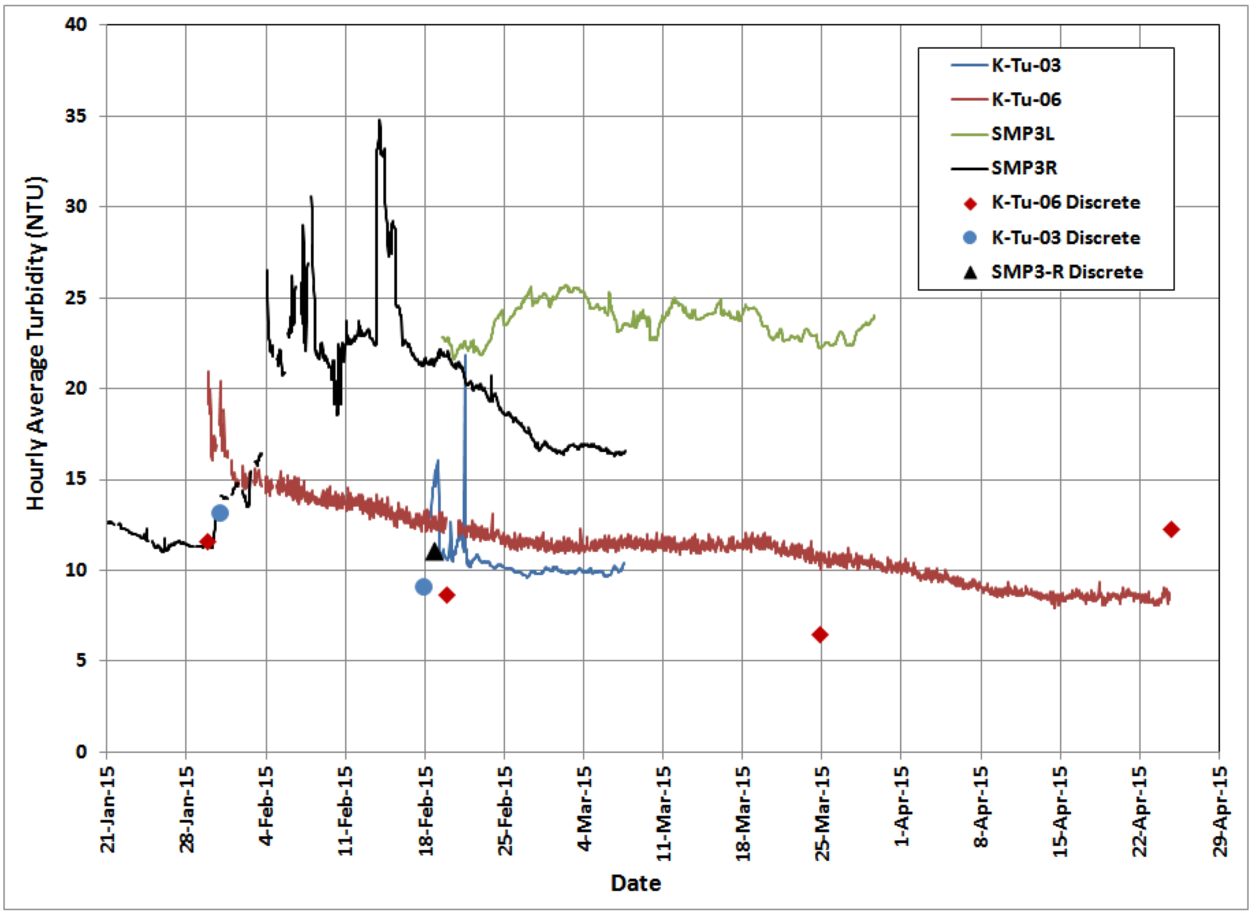


Figure 7: Continuous and Discrete Turbidity (Winter 2014/15)

4.3 SUMMER 2015

In summer 2015, the five locations at which continuous turbidity, TSS and additional water quality were monitored and the dates when Tu probes were installed and removal are:

- K-Tu-06, Clark Lake, June 26 to October 29
- K-Tu-05, entrance of Gull Lake, June 19 to October 20
- K-Tu-03, head of Gull Rapids, July 11 to October 16
- K-Tu02, entrance of Stephens Lake, June 27 to October 3
- K-Tu-04, near Kettle GS, June 25 to October 23

The data collected at each of the monitoring sites was reviewed to identify and remove poor quality data that may result due to factors such as: algae growth and vegetation on probes (Photo 7); dead batteries; and equipment malfunction. A wiper on the sensor helps to reduce the potential effect of algae growth on sensor (Photo 7).

Photo 6: Turbidity Monitoring Site K-Tu-05 and Worker Performing Site Maintenance

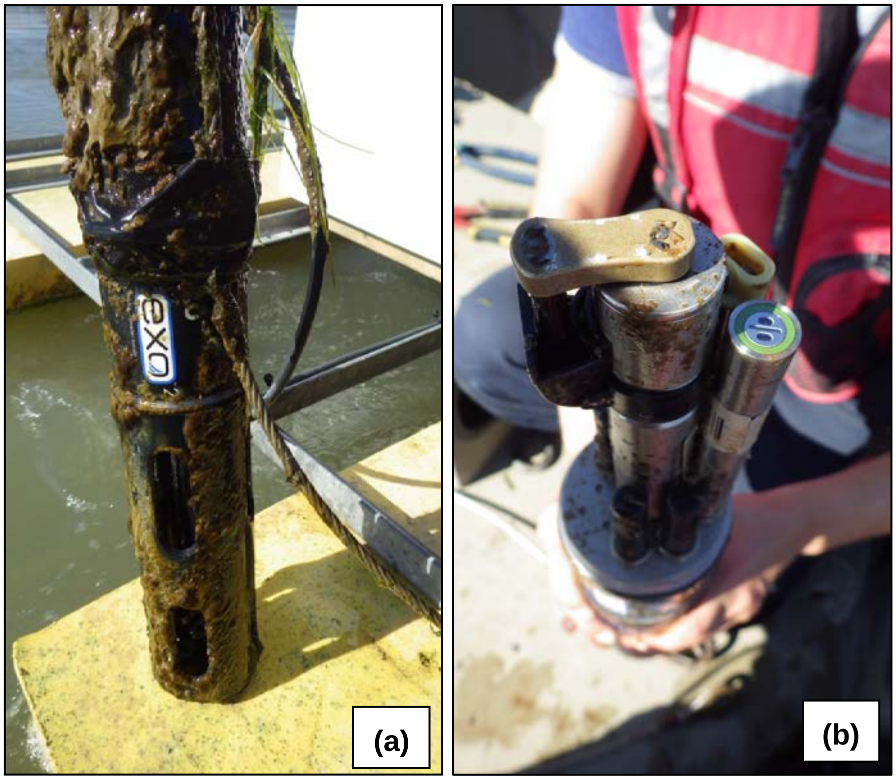


Photo 7: Site K-Tu-05 (a) Algae and Vegetation on Turbidity Probe, and (b) Sensor with Wiper (24/07/2015)

4.3.1 CONTINUOUS TURBIDITY

The data sets resulting from the quality review process were analyzed to calculate the hourly average turbidity at each of the five monitoring sites (Figure 8). As in seen in the 2014 summer data (Figure 9, from 2014/15 annual report), the 2015 results show very similar patterns of variation among the four monitoring sites from Clark Lake to the entrance of Stephens Lake (K-Tu-06, K-Tu-05, K-Tu-03, and K-Tu-02). Overall, the turbidity at these sites varies from about 16-30 NTU during the monitoring period. Somewhat higher values occur in July and August (approx. 18-30 NTU) with somewhat lower values in September and October (approx. 16-23 NTU). The range of variation in 2015 was somewhat less than in 2014 when it varied overall from about 15-40 NTU, although values in July and August were somewhat higher in 2014, while September and October were more similar between the two years.

While the 2015 results show a good correlation in the patterns of variability, they also indicate a shift in timing between corresponding peaks and valleys. Between the upstream site at Clark Lake (K-Tu-06) and the next site at the entrance of Gull Lake (K-Tu-05) the highest correlation in turbidity values occurs with a 5 hour offset. That is, turbidity at K-Tu-06 was highly correlated with the turbidity seen 5-hours later at K-Tu-05, indicating a travel time of about 5 hours

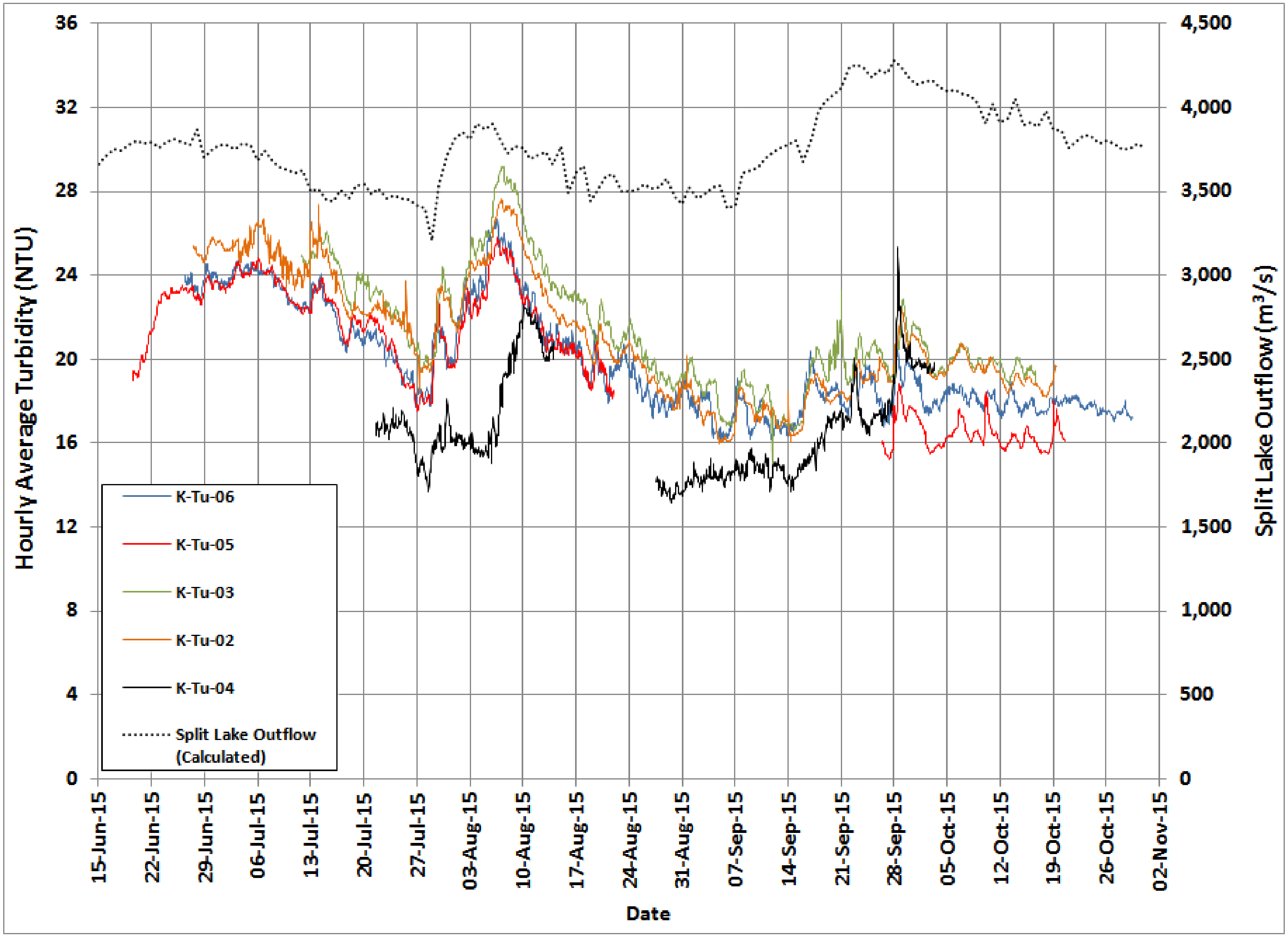
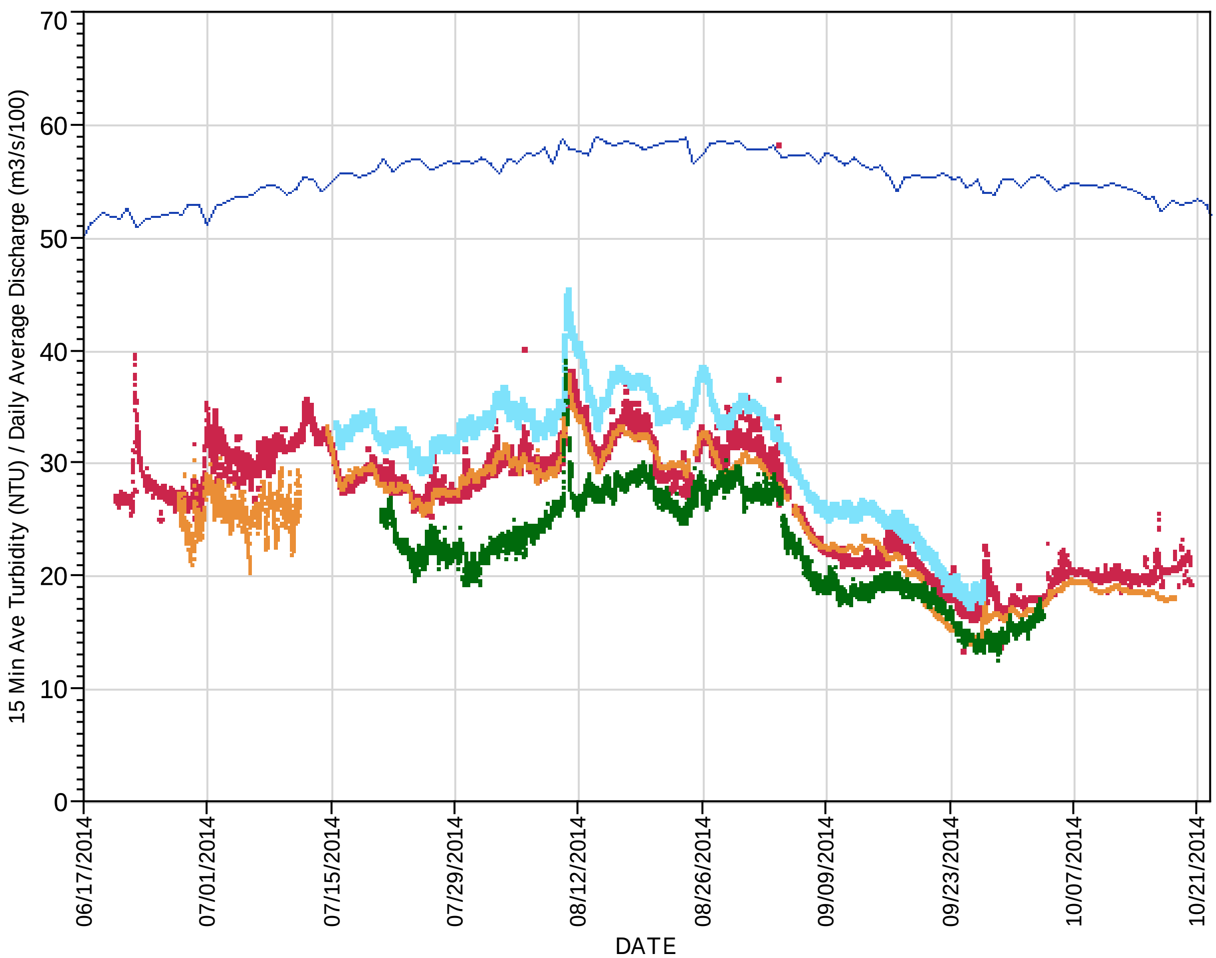


Figure 8: Continuous Turbidity and Flow (Summer 2015)

between the two sites. Similarly, the highest correlations between turbidity at K-Tu-06 and the sites at Gull Rapids (K-Tu-03, K-Tu-02) occurred with a 15 to 20 hour offset, indicating a 15-20 hour travel time between Clark Lake and Gull Rapids.



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 9: Continuous Turbidity and Flow (Summer 2014)

Aligning the data sets based on the different offset times, it was found that the turbidity levels observed at the downstream sites (K-Tu-05, K-Tu-03, K-Tu-02) were typically within +/-1.5 NTU of the value observed at K-Tu-06. This negligible difference between the sites suggests there is essentially no change in turbidity, and correspondingly TSS, from Clark Lake to the entrance of Stephens Lake even though flows were typically above average.

Although the data set from site K-Tu-04 near the Kettle GS (about 30 km downstream) was limited due to data quality issues, the results still show some similarity in the pattern of variation between this site and the upstream sites. Although this site is expected to be primarily affected by conditions on the Nelson River upstream, it is also influenced by conditions on Stephens Lake. Conditions at K-Tu-04 are most correlated with turbidity at site K-Tu-02 below Gull Rapids for a time offset of about 1.5 days. The results also show that turbidity at K-Tu-04 is generally lower than the other sites. Accounting for the time offset, the turbidity at K-Tu-04 is about 5.5 NTU or 22% lower than at K-Tu-02. This decrease is consistent with conditions observed prior to construction as the pre-construction studies found that the suspended sediment "concentrations in Stephens Lake decrease in the stream wise direction because some of the relatively coarser particles transported by the Nelson River settles in Stephens Lake" (KHLP 2012b).

4.3.2 TOTAL SUSPENDED SEDIMENT AND TURBIDITY

During the summer (open water) period, discrete monitoring was performed at the discrete monitoring sites and the continuous turbidity sites (see maps in Appendix B). Discrete sampling was performed up to five times at each site, typically coinciding with the scheduled maintenance visits at the continuous turbidity sites. In total, 12 different locations were monitored with a total of 23 individual sites being sampled since some locations have two or more sites being monitored across the width of the river. Specifically, the sites visited were: K-S-01b; K-S-02b; K-S-03 (a, b, c, d); K-S-04b; K-S-05b; K-S-06 (b, c, d); K-S-07 (a, b, c, d, e); K-S-09 (a, b, c); K-S-10c; K-S-11c; K-Tu-04; and K-Tu-05.

The average laboratory TSS and in-situ turbidity values for each site visit were calculated for each of the 23 individual sites that were monitored. Since the PEMP monitoring area (Map 1) has a predominantly east-west alignment, the results were plotted based on the easting component of each sites UTM co-ordinate by using the easting values as the as the horizontal axis (Figure 10). Thus the plotted results show the TSS and Tu variations in an upstream to downstream direction (from left to right) while also indicating the relative distance between the different monitoring sites: the difference in easting value between two sites is an estimate of the distance between the sites.

Overall, the results show that among all sites and months, the TSS concentrations predominantly fell within a narrow range from about 8 to 16 mg/L. Only a few observations fell outside this range, with the highest value of 21 mg/L recorded for site K-S-07 just below Gull Rapids while the two lowest values of 5.4 mg/L and 6.7 mg/L were recorded at K-Tu-04, just upstream of the Kettle GS. That the two lowest TSS values occurred at site K-Tu-04 is not surprising considering the generally lower turbidity levels observed at this site through the continuous monitoring (Figure 8). While the overall range of TSS concentrations observed in 2015 was similar to the range observed in 2014 when TSS varied from 7-27 mg/L, the 2015 values were generally lower than observed in 2014. The 2015 TSS values are also well within the pre-project range of about 5-30 mg/L reported in the Keeyask EIS. There are no clear

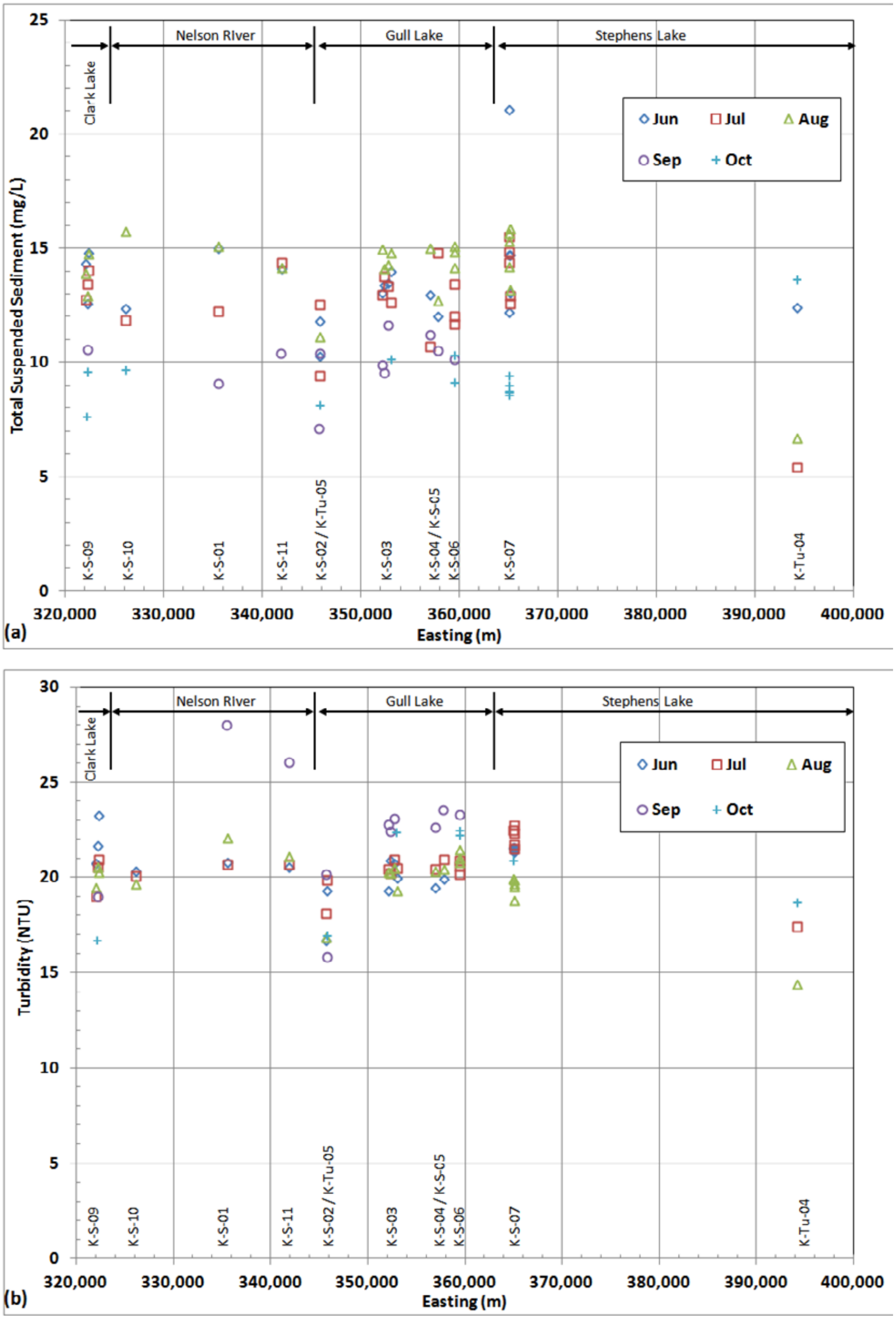


Figure 10: Discrete Monitoring Results: (a) TSS; (b) Turbidity (Summer 2015)

upstream to downstream trends in the data, although levels at the K-S-02 and K-Tu-05 locations in the entrance to Gull Lake appear a bit lower than nearby sites upstream and downstream.

As with TSS, the in-situ turbidity measurements predominantly lie within a relatively narrow range from about 16 to 24 NTU. Few observations fall outside this range. The highest value of about 28 NTU recorded was observed at site K-S-01 just below Birthday Rapids while the lowest value of 14 NTU was recorded at K-Tu-04, just upstream of the Kettle GS. Here again there are no clear trends in the results, although turbidity at the K-S-02 and K-Tu-05 sites at the entrance to Gull Lake appear somewhat lower than at nearby sites upstream and downstream. The range of variability in the discrete results is consistent with conditions observed from the continuous monitoring results which showed an overall range of variability from about 16-28 NTU with relatively steady levels of turbidity from upstream to downstream.

4.3.3 ORGANIC CARBON

On two rounds of discrete sampling, water samples were collected for laboratory testing to measure Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC). These results are used to calculate the third component, Particulate Organic Carbon (POC), since POC is the difference between the DOC and TOC concentrations. The first round of organic carbon sampling occurred in the third week of August and the second round was at the end of September and beginning of October.

Organic carbon in the water is not expected to be affected by construction prior to impoundment. However, it is being measured during this period to provide baseline information. When the reservoir is filled, it will flood organic material such as peat and other vegetation that may add organic carbon to the water in both dissolved and particulate forms.

The organic carbon monitoring collected water samples at 10 different locations (K-S-01 to K-S-11, except K-S-08). Because the monitoring results did not indicate any particular trends at any of the sampling locations, the results have been summarized by simply averaging the results obtained at each location in each round of sampling (Figure 11). TOC was essentially equal across all sites and both rounds of motoring, with the average values ranging from 8.1 mg/L to 8.7 mg/L. This organic carbon was present almost entirely in a dissolved form, with averaged POC values being less than 0.5 mg/L in most cases.

The TOC and DOC concentrations measured in summer 2015 are much the same as those reported in the Keeyask EIS for the pre- construction, which showed mean TOC and DOC concentrations of about 8-9 mg/L (KHLP 2012c, Appendix 2H).

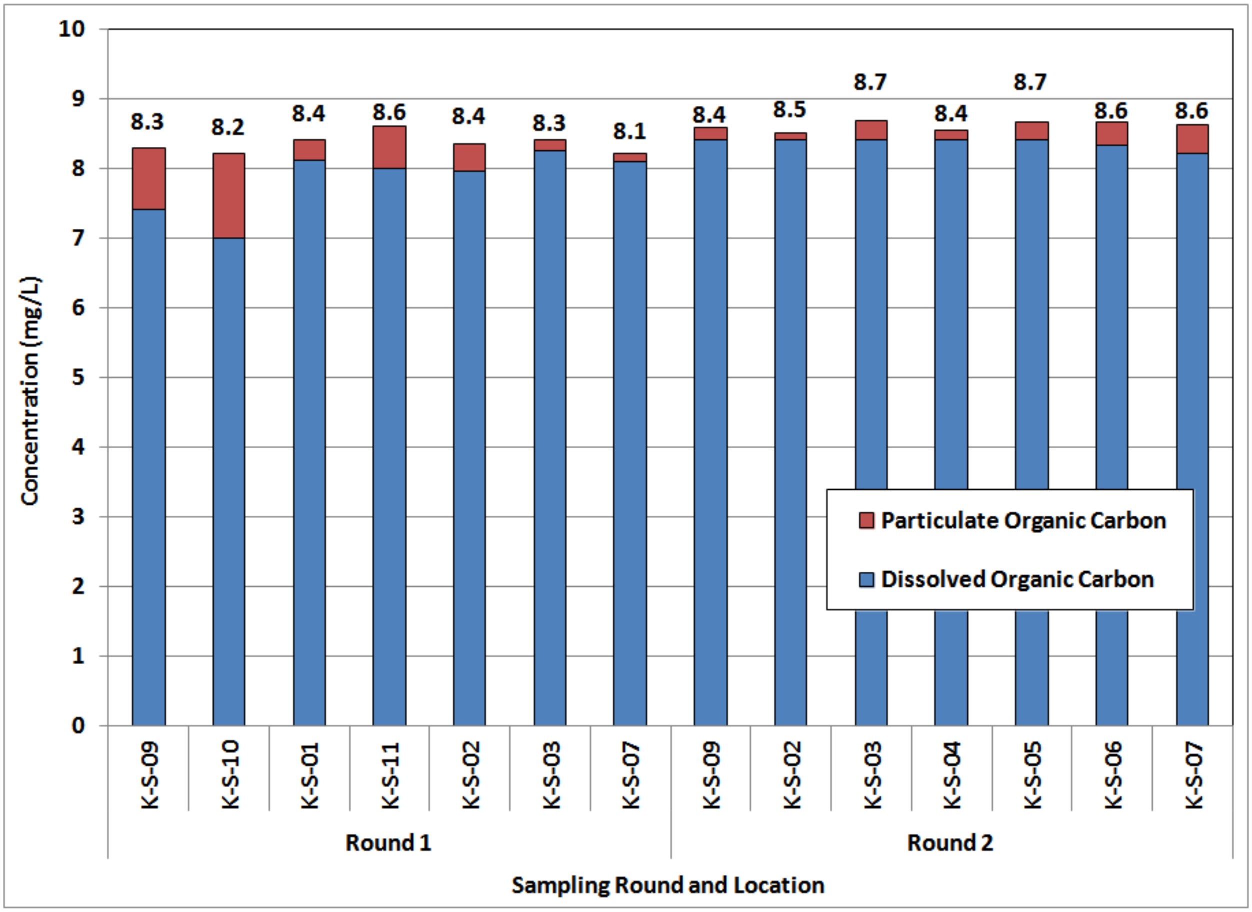


Figure 11: Summary of Particulate, Dissolved and Total Organic Carbon

4.3.4 DISSOLVED OXYGEN

The in-situ monitoring performed during site visits included measuring the water temperature and dissolved oxygen (DO) concentration at the sites. Based on the water temperature, the DO saturation concentration can be calculated using a standard formula and the degree of saturation, or percent saturation, can be calculated as the actual concentration divided by saturation concentration. The amount of oxygen dissolved in the water will attempt to balance out at the saturation concentration (i.e., 100% saturation).

Pre-construction monitoring found that DO concentrations were typically at or near saturation concentration (100% saturation) in the PEMP monitoring area and during construction prior to reservoir impoundment the project is not anticipated to affect DO (KHLP 2012b, Section 9). Monitoring results confirmed this as saturation levels varied from about 97% to 105% with an average saturation of about 101%. Actual concentrations only varied over a small range from 9.7 mg/L to 10.8 mg/L.

4.3.5 BEDLOAD

The Keeyask PEMP included a plan to collect bedload samples at the entrance to Gull Lake and the entrance to Stephens Lake while noting that during pre-construction monitoring, many of the sample attempts were not able to collect a meaningful amount of bed load to test in the lab. Bedload monitoring involves lowering a Helley-Smith bedload device that has an opening to which a filter sock is attached (Photo 8) to the bed of the river/lake. If sediment is moving along the bottom (e.g., rolling/bouncing in the flow) it will be caught by the trap and the sample can be tested to determine the size and amount of material. For Keeyask PEMP, multiple sites were tested across the river width at both locations and multiple attempts were made at each site.

In both 2014 and 2015, the bedload sampling programs were unable to obtain meaningful samples for laboratory testing, typically yielding no sample at all. These observations are consistent with past results and therefore were not unanticipated.

The PEMP document noted that if bedload monitoring was unable to obtain samples in the first two years of construction then bedload monitoring would not take place in the remaining years of construction. Therefore, bedload monitoring will not be performed in 2016 and the remaining years of construction.

Photo 8: Worker Preparing to Use a Helley-Smith Bedload Sampler

4.4 DEPOSITION AND SUBSTRATE

Deposition monitoring is being performed to provide understanding of pre-impoundment data on the potential for deposition after the reservoir is impounded. The sediment trap data provides information on the type of sediment being transported that could potentially settle in an area. This, coupled with substrate sampling in the area provides information whether the trapped sediment is deposits in the area or remains in suspension.

Sediment traps were placed at two locations to monitor deposition in the waterway: one at the entrance to Gull Lake, site K-ST-01, and another at the entrance to Stephens Lake, K-ST-02 (Map 5).The sediment traps were initially installed in the fall of 2014 to be recovered in spring 2015 to collect sediment trapped over the winter. The traps were to be re-deployed and then retrieved at the end of the summer monitoring period to collect any sediment trapped over the summer, whereupon they would be redeployed to again collect any samples over winter.

The sediment trap deployed at the entrance to Gull Lake (K-ST-01) could not be recovered in spring 2015). An automated buoy attached to the trap did not deploy either on schedule or when manually signalled to release. Attempts to snag the trap using a grapple were unsuccessful and this sediment trap is considered lost. Another trap was deployed for the 2015 summer season. Despite several attempts, the second sediment trap could not be recovered in the fall and this trap is also considered lost. High flow velocities in this area of the Gull Lake produce conditions that make it extremely difficult to recover a sediment trap. As noted in the PEMP document (KHLP, 2015), traps would be placed “if possible (e.g., water velocity not too high)”. The decision was made not re-install a sediment trap at this site in fall 2015 due to the likelihood of losing the equipment a third time.

While sediment trap monitoring was planned to round out the monitoring of potential changes to the substrate by identifying the material available for deposition, the sediment trap data are not critical to the primary objective of trying to determine if the substrate changes after impoundment. Proceeding without the sediment trap data, the monitoring program will attempt to obtain and identify the substrate material at the upstream end of Gull Lake near K-ST-01 prior to reservoir impoundment. This will identify the starting condition of the substrate and subsequent monitoring will be performed to determine if the nature of the substrate is changing. In particular, the concern would be deposition of finer material (e.g., silt) over coarser material (e.g., cobble, gravel) is present before impoundment.

At the Stephens Lake site (K-ST-02) a trap was installed on October 18, 2014. It was intended that a trap consisting of five 10-cm tubes would be used for monitoring. However, because it was not yet available, a simpler trap consisting of three plastic tubes 5 cm (2-inch) in diameter was used instead (Photo 9). The trap and samples were retrieved on July 22, 2015, and a new 5-tube trap was put in place the same day. The 5-tube trap was retrieved and returned to the water on October 2, 2015. The 5-tube trap has two tubes with open tops to catch vertically settling sediments while the three other tubes have closed tops with a dozen 18 mm holes drilled around their circumference and will trap more sediment that is being advected horizontally with the flow.

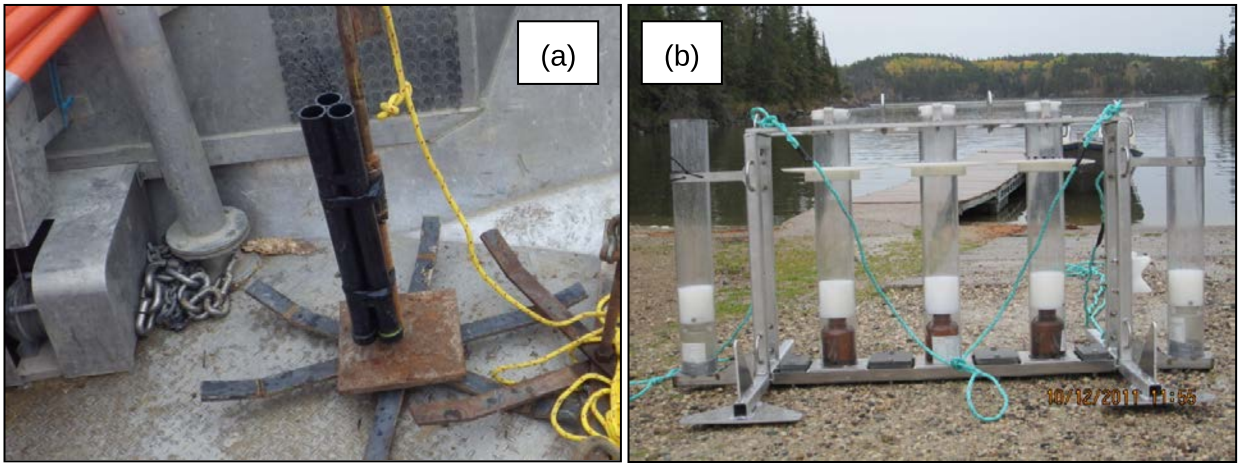


Photo 9: Sediment Traps used at Site K-ST-02: a) 3-tube; b) 5-tube

The monitoring found the deposition rates over the 72 days of deployment in summer 2015 were almost twice as high as the rate over the 277 days of deployment over winter from October 2014 to July 2015 (Table 3). Almost all of the sediment collected was comprised of fine silt and clay material, with six of the samples having a 90th percentile grain size of less than 0.07 mm (i.e., only 10% of the sample has a grain size larger than the 90th percentile size). Two of the over-winter samples had somewhat larger 90th percentile values, but the bulk of each sample was in the silt to clay size range. Grain sizes were less than 0.3 mm in all of the samples. The fact the five samples from the 5-tube sediment trap were uniform for each parameter measured is consistent with the transported sediment being almost entirely fine material with no coarser material that would be settling vertically.

In all samples the settled material was almost entirely mineral, with less than 1% organic material in the samples for the over winter period and only 2% for the summer period in 2015. Somewhat higher organic content might be anticipated in summer because of a greater amount of biological activity in that season.

Attempts were made to obtain substrate samples from both of the deposition monitoring sites using a ponar grab sampler, which is a spring-loaded metal jaw that snaps shut to grab a sample of bottom material. However, field crews were unable to collect testable samples from either K-ST-01 or K-ST-02 despite repeatedly attempts. Crews reported that a metallic sound was audible when the ponar hit bottom, indicating a hard substrate. The sampler never grabbed onto anything at the Gull Lake site, K-ST-01, but did grab some individual cobbles of various size at the Stephens Lake site, K-ST-02 (Photo 10). Based on the results, it is assumed that the substrate at the K-ST-01 site is comprised of cobbles, although they may be somewhat larger than those captured at K-ST-02. Though not collected, it is likely that the substrate would include a range of material from gravels to small boulders: the former being hard to collect if mixed with the cobbles (i.e., falls out since ponar jaws are not closed) and the latter being too large for the ponar to grab. From these results, it is clear that the fine material captured by the sediment trap is not being deposited and accumulated on the lake bed.

Photo 10: Coarse Substrate Material at Site K-ST-02

Table 3: Sediment Trap Monitoring Results for Site K-ST-02

Sample	1	2	3	Average*
Placed Removed # of Days	Oct. 18, 2014 Jul. 22, 2015 277			
Organic Carbon	0.4%	0.4%	0.9%	0.4%
Total Dry Mass (g)	**46.2**	**52**	**14.64**	49.1
Deposition (g/cm^2)	**2.59**	**2.92**	**0.82**	2.76
Deposition Rate ($g/m^2/day$)	**94**	**105**	**30**	100
90th %ile Grain Size (mm)	**0.049**	**0.101**	**0.146**	

Sample	1	2	3	4	5	Average
Placed Removed # of Days	Jul. 22, 2015 Oct. 2, 2015 72					
Organic Carbon	2.1%	2.0%	2.2%	2.1%	2.1%	2.1%
Total Dry Mass (g)	96.6	96.4	102.8	86.4	86.4	91.9
Deposition (g/cm^2)	1.31	1.30	1.39	1.17	1.17	1.24
Deposition Rate ($g/m^2/day$)	182	181	193	162	162	173
90th %ile Grain Size (mm)	0.069	0.061	0.046	0.060	0.054	
				Total Average Deposition (kg/m^2)		*40*
				Total Average Deposition (g/cm^2)		*4*
				Average Deposition Rate ($g/m^2/day$)		*115*

*Because sample 3 results are much lower than the other results for the Oct. 2014 to Jul. 2015 period, the sample 3 results are omitted from the average.

5.0 DEBRIS

As part of the Keeyask Project, in accordance with the Joint Keeyask Development Agreement, a waterways management program was implemented in 2015 for the Project area from Clark Lake to Gull Rapids (see Map 1). A component of this program is the operation of a two person boat patrol to identify and remove floating woody debris that may pose a safety hazard to navigation. Based out of the Split Lake community, the boat patrol was staffed by members of TCN and operated daily in the Project area during the open water season, weather conditions permitting. Prior to 2015, this area was only visited about once each week (20% of the time) by the boat patrol that also operated on Split Lake.

Woody debris removed by the boat patrol was 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).In 2015 the boat patrol travelled approximately 5,500 km and recorded the removal of 10 pieces of debris (Table 2). In addition to the woody debris, the boat patrol removed a couple of old fishing nets, marked reefs and engaged with waterway users including domestic and commercial fishermen and recreational users.

The amount of woody debris removed in 2015 was low compared with the range of debris amounts indicated in previous years. This likely results from 2015 being the first year in which actual amounts of debris removed from the the Clark Lake to Gull Rapids area have been tracked separately. Previously, when the Split Lake boat patrol visited the area once a week, it was assumed that 20% of the debris they collected from the Gull Lake area since that was not recorded separately. It seems likely that this assumption overestimated the debris removed from Gull Lake.

Table 4: Debris Removed from the Keeyask Area

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
2015	4	0	6	0	10

6.0 LITERATURE CITED

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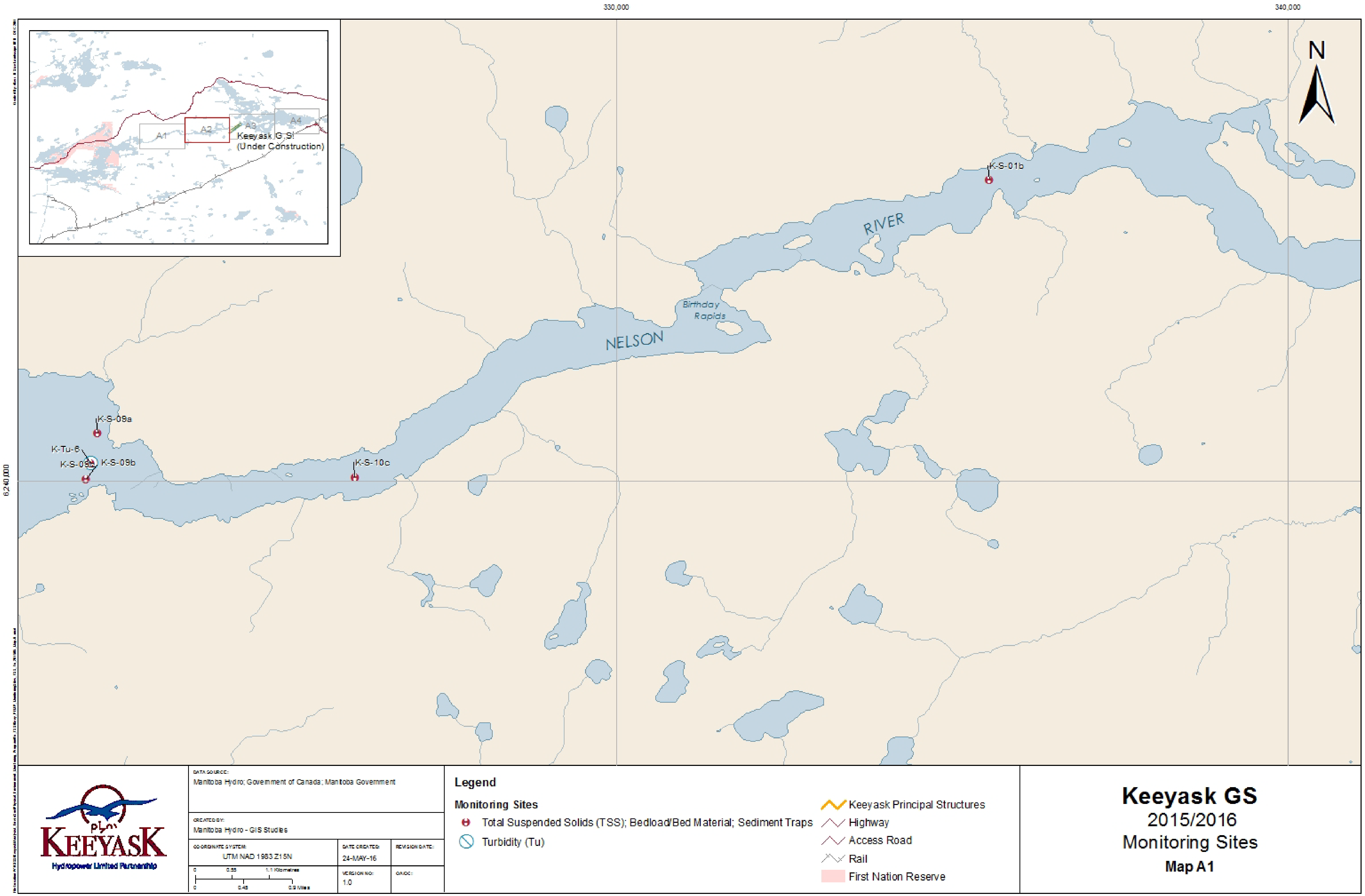
APPENDIX A – Maps of Monitoring Sites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340,000
6,240,000
N
A1
A2
A3
A4
Keeyask G.S.
(Under Construction)
K-S-01b
RIVER
Birthday
Rapids
NELSON
K-S-09a
K-Tu-6
K-S-09c
K-S-09b
K-S-10c
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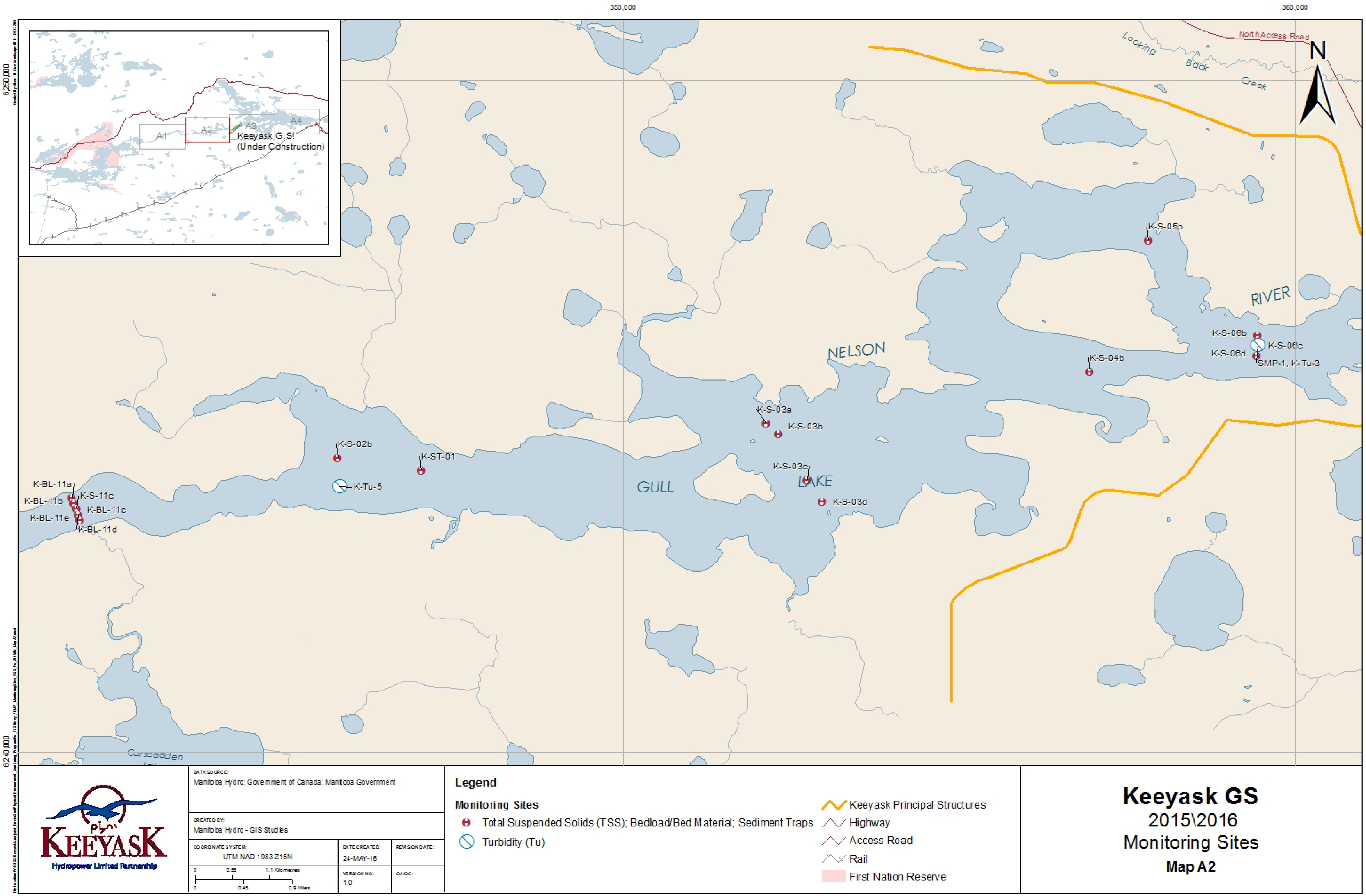
Manitoba Hydro; Government of Canada; Manitoba Government
CREATED BY:
Manitoba Hydro - GIS Studies
COORDINATE SYSTEM:
UTM NAD 1983 Z15N
DATE CREATED:
24-MAY-16
REVISION DATE:
VERSION NO:
1.0
QA/QC:
0 0.55 1.1 Kilometres
0 0.45 0.9 Miles
KEEYASK
Hydropower Limited Partnership
Legend
Monitoring Sites
Total Suspended Solids (TSS); Bedload/Bed Material; Sediment Traps
Turbidity (Tu)
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
2015/2016
Monitoring Sites
Map A1


350,000
360,000
6,250,000
6,240,000
Keeyask G.S. (Under Construction)
A1
A2
A3
A4
North Access Road
Looking Back Creek
N
NELSON
RIVER
GULL
LAKE
Curscadden
K-S-05b
K-S-06b
K-S-06c
K-S-06d
SMP-1, K-Tu-3
K-S-04b
K-S-03a
K-S-03b
K-S-03c
K-S-03d
K-S-02b
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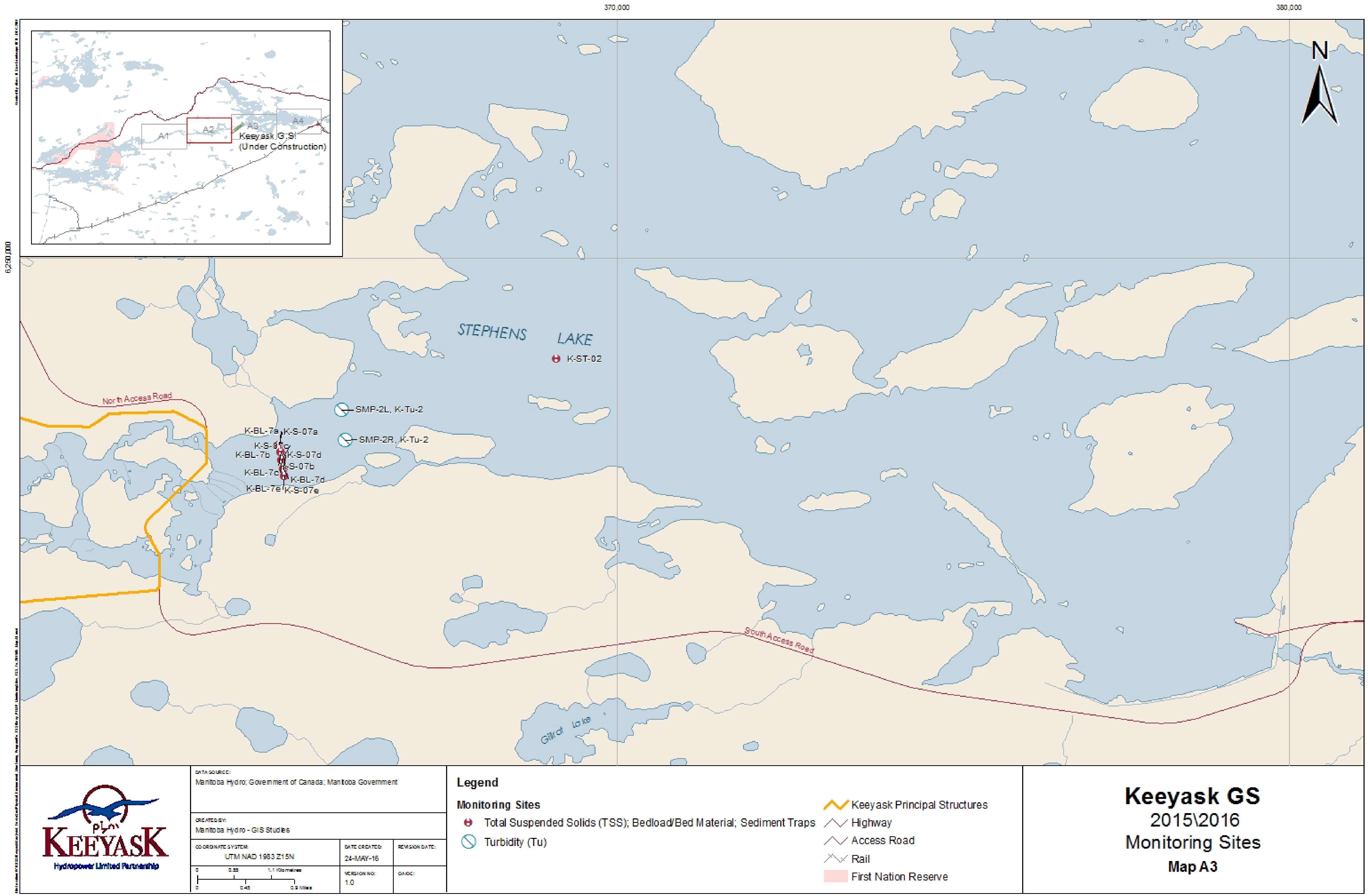
0 0.45 0.9 Miles
VERSION NO:
1.0
QA/QC:
Legend
Monitoring Sites
Total Suspended Solids (TSS); Bedload/Bed Material; Sediment Traps
Turbidity (Tu)
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
2015\2016
Monitoring Sites
Map A2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N
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A2
A3
A4
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(Under Construction)
STEPHENS LAKE
K-ST-02
SMP-2L, K-Tu-2
SMP-2R, K-Tu-2
K-BL-7a
K-S-07a
K-BL-7b
K-S-07d
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Total Suspended Solids (TSS); Bedload/Bed Material; Sediment Traps
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Rail
First Nation Reserve
Keeyask GS
2015\2016
Monitoring Sites
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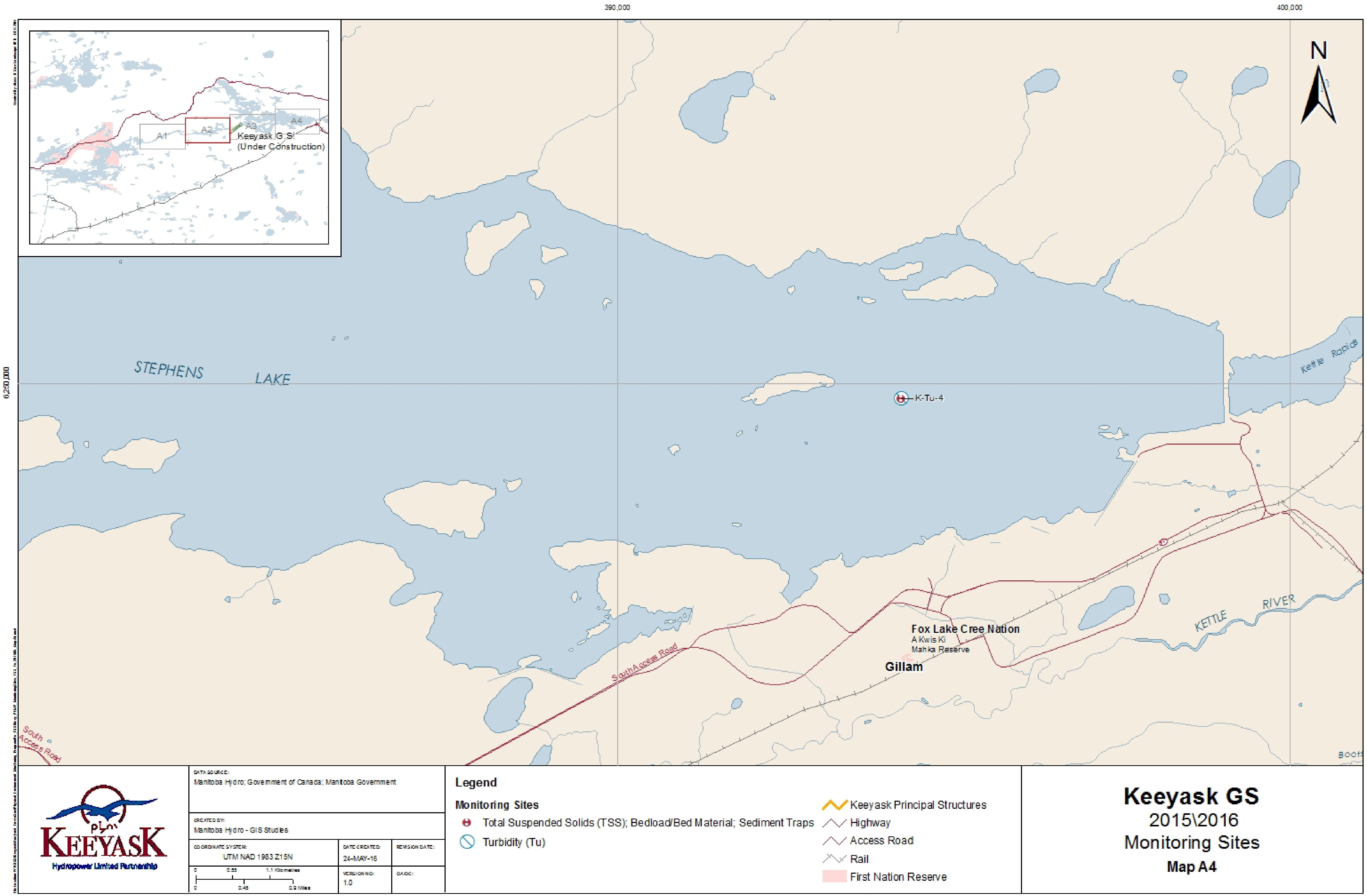
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400,000
6,250,000
A1
A2
A3
A4
Keeyask G.S.
(Under Construction)
N
STEPHENS LAKE
K-Tu-4
Kettle Rapids
Fox Lake Cree Nation
A Kwis Ki
Mahka Reserve
Gillam
KETTLE RIVER
South Access Road
DATA SOURCE:
Manitoba Hydro; Government of Canada; Manitoba Government
CREATED BY:
Manitoba Hydro - GIS Studies
COORDINATE SYSTEM:
UTM NAD 1983 Z15N
DATE CREATED:
24-MAY-16
REVISION DATE:
VERSION NO:
1.0
QA/QC:
0 0.55 1.1 Kilometres
0 0.45 0.9 Miles
KEEYASK
Hydropower Limited Partnership
Legend
Monitoring Sites
Total Suspended Solids (TSS); Bedload/Bed Material; Sediment Traps
Turbidity (Tu)
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
2015\2016
Monitoring Sites
Map A4

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