Rook I Project

Environmental Impact Statement

Annex IV.5: Forrest Lake Mixing Study Report

GOLDER
MEMBER OF WSP

FORREST LAKE MIXING STUDY REPORT FOR THE ROOK I PROJECT

Prepared for:

NexGen Energy Ltd.

Prepared by:

Golder Associates Ltd.

March 2022

Executive Summary

The Forrest Lake mixing study was completed as part of the hydrology program to establish baseline conditions to support an Environmental Assessment (EA) for the Rook I Project (Project). The mixing study was conducted from 30 September 2018 to 3 October 2018 and evaluated the extent that water from the Clearwater River flowing from the Patterson Lake outlet mixes within Forrest Lake, which is the nearest downstream lake. The objectives of the Forrest Lake mixing study were to:

- determine the dominant flow path from Patterson Lake and the degree of mixing within the Forrest Lake – North Basin; and
- determine if and how the lake water in the North Basin and South Basin of Forrest Lake mix.

The main component of the mixing study involved the use of a harmless fluorescent rhodamine dye to trace the flow of water into and through Forrest Lake. The dye was released into the water at the access road bridge downstream of Patterson Lake, and the plume was traced visually and with YSI-brand sonde (i.e., water quality sensor) probes. The probes were initially deployed at the two Clearwater River stream channels that enter Forrest Lake from Patterson Lake and were redeployed at the Forrest Lake outlet the next day. Plume delineation was completed over four days using visual tracing and probes.

Complementary physical measurements and observations were collected to provide additional context for the plume mapping:

- Wind speed and direction data were downloaded from the Rook I Meteorological Station to characterize local meteorological conditions.
- Forrest Lake inflows and outflows were monitored during the study.
- Forrest Lake physical properties (i.e., water surface elevation, volume, area) were calculated from bathymetric maps.
- Forrest Lake water temperatures were monitored in a profile from the lake surface to lake bed in the North Basin during the study.
- Drogues (i.e., floating “sails” or similar designs that are fitted with GPS and drift below the water surface) were released in the North Basin at the same time as the dye was released to provide data on lake current speeds and directions during the field study.

The baseline mixing study achieved the objective of determining the dominant flow paths from Patterson Lake through Forrest Lake and the degree of mixing within Forrest Lake. The study results indicated the flow path from Patterson Lake to the Forrest Lake – North Basin is clearly defined. Once in the North Basin, the plume spread in two directions. One plume flowed north along the northern shore of Forrest Lake before reaching the Forrest Lake outlet. The second plume flowed south and along the west shore of the North Basin before turning to the northeast and crossing the North Basin toward the Forrest Lake outlet. The North Basin was shown to become well mixed, but there was limited mixing between the North and South basins.

If referencing this report, please use for the following citation:

Golder (Golder Associates Ltd.). 2022. Forrest Lake Mixing Study Report for the Rook I Project. Prepared for NexGen Energy Ltd.

Table of Contents

TABLES

FIGURES

APPENDICES

Abbreviations and Units of Measures

Acronym	Definition
EA	Environmental Assessment
EIS	Environmental Impact Statement
GPS	Global Positioning System
HEC-RAS	Hydrologic Engineering Center River Analysis System
NexGen	NexGen Energy Ltd.
Project	Rook I Project
TLU	Traditional Land Use

Unit/Symbol	Definition
%	percent
ºC	degrees Celsius
µg/L	micrograms per litre
ha	hectare
kg	kilogram
km	kilometre
km/h	kilometres per hour
km^2	square kilometre
L	litre
m	metre
m^3/s	cubic metres per second
masl	metres above sea level
mm	millimetre
Mm^3	million cubic metres
m/s	metres per second

1.0 INTRODUCTION

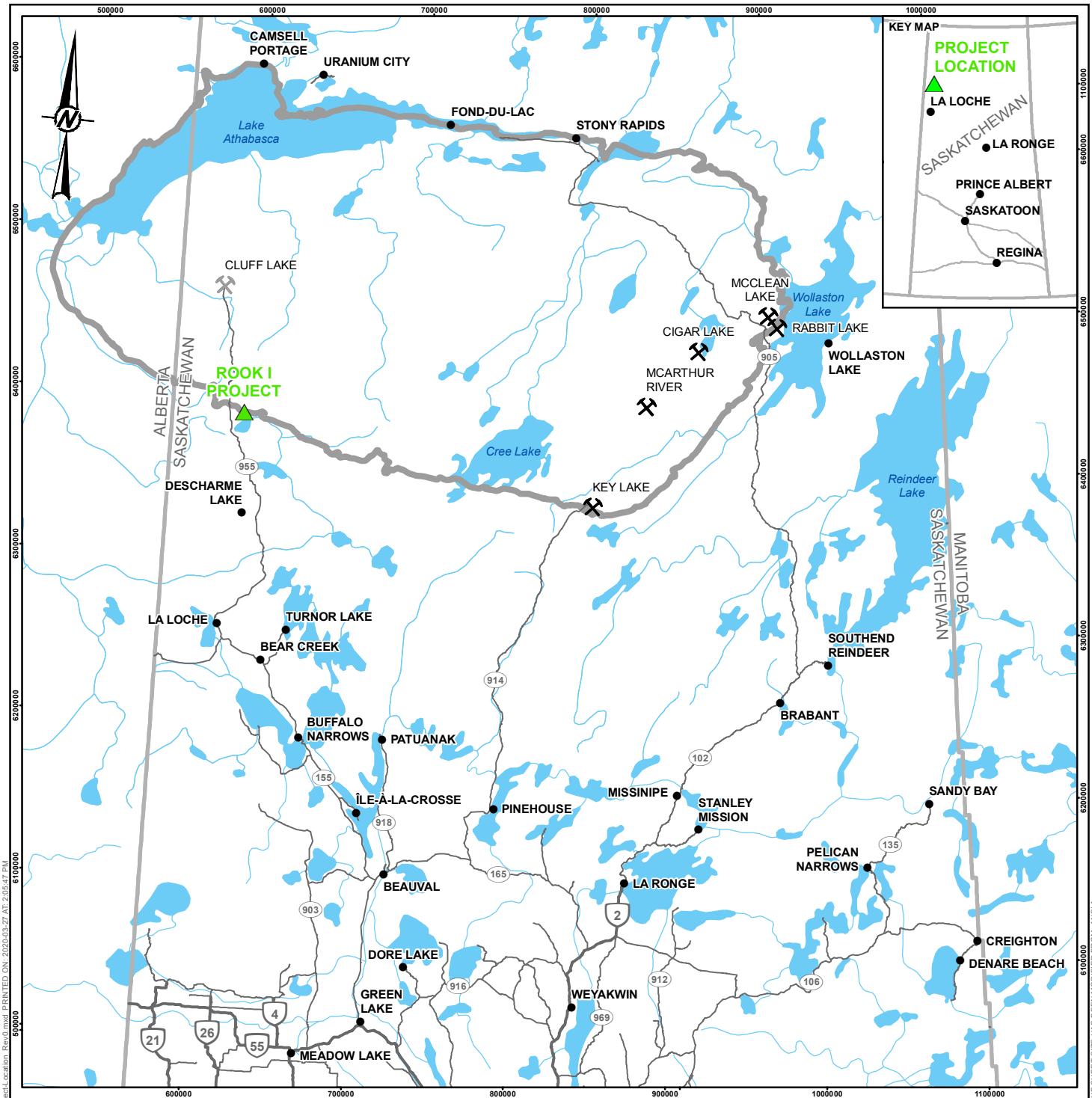
The Rook I Project (Project) is a proposed new uranium mining and milling operation that is 100% owned by NexGen Energy Ltd. (NexGen). The Project would be located in northwestern Saskatchewan, approximately 40 km east of the Saskatchewan-Alberta border, 130 km north of the town of La Loche, and 640 km northwest of the city of Saskatoon (Figure 1). The Project would reside within Treaty 8 territory and within the Métis Homeland. At a regional scale, the Project would be situated within the southern Athabasca Basin adjacent to Patterson Lake, and along the upper Clearwater River system (Figure 2). Access to the Project would be from an existing road off Highway 955. The Project would include underground and surface facilities to support the extraction and processing of uranium ore from the Arrow deposit, a land-based, basement-hosted, high-grade uranium deposit.

The Forrest Lake mixing study report represents a component of a comprehensive baseline program that documents the natural and socio-economic environments in the anticipated area of the Project. The hydrology baseline program, of which the Forrest Lake mixing study is a part, was undertaken to provide context from which Project environmental hydrological effects could be assessed in the Environmental Impact Statement (EIS).

Since exploration at the Project commenced in 2013, NexGen has engaged regularly and established relationships with local First Nation and Métis Groups (collectively referred to as Indigenous Groups) and northern communities, specifically those closest and with greatest access to the proposed Project. NexGen respects the rights of Indigenous Peoples and the unique relationship Indigenous Peoples have with the environment, and recognizes the importance of full and open discussion with interested or potentially affected Indigenous communities regarding the development, operation, and decommissioning of the proposed Project. Engagement activities to date, as well as future planned engagement activities, reflect the value NexGen places on meaningful engagement with Indigenous and northern communities who could be potentially affected by the proposed Project. Engagement mechanisms have included, but are not limited to: meetings with leadership, workshops and community information sessions, Project site tours, establishing Joint Working Groups to support the gathering and incorporation of Indigenous and Local Knowledge throughout the Environmental Assessment (EA) process, and providing funding for Traditional Land Use (TLU) Studies[1] to understand how the proposed Project may interact with the Indigenous communities' traditional use of the anticipated area of the Project.

Feedback received during engagement activities was documented for contribution to the EIS for the Project; examples of feedback received include discussion of concerns, interests, potential adverse effects, mitigation, and design alternatives. Many baseline studies were initiated in advance of formal engagement on the EA for the Project; however, engagement during the execution of baseline studies has helped inform the understanding of baseline conditions and confirmed components of the natural and socio-economic environments that required study. A summary of feedback related to the hydrology baseline program is presented in Appendix A of the Hydrology Baseline Road Map (Annex IV).

[1] Traditional Land Use (TLU) Studies include all land use studies developed by the Project's affected Indigenous Groups, including Traditional Land Use and Occupancy studies, Traditional Knowledge and Use studies, and Indigenous Rights and Knowledge studies, henceforth referred collectively as TLU Studies.



LEGEND

- POPULATED PLACE
- URANIUM MINING FACILITY (ACTIVE)
- URANIUM MINING FACILITY (DECOMMISSIONED)
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- ATHABASCA BASIN BOUNDARY
- PROJECT LOCATION

0 100 200

1:3,500,000 KILOMETRES

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

LOCATION OF THE ROOK I PROJECT, SASKATCHEWAN

CONSULTANT

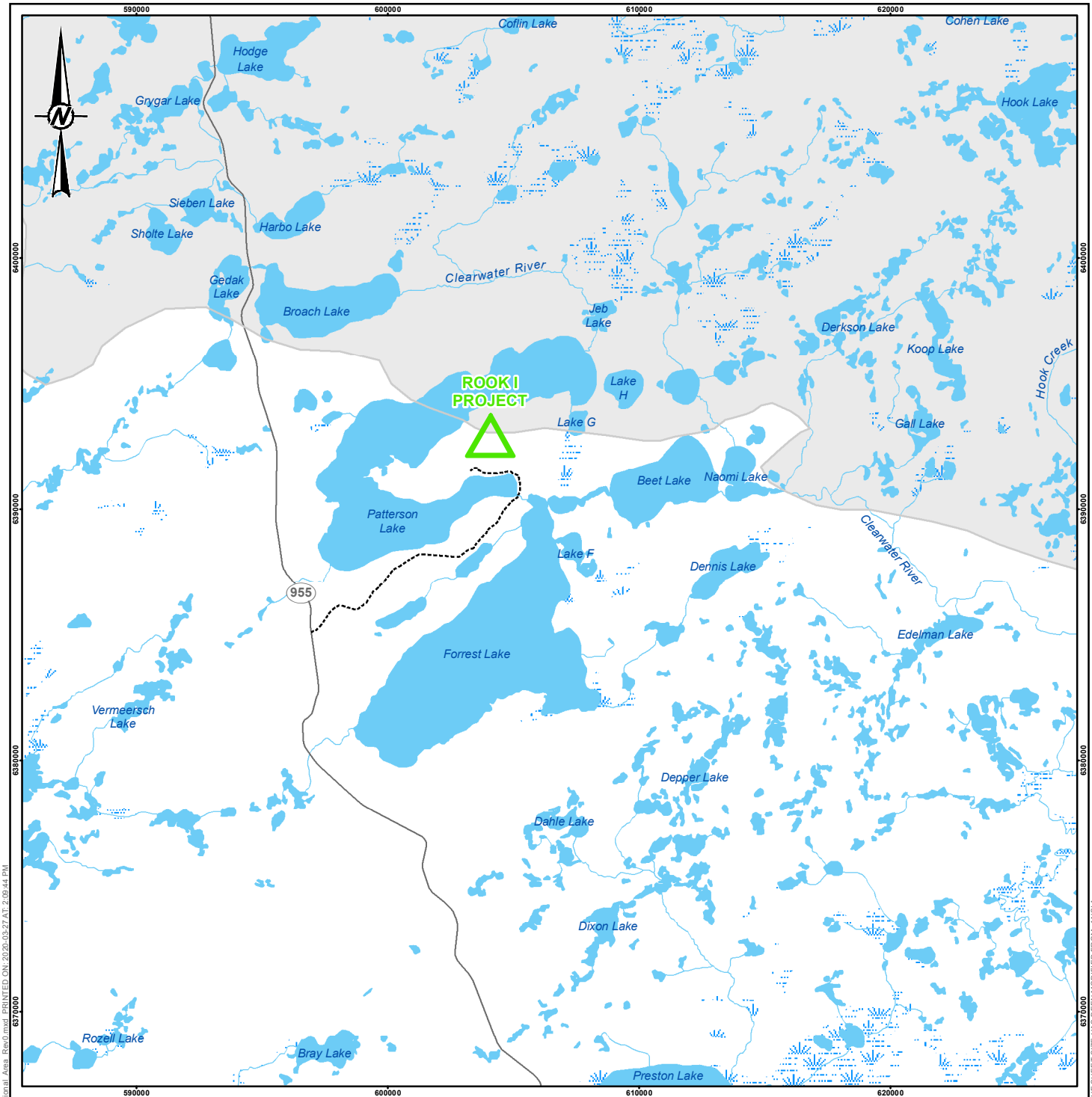
GOLDER

YYYY-MM-DD	2020-03-27
DESIGNED	SS
PREPARED	NO/AK
REVIEWED	JMC
APPROVED	MM

PROJECT NO.	PHASE	REV.	FIGURE
19114981		0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

PATH: I:\CLIENTS\NexGen\19114981\Mapping\Products\General\Baseline_General\19114981_Fig1_RookIProjectLocation_Revised.mxd PRINTED ON: 2020-03-27 AT: 2:05:47 PM



LEGEND

- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- ATHABASCA BASIN
- PROJECT LOCATION
- EXISTING ACCESS ROAD

0 5,000 10,000

1:225,000 METRES

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

REGIONAL AREA OF THE ROOK I PROJECT

CONSULTANT

GOLDER

YYYY-MM-DD	2020-03-27
DESIGNED	JMC
PREPARED	NO/AK
REVIEWED	JMC
APPROVED	MM

PROJECT NO.	PHASE	REV.	FIGURE
19114981		0	2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

25mm

0

PATH: I:\CLIENTS\NexGen\19114981\Mapping\Products\General\Baseline_General\19114981_Fig2_RookI_Regional_Area_Rev0.mxd PRINTED ON: 2020-03-27 AT 2:09:44 PM

2.0 STUDY OBJECTIVES

Forrest Lake is composed of two basins: the Forrest Lake – North Basin and the Forrest Lake – South Basin. The two basins are separated by a large sand bar. Water flows from Patterson Lake into the western side of the North Basin and out of the eastern side of the North Basin, both via the Clearwater River. Given the potential for short circuiting of the inflow and outflow located at the northern extent of the North Basin, the degree to which inflows mix with the South Basin is uncertain. This study was undertaken to gain a better understanding of the surface water mixing occurring within Forrest Lake and to provide sufficient information to assess potential Project effects in the EA process.

The objective of the mixing study was to establish the extent that water from the Patterson Lake outlet mixes within the downstream Forrest Lake. Specific objectives of the study were to:

- determine the dominant flow path from Patterson Lake through Forrest Lake;
- determine the degree of mixing within the North Basin; and
- determine the degree of mixing between the North and South basins.

3.0 STUDY AREAS

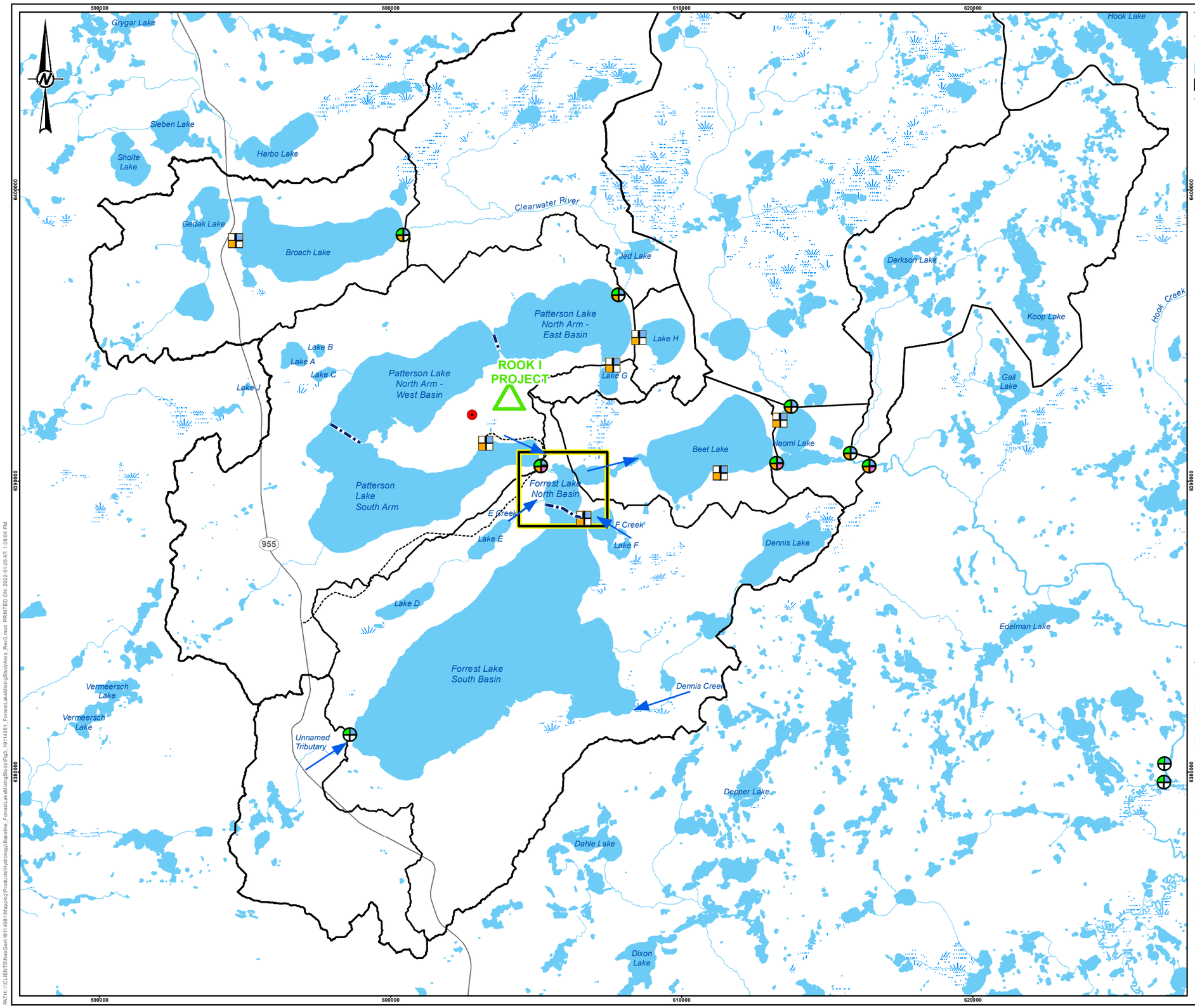
The Forrest Lake mixing study area (Figure 3) is contained within the local study area for the hydrological baseline program. An aerial view of where the Clearwater River flows into the North Basin is shown in Figure 4. The Forrest Lake outflow into Beet Lake is shown in Figure 5. The North Basin is separated from the South Basin by a sand bar. Water depths over the sand bar are typically less than 1 m.

Outflow from Patterson Lake is conveyed to Forrest Lake by a section of the Clearwater River, which for the purposes of this study is divided into an upstream and downstream length: the Upper Reach and Lower Reach. The Clearwater River Upper Reach is 580 m long and varies from 0.5 to 1.5 m deep. At the downstream end of the Upper Reach, the Clearwater River mainstem divides into two channels that constitute the Lower Reach: the Lower Reach North Channel, which is 170 m long; and the Lower Reach South Channel, which is 300 m long. The outlets where each channel flows into the North Basin are shown in Figure 4.

The South Basin is larger than the North Basin. By volume, the South Basin comprises approximately 99.9% of the total, with the North Basin accounting for 0.1%. By area, the South Basin accounts for 97.5% of the total while the North Basin accounts for 2.5% based baseline digital bathymetry data (Annex V.1 Aquatic Environment Baseline).

The drainage area contributing to Patterson Lake is 264 km^2 and a total of 445 km^2 drains into Forrest Lake. In addition to inflows from the Clearwater River, Forrest Lake receives inflows from four other tributaries: E Creek, F Creek, Dennis Creek, and an unnamed tributary at the southwest corner of Forrest Lake (Figure 3). The E Creek flows into the west side of the North Basin and drains an area of 15 km^2. The F Creek drains an area of 13 km^2 into the east side of Forrest Lake just south of the sand bar, which separates the Forrest Lake North and South basins. The unnamed tributary flows into the southwest corner of Forrest Lake, which is gauged by a continuous hydrometric monitoring instrumentation at station CR-WC-TI-01 (Figure 3), and drains an area of 35 km^2. Dennis Creek flows into the east side of Forrest Lake and drains an area of 10.4 km^2 including Dennis Lake, which lies at the headwaters of Dennis Creek.

The study was completed over a three-day period from 30 September 2018 to 2 October 2018.



LEGEND

- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WATERSHED
- WETLAND
- EXISTING ACCESS ROAD
- PROJECT LOCATION
- METEOROLOGICAL STATION

WATERBODY HYDROMETRIC STATIONS

- DISCHARGE
- SURVEYED BENCHMARK (GEODETIC DATUM)
- TOTAL SUSPENDED SOLIDS AND BEDLOAD
- WATER SURFACE ELEVATION

WATERCOURSE HYDROMETRIC STATIONS

- DISCHARGE
- SURVEYED BENCHMARK (GEODETIC DATUM)
- TOTAL SUSPENDED SOLIDS AND BEDLOAD
- WATER SURFACE ELEVATION
- FORREST LAKE MIXING STUDY AREA

0 3,000 6,000
1:130,000 METRES

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. WATERSHEDS DELINEATED BY GOLDER USING GREENKENUE SOFTWARE BASED ON CANADIAN DIGITAL ELEVATION DATA AND NATIONAL HYDROGRAPHIC NETWORK WATERCOURSES.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
NexGen Energy Ltd.

PROJECT
ROOK I PROJECT

TITLE
FORREST LAKE MIXING STUDY AREA

CONSULTANT
GOLDER

YYYY-MM-DD	2022-01-26
DESIGNED	RP
PREPARED	LMS/NO
REVIEWED	RWP
APPROVED	GVA

PROJECT NO.	PHASE	REV.	FIGURE
19114981	7000	0	3

Figure 4: Aerial View of the Clearwater River Where It Flows into the Forrest Lake – North Basin

Note: Direction of flow is toward camera. View is from a helicopter facing southwest, 2 October 2018.

Figure 5: Aerial View of the Forrest Lake Outlet with the Beet Lake Channel in the Distance

Note: Direction of flow is away from the camera. View is from helicopter over Forrest Lake North Basin facing east,, 4 August 2018.

4.0 METHODS

The Forrest Lake mixing study included both a field program to collection information as well as a desktop analysis and interpretation of the collected field data.

4.1 Review of Existing Information

No previous studies exist related to this assessment. Local meteorological data collected from 2015 to 2018 from the Rook I Meteorological Station (Figure 3) were reviewed and used for high-level field planning.

4.2 Approach

4.2.1 Field Data Collection

The field component of the mixing study was completed by releasing benign (EC 2003) fluorescent rhodamine[2] dye and monitoring its movement in the environment. The dye was released into the Clearwater River at the access road bridge (Figure 6) near the Patterson Lake outlet and the extent of the plume in Forrest Lake was mapped. Tracer concentrations at the Clearwater River inflow channels into Forrest Lake and at the Forrest Lake outlet were measured and complementary physical measurements were also collected to provide additional context for the plume mapping.

A plan view of the study area centred on the North Basin is presented in Figure 6. Photographs that provide context for other measurements are included as Appendix A.

The mixing study involved the following environmental data and observations:

- local meteorological conditions;
- Forrest Lake inflows and outflows;
- Forrest Lake physical properties (e.g., water surface elevation, volume, area);
- Forrest Lake temperature;
- drogue (i.e., floating “sails” or similar designs that drift below the water surface and are fitted with GPS devices to record their movements in detail) releases; and
- rhodamine dye release:
  - YSI-brand sonde (i.e., water quality sensor) probes.
  - visual plume tracing.

An Argonaut XR acoustic doppler current profiler was also deployed but did not collect data due to instrument failure; other methods of obtaining information on lake current patterns such as dye tracing provided sufficient information to complete this study.

[2] Rhodamine is a harmless dye that is often used in tracing water flows and is the tracer preferred in guidance published by Environment Canada (2003)

4.2.1.1 Local Meteorological Conditions

Local meteorological conditions are important to interpreting mixing study data: Wind and ice may affect plume dispersion and air temperature, ice conditions, and wave action can all influence the behaviour of the plume. Meteorological data was used to understand how wind acting on Forrest Lake may have induced currents or waves. Local meteorological conditions are monitored by the Rook I Meteorological Station, which is located near the existing exploration camp (Universal Transverse Mercator 12V 602795E 6392291N) (Figure 3). The meteorological station has been operating since installation in 2015. Hourly wind speed and direction data for the mixing study period (i.e., 30 September 2018 to 2 October 2018) were downloaded and used as representative of conditions in the study area. Anecdotal qualitative observations of wind speed and direction at the North Basin corroborated the quantitative observations made at the meteorological station.

4.2.1.2 Forrest Lake Inflow and Outflow

Inflows and outflows were monitored to calculate rates of mass loading of dye tracers during the study. Instantaneous velocity and depth were measured to calculate discharge upstream and downstream of Forrest Lake at the Clearwater River below Patterson Lake hydrometric station and the Clearwater River below the Beet Lake hydrometric station. A Sontek-brand FlowTracker acoustic doppler velocimeter was used to measure discharge. Manual discharge measurements were conducted according to the Water Survey of Canada standard described by Terzi et al. (1994). Velocity and depth measurements used for discharge calculations were collected using the FlowTracker and a top-setting wading rod. A Sontek-brand M9 acoustic doppler current profiler was used to measure discharge at the Clearwater River below Beet Lake. Discharge was also monitored continuously during the study period at the nearby hydrometric stations (i.e., Clearwater River below Patterson Lake and Clearwater River below Beet Lake) as a function of continuous water level measurements.

4.2.1.3 Forrest Lake Physical Properties

Water level was measured to understand the volume of water available for plume mixing and dispersion. During the mixing study, a levelling survey was conducted to measure the surface water elevation of Forrest Lake relative to a local benchmark, CR-WB-MS-03-BM1. Optical level surveys were supplemented by reading local staff gauges concurrent with the optical level survey and surveying the top of the staff gauge relative to the primary benchmark. Stage-storage-area relationships developed from bathymetric data collected in June 2019 (Annex V.3, Naomi Lake Bathymetry Report) were used to estimate the volume and area of the North and South basins at the water surface elevation observed on 30 September 2018.

4.2.1.4 Forrest Lake Temperature Profile

Temperature was used to monitor ice conditions and thermal stratification which can influence currents and the behaviour of the plume. Temperature sensors were deployed to measure temperature from the water surface to near the lakebed at a buoy in the middle of the North Basin. The central thermistor string consisted of Solinst Levelogger Edge temperature and pressure sensors at 0.3 m depth intervals established in the middle of the North Basin (Figure 6) from 30 September 2018 to 1 October 2018.

LEGEND

PROJECT FEATURES

- EXISTING ACCESS ROAD

- 1981 DEPTH MEASUREMENT POINT (APPROXIMATE)
- 1981 BATHYMETRIC CONTOUR (APPROXIMATE)
- 1981 INTERPOLATED BATHYMETRIC CONTOUR (1 M INTERVAL)
- FLOW DIRECTION

0 200 400
1:10,000 METRES

REFERENCE(S)

1. IMAGERY OBTAINED FROM CLIENT, DATED: 2015.
2. HISTORIC BATHYMETRY DIGITIZED FROM 1981 MAP OBTAINED FROM GOEVERNMENT OF SASKATCHEWAN.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT
ROOK I PROJECT

TITLE
FORREST LAKE – NORTH BASIN

CONSULTANT
GOLDER

YYYY-MM-DD	2020-03-20
DESIGNED	RP
PREPARED	LMS/NO
REVIEWED	RWP
APPROVED	GVA

PROJECT NO.	PHASE	REV.	FIGURE
19114981	7000	0	**6**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

0 25mm

PATH: I:\CLIENTS\NewGen\19114981\Mapping\Products\Hydrology\Baseline_ForestLake\MixingStudy\Fig6_19114981_ForrestLake_NorthBasin_Rev0.mxd

4.2.1.5 Drogues

Drogues are passive devices designed to float below the water surface and move with the ambient current. Drogues provide a method of tracking near-surface dispersion over a short period of time. The drogues used in the mixing study floated just below the water surface within the rhodamine plume to measure the speed and direction of currents in the North Basin. Three drogues were released near the mouth of the Clearwater River Lower Reach, North and South channels, where there was sufficient depth for the drogues to float freely. The drogues were deployed within the water column (from surface to 1 m or 2 m depth) to document lake currents near the surface with less effect from wind. The drogues consisted of a central axial tube with four rectangular panels extending out from the axial tube at right angles to one another. Each of the drogues was equipped with an internal Global Positioning System (GPS) to record the path of movement. The GPS units were encased in a waterproof container within the drogue float.

During the second release, sustained aggressive wave action and the onset of ice resulted in lost seal and entry of water into one drogue float which prevented retrieval of data from one of the GPS units. The proximity upon retrieval of the drogue without data to the other drogues with data suggests a similar path was travelled by all three drogues released. A similar release location and retrieval location for all drogues means that it is unlikely that the data not retrieved would have been substantially different than the data retrieved, and sufficient data were collected from the other drogues to complete the study.

4.2.1.6 Rhodamine Dye Tracer

A tracer is a conservative substance that can move with the fluid. Rhodamine WT was used as a dye tracer for the study. Rhodamine WT is a fluorescent dye that is the preferred added tracer for plume delineation studies (EC 2003): It is not harmful to the environment, has a zero background level as it does not occur naturally, it can be readily measured in the field at low concentrations, and it mixes freely into receiving water. A dye slug was released at the access road bridge over the Clearwater River upstream of Forrest Lake and downstream of Patterson Lake (Figure 7). The slug consisted of 15 L of Rhodamine WT liquid dye (rhodamine dye concentration is 20% active ingredient), which was diluted in two five-gallon pails with 15 L of water from the Clearwater River. The total mass of dye released was 3 kg.

During the release, the dye was poured evenly across the channel to approximate full lateral mixing of the rhodamine slug. Observations of the rhodamine dye were a combination of visual observations of the presence or absence of the plume or concentration measurements using two YSI OMS600 sonde probes. The probes were calibrated on 29 September 2018 using a two-point (i.e., 0 µg/L and 100 µg/L) calibration per instructions in the instrument user manual. Following preliminary review of the rhodamine concentrations observed at the inflow into Forrest Lake, observed values were adjusted using a constant multiplier to calibrate total mass to approximately equal the initial slug release.

Figure 7: Dye Release from the Access Road Bridge, 30 September 2018 at 13:51

The chronological steps associated with observing rhodamine dye concentrations following the release are described below:

1) A GPS and boat were used to track the speed of the visible plume front as it advanced downstream toward Forrest Lake.

2) Two sonde probes, one stationed at the Lower Reach North Channel outlet and one stationed at the Lower Reach South Channel outlet, logged temperature and rhodamine concentration with the passing of the plume.

3) Once the plume reached Forrest Lake, a canoe equipped with a GPS was used for a period of approximately two hours to trace the outline of the visible plume as it advanced out into Forrest Lake.

4) Once the visible plume had passed the probe at the Lower Reach North Channel outlet, the probe was retrieved and used to map the advance of the plume into Forrest Lake based on a grid of points at the northwest corner of the North Basin.

5) Following the grid collection on 30 September 2018 at 18:30, one probe was moved to the middle of the North Basin (i.e., at the location of the thermistor string), where it was suspended from a floating platform, and the other probe was moved to the Forrest Lake outflow to observe rhodamine concentrations in the channel overnight.

6) On 1 October 2018, the probe that had been stationed in the middle of the North Basin overnight was used to map rhodamine concentrations with the objective of delineating the plume boundary.

7) Following the grid on 1 October 2018, both probes were re-established to collect data at the outlet of Forrest Lake.

8) On the morning of 2 October 2018, visual observations of the plume extent were made from a helicopter. A video was collected during the helicopter flight to document visual observations.

9) On 3 October 2018, the probes and all other instrumentation were retrieved, and observations ceased.

5.0 RESULTS

5.1 Local Meteorological Conditions

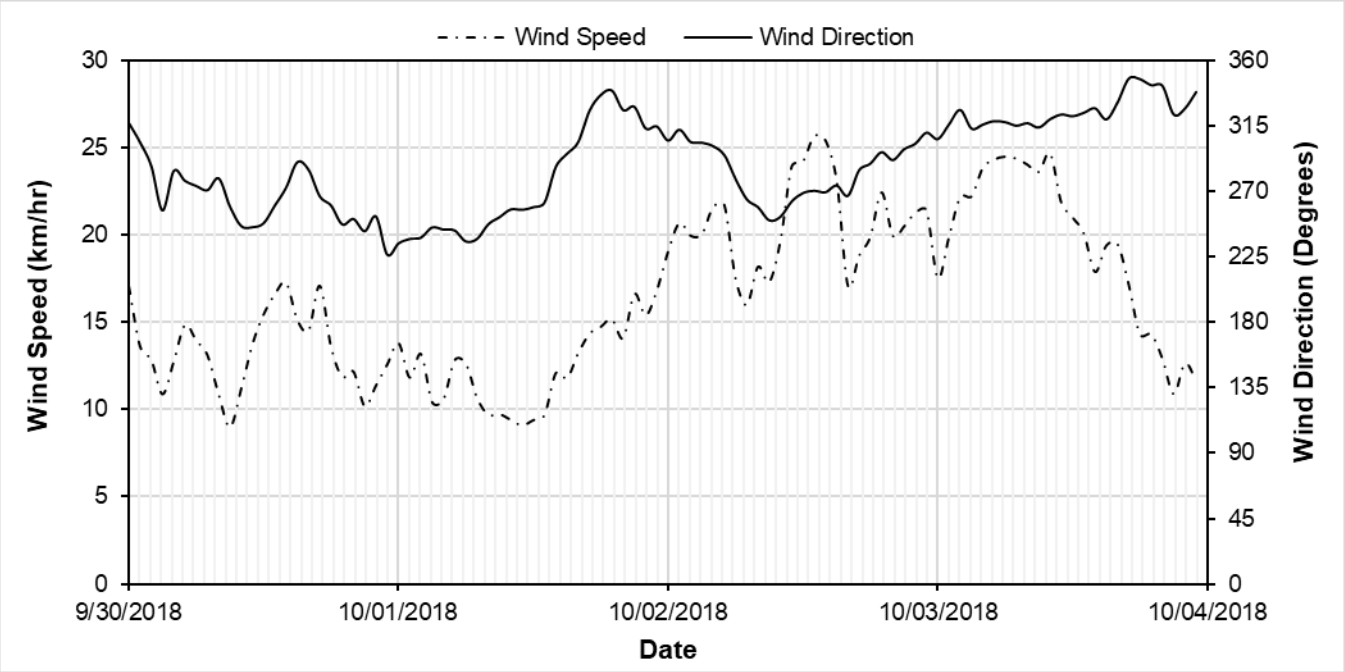
Local meteorological conditions monitored during the field investigation are summarized in Table 1 and Figure 8. No rainfall occurred during the study period; however, minimal precipitation in the form of snowfall was observed. Temperatures during the three day field study ranged from approximately -8°C to 3°C.

On 30 September 2018, conditions were generally overcast in the morning turning to clear around 12:00 and remained clear until sunset. At the time of the dye release on 30 September 2018 at 13:51, winds were from the west-northwest at roughly 15 km/h. Wind remained from the west-northwest with wind speeds generally decreasing until 1 October 2018 at 14:00. After 1 October 2018 at 14:00, the wind direction changed to north-northwest before returning to the west-northwest 1 October 2018 around 18:00. Wind speeds increased through 1 October 2018 and 2 October 2018, ultimately reaching a maximum average hourly wind speed of 25 km/h with gusts exceeding 45 km/h. Throughout the duration of the study, the wind was generally from the northwest.

Table 1: Summary of Local Meteorological Conditions during Forrest Lake Mixing Study, 30 September 2018 to 2 October 2018

Date	Precipitation (mm)			Temperature (°C)		
	Rainfall	Snowfall	Total Precipitation	Minimum	Average	Maximum
30 September 2018	0.0	0.1	0.1	-7.7	-1.7	2.5
1 October 2018	0.0	0.3	0.3	-2.6	-0.6	2.1
2 October 2018	0.0	2.2	2.2	-6.7	-4.2	-0.7
3 October 2018	0.0	1.6	1.6	-6.4	-5.0	-2.5

Figure 8: Local Hourly Wind Speed and Direction Monitored during the Forrest Lake Mixing Study



5.2 Forrest Lake Inflow and Outflow

Forrest Lake inflow and outflow were measured at the hydrometric monitoring stations shown in Figure 3. Discharge at the Clearwater River downstream of Patterson Lake (CR-MS-WC-03) on 29 September 2018 at 17:50 was measured to be 0.98 m^3/s. Discharge at the Clearwater River downstream of Beet Lake (CR-MS-WC-04) on 1 October 2018 was measured to be 1.70 m^3/s. Outflow from Forrest Lake during the mixing study was estimated to be 1.60 m^3/s based on prorating observations made at the Clearwater River downstream of Beet Lake (CR-MS-WC-04). During the mixing study, the total inflows to Forrest Lake of 1.60 m^3/s were estimated to be composed of 0.98 m^3/s from the Clearwater River, as well as inflows of 0.62 m^3/s from other tributaries (i.e., E Creek, F Creek, Dennis Creek, and the unnamed tributary).

Continuous measurements of water level at both hydrometric monitoring stations indicate that discharge rate remained unchanged over the duration of the mixing study.

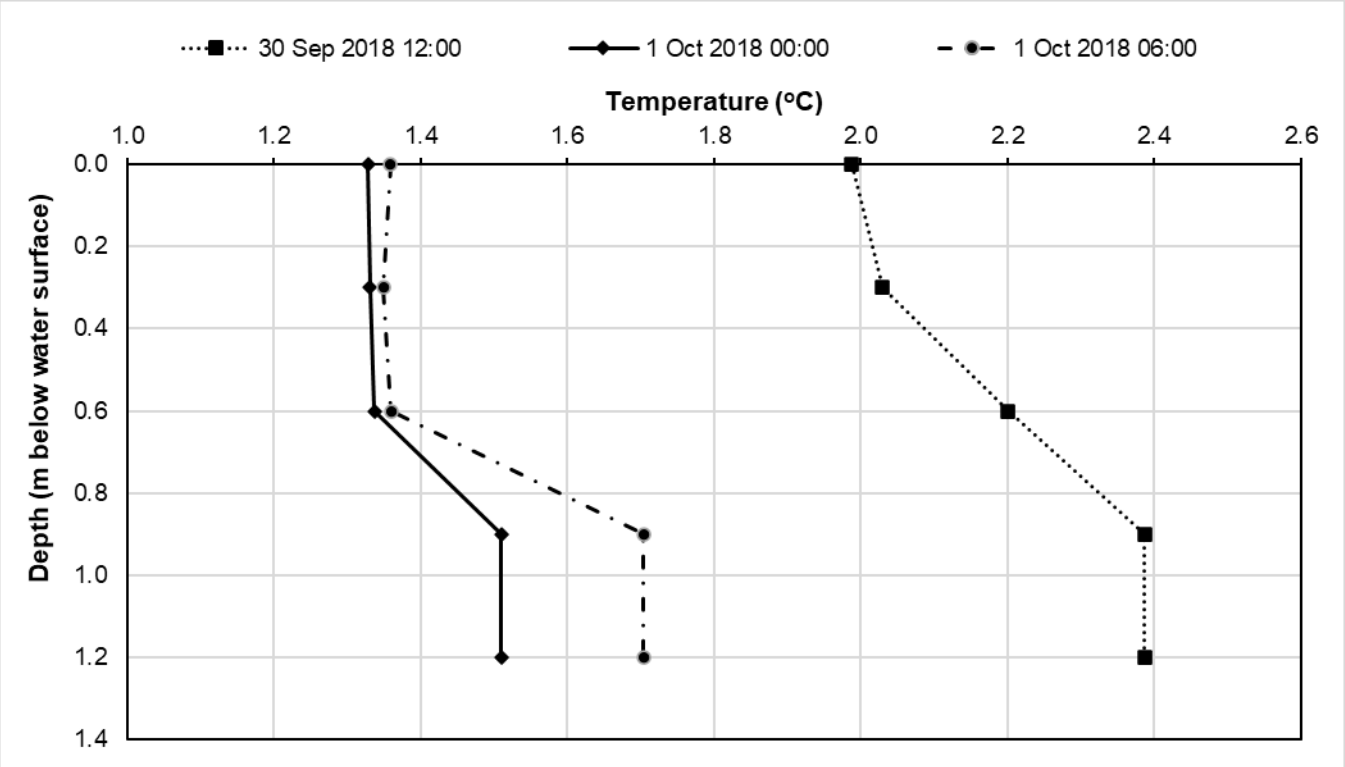
5.3 Forrest Lake Physical Properties

The water surface elevation of Patterson Lake was 498.51 metres above sea level (masl; surveyed on 30 September 2018) and the water surface elevation of Forrest Lake was 498.23 masl (surveyed on 1 October 2018). At an elevation of 498.23 masl, the volume of the North Basin was 0.55 Mm^3 and the surface area was 98 ha. Based on these dimensions, the average depth in the North Basin was estimated to be 0.6 m and the residence time was estimated to be approximately four days based on an average outflow of 1.60 m^3/s. At an elevation of 498.23 masl, the volume of the South Basin was estimated to be 1,202 Mm^3 and the surface area was estimated to be 379 ha.

5.4 Forrest Lake Temperature Profile

Forrest Lake temperature profiles in the North Basin were measured by the central thermistor string (Figure 6) at depth intervals of 0.3 m, and measurements from every six hours over the period of deployment are summarized in Figure 9. Water temperature decreased by about 0.6°C in the evening of 30 September 2018 and remained roughly the same temperature until the thermistor string was removed the morning of 1 October 2018. The thermistor string was removed at this time as the leveloggers being used to monitor temperature needed to be deployed elsewhere as part of the hydrometric monitoring program.

Figure 9: Temperature Profile in Forrest Lake – North Basin, 30 September 2018 and 1 October 2018



5.5 Drogues

A cluster of three drogues was released near the North Channel outlet on 30 September 2018 at 17:20 and retrieved at 18:43 on 30 September 2018. The details of each drogue trial, including the start and end time, are provided in Table 2. The drogues at the point of retrieval on 30 September 2018 are shown in Figure 10. The same cluster of three drogues was released near the South Channel outlet on 1 October 2018 at 13:39. The drogues released on 1 October 2018 were retrieved at 10:30 3 October 2018 after becoming encased in ice as shown in

Figure 11. The GPS tracks were used to calculate the travel time, distance, and speeds associated with each drogue.

During the drogue release on 30 September 2018, winds blew steadily from the west (i.e., 263°) and averaged 4.3 m/s. During the drogue release on 1 October 2018, winds increased from 2.7 m/s at the time of release to 5.6 m/s (average of 4.3 m/s) when the drogues would have encountered the shore. As the wind speed increased during the second drogue release, the wind direction changed from west to northwest . The drogues released on 1 October 2018 were retrieved on 3 October 2018. However, according to the GPS data, the drogues had run aground on the east shore of Forrest Lake on 2 October 2018 at 3:20.

The Drogue 3 waterproof seal failed during the South Channel outlet release and the GPS was irreparably damaged after getting wet and freezing. As a result, no travel time or average velocity data were recorded for Drogue 3 during the Lower Reach South Channel outlet release. Drogue 3 was released at the same point and was recovered within 25 m of Drogue 1 and Drogue 2, suggesting that the path of all three drogues was similar and that the data lost from Drogue 3 would have been similar to the data collected by Drogue 1 and Drogue 2.

Table 2: Drogue Release Details

Parameter	Units	North Channel Outlet Release			South Channel Outlet Release		
		Drogue 1	Drogue 2	Drogue 3	Drogue 1	Drogue 2	Drogue 3
Start date/time	-	30 Sep 2018 17:20	30 Sep 2018 17:20	30 Sep 2018 17:20	1 Oct 2018 13:39	1 Oct 2018 13:39	1 Oct 2018 13:39
End date/time	-	30 Sep 2018 18:43	30 Sep 2018 18:43	30 Sep 2018 18:43	2 Oct 2018 3:20[a)]	2 Oct 2018 3:20[a)]	n/d
Average drogue direction	-	NW	NW	NW	SW	SW	SW
Average wind speed	m/s	4.30	4.30	4.30	4.30	4.30	n/d
Average wind direction	-	W	W	W	NW	NW	n/d
Distance	m	361	367	399	1,440	1,500	1,500
Release easting	m	605626	605626	605626	605691	605691	605691
Release northing	m	6390409	6390409	6390409	6390299	6390299	6390299
Retrieval easting	m	605843	605843	605843	606509	606509	606509
Retrieval northing	m	5390578	5390578	5390578	6389210	6389210	6389210
Travel time	s	4,980	4,980	4,980	49,300	49,300	n/d
Travel time	h	1.38	1.38	1.38	13.7	13.7	n/d
Average velocity	m/s	0.072	0.074	0.080	0.029	0.030	n/d
Release average velocity	m/s	0.075			0.030		

n/d = no data; NW = northwest; SW = southwest; W = west

Time is for last recorded movement of drogues prior to running aground rather than time of retrieval. Droques were retrieved on 3 October 2018, after they had run aground on the east shoreline and became encased in ice.

Figure 10: View of Drogues at Retrieval Point, 30 September 2018

Note: Drogues are floating in the North Basin with the northern shoreline of Forrest Lake visible on the right; view is from east facing west toward the outflow channels of the Clearwater River below Patterson Lake.

Figure 11: View of Drogues at Retrieval Point, 3 October 2018

Note: Drogues are encased in ice; view is from west facing east toward the east shoreline of Forrest Lake.

5.6 Rhodamine Dye Tracer Observations

The dye tracer slug was released downstream of Patterson Lake and upstream of Forrest Lake. The dye was transported to Forrest Lake by the Clearwater River and once in the North Basin, the plume spread in two directions. The visible plume emanating from the North Channel outlet flowed north towards and along the northern shore of Forrest Lake before reaching the Forrest Lake outlet. The visible plume emanating from the South Channel outlet flowed south and followed along the west shore of the North Basin approximately 1 km south to the mouth of E Creek. At this point, the plume flowed to the northeast and crossed the North Basin toward the Forrest Lake outlet. Outflow from Patterson Lake was observed to remain nearly completely isolated from the South Basin.

The rhodamine dye was released at the access road bridge on 30 September 2018 at 13:51 (Figure 7). As the plume advanced downstream, it was first concentrated on the outside of meander bends before full lateral mixing, which occurred before reaching Forrest Lake. Where the Clearwater River Lower Reach separates into the North Channel and South Channel, the dye was observed to flow first and more rapidly through the North Channel.

The visible plume arrived first at the North Channel outlet at 14:34, roughly 43 minutes after the initial release (i.e., 13:51). The plume front had passed the North Channel outlet completely by 17:00. The plume front arrived at the South Channel outlet at 15:05 and had passed completely by 18:00. Rhodamine concentrations observed at the North Channel outlet and South Channel outlet are shown in Figure 12. The elapsed time and associated average channel velocity are presented in Table 3.

Peak rhodamine concentrations could not be logged as the plume passed the North Channel and South Channel outlets because they were too far outside the calibration bounds. A Gaussian distribution was fitted to the observed concentration curves to estimate rhodamine concentrations during the periods of missing data. An estimated mass of 1.77 kg (or 59% of released mass) passed through the North Channel outlet and 1.17 kg (or 39% of released mass) through the South Channel outlet (total mass of 2.94 kg or 98% of released mass). Measurement of 98% of the mass released is considered satisfactory and 2% error does not influence confidence in the interpretation of results. The remaining 2% that was not measured may have been caught in slack or recirculating currents in the Clearwater River or adsorbed to vegetation.

The temperature observed during the transit of the dye tracer through the North Channel outlet and the South Channel outlet is shown in Figure 13. Temperature averaged 6.1°C in the North Channel outlet and 6.0°C in the South Channel outlet.

The velocity in the Clearwater River Upper Reach mainstem and Lower Reach North Channel were consistent (0.29 m/s and 0.28 m/s, respectively), with the velocity in the Lower Reach South Channel being notably smaller at 0.14 m/s. The division of flow observed in the field between the two channels is supported by preliminary one-dimensional hydraulic modelling of the reach using HEC-RAS (USACE 2018), which is standard software for the modelling of open channel hydraulics developed by the United States Army Corps of Engineers. According to the preliminary modelling, approximately 34% of the flow in the Upper Reach mainstem flows through the Lower Reach South Channel and 66% Lower Reach North Channel (Appendix 9A, Hydrological Modelling Summary Report), which agrees with the approximate proportions of measured dye mass in each channel.

Table 3: Summary of Plume Advance through Clearwater River below Patterson Lake, 30 September 2018

Location / Reach	Plume Arrival Time[(a)]	Time Since Release (minutes)	Incremental Elapsed Time (minutes)	Distance (m)	Velocity (m/s)
Access Road Bridge (release point)	13:51	0	0	0	n/a
Access Road to Channel Fork	14:24	33	33	569	0.29
Channel Fork to North Channel outlet	14:34	43	10	168	0.28
Channel Fork to South Channel outlet	15:05	84	41	341	0.14

a) The plume arrival time is at the downstream end of the reach.
n/a = not applicable.

Figure 12: Concentration of Rhodamine Observed in Outflow from the Clearwater River into the Forrest Lake – North Basin via the North Channel and South Channel

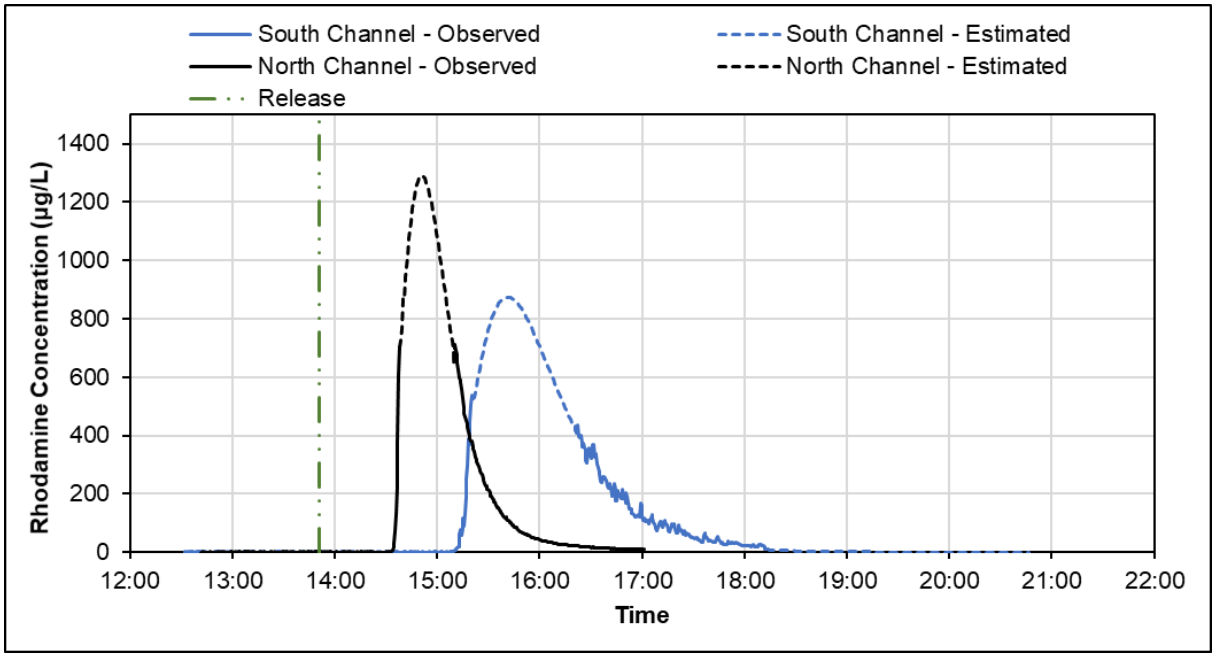
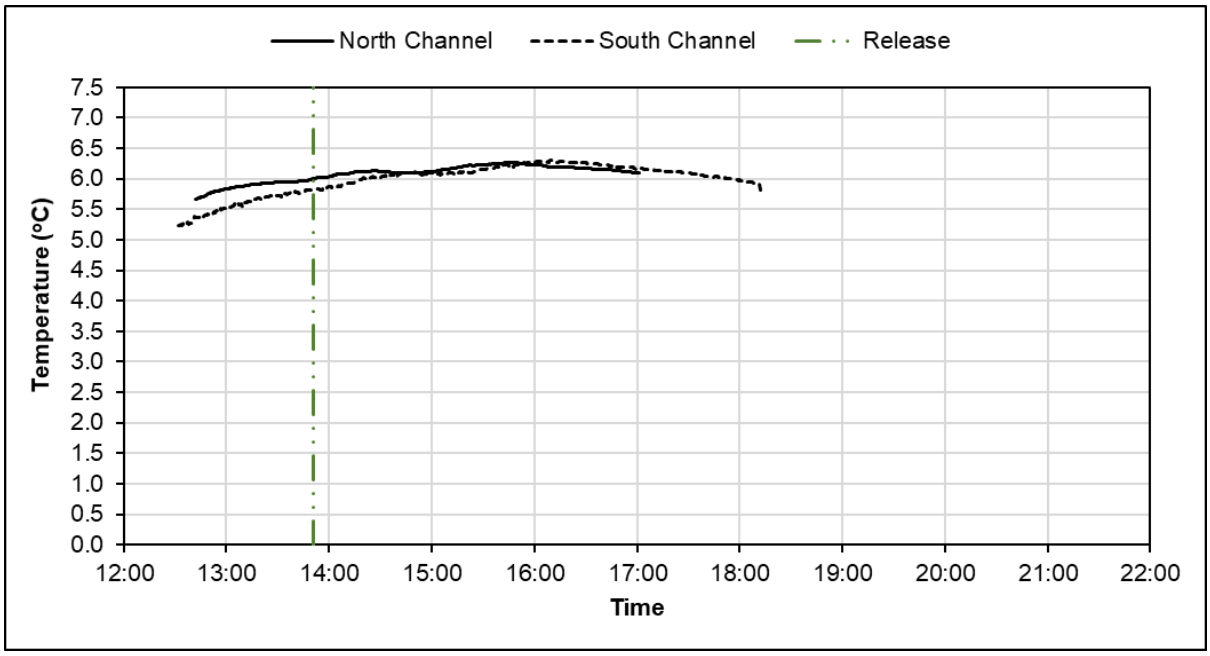
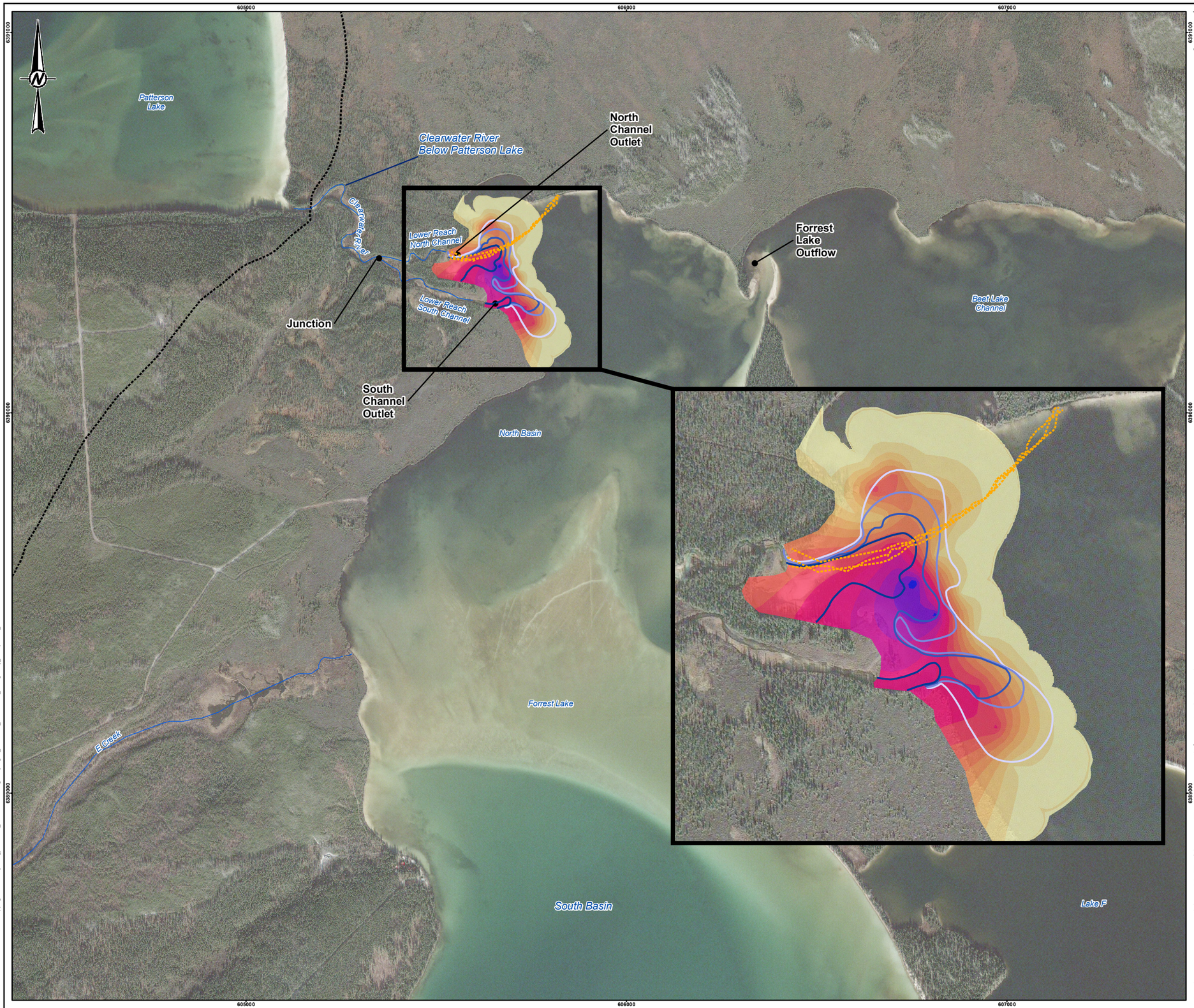


Figure 13: Observed Temperature of Outflow from the Clearwater River into the Forrest Lake – North Basin via the North Channel and South Channel



The observations of the plume advance into the North Basin on 30 September 2018 are shown in Figure 14. The emergence of two distinct flow paths, one emanating from the North Channel outlet and one emanating from the South Channel outlet, are visible in Figure 14 based on the visual plume outlines traced by canoe with GPS and on the plume boundaries from interpolated concentration measurements. Also visible in Figure 14 is the development of a high concentration pocket situated approximately 50 m from the west shore between the two developing flow paths. The drogue paths for the release on 30 September 2018 further validate the direction of the currents from the outflow of the North Channel outlet.



LEGEND

PROJECT FEATURES

- EXISTING ACCESS ROAD
- DROGUE PATH

VISUAL PLUME OUTLINES

- 15:09-15:38
- 15:38-15:59
- 15:59-16:28
- 16:28-16:57

PLUME BOUNDARIES INTERPOLATED FROM CONCENTRATION MEASUREMENTS (µg/L)[1]

- 1-50
- 50-100
- 100-150
- 150-200
- 200-250
- 250-300
- 300-350
- 350-400
- 400-450
- 450-500
- 500-550
- 550-600
- 600-650
- 650-700

0 200 400

1:10,000 METRES

NOTE(S)

1. CONCENTRATION MEASUREMENTS COLLECTED ON SEPTEMBER 30, 2018 BETWEEN 17:23 AND 17:48.

REFERENCE(S)

1. IMAGERY OBTAINED FROM CLIENT, DATED: 2015.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

ROOK I PROJECT

TITLE

FORREST LAKE MIXING STUDY - SEPTEMBER 30, 2018 OBSERVATIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2020-03-20
DESIGNED	RP
PREPARED	LMS/NO
REVIEWED	RWP
APPROVED	GVA

PROJECT NO.	PHASE	REV.	FIGURE
19114981	7000	0	**14**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

0 25mm

PATH: I:\CLIENTS\NexGen\19114981\Mapping\Products\Hydrology\Baseline_ForrestLake\MixingStudy\Fig14_19114981_ForrestLake_MixingStudy_30Sept2018_Rev0.mxd

The rhodamine concentrations observed at the Forrest Lake outlet are shown in Figure 15, while the observed water temperatures at the Forrest Lake outlet are shown in Figure 16. The initial plume front was visually observed to arrive at the Forrest Lake outlet on 1 October 2018 at 10:30. The sonde probe at the outlet of Forrest Lake failed to log rhodamine concentrations on 1 October 2018 between 01:28 and 13:01. The probe began to successfully log beginning at 13:01 and continued to log until its eventual retrieval on 3 October 2018 at 09:14. The observed peak was 15.6 µg/L at 13:03; however, actual rhodamine concentrations at the Forrest Lake outlet were expected to have peaked sometime between 10:30 and 13:01 when the probe was not logging. This means that there is some uncertainty in the timing and magnitude of the peak concentrations at the Forrest Lake outlet but the gap does not have a meaningful impact on the interpretation of the results. Rhodamine concentrations declined from the observed peak through the afternoon and evening of 1 October 2018.

Between 10:58 and 13:03 on 1 October 2018, rhodamine concentrations and the plume extent in the North Basin were mapped using one of the probes. The observed plume extent, shown in Figure 17, was focused on the west shore and north shore of the North Basin. Flow to the south along the west shore was validated by observation of aquatic vegetation bending with a long shore current in a southerly direction. The plume went to the east at the mouth of E Creek along the sand sill that separates the North Basin from the South Basin. The plume did not pass over the sand sill into the South Basin, suggesting that exchange flows between the two basins are limited.

The drogue paths for the release on 1 October 2018 are shown in Figure 17. The drogue paths on 1 October are likely to have been heavily influenced by wind conditions at surface that may not have influenced the water column as a whole. The path does not appear to reflect the path travelled by the plume itself.

One key observation on 1 October 2018 was that a substantial portion of the plume remained just offshore between the North Channel outlet and South Channel outlet. This extended residence time was likely the result of a circulating current or eddy generated between the two flow paths.

Rhodamine concentrations at the Forrest Lake outlet began to increase again on 2 October 2018 at 0:00 (Figure 15) and continued to increase to a peak at 14.7 µg/L on 2 October 2018 at 12:00 before decreasing. On 2 October 2018 around 19:00, the rhodamine concentration observed at the outlet appeared to have stabilized at around 3 µg/L until the probe was removed the morning of 3 October 2018. This indicated a high degree of mixing occurring in the North Basin. The degree of mixing in the North Basin likely increased during the afternoon of 2 October 2018 in response to wind and wave action. However, since the measured concentrations at the outlet of Forrest Lake showed considerable variation over the first two days of the study, including two peaks, it is expected that the time required for the North Basin to become well mixed is approximately two days based on the water level and wind conditions at the time of the survey.

An aerial survey was completed the morning of 2 October 2018 at 10:30, and the observed plume extent is shown in Figure 18. Video footage and photographs collected during the aerial survey indicated a more uniformly distributed but not completely mixed coverage of the North Basin by the plume. A key observation, visible in Figure 19 and Figure 20, was that the boundary of the plume roughly coincided with the sand sill that separates the North and South basins. The plume was not observed to cross over the sand sill into the South Basin. Light conditions were poor during the helicopter flight, and it was difficult to see the dye clearly except over the sand sill where the white sand backdrop accentuated the plume boundary.

Over the period that the sonde probes were deployed at the Forrest Lake outlet, diurnal temperature fluctuations were visible but the general trend beginning on 1 October 2018 was downward (i.e., cooler), with temperatures eventually reaching approximately 0°C by the time the probes were retrieved.

The mass of dye that was observed to leave Forrest Lake was 1.67 kg. At the end of the study on the morning of 3 October 2018, there would have been 1.30 kg remaining in the North Basin if the area of the visible plume observed on 2 October 2018 in the North Basin (86 ha) was fully mixed with a rhodamine concentration of 3 µg/L equal to that observed at the outlet. This accounts for approximately 2.97 kg of dye, which is within 1% of the amount released (3.00 kg) at the access road bridge below Patterson Lake. This recovery is higher than the 98% calculated at the inflow to the lake but reflects relatively low analytical variability considering the measurement errors inherent in the volumes, flows and concentrations required to close the mass balance. Overall, the mass balance suggests the study was well constrained and provided sufficient information for understanding circulation and mixing patterns in the North Basin and the limited connection to the South Basin.

Figure 15: Rhodamine Dye Concentration Observed in Outflow from Forrest Lake

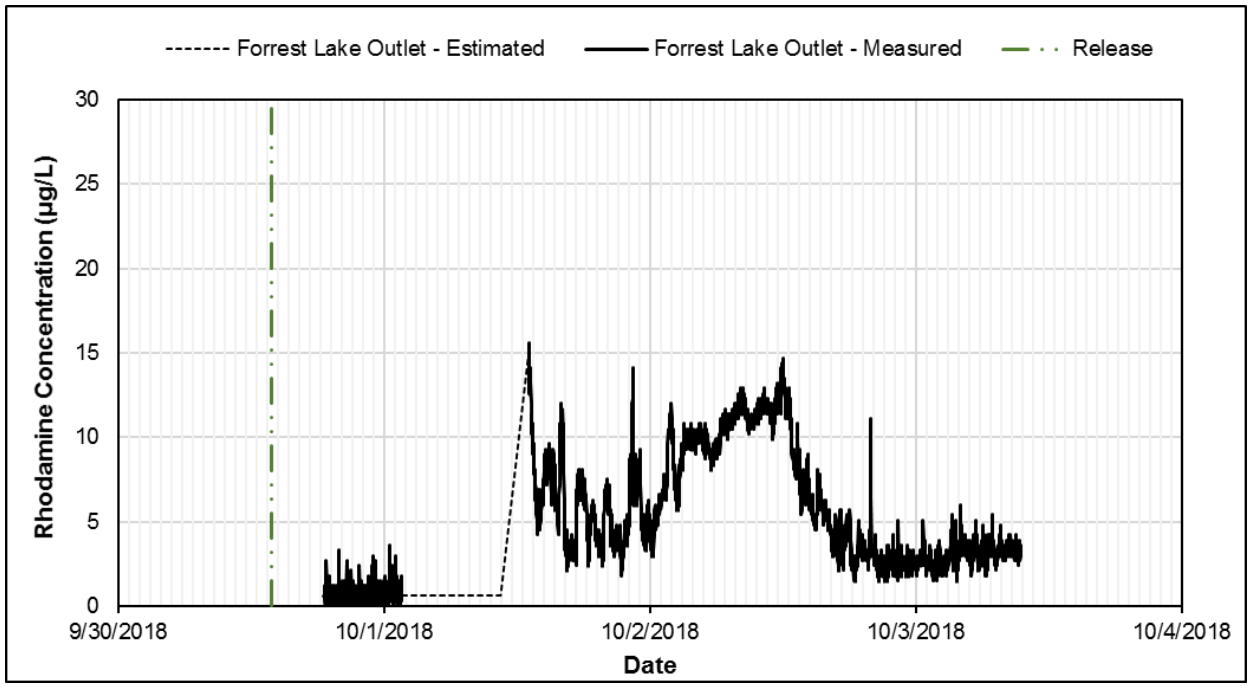
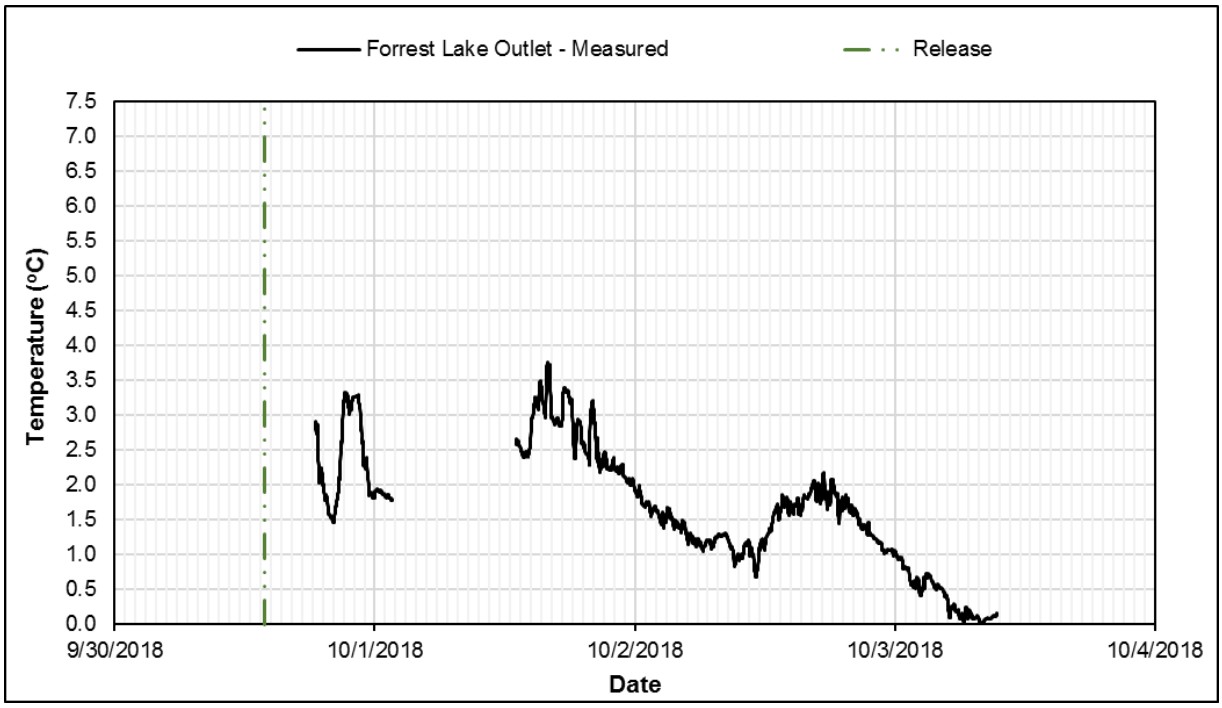


Figure 16: Water Temperature Observed in Outflow from Forrest Lake



The dye tracer observations discussed here are specific to the physical, hydrological, and meteorological conditions that existed during the study. However, the key finding that Patterson Lake outflow was nearly completely isolated from the South Basin is not anticipated to be highly sensitive to changes in wind or changes in water level.

During the study, wind speed and direction varied. On 30 September 2018 and 1 October 2018 wind speeds were low and remained less generally less than 15 km/hr. Wind speeds increased through 2 October 2018, ultimately reaching a maximum average hourly wind speed of 25 km/h with gusts exceeding 45 km/h. Throughout the duration of the study, the wind was generally from the northwest. Winds of 25 km/h are anticipated to represent routine windy conditions in the vicinity of Rook I. Sustained winds from the northwest of 25 km/hr (approximately 7 m/s) did not result in flow over the sand sill to the south. Winds from any other direction would not be expected to increase likelihood of flow over the sand sill to the south. Wind speeds greater than 25km/hr are likely to occur for a period but winds sustained over a period of days are not likely

Water levels in Forrest Lake are expected to range 0.7 m in a typical year with the annual maximum approximately 0.5 m higher than the water level observed during the field study. The sill would be more of a barrier in low water levels due to shallow water depth. Even at maximum water levels, the water depth above the sill would be relatively shallow with depths of approximately 1.0 m to 1.1 m. As a result, seasonal increase to water level is not expected result in a meaningful change to the lack of connectivity between the North Basin and South Basin observed during this field study.

605000
606000
607000
6391000
6390000
6389000
6388000

Patterson Lake
Clearwater River Below Patterson Lake
Clearwater River
Lower Reach North Channel
Lower Reach South Channel
Junction
North Channel Outlet
South Channel Outlet
Forrest Lake Outflow
Beet Lake Channel
North Basin
Forrest Lake
South Basin
Lake F
E Creek

LEGEND

PROJECT FEATURES

EXISTING ACCESS ROAD

DROGUE PATH

PLUME BOUNDARIES INTERPOLATED FROM CONCENTRATION MEASUREMENTS (µg/L)[1]

- 1-25
- 25-50
- 50-75
- 75-100
- 125-150
- 100-125

0 200 400

1:10,000 METRES

NOTE(S)

1. CONCENTRATION MEASUREMENTS COLLECTED ON OCTOBER 1, 2018 BETWEEN 10:58 AND 13:03.

REFERENCE(S)

1. IMAGERY OBTAINED FROM CLIENT, DATED: 2015.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

ROOK I PROJECT

TITLE

FORREST LAKE MIXING STUDY - OCTOBER 1, 2018 OBSERVATIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2020-03-20
DESIGNED	RP
PREPARED	LMS/NO
REVIEWED	RWP
APPROVED	GVA

PROJECT NO.	PHASE	REV.	FIGURE
19114981	7000	0	17

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI B

0 25mm

PATH: I:\CLIENTS\NexGen\19114981\Mapping\Products\Hydrology\Baseline_ForrestLake\MixingStudy\Fig17_19114981_ForrestLake_MixingStudy_1Oct2018_Rev0.mxd

LEGEND

PROJECT FEATURES

- EXISTING ACCESS ROAD
- VISUAL PLUME BASED ON HELICOPTER RECONNAISSANCE

0 200 400

1:10,000 METRES

REFERENCE(S)

1. IMAGERY OBTAINED FROM CLIENT, DATED: 2015.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

ROOK I PROJECT

TITLE

FORREST LAKE MIXING STUDY - OCTOBER 2, 2018 OBSERVATIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2020-03-20
DESIGNED	RP
PREPARED	LMS/NO
REVIEWED	RWP
APPROVED	GVA

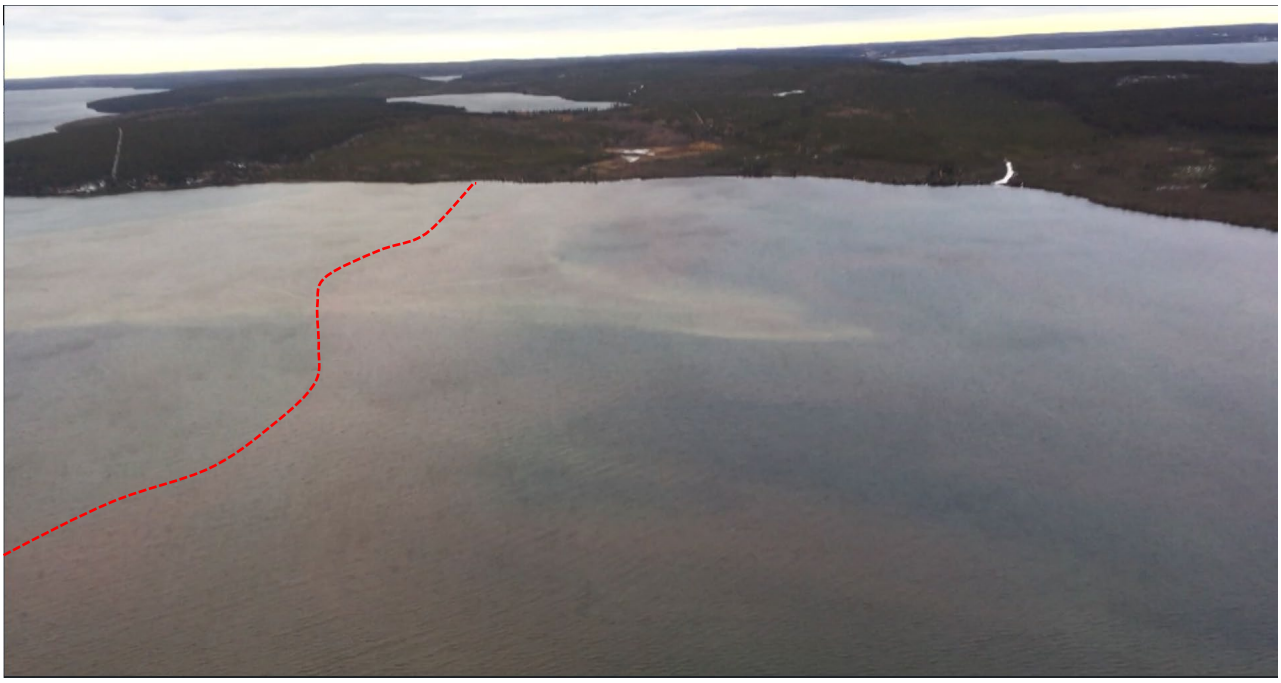
PROJECT NO.	PHASE	REV.	FIGURE
19114981	7000	0	**18**

PATH: I:\CLIENTS\NewCen\19114981\Mapping\Products\Hydrology\Baseline_Forrest\Lake\MixingStudy\Fig18_19114981_ForrestLake_MixingStudy_20220218_Rev0.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI B

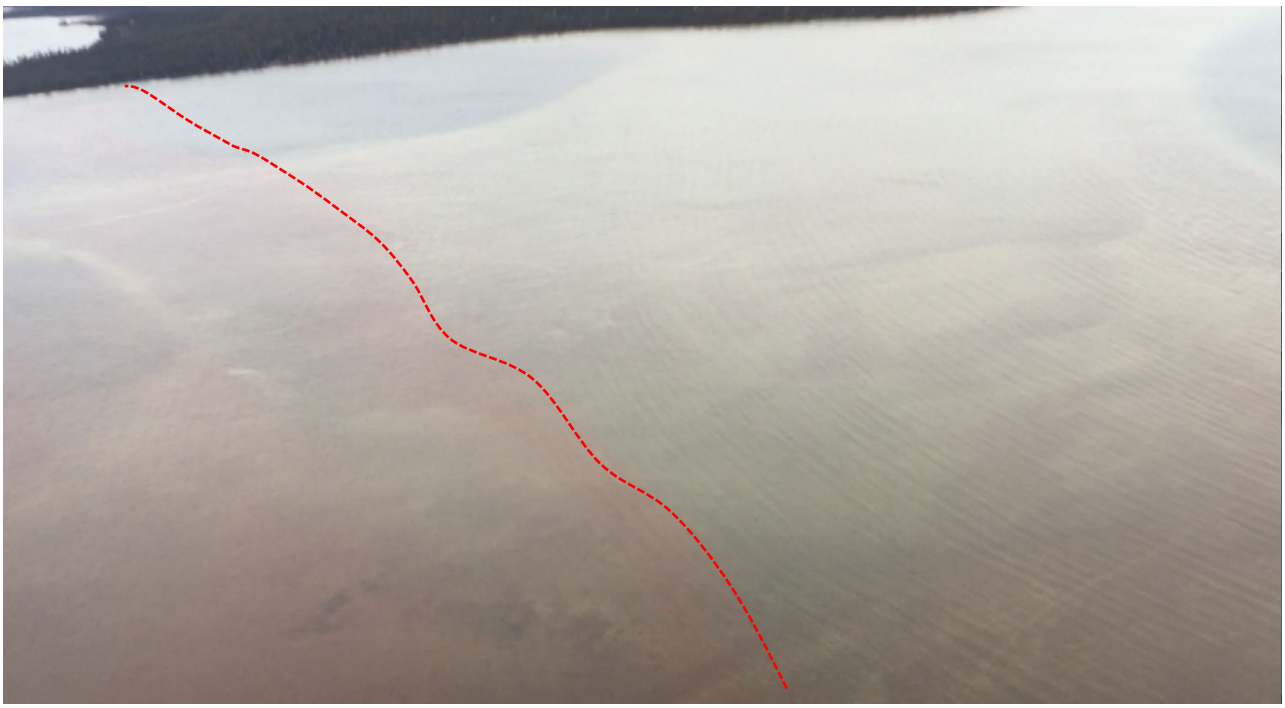
0 25mm

Figure 19: Aerial View from East Showing the Maximum Observed Plume Extent, 2 October 2018



Note: Plume extent is indicated by red dashed line; helicopter view from the east facing west-southwest.

Figure 20: Aerial View from West Showing the Maximum Observed Plume Extent, 2 October 2018



Note: Plume extent is indicated by red dashed line; helicopter view from the west facing east.

6.0 SUMMARY

The 2018 Forrest Lake mixing study was completed to evaluate the extent that water from the Clearwater River flowing from the Patterson Lake outlet mixes within Forrest Lake. A visual overview of the 2018 Forrest Lake mixing study is provided in Figure 21.

The study was conducted primarily with a rhodamine dye tracer that was observed visually and by logging concentration measurements from YSI sonde probes. To provide additional context to the plume mapping, complementary physical measurements were collected from the Rook I Meteorological Station and drogues that followed surficial lake currents.

Dye tracer observations indicated that most of the dye/flow from Patterson Lake to Forrest Lake was conveyed through the Lower Reach North Channel outlet. The plume front arrived at the North Channel outlet first and passed more rapidly than that observed at the South Channel outlet.

Once in the North Basin, the plume spread in two directions. The visible plume emanating from the North Channel outlet flowed north towards and along the northern shore of Forrest Lake before reaching the Forrest Lake outlet. The visible plume emanating from the South Channel outlet flowed south and followed along the west shore of the North Basin approximately 1 km south to the mouth of E Creek. At this point, the plume flowed to the northeast and crossed the North Basin toward the Forrest Lake outlet. A substantial portion of the plume remained just offshore between the North Channel outlet and South Channel outlet. This effect is likely the result of a circulating current or eddy generated between the two flow paths.

Based on measured conditions at the time of the study, the residence time of the North Basin was approximately four days, and it took two days for the basin to become fully mixed.

Outflow from Patterson Lake was observed to remain nearly completely isolated from the South Basin. Three lines of evidence confirmed this observation:

1) The plume was measured in real time from a boat and observed to end at the sand sill.
2) The plume was visually delineated from helicopter and seen to stop at the sill.
3) A mass balance confirmed to within 1% that the plume was entirely contained within the North Basin or flowed out of Forrest Lake after two days.

Consequently, the flow over the sand sill can be considered unidirectionally north, and flow from Patterson Lake can be thought of as unidirectionally to the east, with a small basin with a residence time of a few days that fully mixes these inflows.

LEGEND

PROJECT FEATURES

- EXISTING ACCESS ROAD

PLUME DIRECTION

- PATH A
- PATH B
- DEPOSITIONAL AREA WITH EXTENDED RESIDENCE TIME

0 200 400

1:10,000 METRES

REFERENCE(S)

1. IMAGERY OBTAINED FROM CLIENT, DATED: 2015.
2. HISTORIC BATHYMETRY DIGITIZED FROM 1981 MAP OBTAINED FROM GOEVERNMENT OF SASKATCHEWAN.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

ROOK I PROJECT

TITLE

FORREST LAKE MIXING STUDY – OVERVIEW

CONSULTANT

GOLDER

YYYY-MM-DD	2020-03-20
DESIGNED	RP
PREPARED	LMS/NO
REVIEWED	RWP
APPROVED	GVA

PROJECT NO.	PHASE	REV.	FIGURE
19114981	7000	0	**21**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

0 25mm

PATH: I:\CLIENTS\NewGen\19114981\Mapping\Product\Hydrology\Baseline_ForestLake\MixingStudy\Fig21_19114981_ForestLake_MixingStudyOverview_Rev0.mxd

CLOSING

Golder is pleased to submit this report to NexGen in support of the environmental assessment for the Rook I Project. For details on the limitations and use of information presented in this report, please refer to the Study Limitations section following this page. If you have any questions or require additional details related to this study, please contact the undersigned.

Golder Associates Ltd.

Prepared By:

Ross Phillips, M.Sc., P.Eng.
Senior Water Resources Engineer

Reviewed By:

Gerard Van Arkel, M.Eng.
Principal Water Resources Engineer

RP/GVA/pls

STUDY LIMITATIONS

This report has been prepared by Golder Associates Ltd. (Golder) for NexGen Energy Ltd. (Client) and for the express purpose of supporting the Environmental Assessment (EA) of the proposed Rook I Project. This report is provided for the exclusive use by the Client. Golder authorizes use of this report by other parties involved in, and for the specific and identified purpose of, the EA review process. Any other use of this report by others is prohibited and is without responsibility to Golder.

The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and are not to be modified, amended, excerpted or revised. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder shall remain the copyright property of Golder, who authorizes the Client to make copies of the report or any portion thereof, but only in such quantities as are reasonably necessary for the specific purpose set out herein. The Client may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express prior written permission of Golder.

Golder has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty expressed or implied is made. The findings and conclusions documented in this report have been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of or variation in the site conditions, purpose or development plans, or if the project is not initiated within a reasonable time frame after the date of this report, may alter the validity of the report.

The scope and the period of Golder’s services are as described in Golder’s proposal, and are subject to restrictions and limitations. Golder did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the report. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by Golder in regard to it. Any assessments, designs and advice made in this report are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this report. Where data supplied by the Client or other external sources (including without limitation, other consultants, laboratories, public databases), including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by Golder for incomplete or inaccurate data supplied by others.

The passage of time affects the information and assessment provided in this report. Golder’s opinions are based upon information that existed at the time of the production of the report. The Services provided allowed Golder to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be to the foregoing and to the entirety of the report. Golder cannot be responsible for use of portions of the report without reference to the entire report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client and were prepared for the specific purpose set out herein. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

REFERENCES

ENV (Saskatchewan Ministry of the Environment). 1981. Bathymetry Map for Forrest Lake.

EC (Environment Canada). 2003. Revised Technical Guidance on How to Conduct Effluent Plume Delineation Studies. 42 p.

Terzi RA, Winkler T, Routledge B. 1994. Hydrometric Field and Related Manual, Water Survey of Canada. Environment Canada, Ottawa, ON.

USACE (United States Army Corps of Engineers). 2018. Hydrologic Engineering Center. 2018. HEC-RAS (5.0.6). Available at https://www.hec.usace.army.mil/software/hec-ras/

APPENDIX A

Photo Appendix

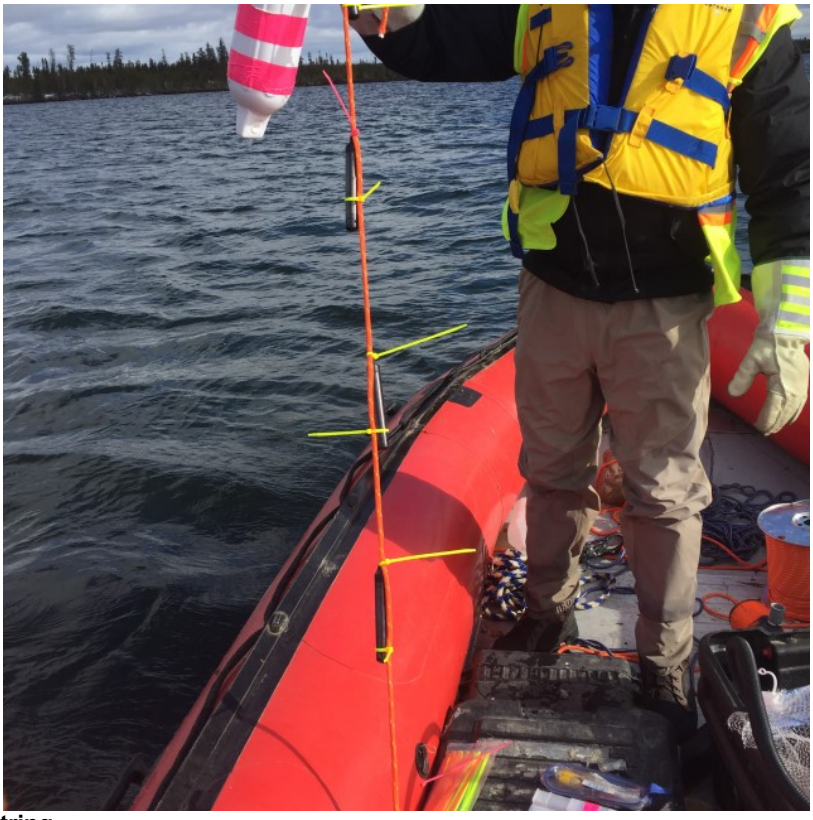


Photo 1: Thermistor String

Photo 2: Thermistor String prior to Deployment

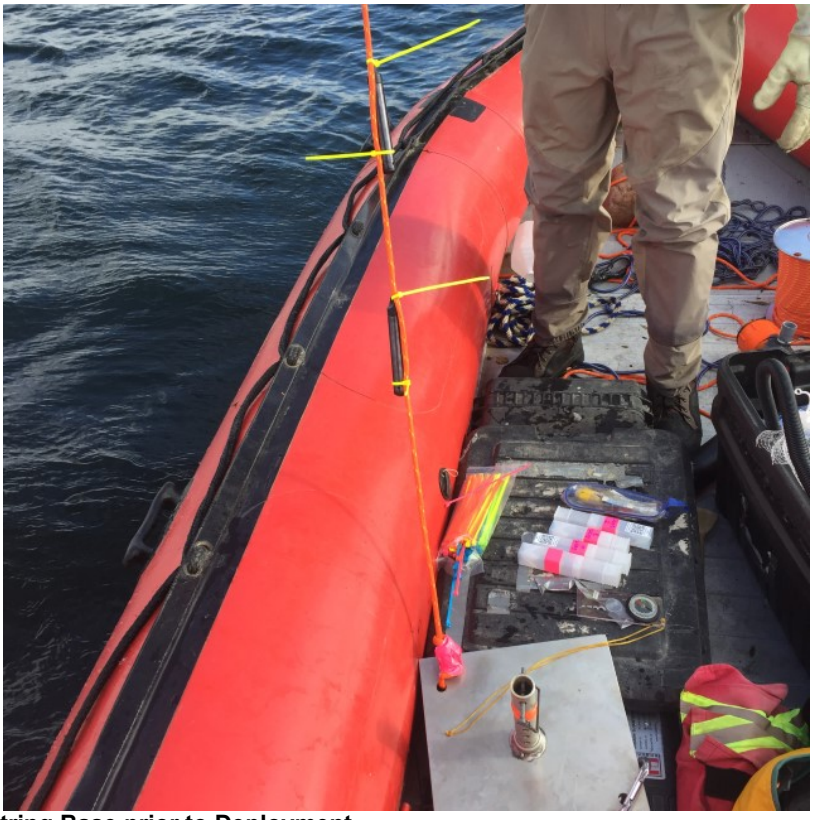


Photo 3: Thermistor String Base prior to Deployment

Photo 4: YSI Probe Installed at South Channel Outlet. View is facing North on 30 September 2018.

Photo 5: Clearwater River above the Access Bridge prior to Dye Release. The view is from the Access Road Bridge facing Upstream (West) on 30 September 2018.

Photo 6: Clearwater River below the Access Bridge prior to Dye Release. The view is from the Access Road Bridge facing Downstream (East) on 30 September 2018.

Photo 7: Water Pail used for Dilution

Photo 8: View of the Clearwater River at the Point of Release. View is from the North Bank facing South on 30 September 2018; 13:54.

Photo 9: View of the Clearwater River at the Point of Release. View is from the North Bank facing South on 30 September 2018; 13:54.

Photo 10: View of the Clearwater River at (Latitude: 57°38"41.38'; Longitude: 109°14'10.20") the Point of Release. View is from the Center facing downstream on 30 September 2018; 14:02.

Photo 11: View of the Clearwater River at (Latitude: 57°38'41.32"; Longitude: 109°14'9.93") facing downstream on 30 September 2018; 14:02.

Photo 12: View of the Clearwater River at (Latitude: 57°37'40.64"; Longitude: 109°14'9.02") facing downstream on 30 September 2018; 14:03.

Photo 13: View of the Clearwater River at (Latitude: 57°38'39.72; Longitude: 109°14'9.66") facing downstream on 30 September 2018; 14:05.

Photo 14: View of the Clearwater River at (Latitude: 57°38'38.91"; Longitude: 109°14'12.15") facing downstream on 30 September 2018; 14:09.

Photo 15: View of the Clearwater River at (Latitude: No Data; Longitude: No Data) facing downstream on 30 September 2018; 14:12.

Photo 16: View of the Clearwater River at (Latitude: 57°38'37.57"; Longitude: 109°14'9.30") facing downstream on 30 September 2018; 14:15.

Photo 17: View of the Clearwater River at (Latitude: 57°38'37.58"; Longitude: 109°14'9.27") facing downstream on 30 September 2018; 14:15.

Photo 18: View of the Clearwater River at (Latitude: 57°38'37.37"; Longitude: 109°14'8.12") facing downstream on 30 September 2018; at 14:17.

Photo 19: View of the Clearwater River at (Latitude: 57°38'37.70"; Longitude: 109°14'6.50") facing downstream on 30 September 2018; 14:19.

Photo 20: View of the Clearwater River at (Latitude: 57°38'37.62"; Longitude: 109°14'5.04") facing downstream on 30 September 2018; 14:20.

Photo 21: View of the Clearwater River at (Latitude: 57°38'37.21"; Longitude: 109°14'2.57") facing downstream on 30 September 2018; 14:22.

Photo 22: View of the Clearwater River at (Latitude: 57°38'37.15"; Longitude: 109°14'2.51") facing downstream on 30 September 2018; 14:23.

Photo 23: View of the Clearwater River at (Latitude: 57°38'37.14"; Longitude: 109°14'2.40") facing downstream on 30 September 2018; 14:23.

Photo 24: View of the Clearwater River at (Latitude: 57°38'37.36"; Longitude: 109°14'1.58") facing downstream on 30 September 2018.

Photo 25: View of the Clearwater River at (Latitude: 57°38'37.37"; Longitude: 109°14'1.55") facing downstream on 30 September 2018; 14:24.

Photo 26: View of the Clearwater River at (Latitude: 57°38'37.33"; Longitude: 109°13'58.92") facing downstream on 30 September 2018; 14:28.

Photo 27: View of the Clearwater River at (Latitude: 57°38'37.37"; Longitude: 109°13'58.94") facing downstream on 30 September 2018; 14:28.

Photo 28: View of the Clearwater River at (Latitude: 57°38'37.33; Longitude: 109°13'58.92") facing downstream on 30 September 2018; 14:28.

Photo 29: View of the Clearwater River at (Latitude: 57°38'37.37; Longitude: 109°13'58.94") facing downstream on 30 September 2018; 14:28.

Photo 30: View of the Clearwater River at (Latitude: 57°38'37.94; Longitude: 109°13'58.31") facing downstream on 30 September 2018; 14:23.

Photo 31: View of the Clearwater River at (Latitude: No Data; Longitude: No Data) facing downstream on 30 September 2018; 14:31.

Photo 32: View of the Clearwater River at (Latitude: 57°38"38.14; Longitude: 109°13'56") facing downstream on 30 September 2018; 14:32.

Photo 33: View of the Clearwater River at the North Channel Outlet at (Latitude: 57°38'37.44"; Longitude: 109°13'54.85") facing Upstream on 30 September 2018.

Photo 34: View of the Clearwater River near the South Channel Outlet at the Location of the Plume Front facing Upstream (West) on 30 September 2018; 14:50.

Photo 35: View of the Clearwater River near the South Channel Outlet at the Location of the Plume Front facing Downstream (East) on 30 September 2018; 14:50.

Photo 36: View of the Clearwater River Outflow from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing North on 30 September 2018; 15:02.

Photo 37: View of the Clearwater River Outflow from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing North on 30 September 2018; 15:03.

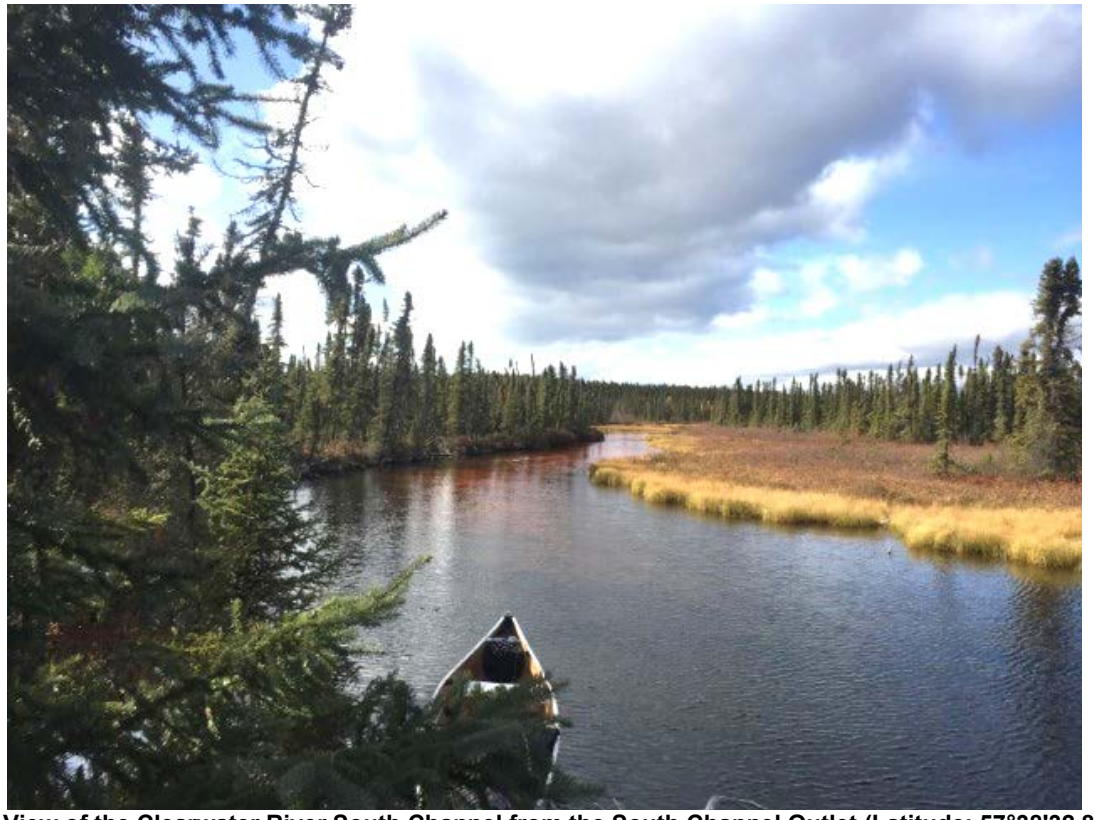


Photo 38: View of the Clearwater River South Channel from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing Upstream (West) on 30 September 2018; 15:03.

Photo 39: View of the Clearwater River South Channel from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing Upstream (West) on 30 September 2018; 15:04.

Photo 40: View of the Clearwater River Outflow from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing North on 30 September 2018; 15:04.

Photo 41: View of the Clearwater River Outflow from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing North on 30 September 2018; 15:05. The Photograph Shows the Point of Plume Arrival at the South Channel Outlet.

Photo 42: View of the Clearwater River South Channel from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing Upstream (West) on 30 September 2018; 15:08.

Photo 43: View of the Clearwater River Outflow from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing North on 30 September 2018; 15:08.

Photo 44: View of the Clearwater River South Channel from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing Downstream (East) on 30 September 2018; 15:09.

Photo 45: View of the Clearwater River South Channel from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing Upstream (West) on 30 September 2018; 15:09.

Photo 46: Panoramic view of the Clearwater River North Channel Outlet (Latitude: 57°38'36.84"; Longitude: 109°13'54.22") facing South on 30 September 2018; 15:17.

Photo 47: View of Forrest Lake from the Mouth of the North Channel Outlet (Latitude: 57°38'36.84"; Longitude: 109°13'54.22") facing Upstream (West) on 30 September 2018; 15:17.

Photo 48: View of Forrest Lake from the Mouth of the North Channel Outlet (Latitude: 57°38'36.84"; Longitude: 109°13'54.22") facing Downstream (East) on 30 September 2018; 15:17.

Photo 49: Panoramic view of the Clearwater River North Channel Outlet (Latitude: 57°38'36.84"; Longitude: 109°13'54.22") facing South on 30 September 2018; at 15:37.

Photo 50: View of the Clearwater River at the North Channel Outlet at (Latitude: 57°38'37.44"; Longitude: 109°13'54.85") facing Upstream on 30 September 2018; 15:37.

Photo 51: View of the Clearwater River South Channel from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing Downstream (East) on 30 September 2018; 15:55.

Photo 52: View of the Clearwater River South Channel from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing Upstream (West) on 30 September 2018; 15:55.

Photo 53: View of the Clearwater River Outflow from the South Channel Outlet (Latitude: 57°38'32.80"; Longitude: 109°13'47.08") facing North on 30 September 2018; 16:55.

Photo 54: Drogues at Point of Retrieval facing Southwest on 30 September 2018; 18:43.

Photo 55: Drogues at Point of Retrieval facing Southwest on 3 October 2018; 10:34.

Photo 56: Drogues at Point of Retrieval (Latitude 57°37'57.08"; Longitude: 109°12'58.85") facing Northeast on 3 October 2018; 10:34.

Photo 57: Drogues at Point of Retrieval (Latitude 57°37'57.08"; Longitude: 109°12'58.85") facing Northeast on 3 October 2018; 10:35.

Photo 58: View of Forrest Lake from North facing South (Latitude: 57°38'55.84"; Longitude: 109°13'51.06") on 2 October 2018; 08:32.

Photo 59: View of Forrest Lake from North facing South-South-West (Latitude: 57°38'51.30"; Longitude: 109°13'49.63") on 2 October 2018; 08:32.

Photo 60: View of Forrest Lake facing South-South-West (Latitude: 57°38'34.65"; Longitude: 109°13'55.54") on 2 October 2018; 08:32.

Photo 61: View of YSI Deployed at Forrest Lake Outlet on 3 October 2018; 09:22.

Photo 62: View of Forrest Lake Outlet from the Outlet facing West on 3 October 2018; 09:48.

Photo 63: View of Forrest Lake Outlet from the Outlet facing North on 3 October 2018; 09:48.

Photo 64: View of Forrest Lake Outlet from the Outlet facing South on 3 October 2018; 09:48.

Photo 65: View of Forrest Lake Outlet from the Outlet (Latitude: 57°38'33.32"; Longitude: 109°13'4.84") facing North on 3 October 2018; 09:48.