Rook I Project

Environmental Impact Statement

Annex IV.4: Patterson Lake Currents Assessment Report

PATTERSON LAKE CURRENTS ASSESSMENT REPORT
FOR THE ROOK I PROJECT

Prepared for:

NexGen Energy Ltd.

Prepared by:

Golder Associates Ltd.

April 2022

Executive Summary

The assessment of potential adverse effects on surface water quantity and quality from industrial water intakes and outfalls is a provincial and federal requirement and is often a concern expressed by Indigenous Peoples and the public. To address these concerns and requirements, two dispersion modelling studies (Golder 2019, 2020) were conducted for the proposed Rook I Project to evaluate whether the releases from submerged outfalls would meet the requirements of the provincial Surface Water Quality Objectives (WSA 2015). Subsequent to the initiation of this study, the location of the treated sewage outfall was moved from Patterson Lake South Arm to Patterson Lake North Arm – West Basin. The revised location of the treated sewage outfall is approximately 400 m to the southwest of the treated effluent diffuser. A wide range of lake current speeds and directions based on available wind speed and direction data measured at the Rook I Meteorological Station were assumed in the dispersion modelling studies.

The two dispersion studies identified uncertainty owing to a lack of measured lake current data to verify the assumed lake current speeds and directions in the specific areas of the proposed intakes and outfalls in Patterson Lake. This baseline study was conducted in 2020 to provide measured site-specific lake currents data. This baseline study was also completed to improve the general understanding of Patterson Lake currents near the anticipated locations of the submerged infrastructure and to supplement the hydrology baseline study.

In this study, lake current speeds and directions were measured through the installation of acoustic Doppler current profilers (ADCPs) on the lake bed at proposed intake and outfall locations during the open-water season from July 2020 to September 2020. The ADCPs provided detailed high-frequency measurements of Patterson Lake currents from near the lake bed to the near the water surface. The ADCPs were installed and near-surface drogues (*note: drogues are floating "sails" or similar designs that are designed to drift below the water surface, and are fit with Global Positioning System [GPS] devices to track their positions*) were deployed for short periods from three lake currents station locations, one in each of the three basins:

1) Patterson Lake North Arm – East Basin (east of the narrows) near the proposed north fresh water intake location;
2) Patterson Lake North Arm – West Basin (west of the narrows) near the proposed treated effluent diffuser location; and
3) Patterson Lake South Arm – approximately 800 m west of the proposed treated sewage outfall, and at the proposed domestic fresh water intake provided in the 2019 site layout (Wood 2019)[1].

Short-term lake current speeds and directions were measured by releasing drogues fitted with GPS devices into the water from the proposed intake and outfall locations and monitoring their travel paths over a period of one to six hours. Two types of drogues designed for inland waters were used and provided data on near-surface lake current movements in the three Patterson Lake basins and on dispersion characteristics.

[1] Subsequent to the initiation of this study, the proposed location of the treated sewage outfall was moved from Patterson Lake South Arm to in Patterson Lake - North Arm – West Basin. The revised location of the treated sewage outfall is approximately 400 m to the southwest of the treated effluent diffuser.

The lake currents assessment met the baseline study objectives as it provided a better understanding of site-specific conditions at proposed locations of submerged infrastructure during open-water conditions. Measured current speeds were influenced by wind and local factors such as the orientation of the waterbody, steepness and height of surrounding shorelines, and bathymetry.

Since the collection of this data, the location of the proposed treated sewage outfall has moved to Patterson Lake North Arm – West Basin and the proposed domestic fresh water intake has been combined with the north fresh water intake (i.e., Patterson Lake North Arm – East Basin).

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

Golder (Golder Associates Ltd.). 2022. Patterson Lake Currents Assessment Report for the Rook I Project. Prepared for NexGen Energy Ltd.

Table of Contents

TABLES

FIGURES

APPENDICES

Abbreviations and Units of Measures

Acronym Abbreviations	Definition
ADCP	acoustic Doppler current profiler
GPS	Global Positioning System
MS	mainstem
NexGen	NexGen Energy Ltd.
PL-North-Intake	proposed north fresh water intake in Patterson Lake North Arm – East Basin
PL-North-Outfall	proposed treated effluent diffuser in Patterson Lake North Arm – West Basin
PL-South	proposed south fresh water intake and treated sewage outfall location in Patterson Lake South Arm[2]
Project	Rook I Project
PVC	polyvinyl chloride
TLU	traditional land use
UTM	Universal Transverse Mercator

Units	Definition
%	percent
°C	degrees Celsius
°	degree
h	hour
km	kilometre
km^2	square kilometre
km/h	kilometres per hour
m	metre
m/s	metres per second
m^2/s	square metres per second
MHz	megahertz
min	minute
mm	millimetre

[2] Subsequent to the initiation of this study, the location of the treated sewage outfall was moved from Patterson Lake South Arm to Patterson Lake North Arm – West Basin. The revised location of the treated sewage outfall is approximately 400 m to the southwest of the treated effluent diffuser. Additionally, the fresh water intake in Patterson Lake South Arm was eliminated from the project.

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.

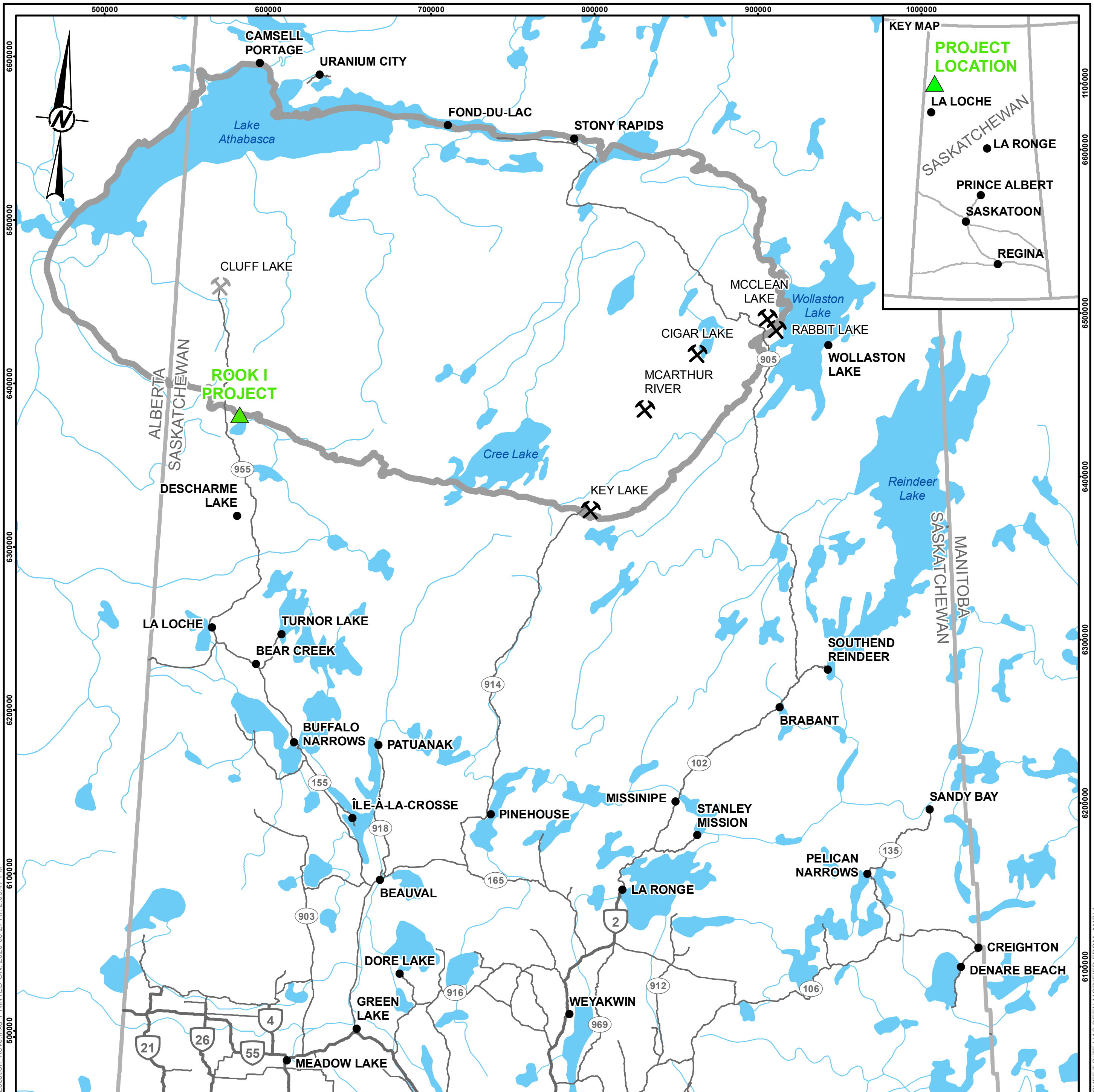
The characterization of Patterson Lake currents represents a component of a comprehensive baseline program that documents the natural and socio-economic environments in the anticipated area of the Project. The hydrology baseline program, of which the Patterson Lake currents assessment is a part, was undertaken to provide context from which Project environmental hydrological effects could be assessed in the Environmental Impact Statement.

Since exploration at the Project commenced in 2013, NexGen has engaged regularly and established relationships 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 Groups 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 Knowledge throughout the Environmental Assessment process, and providing funding for Traditional Land Use (TLU) Studies[3] 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 EA 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).

[3] 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.

Potential adverse effects on surface water quantity and quality from industrial water intakes and outfalls require assessment prior to construction installation and are often a concern expressed by the public including Indigenous Peoples. Two dispersion modelling studies were conducted (Golder 2019, 2020) for the proposed Project to evaluate whether the releases from submerged outfalls would meet the requirements of the provincial Surface Water Quality Objectives (WSA 2015). A wide range of lake current speeds and directions were assumed in the dispersion modelling studies and were based on available wind speed and direction data measured at the Rook I Meteorological Station. The dispersion studies identified uncertainty in lake currents because measured current data were not available to verify the assumed lake current speeds and directions in the specific areas of the proposed intakes and outfalls in Patterson Lake. This baseline study was conducted in 2020 to provide measured-site specific lake currents data. This baseline study was also completed to improve overall understanding of Patterson Lake currents near the anticipated locations of the submerged infrastructure.



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

PATH: I:\CLIENTS\NexGen\19114981\Mapping\Products\General\Baseline_General\19114981_Fig1_RookI-Project-Location_Rev0.mxd PRINTED ON: 2020-03-27 AT: 2:05:47 PM

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

25mm

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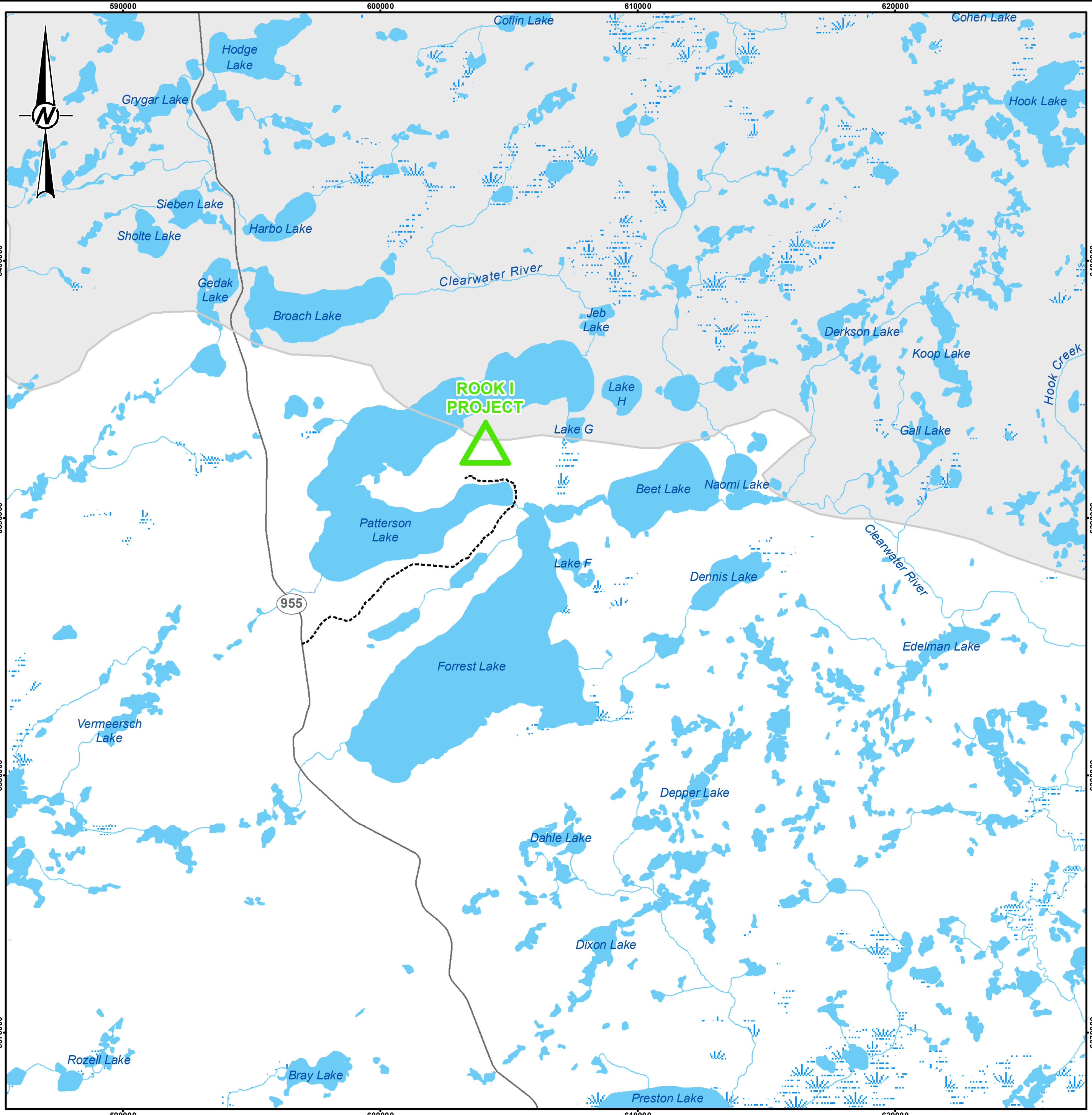


LEGEND

- 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

2.0 STUDY OBJECTIVES

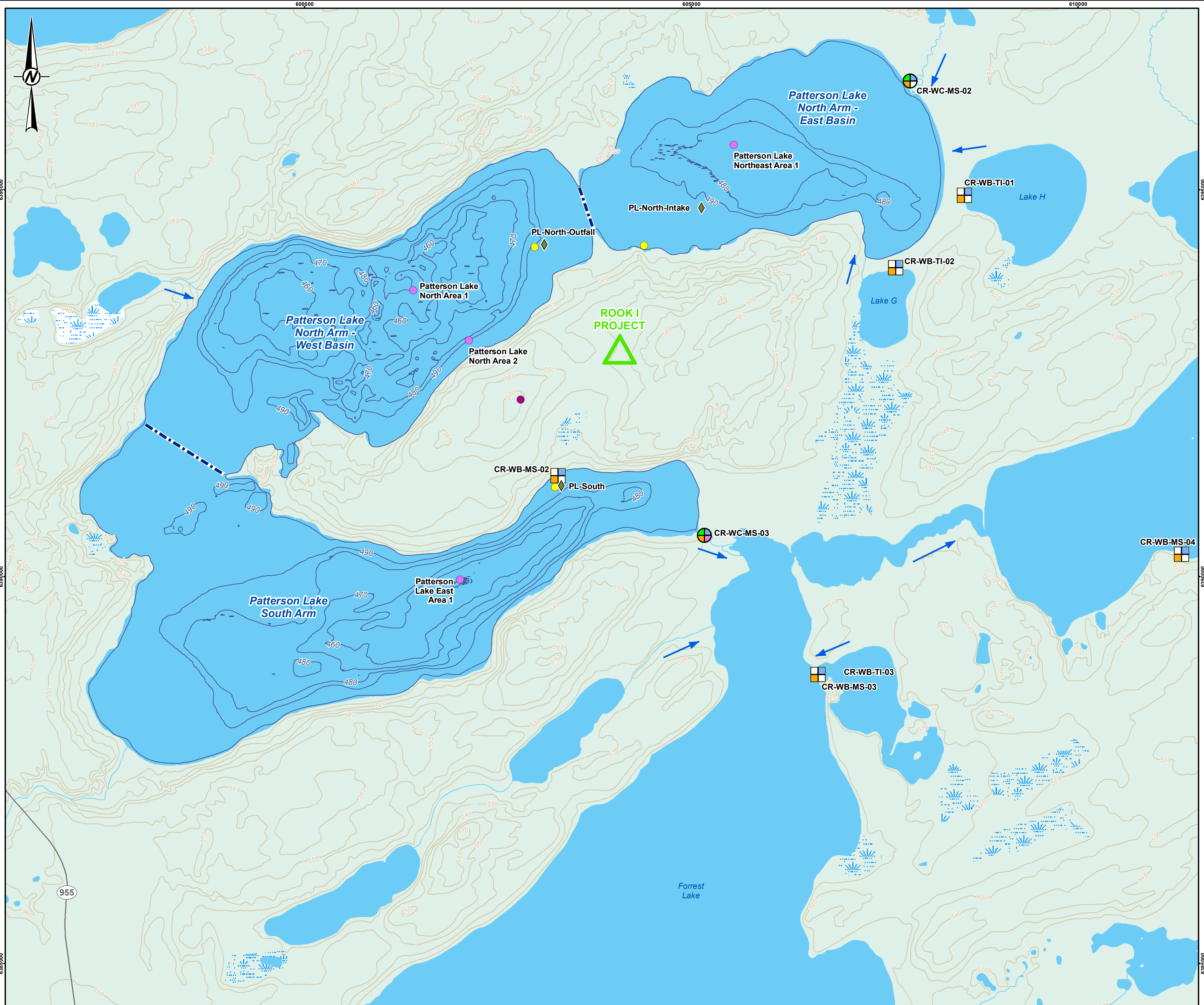
The Patterson Lake currents assessment was completed to supplement the hydrology baseline study and provide supporting information for both the conceptual design of a treated effluent diffuser and the modelling completed for the surface water quality effects assessment. This study was focused on Patterson Lake due to its proximity to the Project and importance as both a potential source of fresh water and as the proposed immediate receiving environment for treated effluent discharge.

The objective of the Patterson Lake currents assessment was to improve understanding of physical conditions, particularly lake currents, in Patterson Lake. Prior to this study, lake currents were estimated from wind speeds. This study was designed using different instruments to collect complementary measurements of lake currents in 2020. Stationary acoustic Doppler current profilers (ADCPs) are electronic instruments that were used in Patterson Lake to regularly measure lake currents at different depths over a long period of time (i.e., July 2020 to September 2020). Underwater sails called drogues were used to measure lake currents at the surface over a shorter period (i.e., days), starting at a specific location and travelling in different directions depending on lake circulation currents. The combination of the measured lake current data from the different instruments provided detailed information on site-specific lake circulation patterns at the proposed locations of the north fresh water intake and treated effluent diffuser (using stationary ADCPs) and beyond the mixing zone (using drogues). The use of different instruments was intended to provide independent measurements to build confidence in the observations.

3.0 STUDY AREAS

The Patterson Lake currents assessment targeted Patterson Lake, which is located within the local study area defined for the hydrology program, and is the waterbody expected to be most influenced by proposed Project activities. Patterson Lake is divided into a North Arm and South Arm and is oriented approximately southwest to northeast (Figure 3). The North Arm is further separated into the West Basin and East Basin by a narrow and shallow sand bar. The Patterson Lake inflow is at the east end of the North Arm – East Basin and the outflow is at the east end of the South Arm.

The anticipated locations of proposed intakes and outfalls for the proposed Project in Patterson Lake at the time the study was designed and executed are shown in Figure 3. Since the collection of this data, the location of the proposed treated sewage outfall has moved to Patterson Lake North Arm – West Basin and the proposed domestic fresh water intake has been combined with the north fresh water intake (i.e., Patterson Lake North Arm – East Basin).



LEGEND

- PROJECT LOCATION
- BATHYMETRY CONTOUR ELEVATION (METRES)
- ELEVATION CONTOUR (10m INTERVAL)
- FLOW DIRECTION
- LAKE BASIN DIVISION
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- AQUATIC BASELINE MONITORING POINT (CANNORTH 2019)
- ROOK I METEOROLOGICAL STATION
- PROPOSED OUTFALL AND INTAKE LOCATIONS
- CURRENT ADCP LOCATIONS

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

0 1,000 2,000

1:50,000 METRES

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. BATHYMETRY CONTOURS DERIVED FROM DATA COLLECTED BY NEXGEN, 2016.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

PATTERSON LAKE CURRENT MEASUREMENT LOCATIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2022-02-11
DESIGNED	JH
PREPARED	NO
REVIEWED	RP
APPROVED	GVA

PROJECT NO.	PHASE	REV.	FIGURE
20138965	1000	0	3

4.0 METHODS

This section outlines existing information, approach, equipment, and methods used to conduct the Patterson Lake currents assessment.

4.1 Review of Existing Information

No previous lake currents studies have been conducted for Patterson Lake. Existing information used in this report includes the following data and reports:

- baseline Patterson Lake basin temperature profiles measured by CanNorth (2020);
- meteorological data from the Rook I Meteorological Station (Golder 2018);
- predicted lake current speeds and directions for Patterson Lake – North Arm contained within the conceptual diffuser design report (Golder 2019);
- predicted lake current speeds and directions included in the downstream user impact study for the treated sewage outfall for the Project (Golder 2020); and
- bathymetric mapping of Patterson Lake collected by NexGen using a Real-Time Kinematic (RTK) GPS and depth sounder.

4.2 Approach

Characterization of Patterson Lake currents was based on field data collected during the summer and fall open-water period between July 2020 and October 2020, with supplementary data from other baseline studies.

The following tasks were undertaken to meet the study objectives, and detailed methods are provided in Sections 4.2.1 to 4.2.3.2:

- Existing information as described in Section 4.1 was reviewed. Relevant supplementary data for this study that have been collected as part of other baseline monitoring activities include:
  - meteorological data, including wind speed and wind direction at the Rook I Meteorological Station for the open-water period in 2020, was reviewed and compared with lake current patterns (see Section 4.2.1); and
  - Patterson Lake water temperature data were reviewed as these data provide information characterizing lake limnology and temperature is one of the main factors determining the density of either fresh water or treated effluent discharge and the mixing characteristics of treated effluent discharge into a lake (Section 4.2.2).
- Lake current profiles were monitored during the summer and fall of 2020 using ADCPs at the following three monitoring locations (near the anticipated locations of the submerged infrastructure) (Section 4.2.3 and Figure 3):
  - proposed north fresh water intake in Patterson Lake North Arm – East Basin (PL-North-Intake);
  - proposed treated effluent diffuser in Patterson Lake North Arm – West Basin (PL-North-Outfall); and

- proposed south fresh water intake and treated sewage outfall location in Patterson Lake South Arm (PL-South). It is noted that a fresh water intake and treated sewage outfall are no longer proposed for the South Arm of Patterson Lake.

- Drogues were released for periods of four to eight hours at the ADCP deployment locations to monitor near-surface lake circulation patterns near these locations. Drogues are floating “sails” or similar designs that are designed to drift below the water surface and are fitted with GPS devices to record their movements in detail (Section 4.2.4).

4.2.1 Meteorological Observations

The Rook I Meteorological Station was originally installed in 2015 and was moved to its current location in fall 2018 (Golder 2018). The station is currently located on a hill in a relatively open area near the exploration camp (Figure 3; UTM NAD83 Zone 12602795 E, 6392291 N). The meteorological parameters used in this study were wind speed and wind direction, which were measured with an RM Young anemometer installed at a height of 10 m above ground, with a 5 second sampling frequency and hourly averaging interval. Meteorological data were quality checked following the data collection period. Wind speed and direction patterns and statistics from the open water observation period are provided in Section 5.1.

4.2.2 Patterson Lake Water Temperature

Lake water temperature was measured by the ADCPs representing conditions near the lake bed, as well as at two hydrometric stations representing near-surface water temperatures, respectively. Water temperatures were recorded by level loggers from the two hydrometric stations: The Clearwater River below Patterson Lake CR-WC-MS-03 located near the lake outlet; and Patterson Lake CR-WB-MS-02 located near the camp in the Patterson Lake South Arm (Figure 3).

Water temperature profiles were recorded in Patterson Lake’s North Arm (i.e., West and East basins) and South Arm as part of aquatic and surface water quality baseline studies completed for the Project (CanNorth 2020).

Lake water temperature profiles and near-surface temperature data provide context for the lake thermal stratification at the time of the lake currents measurements. Water temperature profile data indicate the depth of the thermocline and the strength of the stratification that can affect lake circulation, as well as the mixing characteristics of the treated effluent discharge in the lake.

4.2.3 Patterson Lake Currents Observations

The configuration of the ADCPs, along with deployment details for each of the three Patterson Lake monitoring locations, is described in the following subsections. The ADCPs were deployed over a period of months from July to September 2020 to collect data that represented open water conditions.

4.2.3.1 *Acoustic Doppler Current Profiler Deployment Details*

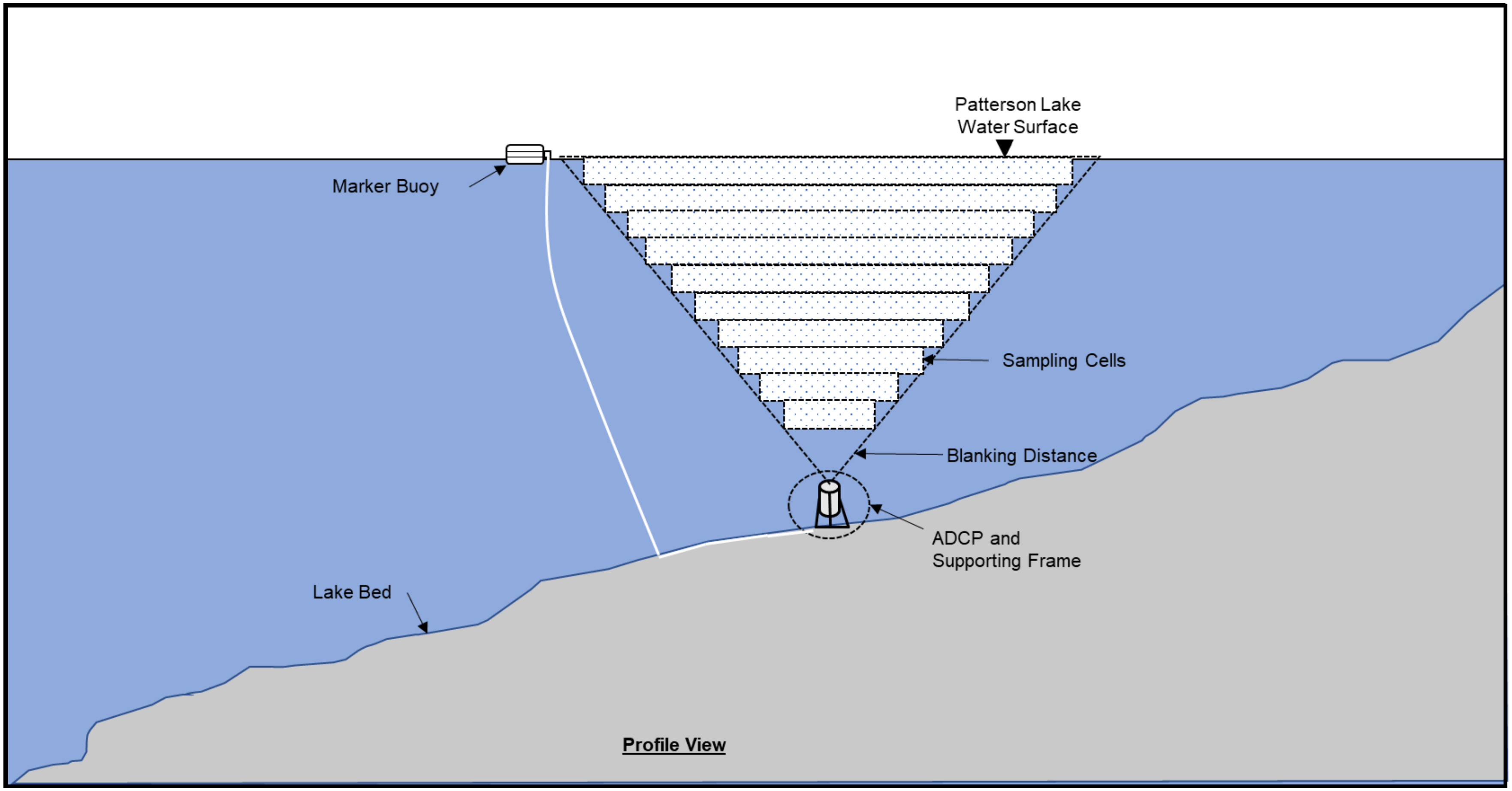
The ADCPs were mounted on the lake bed using purpose-built frames. The ADCPs measure current speed and direction in multiple layers throughout the water column; the layers are referred to as cells, with the lowest cell numbers being closest to the lake bed. Water velocity is measured using a physical principle called the “Doppler Effect”, which measures the change in sound signal frequency reflected off particles in the water passing by the ADCP. Each of the ADCPs has three beams that transmit a short sound signal up into the water column. When the signals reflect off the particles in the water such as sediment, zooplankton, or air bubbles, the returning echo is recorded and the ADCP measures the difference in frequency between transmitted and received sound signals (Nortek 2018). When the water is not moving, there is no change in frequency between transmitted and received sound signals and the velocity calculated from each of the three beams is zero.

Each ADCP used in the study had slightly different configuration and sampling parameters designed to capture the most accurate velocity measurements for a certain range of water depths. The three beams of the ADCPs all faced upward and outward at fixed angles of about 35° to 45° from vertical. There is a fixed distance immediately above the ADCP that cannot collect data (this fixed distance is called a blanking distance). Details of the ADCP instrumentation and deployment parameters are provided in Table 1.

The ADCPs were installed on 9 July 2020 and removed from 23 August 2020 to 24 August 2020. Data were downloaded, batteries were replaced, and the ADCPs were redeployed at the same locations. All ADCPs were removed on 23 September 2020. No ADCP data were collected after 23 August 2020 for PL-South due to battery issues; however, the dataset collected prior to 23 August 2020 is considered adequate to represent open-water conditions at this location.

The typical deployment configuration is depicted on the sketch provided in Figure 4. Photos are included in each of the following subsections.

Figure 4: Typical Acoustic Doppler Current Profiler Deployment Sketch



ADCP = acoustic Doppler current profiler.

Table 1: Acoustic Doppler Current Profiler Instrumentation and Deployment Details

Proposed Location	Station ID	Easting[a] (m)	Northing[a] (m)	Water Depth at the ADCP (m)	ADCP Type	Cell Size (m)	Number of Cells Recording Data	Sampling Interval	Blanking Distance[b] (m)	Standard deviation (m/s) [d,e]	Dates Installed
North Arm – East Basin[c]	PL-North-Intake	605053	6394821	3.0	Nortek Aquadopp 1,000 MHz	0.25	7	10 minutes sampling every 30 minutes	0.4	0.023	9 July 2020 to 23 September 2020
North Arm-West Basin	PL-North-Outfall	603024	6394347	11.0	Nortek Aquadopp 600 MHz	1.0	10	10 minutes sampling every 20 minutes	0.5	0.020	9 July 2020 to 23 September 2020
South Arm [c]	PL-South	603245	6391230	3.5	Sontek Argonaut XR 3,000 MHz	0.4	9	10 minutes sampling every 30 minutes	0.2	0.013	8 July 2020 to 23 August 2020

a) All coordinates referenced are in UTM Zone 12 and North American Datum 1983 (NAD83).
b) Blanking distance is the region closest to the transducers that minimizes interference during attenuation of the sound waves; the minimum blanking distance is the distance sound travels during attenuation (Nortek 2018).
c) The Patterson Lake South outfall was proposed to be located about 800 m east of the proposed intake location at a water depth of 3.0 m and it is 50 m from the north shoreline. This outfall is no longer part of the proposed Project.
d) The precision of horizontal measurements is set in the deployment process and it increases by using larger cell sizes and collecting a larger sample.
e)The Sontek measures accuracy directly using the standard deviation, which is based on a formula $\sigma = 20 / (\sqrt{N} * (\sqrt{CS}))$ where N = number of samples in seconds and CS = cell size in metres (Sontek 2007).
ADCP = acoustic Doppler current profiler.

4.2.3.1.1 Patterson Lake North Fresh Water Intake Location

The ADCP at PL-North-Intake was deployed to collect information on ambient lake currents near the anticipated location of the proposed north fresh water intake. The originally proposed deployment location was near shore in the Patterson Lake North Arm – East Basin (Wood 2019). However, that location was determined to be too shallow (i.e., less than 1.5 m) for reliable deployment of the ADCP. A more suitable location for the deployment was identified approximately 800 m northeast of the originally proposed location as shown in the Figure 3 which includes bathymetry data.

A Nortek Aquadopp 1,000 MHz ADCP was deployed on 9 July 2020 at PL-North-Intake (Figure 5, Table 1). The ADCP was deployed approximately 600 m from shore at a water depth of 3.0 m, with the top of the ADCP at approximately 1.0 m from the lake bed. At the deployment location, the lake bed is flat. To the west and south, the lake bed slope is gradual with depth decreasing towards shore. To the east and north, the lake bed slope increases where there is a drop-off.

Figure 5: Nortek Aquadopp Acoustic Doppler Current Profiler and Mounting Frame Deployed at Patterson Lake North Intake

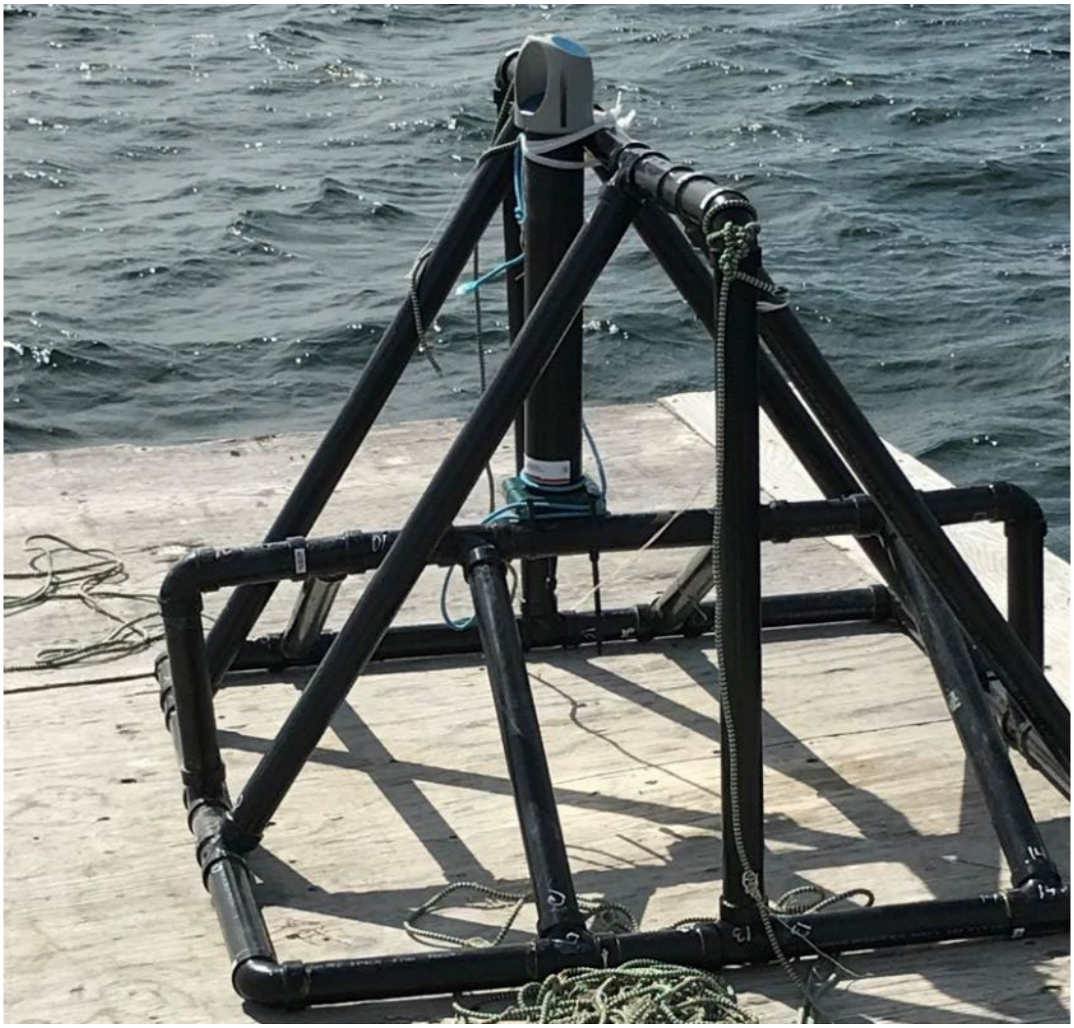
4.2.3.1.2 Patterson Lake Treated Effluent Diffuser Location

Lake currents monitoring at station PL-North-Outfall was initiated on 8 July 2020. PL-North-Outfall provided information on ambient lake currents near the anticipated location of the treated effluent diffuser. The proposed point for deployment was located offshore in the Patterson Lake North Arm – West Basin, based on the preferred location of the treated effluent diffuser (Golder 2019). The proposed deployment location was west of the narrows that separates the East and West basins of the North Arm and had a water depth of 10.0 m (Figure 3).

The ADCP was located approximately 50 m east of the proposed diffuser location on a small shelf that had a total water depth of 11.0 m, with the top of the ADCP at approximately 1.0 m from the lake bed. To the west, the depth decreases rapidly, and to the east and south, the depth rapidly decreases by several metres then gradually decreases thereafter.

The ADCP at station PL-North-Outfall was deployed on 8 July 2020, checked, and redeployed at the same location on 9 July 2020. Figure 6 shows the ADCP mounted on the frame; deployment details are provided in Table 1.

Figure 6: Nortek Aquadopp Acoustic Doppler Current Profiler and Mounting Frame Deployed at Patterson Lake North Outfall



4.2.3.1.3 Patterson Lake South Location

Lake currents monitoring at station PL-South was initiated on 8 July 2020 to provide information on ambient lake currents near the anticipated locations of the south fresh water intake and the treated sewage outfall. The proposed point for deployment was located near shore in the Patterson Lake South Arm based on the downstream use and impact study for the sewage discharge (Golder 2020).

The proposed location was confirmed in the field to be suitable based on water depth similar to the proposed outfall location and low gradient slope of the lake bed. The ADCP was deployed on 8 July 2020 as shown in Figure 3. The ADCP was installed on the lake bed at a depth of 3.5 m, with the top of the ADCP at approximately 0.5 m from the lake bed. The ADCP prepared for deployment is shown in Figure 7.

Figure 7: Sontek Argonaut-XR Acoustic Doppler Current Profiler and Mounting Frame Deployed at Patterson Lake South

4.2.3.2 *Acoustic Doppler Current Profiler Data Analysis*

ADCP data were reviewed for quality, representative cells were chosen for each location, and current speeds were classified into current speed and direction categories to show the current patterns in a visible way.

- Data were reviewed for completeness and quality according to standard methods as outlined by the manufacturers and industry (NOAA 2000; QARTOD 2019). ADCP data showed all ADCPs had sufficiently low tilt and roll values when installed (i.e., they were nearly level), stable water depth, small shifts in compass direction between two short deployments, the signal-to-noise ratios were sufficiently high to provide strong acoustic signal for the required signal range, and that the transducers were clear of obstructions. Data that was negatively affected by interference from the water surface and waves was removed by using data from a lower cell.
- Specific cells were chosen to represent the near-lake-bed, mid-profile and near-surface depths as follows:
  - PL-North-Intake (cell 1 for near-lake-bed, cell 3 for mid-profile, and cell 5 for near-surface).
  - PL-North-Diffuser (cell 2 for near-lake-bed, cell 4 for mid-profile, and cell 7 for near-surface).
  - PL-South (cell 2 for near-lake-bed, cell 4 for mid-profile, and cell 6 for near-surface).
- Current data were classified according to speed categories and direction as follows:
  - Magnitude of current speeds for each ADCP dataset were ranked and plotted against percent frequency of exceedance calculated as the rank (with the highest current speed having the highest rank) divided by sample size plus 1.
  - In general, current speed that exceeds 0.1 m/s is considered high speed for a lake environment while speed < 0.005 m/s is classified as near-zero or calm.

4.2.4 Drogue Releases

Drogues are passive devices designed to float below the water surface and move with the ambient lake currents. Drogues provide a method of tracking near-surface lake circulation patterns over a short period of time. GPS devices were attached to each drogue to track their movement over a period of one to six hours. A photo showing how the drogues moved at Patterson Lake South Location is provided in Figure 8.

Figure 8: View Facing North of Acoustic Doppler Current Profiler Location at Patterson Lake South Arm

Photo taken facing north. Note the arrow is pointing to retrieval buoy. The three flags mark the positions of the drogues that were deployed at the same location, which are discussed in Section 4.2.4.

For this study, a set of drogues were released at each ADCP location during the field visits in July 2020, August 2020, and September 2020, and one set was released on 29 October 2020 to provide additional results using the sail drogue type at PL-South. Details of the drogue releases are provided in Table 2.

Two types of drogues were used in the study: polyvinyl chloride (PVC) and sail. The PVC-type drogues are designed for shallow water and extend to a depth of about 0.3 m. These drogues are made of PVC pipe connected in a cross-configuration that floats on the water surface, with a larger diameter central pipe with a screw-in cap that holds the GPS (Figure 9). The “sail-type” drogues are a longer design of about 2 m in length with nylon “sails” attached in a cross-configuration with aluminum cross-bars about 1 m in length at the top and bottom, with a float at the surface, and a weight attached at the base (Figure 10). The sail drogues are better designed for deeper water deployment as they will run aground sooner than the PVC type. Three drogues of each type were released during all field visits except the August field visit, where one PVC drogue was damaged and, consequently, only two PVC drogues were released at PL-North-Intake and PL-South.

Table 2: Drogue Release Details

Station ID	Date	Time Released	Time Picked up	Number of Drogues	Type of Drogue	Notes
PL-North-Intake	9 July 2020	12:15	17:54	3	PVC type	Light winds. All three GPS lost reception at times
	19 August 2020	12:30	16:42	2	PVC type	High westerly winds
	24 August 2020	09:04 and 10:23	14:56	2	PVC type	Moderate wind. One drogue deployed later after a lost one was found
	23 September 2020	11:00	16:05	3	PVC type	Moderate southeast winds shifting to southwest and wind speeds increasing
PL-North-Outfall	9 July 2020	09:30	18:09	3 (2 complete)[(a)]	Sail type	Light winds. One GPS lost reception
	19 August 2020	11:48	18:35	3 (2 complete)[(a)]	Sail type	High westerly winds. One drogue GPS lost signal. Drogues ran ashore at about 17:00 [(b).]
	24 August 2020	08:35	14:40	3	Sail type	Moderate wind
	23 September 2020	10:05	16:40	3 (2 complete)[(a)]	Sail type	Moderate southeast winds shifting to southwest and wind speeds increasing. One GPS lost reception
PL-South	8 July 2020	11:30	17:53	3 (2 complete)[(a)]	Sail type	Light northerly winds. One GPS lost reception at times
	23 August 2020	10:11	16:52	2	PVC type	Light southerly winds
	26 September 2020	08:03	13:35	3	PVC type	Light west or southwest wind increasing to moderate in the afternoon
	29 October 2020	10:45	15:12	3	Sail type	Moderate northwest wind

a) Although three drogues were released, there were issues with one of the drogues tipping over or being submerged such that the drogue’s GPS track did not provide useful data.

b) Drogues were often retrieved after they had drifted ashore; data that showed the drogues slowing down near shore were removed from the analysis.

PVC = polyvinyl chloride.

Figure 9: View of a Polyvinyl Chloride Drogue Retrieved after Deployment

Figure 10: View of a Sail Drogue after Release

The GPS tracks, travel time, distance, and speeds were calculated for each drogue deployment. Dispersion coefficient(s) for the model were estimated from the movements of the individual drogues by determining the variance of the drogues about their centroid path (List et al. 1990). The method outlined below was used to estimate dispersion rates near the ADCP locations in the 2020 field program. Dispersion rates were only estimated when there was coincident data for three drogues.

The variance of the drogue positions in the X and Y directions are calculated by:

$$\sigma_{xi}^2 = \frac{\sum_j \left(X_{ij} - \bar{X}_i\right)^2}{N-1} \qquad \text{Equation 1}$$

$$\sigma_{yi}^2 = \frac{\sum_j \left(Y_{ij} - \bar{Y}_i\right)^2}{N-1} \qquad \text{Equation 2}$$

Where: X_{ij} X position of Drogue j at time i (m),
Y_{ij} Y position of Drogue j at time i (m),
σ_{xi} variance in X direction at time i (m²),
σ_{yi} variance in Y direction at time i (m²),
$\bar{X}_i$ mean X position of drogues at time i (m),
$\bar{Y}_i$ mean Y position of drogues at time i (m), and
N number of drogues.

The direction independent variation in location can be estimated as:

$$\sigma_i^2 = \frac{\sigma_{xi}^2 + \sigma_{yi}^2}{2} \qquad \text{Equation 3}$$

The dispersion coefficient (K) can then be estimated by:

$$K_i = \frac{1}{2}\frac{\partial \sigma_i^2}{\partial t} \cong \frac{1}{2}\frac{\Delta \sigma_i^2}{\Delta t} \qquad \text{Equation 4}$$

5.0 RESULTS

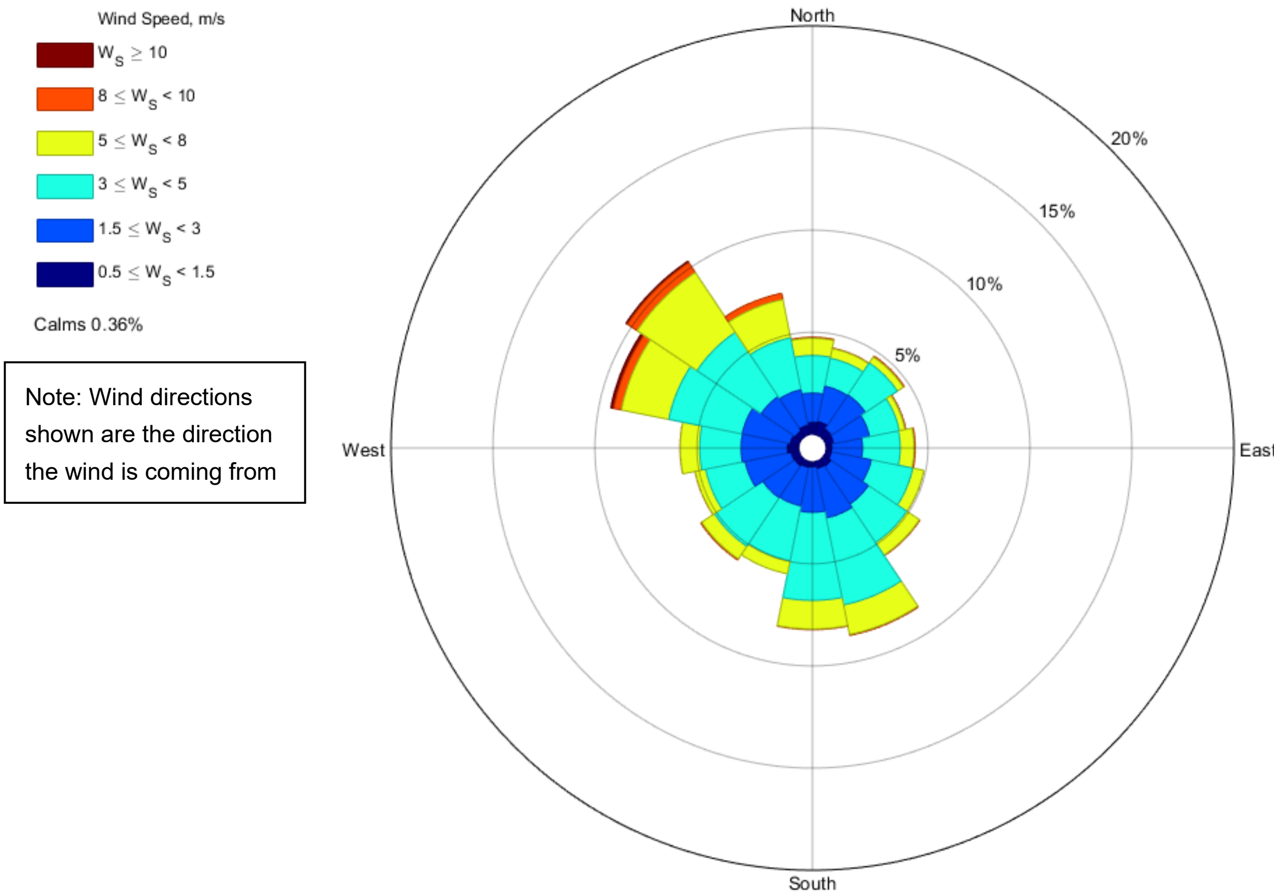
The results of the 2020 Patterson Lake currents assessment for wind speed and direction, water temperature, and currents are presented in Sections 5.1 to 5.3.

5.1 Meteorological Observations

Local weather conditions between July and September 2020 were windier, wetter, and slightly cooler than long-term regional averages for the months of July to September; there was cumulatively 297 mm of rainfall during the study months which is much higher than the long-term average of 223 mm for July to September based on European Re-Analysis Interim (ERAI) model data to 2019 (Annex IV.2). Cooler air temperatures influence water temperature (Section 5.2) and higher precipitation increases surface water inflows and outflows at Patterson Lake. Wind conditions have the most direct influence on lake currents and details are provided in this section.

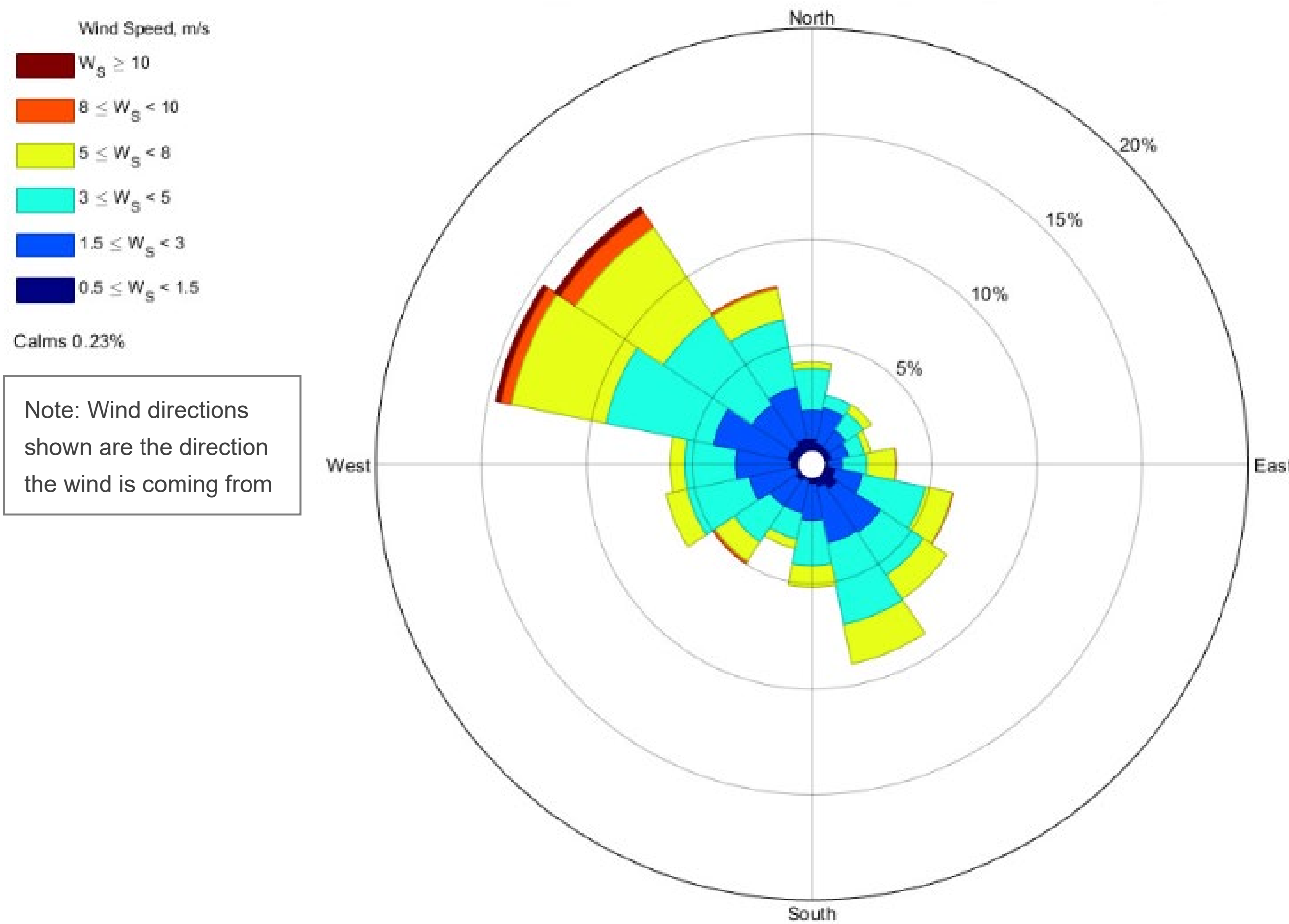
Wind speed and direction data were analyzed for the open-water period from May to October for a five-year period from 2016 to 2020. Prevailing winds were from the northwest and west-northwest, followed by south-southeast and south directions (Figure 11). Higher winds exceeding 5 m/s occurred 25% of the time and were most frequently from the west-northwest to north-northwest (Golder 2019).

Figure 11: Rook I Meteorological Station Wind Rose for the Open-Water Period, May 2016 to October 2020



The wind conditions during the Patterson Lake currents monitoring studies completed between July 2020 and September 2020 were compared with the five-year open-water period wind record, collected between May 2016 and October 2020, to verify if the measured field values were representative. The prevailing wind directions were similar to the five-year open-water period dataset, with west-northwest and northwest being the most frequent, followed by south-southeast, though south winds were relatively infrequent in summer and fall 2020 (Figure 12). The average hourly wind speed of 3.9 m/s in the 2020 observation period was slightly higher than the 3.7 m/s wind speed over the five-year period. Moderately high wind speeds between 5 m/s and 8 m/s (18 km/h and 29 km/h) were 5% more frequent than usual during the monitoring period (i.e., 22.5% compared to 17.5%). Lower wind speeds below 3.0 m/s were 1.8% less frequent in 2020 compared to the five-year average. High wind speeds (i.e., exceeding 10 m/s) in the observation period were three times more frequent than the five-year period; however, these high wind speeds made up only 0.6% of the record.

Figure 12: Frequency of Wind Direction and Speed, 1 July 2020 to 30 September 2020

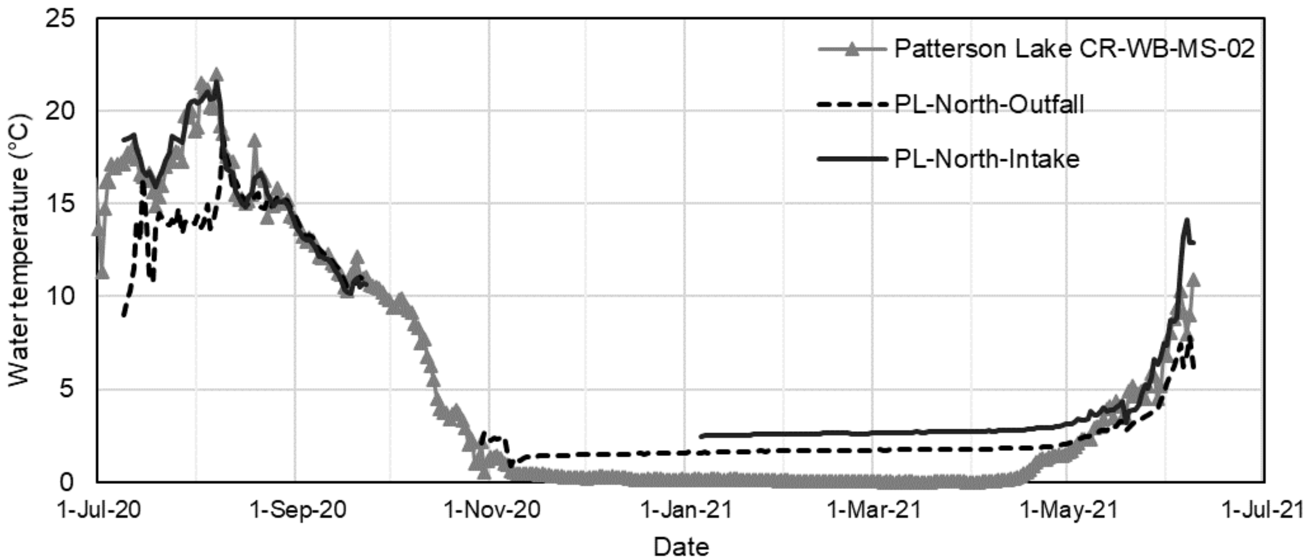


5.2 Patterson Lake Water Temperatures

Water temperature is one of the main factors determining water density, and results from water temperatures measured at the ADCP locations as well as at profiles in the water column during different seasons are provided in this section. Nearly a full year of ambient Patterson Lake water temperatures monitored during this study are provided in Figure 13. Data at PL-North-Outfall and PL-North-Intake were measured at the ADCPs which were mounted about 1 m above the lake bed in these locations. Data at CR-WB-MS-02 was measured in PL-South at the hydrometric station in shallow water near shore.

The ADCP installed at PL-North-Outfall had lower temperatures than the other locations until early August 2020 and had similar temperatures thereafter. PL-North-Outfall ADCP was below or within the thermocline in the North Arm – West Basin until 9 August 2020.

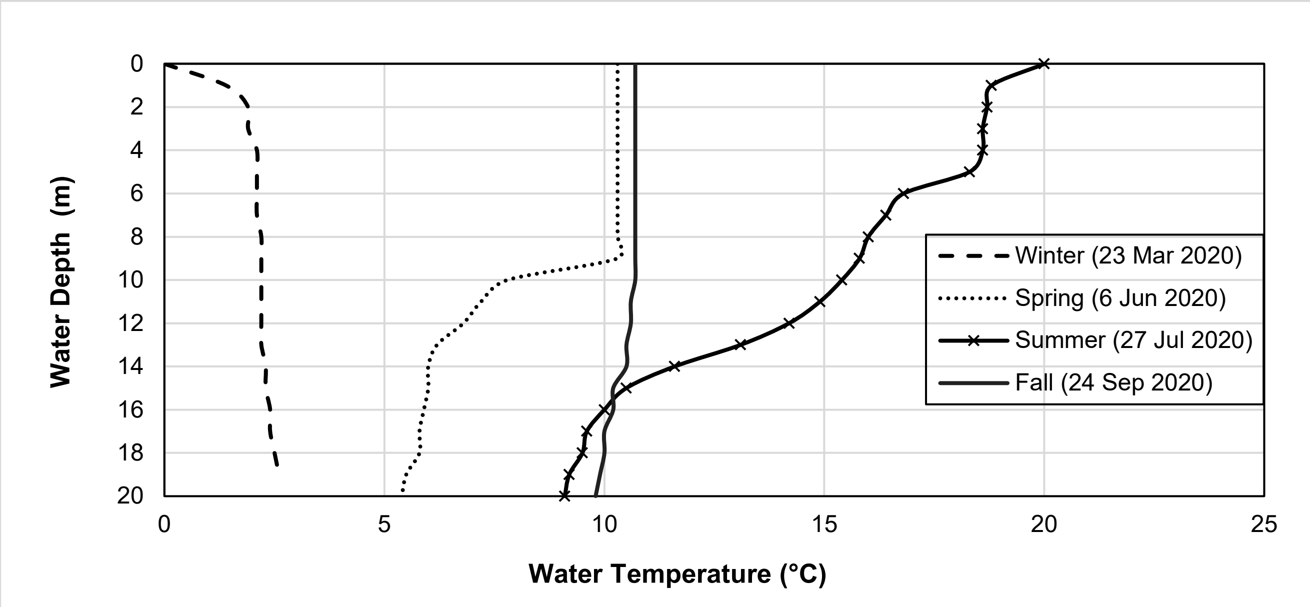
Figure 13: Patterson Lake Water Temperatures during Lake Currents Measurement Period



In the baseline dataset, water temperature profiles ranged from near 0°C in winter to above 20°C in mid-summer. Results of the baseline surveys for 2020 are shown in Figure 14, Figure 15, and Figure 16. Thermal lake stratification, indicated by decreases in water temperature with depth, was evident during the spring, summer, and fall field visits. During the spring 2020 field visit, the thermocline started at a water depth of about 9 m to 10 m in the North Arm in both East and West basins, and was at a depth of about 5 m in the South Arm. During the summer 2020 field visit, the top of the thermocline was at an approximate depth of between 5 m and 7 m for all three locations. During the fall 2020 field visit, the top of the thermocline was at depths of about 15 m and 17 m in the North Arm – West Basin and South Arm, respectively. However, the North Arm – East Basin was nearly isothermal (i.e., not clearly stratified).

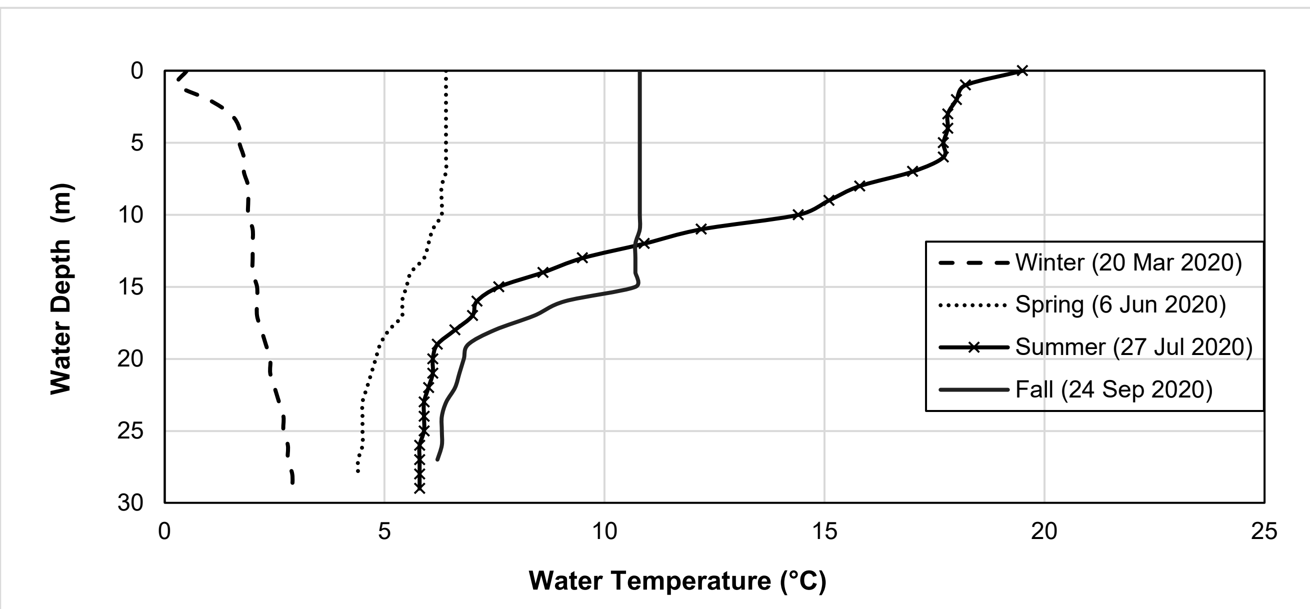
Winter water temperatures were all close to 0°C near the ice-covered surface, increasing to approximately 3°C at depth.

Figure 14: Patterson Lake North Arm – East Basin Water Quarterly Temperature Profiles



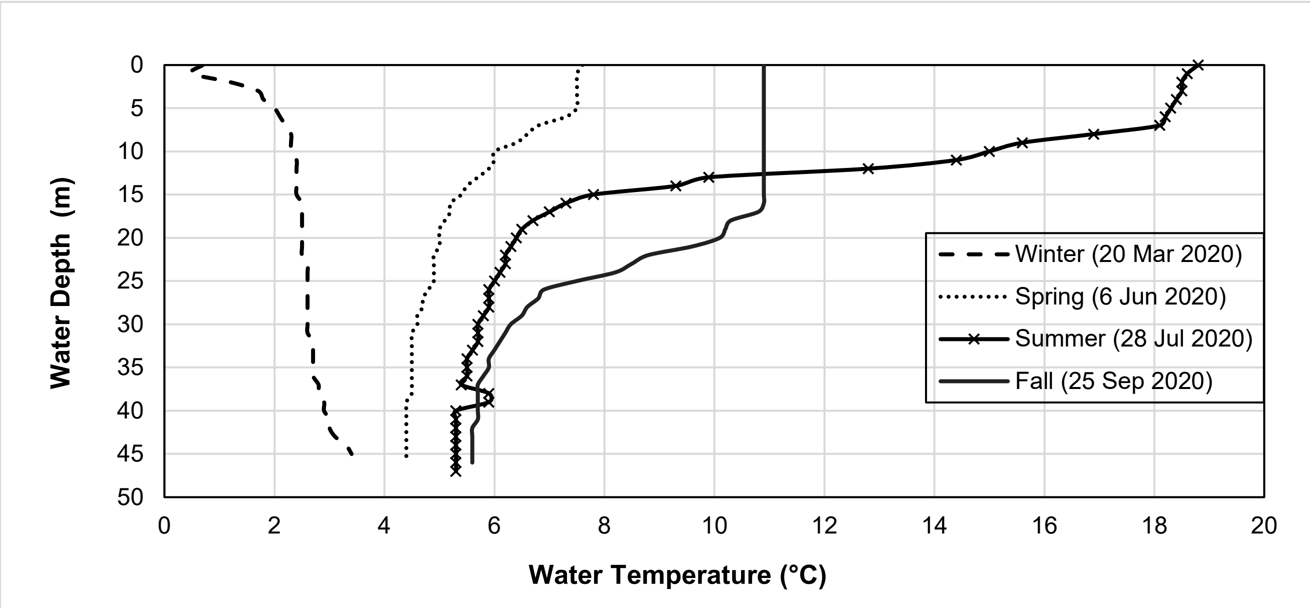
Source: CanNorth 2020.

Figure 15: Patterson Lake North Arm – West Basin Quarterly Water Temperature Profiles



Source: CanNorth 2020.

Figure 16: Patterson Lake South Arm Quarterly Water Temperature Profiles



Source: CanNorth 2020.

5.3 Patterson Lake Currents Observations

The ADCP and drogue results for the PL-North-Intake, PL-South-Outfall, and PL-South locations are presented in Sections 5.3.1 to 5.3.4.

5.3.1 Patterson Lake North Fresh Water Intake Location

The speed and direction frequencies of Patterson Lake currents at PL-North-Intake location for the period of 9 July 2020 to 23 September 2020 are shown in Figure 17. Tabular results from this analysis are provided in Appendix A (Table A-3, Table A-4 and Table A-5).

Near-surface current speeds and directions shown are from Cell 5 (Figure 4), which had an average measurement height of 2.75 m above the lake bed and approximately 0.25 m below the water surface. The mid-profile is represented by data collected from Cell 3, which had an average measurement height of 2.25 m above the lake bed and approximately 0.75 m below the water surface. The near-lake bed is represented by data collected from Cell 1, which had an average measurement height of 1.75 m above the lake bed and 1.25 m below the water surface.

Current Direction

Near-surface, mid-profile, and near-lake bed currents were all dominated by lake currents moving to the southeast and east-southeast. The next highest frequencies of current direction were west-northwest and west. In general, the dominant lake currents directions appear to be related to the dominant wind directions for the same period, which are from west-northwest and northwest. Lake currents were alongshore (i.e., flowing in a direction perpendicular to shore, in this case the Patterson Lake North Arm – East Basin is oriented in a west or west-southwest and east or east-northeast direction) between 26% to 28% of the monitoring period. The Patterson Lake North Arm – East Basin does not have steep or high topography on most sides, which may be the reason the dominant wind direction aligns with the dominant lake current direction in this basin.

Current Speed

The cumulative frequency curve for current speeds is shown in Figure 18. Results are similar throughout the profile with slightly higher current speeds occurring mid-profile. Median current speeds were 0.079 m/s near-lake bed, 0.083 m/s at mid-profile, and 0.081 m/s at the near-surface. A comparison of current speeds statistics for the three ADCP locations is provided in Table 3.

Figure 17: Frequency of Current Speed and Direction at the Patterson Lake North Fresh Water Intake Location – Open Water Conditions

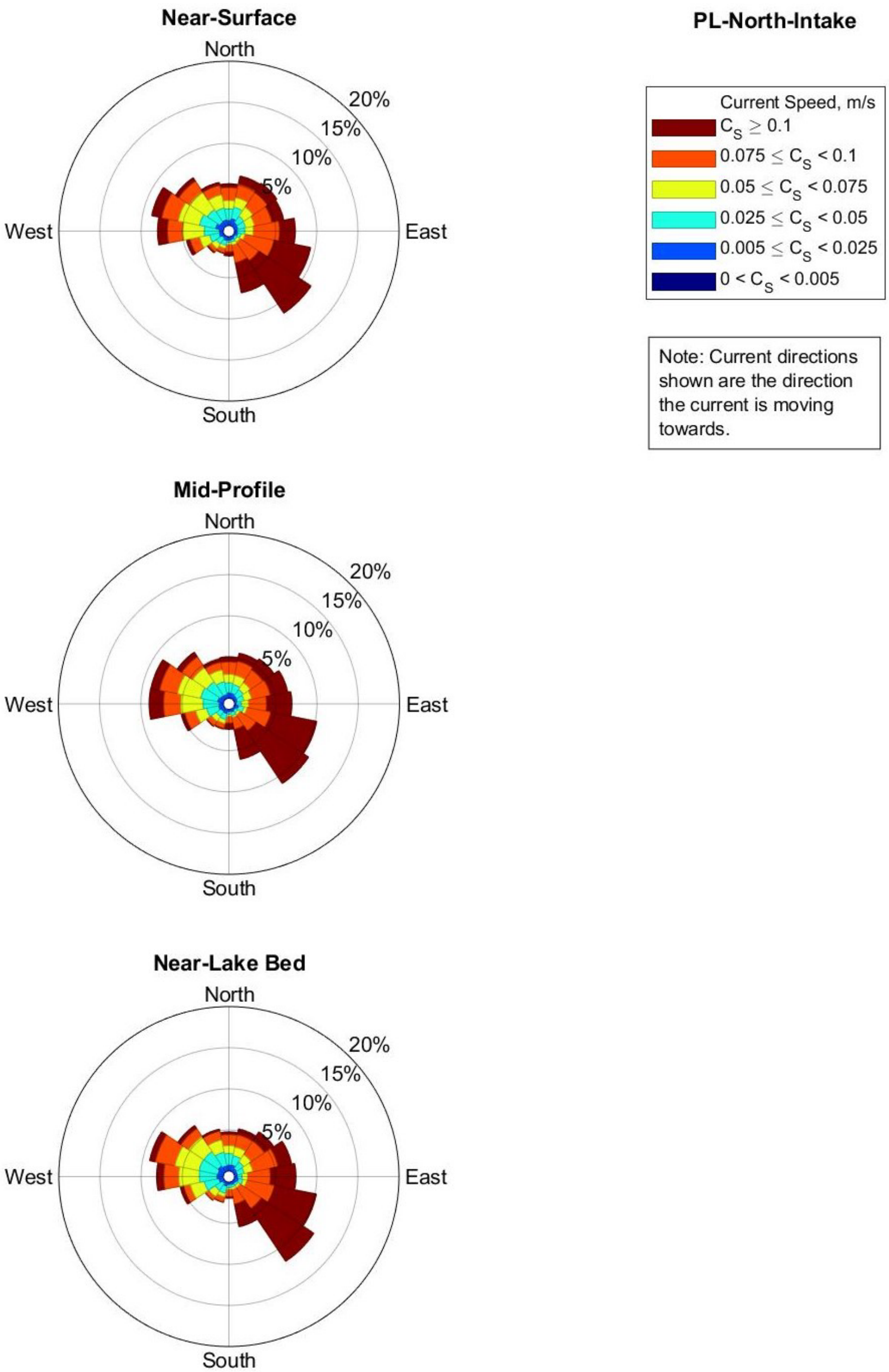


Figure 18: Cumulative Frequency Curve for Lake Current Speeds at Patterson Lake North Fresh Water Intake

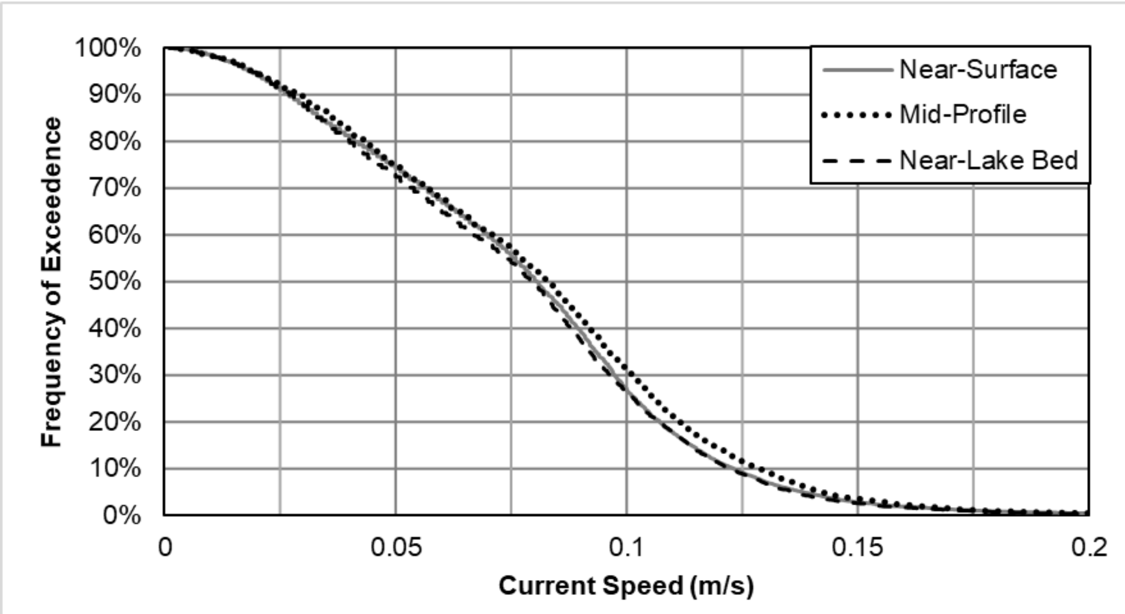


Table 3: Acoustic Doppler Current Profiler Lake Currents Speed Statistics

Statistic	Measured Lake Current Speeds (m/s)								
	PL-North-Intake			PL-North-Outfall			PL-South		
	Near-Lake Bed	Mid-Profile	Near-Surface	Near-Lake Bed	Mid-Profile	Near-Surface	Near-Lake Bed	Mid-Profile	Near-Surface
Maximum	0.250	0.302	0.252	0.186	0.192	0.208	0.164	0.168	0.183
75th Percentile	0.102	0.106	0.102	0.068	0.053	0.052	0.032	0.034	0.063
Mean	0.077	0.081	0.078	0.052	0.042	0.041	0.025	0.026	0.045
Median	0.079	0.083	0.081	0.049	0.039	0.039	0.021	0.021	0.040
25th Percentile	0.047	0.050	0.049	0.033	0.028	0.028	0.013	0.013	0.022
Minimum[(a)]	0.001	0.001	0.001	0	0.001	0	0	0	0

Note: Statistics are based on all available data at 20-minute intervals for PL-North-Intake and PL-North-Outfall, and at 30-minute intervals for PL-South.

a) The acoustic Doppler current profiler had a horizontal velocity accuracy of 0.022 m/s or less however they record data to the nearest 0.001 m/s.

5.3.2 Patterson Lake Treated Effluent Diffuser Location

Patterson Lake currents at the PL-North-Outfall ADCP location for the period from 9 July 2020 to 23 September 2020 are shown in Figure 20, for open water conditions. Tabular results from this analysis are provided in Appendix A (Table A-6, Table A-7 and Table A-8). Near-surface current speeds and directions shown are from Cell 7, which had an average measurement height of 8.6 m above the lake bed (i.e., 1.4 m below the water surface). The mid-profile is represented by data collected from Cell 4, which had an average measurement height of 5.6 m above the lake bed (i.e., 1.4 m below the water surface). The near-lake bed is represented by data collected from Cell 1, which had an average measurement height of 2.6 m above the lake bed.

Current Direction

The Patterson Lake North Arm – West Basin is oriented southwest–northeast and it has relatively steep and high topography that may influence local wind directions. The PL-North-Outfall ADCP location was exposed to a maximum wind fetch of about 5 km in the North Arm – West Basin from the southwest.

At PL-North-Outfall, lake currents throughout the profile were predominantly onshore between east-southeast and south-southwest 41% to 43% of the time, and less frequently alongshore (i.e., moving southwest through west and northeast through east) 27% to 29% of the time and offshore 28% to 30%.

The high frequency of onshore current directions may be related to the 4% to 5% more frequent west-northwest and northwest winds during the 2020 lake currents observation period compared to the five-year open-water period (Section 5.1).

Current Speed

The cumulative frequency curve for current speeds is shown in Figure 20. Results show current speeds were similar throughout the profile at this location and the higher speeds occurred more frequently in south or northeast directions. The slightly higher speeds near the lake bed may be related to the ADCP location being near the edge of a drop-off (Figure 3). Median current speeds were between 0.041 m/s at the near-surface to 0.043 m/s near the lake bed. A comparison of current speeds statistics for the three ADCP locations is provided in Table 3.

Figure 19: Frequency of Current Speed and Direction at Patterson Lake Treated Effluent Diffuser Location - Open Water Conditions

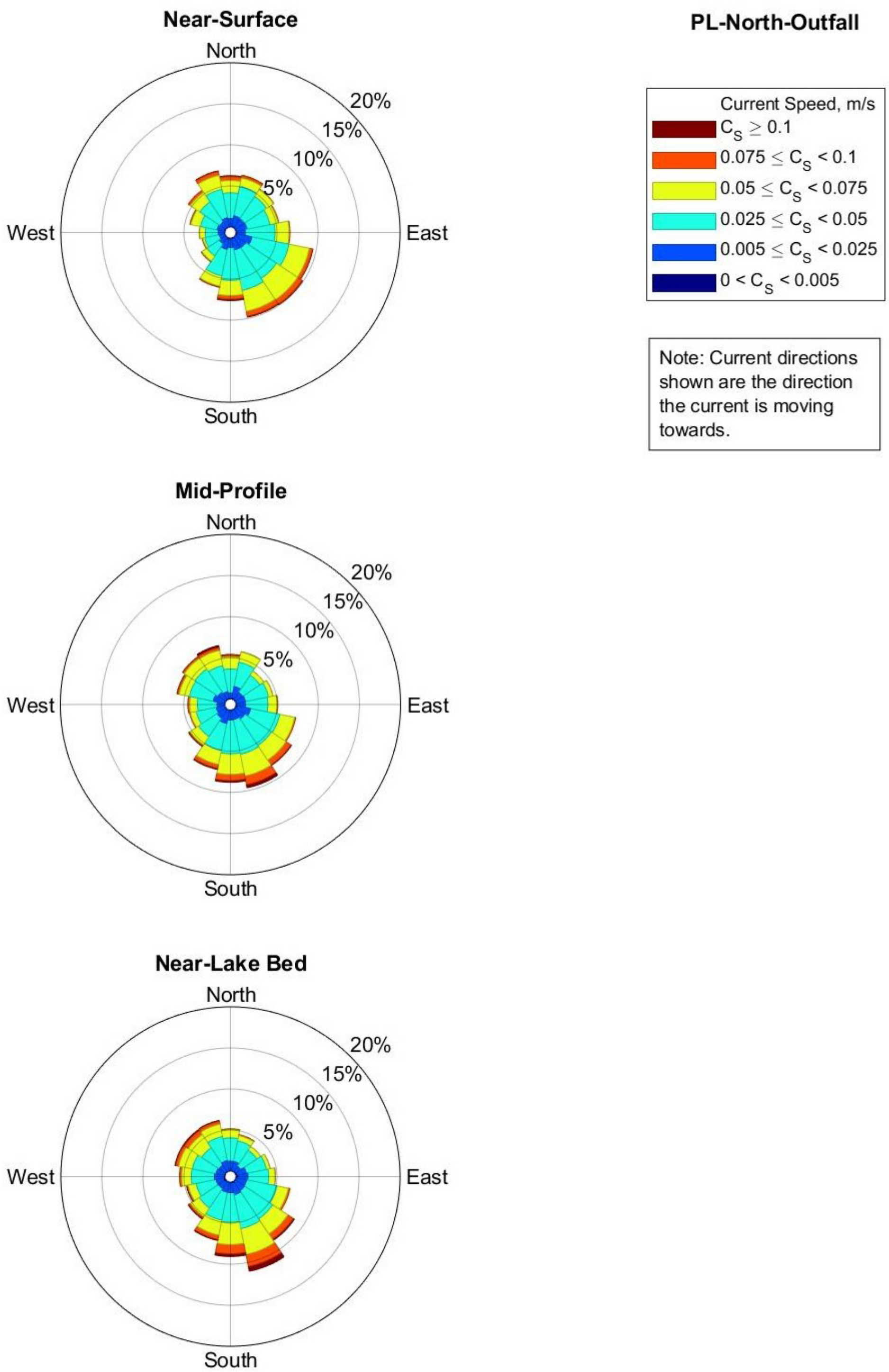
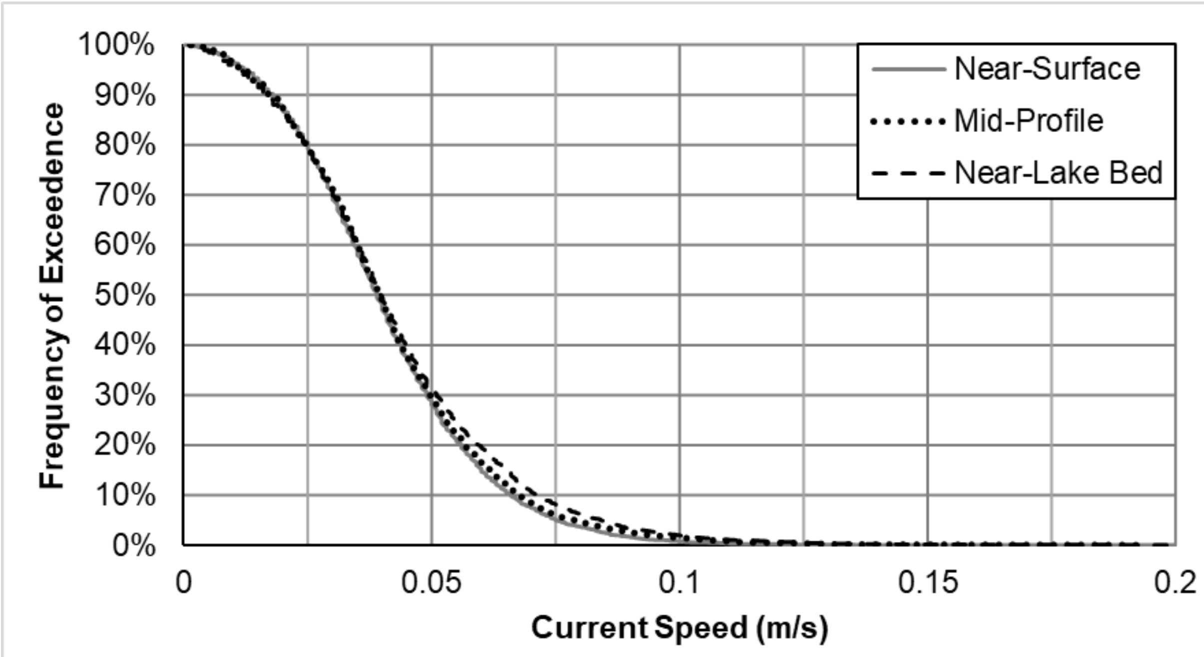


Figure 20: Cumulative Frequency Curve for Patterson Lake Treated Effluent Diffuser Current Speeds



5.3.3 Patterson Lake South Fresh Water Intake Location

Patterson Lake currents at PL-South for the period from 8 July 2020 to 23 August 2020 are shown in Figure 21 for open water conditions. Tabular results from this analysis are provided in Appendix A (Table A-9, Table A-10 and Table A-11). Current speeds and directions shown are from Cell 6, which had an average measurement height of 2.9 m above the lake bed (i.e., 0.6 m below the water surface); this cell represented the near-surface lake currents at this location. The mid-profile is represented by data collected from Cell 4, which had an average measurement height of 2.1 m above the lake bed (i.e., 1.4 m below the water surface). The near-lake bed currents are represented by data collected from Cell 2, which had an average measurement height of 1.3 m above the lake bed (i.e., 2.2 m below the water surface).

Current Direction

Patterson Lake South Arm is oriented in a southwest to west-southwest and east-northeast to east direction. The PL-South ADCP location is about 100 m from the north shore and is exposed to a maximum wind fetch of about 5 km from the west-southwest, which corresponds with the dominant current directions. At PL-South, the near-surface, mid-profile and near-lake bed current directions were bimodal, predominantly alongshore in the same orientation as the waterbody occurring 40% to 41% of the monitoring period. Currents were onshore between 31% and 36% of the time and offshore the remaining time.

Current Speed

The cumulative frequency curve for current speeds is shown in Figure 22. Results show current speeds were relatively homogeneous throughout the water profile. Median current speeds were 0.024 m/s at the near-surface, 0.021 m/s in mid-profile and near-lake bed. Current speeds at this location (Figure 22) were much lower than at the shallower PL-North Intake location (Figure 17), and somewhat lower at PL-North Outfall (Figure 20). A comparison of current speed statistics for the three ADCP locations is provided in Table 3.

Figure 21: Frequency of Current Speeds and Directions at the Patterson Lake South Fresh Water Intake Acoustic Doppler Current Profiler – Open Water Conditions

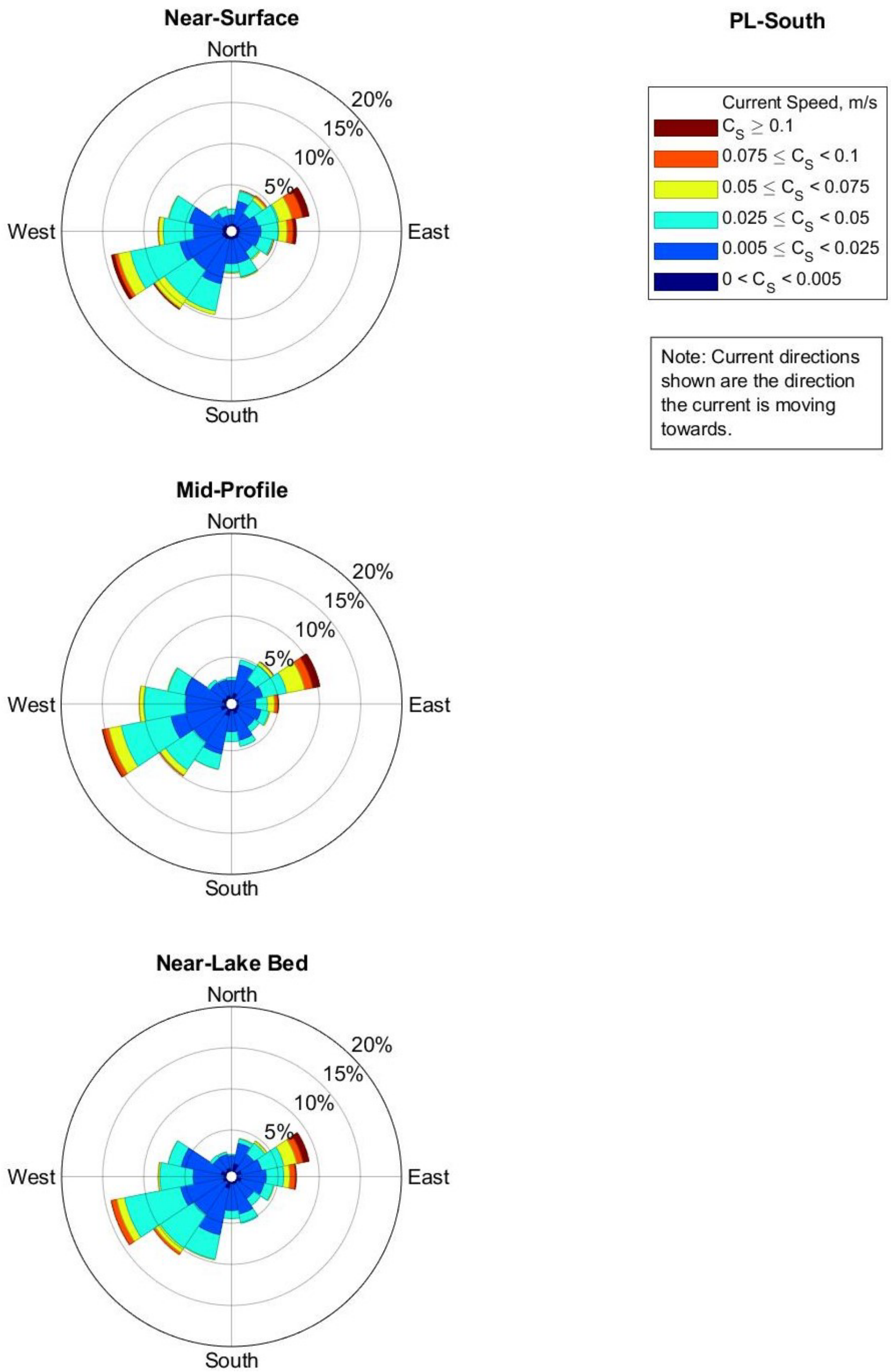
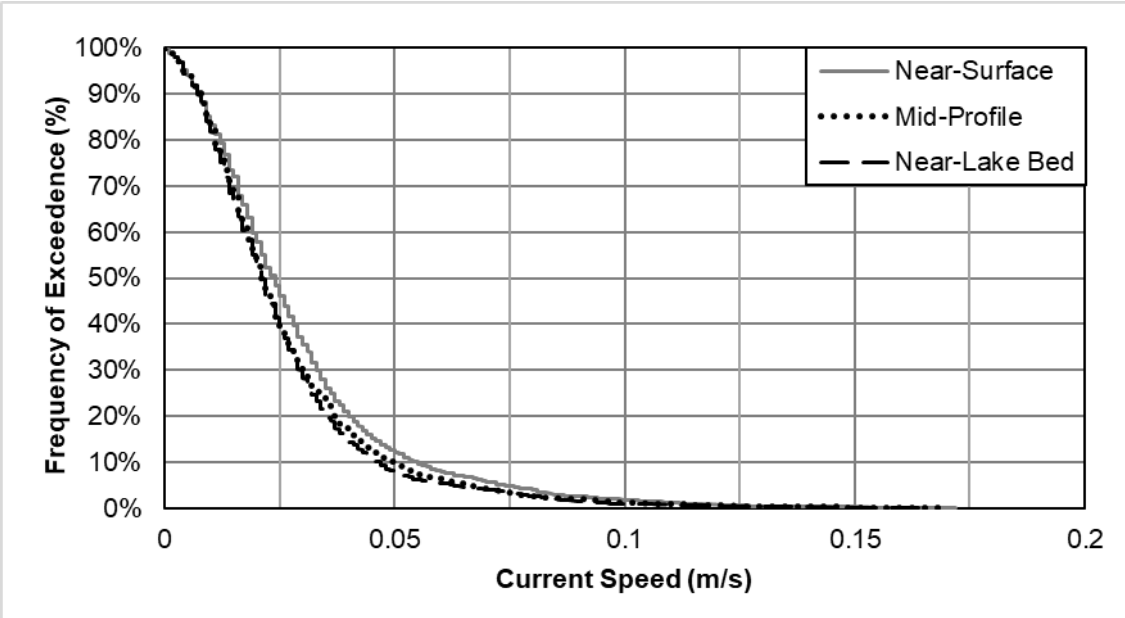
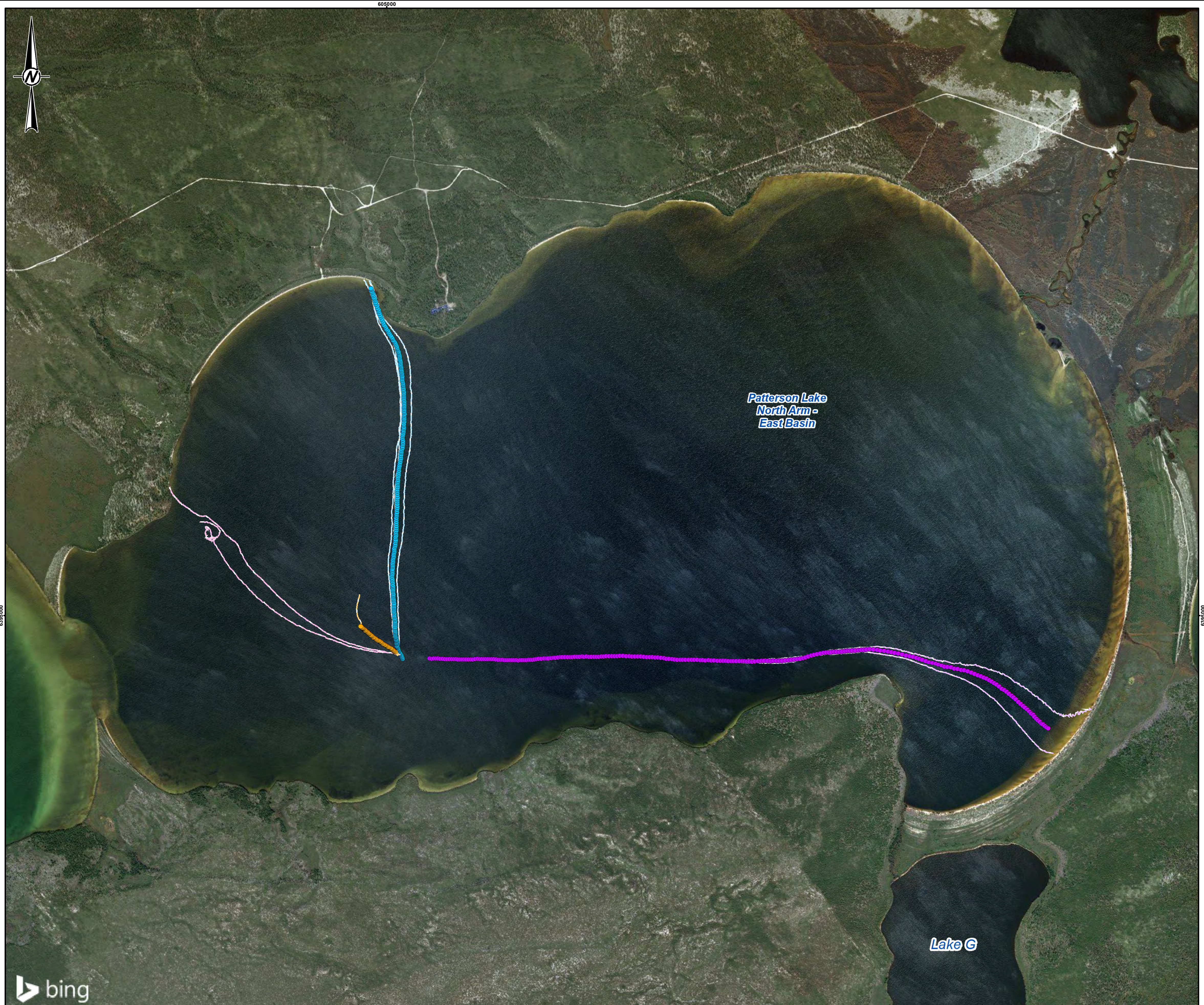


Figure 22: Cumulative Frequency Curve for Patterson Lake South Fresh Water Intake Current Speeds



5.3.4 Drogue Paths and Results

The GPS tracks, travel time, distance, and speeds were calculated for each of the drogues deployed in Patterson Lake for the 2020 field program. The average and individual drogue paths are provided in Figure 23, Figure 24, and Figure 25, and a summary of the drogue results is provided in Table 4. The drogues were released from the three ADCP locations during a wide range of wind conditions. In general, the drogues travelled downwind and tended to have higher speed when the wind strength was higher. The average speed of the drogues ranged between 0.014 m/s on 8 July 2020 and 0.192 m/s on 19 August 2020. The lower current speeds corresponded with lower wind conditions, while the higher current speeds corresponded with higher wind conditions.



LEGEND

- AVERAGE DROGUE PATH JULY 09, 2020
- ACTUAL DROGUE PATH LINE JULY 09, 2020
- AVERAGE DROGUE PATH AUGUST 19, 2020
- ACTUAL DROGUE PATH LINE AUGUST 19, 2020
- ACTUAL DROGUE PATH LINE AUGUST 24, 2020
- AVERAGE DROGUE PATH SEPTEMBER 23, 2020
- ACTUAL DROGUE PATH LINE SEPTEMBER 23, 2020

0 500 1,000

1:17,000 METRES

REFERENCE(S)

1. IMAGERY OBTAINED FROM BING MAPS FOR ARCGIS PUBLISHED BY MICROSOFT CORPORATION, REDMOND, WA, MAY 2009.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

PATTERSON LAKE AVERAGE AND ACTUAL DROGUE PATHS FROM THE PATTERSON LAKE NORTH INTAKE (MULTIPLE DATES)

CONSULTANT

GOLDER

YYYY-MM-DD	2022-02-11
DESIGNED	JH
PREPARED	NO
REVIEWED	RP
APPROVED	GVA

PROJECT NO.	PHASE	REV.	FIGURE
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

LEGEND

- AVERAGE DROGUE PATH JULY 09, 2020
- ACTUAL DROGUE PATH LINE JULY 09, 2020
- AVERAGE DROGUE PATH AUGUST 19, 2020
- ACTUAL DROGUE PATH LINE AUGUST 19, 2020
- AVERAGE DROGUE PATH AUGUST 24, 2020
- ACTUAL DROGUE PATH LINE AUGUST 24, 2020
- AVERAGE DROGUE PATH SEPTEMBER 23, 2020
- ACTUAL DROGUE PATH LINE SEPTEMBER 23, 2020

0 400 800

1:15,000 METRES

REFERENCE(S)

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

NexGen Energy Ltd.

PROJECT

ROOK I PROJECT

TITLE

PATTERSON LAKE AVERAGE AND ACTUAL DROGUE PATHS FROM THE PATTERSON LAKE NORTH OUTFALL (MULTIPLE DATES)

CONSULTANT

GOLDER

YYYY-MM-DD	2022-02-11
DESIGNED	JH
PREPARED	NO
REVIEWED	RP
APPROVED	GVA

PROJECT NO.	PHASE	REV.	FIGURE
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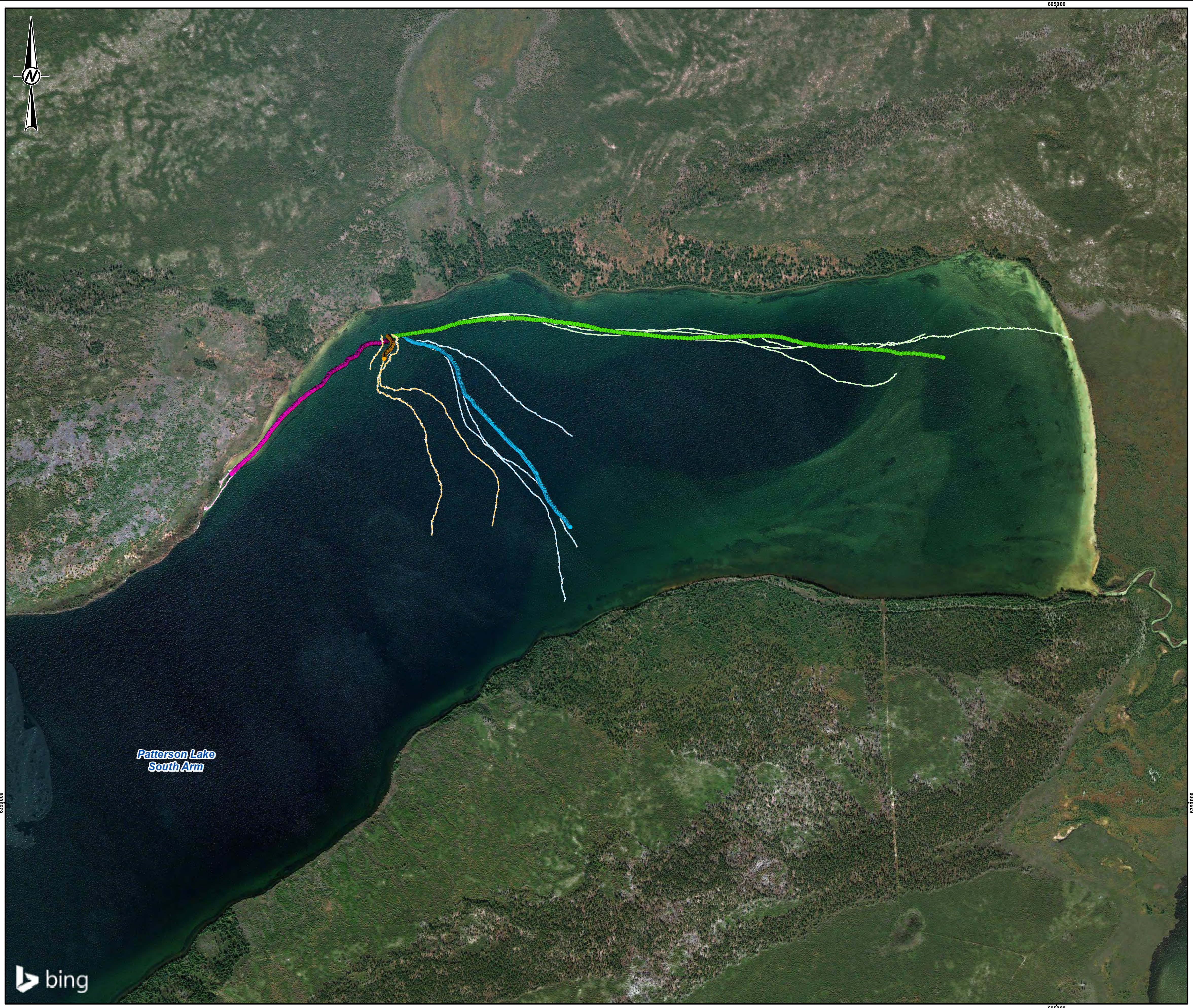

LEGEND

- AVERAGE DROGUE PATH JULY 08, 2020
- ACTUAL DROGUE PATH LINE JULY 08, 2020
- AVERAGE DROGUE PATH AUGUST 23, 2020
- ACTUAL DROGUE PATH AUGUST 23, 2020
- AVERAGE DROGUE PATH SEPTEMBER 26, 2020
- ACTUAL DROGUE PATH LINE SEPTEMBER 26, 2020
- AVERAGE DROGUE PATH OCTOBER 29, 2020
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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
NexGen Energy Ltd.

PROJECT
ROOK I PROJECT

TITLE
PATTERSON LAKE AVERAGE AND ACTUAL DROGUE PATHS FROM THE PATTERSON LAKE SOUTH INTAKE (MULTIPLE DATES)

CONSULTANT
GOLDER

YYYY-MM-DD	2022-02-11
DESIGNED	JH
PREPARED	NO
REVIEWED	RP
APPROVED	GVA

PROJECT NO.	PHASE	REV.	FIGURE
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25mm

Table 4: Summary of Drogue Deployment Results

Station ID	Date	Time of Release	Duration[a] (h, min)	Mean Distance travelled (m)	Mean Drogue Speed (m/s)	Drogue Travelled	Mean Wind Direction and Speed [b]	Estimated Dispersion Rate (m^2/s)	Drogues Deployed	Near-Surface ADCP Directions and Speed (m/s) [d]
PL-North-Intake	9 Jul 2020	12:15	49 min	202	0.069	NW	NNW, 1.3 m/s	Not available[c]	2 PVC drogues	W, 0.057
	19 Aug 2020	12:30 – 16:42	4 h 12 min	2,735	0.192	E, SE	WNW, 4.4 m/s	Not available[c]	2 PVC drogues	SE, 0.084
	24 Aug 2020	09:04 – 10:00	4 h 36 min	1,107	0.098	WNW	SE, 3.8 m/s	Not available[c]	2 PVC Drogues released an hour apart	N to NE, 0.086
	23 Sep 2020	11:04	4 h 4 min	1,634	0.111	N, then NW	SSE, 4.8 m/s	10.2	3 PVC drogues	NNW shifting to SSE, 0.102 [e]
PL-North-Outfall	9 Jul 2020	09:30	2 h 1 min	253	0.035	SSW	NNW, 1.2 m/s	13.7	3 sail drogues	SE, 0.050
	19 Aug 2020	11:48	5 h 12 min	546	0.029	NE, then N	W, 4.0 m/s	Not available[c]	2 sail drogues. Separated into two paths based on change in direction	Variable, 0.042
		17:00	1 h 36 min	136	0.024	SE	W, 4.3 m/s			Variable, 0.032
	24 Aug 2020	10:20	4 h 19 min	768	0.035	WNW	SE, 4.0 m/s	6.48	3 sail drogues	Variable, 0.036
	23 Sep 2020	10:15	6 h 23 min	1,161	0.050	N, then NW, then W	SSE, 4.7 m/s	Not available[c]	2 sail drogues (GPS issue)	N, 0.056 [e]
PL-South	8 Jul 2020	11-11:30	1 h 10 min	60	0.014	S	N, 5.0 m/s	16.6	3 PVC drogues	SSE shifting to N, 0.016
	23 Aug 2020	10:11	5 h 4 min	533	0.029	SW	NNE, 1.5 m/s	Not available[c]	2 PVC drogues	no concurrent data [f]
	26 Sep 2020	08:02	4 h 43 min	1,435	0.084	E	WNW, 3.8 m/s	169	3 PVC drogues	no concurrent data [f]
	29 Oct 2020	10:45	4 h 27 min	676	0.042	SE	NW, 5.3 m/s	87.5	3 sail drogues	no concurrent data [f]

a) Duration included in this table indicates time from release to the end of the edited drogue GPS track datasets. The datasets were edited to remove periods when GPS signals were lost or when the drogues started to drag on the lake bed or reached shore.
b) Wind data are from the Rook I Meteorological Stations during the drogue deployment hours; wind directions indicate direction that the wind is coming from per World Meteorological Organization standards (WMO 2018).
c) Data from three or more drogues are required to estimate dispersion rate.
d) Average ADCP current speed and direction are provided for the same time periods that the drogues were deployed. Current directions are the direction towards which the currents are moving per industry standard convention (NOAA 2000; QARTOD 2019).
e) On these dates, ADCP data collection only partially overlapped the drogue deployment time periods and thus results represent only one or two ADCP samples.
f) On these dates, ADCP data collection did not overlap with the drogue deployment time periods and no direct comparison could be made.

PVC = polyvinyl chloride; NW = northwest, NNW = north-northwest, N = north, NNE = north-northeast, NE = northeast, E = east, SE = southeast, SSE = south- southeast, S = south, SSW = south-southwest, SW = southwest, W = west, WNW = west-northwest; n/d = no data.

5.3.5 Comparison of Concurrent Drogue and Acoustic Doppler Current Profiler Results

A comparison of current speed and direction data collected during 2020 drogue deployments with concurrent near-surface stationary ADCP measurements is presented in Table 5. The results were only compared when the drogues were within 100 m of the ADCP (i.e., not the entire deployment period per Table 4), as the ADCP measurements were stationary, whereas the drogues travelled across the lake surface over a period of hours. The focus was on comparing the near-surface ADCP results with the drogue results to provide additional confidence when these results agreed (Table 5).

Mean drogue speed (i.e., the average path speed of two or three drogues moving at the same time) was usually lower than what was measured at the ADCPs, as the different drogues did not take identical paths. In general, when the drogues had higher (i.e., faster) average speeds, the ADCP lake current speeds were also higher, as observed at PL-North-Intake on 24 August 2020. The lowest drogue speeds were observed when the current direction was actively shifting (e.g., at PL-North-Outfall on 24 August 2020), or if winds were light or from offshore (e.g., at PL-South on 8 July 2020).

Current directions of the mean drogue direction and near-surface ADCP current direction were generally aligned.

Table 5: Concurrent Drogue and Acoustic Doppler Current Profiler Results

Station ID	Date	Concurrent Deployment Time	Mean Drogue Speed first 100 m (m/s) [a]	Near-Surface ADCP Speed (m/s)	Mean Drogue Direction	Near-Surface ADCP Current Direction
PL-North-Intake	9 Jul 2020	12:15–12:41	0.069	0.087	NW	W
	24 Aug 2020	09:04–09:20	0.100	0.076	W	NW to NE
	23 Sep 2020	11:04–11:32	0.058	0.102	NW	Variable NNW shifting to SSE
PL-North-Outfall	9 Jul 2020	10:20	0.046	0.055	SW	ENE shifting to SE
	19 Aug 2020	11:48–12:46	0.029	0.035	NE	N to NE, SW
	24 Aug 2020	08:39–10:05	0.019	0.037	W	Variable
PL-South	8 Jul 2020	11:00–13:34	0.013	0.014	S and SE	SSE shifting to N

Note: **Bold** text indicates the Near-Surface ADCP observations for which comparison to droque data is most appropriate.
a)observations were compared for the period when the drogues were within 100 m of the ADCP.
ADCP = acoustic Doppler current profiler; ; NW = northwest, NNW = north-northwest, N = north, NNE = north-northeast, NE = northeast, E = east, SE = southeast, SSE = south- southeast, S = south, SSW = south-southwest, SW = southwest, W = west, WNW = west-northwest.

6.0 SUMMARY

Lake current patterns were monitored at three locations in Patterson Lake between July and September 2020 to improve understanding of lake currents near the anticipated locations of the Rook I Project submerged north fresh water intake, treated sewage outfall, and treated effluent diffuser.

The dominant lake current directions varied at each acoustic Doppler current profiler (ADCP) location and were influenced by wind and local factors such as the orientation of the waterbody, steepness and height of surrounding shorelines, and bathymetry. The observation period from July 2020 to September 2020 had slightly windier conditions than those during the five-year open-water period wind record although average hourly wind speeds were similar. Prevailing wind directions were similar for the 2020 observation period (Figure 11) and 5-year open water period (Figure 10), with west-northwest and northwest being the most frequent, followed by south-southeast.

Key findings for the Patterson Lake North Intake location were as follows:

- The range of observed current speeds during open water conditions in 2020 was 0.001 m/s to 0.252 m/s.
- Median current speed ranged from 0.079 m/s near-lake-bed to 0.083 m/s at mid-profile
- Average current speed during open water conditions was 0.081 m/s in the mid-profile.
- Dominant current directions at this location (i.e., southeast and east-southeast, followed by west-northwest and west) were aligned with wind directions monitored at the Rook I Meteorological Station.
- The higher current speeds and agreement with wind direction results may be due to the East Basin being more exposed to regional wind as the topography is relatively flat compared to other basins of Patterson Lake.

Key findings for the Patterson Lake North Outfall location were as follows:

- The range of observed current speeds in the mid-profile was 0.001 m/s to 0.192 m/s.
- Median current speed ranged from 0.039 m/s at near-surface and mid-profile to 0.040 m/s near the lake bed.
- Average current speed was 0.039 m/s in the mid-profile, which is less than the assumed average current speed of 0.055 m/s used in the conceptual diffuser design (Golder 2019) which was based on wind speed.
- At PL-North-Outfall, lake currents throughout the profile were predominantly onshore between east-southeast and south-southwest 41% to 43% of the time, and less frequently alongshore (i.e., moving southwest through west and northeast through east) 27% to 29% of the time and offshore 28% to 30%. Local wind speed and direction may be affected by the topography around the Patterson Lake North Arm – West Basin, which may have an influence on current speeds.
- The high frequency of onshore current directions at PL-North-Outfall may be related to the 4% to 5% more frequent west-northwest and northwest winds during the 2020 lake current observation period compared to the five-year open-water period. However, it is not certain if onshore lake currents are normally more frequent than alongshore currents during the open-water period.

- Lake bathymetry near the ADCP location may also be an important factor affecting current directions and speeds in the water column, particularly near the lake bed. The slope of the lake bed is relatively steep, with a drop-off just north and northwest of the ADCP location (Figure 24), and the drogue paths appeared to follow the edge of the drop-off.

For PL- South, key findings were as follows:

- The range of measured current speeds in the mid-profile was from zero to 0.168 m/s.
- Median current speeds were 0.024 m/s at the near-surface, 0.021 m/s in mid-profile and near-lake bed.
- Average current speed was 0.028 m/s in the mid-profile.
- Dominant current directions were bimodal, predominantly alongshore in the same orientation as the Patterson Lake - South Arm occurring 40% to 41% of the monitoring period. Currents were onshore between 31% and 36% of the time and offshore the remaining time.
- Higher current speeds were most often alongshore, particularly between east and northeast, while average current speeds were more often in the opposite alongshore direction between west and southwest.

Although the general direction of flow through Patterson Lake is from the North Arm – East Basin, through the narrows to North Arm – West Basin, and out through the South Arm, this overall flow may not have influenced lake currents during the open-water period in 2020.

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:

PROFESSIONAL GEOSCIENTIST
J.M. HOGAN
MEMBER 13123
22 02 10
SASKATCHEWAN

Jaime Hogan, M.Sc., P.Geo.
Hydrologist

Ross Phillips, M.Sc., P.Eng.
Water Resource Engineer

Reviewed by:

Gerard Van Arkel, M.Eng.
Associate, Senior Water Resources Specialist

JH/RP/GVA/rd

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Number C0230
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Hydrology	13123	Jaime Hogan

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REFERENCES

CanNorth (Canada North Environmental Services). 2020. Rook I Project Aquatics and Terrestrial Environmental Baseline Report – Draft Report. Prepared for NexGen Energy Ltd.

Golder (Golder Associates Ltd.). 2018. Rook I Atmospheric Studies Baseline Field Report. Prepared for Prepared for NexGen Energy Ltd. October 2, 2018, 10 p.

Golder. 2019. Conceptual Diffuser Design Report for the Rook I Project. Prepared for NexGen Energy Ltd. December 2019. 29 p.

Golder. 2020. Downstream Use and Impact Study for Proposed Sewage Discharge for the Rook I Project. Submitted March 10, 2020. 15 p.

List EJ, Gartrell G, Winant CD. 1990. Diffusion and Dispersion in Coastal Waters. Journal of Hydraulic Engineering, 116(10): 1158-1179 p.

NOAA (National Oceanic and Atmospheric Administration). 2000. Tide and Current Glossary. National Ocean Service, Center for Operational Oceanographic Products and Services. 33 p.

Nortek. 2018. The Comprehensive Manual for ADCP’s. 137 p.

QARTOD (Quality Assurance / Quality Control of Real-Time Oceanographic Data). 2019. Manual for Real-Time Quality Control of In-Situ Current Observations. A Guide to Quality Control and Quality Assurance of Acoustic Doppler Current Profiler Observation. Version 2.1. Integrated Ocean Observing System. 54 p.

Sontek. 2007. Sontek/YSI Argonaut Acoustic Doppler Current Meter Technical Documentation. 240 p.

Wood. 2019. Civil Surface Infrastructure Overall Area Plan. Drawing No. 2100-DD10-GAD-00001 RevC dated 22 October 2019.

WMO (World Meteorological Organization). 2018. Guide to Instruments and Methods of Observation, Volume 1 – Measurement of Meteorological Variables. WMO-No.8. 573 p.

WSA (Water Security Agency). 2015. Surface Water Quality Objectives Interim Edition, EPB 356. June 2015, 9 p.

APPENDIX A

Wind Rose and Lake Currents Rose Statistics

Table A-1: Wind Speed and Direction Frequency at Rook I Meteorological Station for the Open Water Period from May 2016 to October 2020

Wind Direction	Direction Interval (°)	Avg. Direction (°)	Wind Speed, W_S (m/s)						
			$0.5 \le W_S < 1.5$	$1.5 \le W_S < 3$	$3 \le W_S < 5$	$5 \le W_S < 8$	$8 \le W_S < 10$	$W_S \ge 10$	TOTAL
N	[348.75 , 11.25]	0	0.6%	1.4%	1.8%	0.8%	0.1%	0.0%	4.8%
NNE	[11.25 , 33.75]	22.5	0.6%	1.8%	1.4%	0.5%	0.0%	0.0%	4.3%
NE	[33.75 , 56.25]	45	0.4%	2.0%	1.9%	0.4%	0.1%	0.0%	4.8%
ENE	[56.25 , 78.75]	67.5	0.4%	1.8%	1.5%	0.3%	0.0%	0.0%	4.0%
E	[78.75 , 101.25]	90	0.3%	1.5%	1.8%	0.7%	0.1%	0.0%	4.4%
ESE	[101.25 , 123.75]	112.5	0.3%	2.0%	2.1%	0.6%	0.0%	0.0%	4.9%
SE	[123.75 , 146.25]	135	0.4%	2.2%	2.3%	0.7%	0.0%	0.0%	5.7%
SSE	[146.25 , 168.75]	157.5	0.3%	2.5%	4.3%	1.5%	0.1%	0.0%	8.7%
S	[168.75 , 191.25]	180	0.2%	2.2%	4.3%	1.4%	0.0%	0.0%	8.2%
SSW	[191.25 , 213.75]	202.5	0.3%	1.9%	2.7%	0.7%	0.0%	0.0%	5.6%
SW	[213.75 , 236.25]	225	0.4%	1.9%	2.9%	0.7%	0.1%	0.0%	5.9%
WSW	[236.25 , 258.75]	247.5	0.4%	2.3%	2.0%	0.5%	0.0%	0.0%	5.2%
W	[258.75 , 281.25]	270	0.6%	2.3%	2.0%	1.0%	0.0%	0.0%	5.8%
WNW	[281.25 , 303.75]	292.5	0.4%	2.4%	3.7%	2.4%	0.4%	0.1%	9.4%
NW	[303.75 , 326.25]	315	0.3%	2.0%	3.8%	3.5%	0.6%	0.1%	10.3%
NNW	[326.25 , 348.75]	337.5	0.5%	1.8%	2.6%	1.9%	0.3%	0.0%	7.1%
Total	[0 , 360]	TOTAL	6.5%	32.1%	41.1%	17.5%	1.7%	0.2%	99.1%
Other	No Direction	Wind Speed = 0							0.9%

Table A-2: Wind Speed and Direction Frequency at Rook I Meteorological Station for July to September 2020

Direction	Direction Interval (°)	Avg. Direction (°)	Wind Speed, W_S (m/s)						
			$0.5 \le W_S < 1.5$	$1.5 \le W_S < 3$	$3 \le W_S < 5$	$5 \le W_S < 8$	$8 \le W_S < 10$	$W_S \ge 10$	TOTAL
N	[348.75 , 11.25]	0	0.5%	1.4%	1.9%	0.3%	0.0%	0.0%	4.2%
NNE	[11.25 , 33.75]	22.5	0.3%	1.7%	0.6%	0.0%	0.0%	0.0%	2.7%
NE	[33.75 , 56.25]	45	0.3%	1.0%	1.0%	0.5%	0.0%	0.0%	2.7%
ENE	[56.25 , 78.75]	67.5	0.3%	0.8%	0.8%	0.3%	0.0%	0.0%	2.2%
E	[78.75 , 101.25]	90	0.1%	0.7%	1.2%	1.4%	0.0%	0.0%	3.4%
ESE	[101.25 , 123.75]	112.5	0.5%	1.3%	3.0%	1.3%	0.0%	0.0%	6.2%
SE	[123.75 , 146.25]	135	0.7%	2.5%	2.4%	1.4%	0.0%	0.0%	7.0%
SSE	[146.25 , 168.75]	157.5	0.4%	2.7%	3.9%	1.9%	0.0%	0.0%	9.0%
S	[168.75 , 191.25]	180	0.2%	1.8%	2.1%	1.0%	0.0%	0.0%	5.2%
SSW	[191.25 , 213.75]	202.5	0.1%	1.6%	1.3%	0.5%	0.0%	0.0%	3.4%
SW	[213.75 , 236.25]	225	0.2%	1.5%	2.0%	1.1%	0.1%	0.0%	5.0%
WSW	[236.25 , 258.75]	247.5	0.1%	2.3%	3.0%	1.0%	0.0%	0.0%	6.4%
W	[258.75 , 281.25]	270	0.3%	2.6%	2.4%	0.7%	0.0%	0.0%	6.1%
WNW	[281.25 , 303.75]	292.5	0.5%	3.6%	5.2%	4.6%	0.5%	0.3%	14.6%
NW	[303.75 , 326.25]	315	0.4%	2.3%	5.1%	5.0%	0.9%	0.3%	14.0%
NNW	[326.25 , 348.75]	337.5	0.5%	2.5%	3.3%	1.5%	0.1%	0.0%	7.9%
Total	[0 , 360]	TOTAL	5.4%	30.3%	39.3%	22.5%	1.7%	0.6%	99.8%
Other	—								0.2%

Table A-3: Lake Current Speed and Direction Frequency at PL-North-Intake (Near-Surface)

Current Direction	Direction Interval (°)	Average Direction (°)	Current Speed (m/s)						
			$0<C_S<0.005$	$0.005\leq C_S<0.025$	$0.025\leq C_S<0.05$	$0.05\leq C_S<0.075$	$0.075\leq C_S<0.1$	$C_S\geq 0.1$	TOTAL
N	[348.75 , 11.25]	0	0.0%	0.6%	1.4%	1.0%	1.6%	0.5%	5.1%
NNE	[11.25 , 33.75]	22.5	0.1%	0.8%	1.4%	1.2%	1.6%	1.0%	6.2%
NE	[33.75 , 56.25]	45	0.0%	0.5%	1.0%	1.3%	2.1%	1.4%	6.3%
ENE	[56.25 , 78.75]	67.5	0.0%	0.4%	1.0%	1.1%	2.1%	1.5%	6.1%
E	[78.75 , 101.25]	90	0.0%	0.3%	0.9%	1.0%	3.2%	2.0%	7.4%
ESE	[101.25 , 123.75]	112.5	0.1%	0.4%	0.4%	0.5%	3.6%	4.6%	9.5%
SE	[123.75 , 146.25]	135	0.0%	0.2%	0.3%	0.4%	2.7%	7.7%	11.3%
SSE	[146.25 , 168.75]	157.5	0.0%	0.3%	0.3%	0.4%	2.1%	3.8%	7.0%
S	[168.75 , 191.25]	180	0.0%	0.4%	0.2%	0.3%	0.9%	0.5%	2.4%
SSW	[191.25 , 213.75]	202.5	0.0%	0.5%	0.6%	0.4%	0.5%	0.1%	2.1%
SW	[213.75 , 236.25]	225	0.0%	0.3%	0.9%	0.7%	0.5%	0.2%	2.5%
WSW	[236.25 , 258.75]	247.5	0.1%	0.5%	1.2%	1.2%	1.2%	0.5%	4.6%
W	[258.75 , 281.25]	270	0.0%	0.5%	1.8%	2.6%	1.9%	1.2%	8.0%
WNW	[281.25 , 303.75]	292.5	0.0%	1.0%	2.0%	2.6%	2.0%	1.3%	8.9%
NW	[303.75 , 326.25]	315	0.0%	0.6%	1.8%	2.6%	1.5%	0.5%	7.2%
NNW	[326.25 , 348.75]	337.5	0.0%	0.7%	1.5%	1.6%	1.2%	0.4%	5.4%
Total	[0 , 360]	TOTAL	0.3%	8.1%	16.7%	18.9%	28.8%	27.1%	100.0%
Other	No Direction	Wind Speed = 0							0.0%

Table A-4: Lake Current Speed and Direction Frequency at PL-North-Intake (Mid-Profile)

Current Direction	Direction Interval (°)	Average Direction (°)	Current Speed (m/s)						
			$0<C_S<0.005$	$0.005 \le C_S<0.025$	$0.025 \le C_S<0.05$	$0.05 \le C_S<0.075$	$0.075 \le C_S<0.1$	$C_S \ge 0.1$	TOTAL
N	[348.75 , 11.25]	0	0.0%	0.6%	1.2%	1.0%	1.5%	0.7%	5.0%
NNE	[11.25 , 33.75]	22.5	0.1%	0.5%	1.1%	1.1%	1.7%	1.0%	5.6%
NE	[33.75 , 56.25]	45	0.0%	0.4%	1.0%	1.0%	1.8%	1.6%	5.9%
ENE	[56.25 , 78.75]	67.5	0.0%	0.4%	0.8%	0.9%	2.3%	2.2%	6.6%
E	[78.75 , 101.25]	90	0.0%	0.2%	0.6%	0.9%	2.2%	3.1%	7.0%
ESE	[101.25 , 123.75]	112.5	0.1%	0.4%	0.7%	0.4%	2.9%	5.7%	10.2%
SE	[123.75 , 146.25]	135	0.0%	0.2%	0.4%	0.3%	2.3%	7.7%	11.0%
SSE	[146.25 , 168.75]	157.5	0.0%	0.3%	0.5%	0.2%	1.4%	3.8%	6.2%
S	[168.75 , 191.25]	180	0.0%	0.3%	0.3%	0.2%	0.8%	0.8%	2.4%
SSW	[191.25 , 213.75]	202.5	0.1%	0.5%	0.8%	0.5%	0.6%	0.1%	2.5%
SW	[213.75 , 236.25]	225	0.0%	0.4%	0.7%	0.7%	0.6%	0.1%	2.6%
WSW	[236.25 , 258.75]	247.5	0.0%	0.6%	1.5%	1.4%	1.3%	0.5%	5.3%
W	[258.75 , 281.25]	270	0.0%	0.5%	1.9%	2.7%	2.0%	1.8%	9.0%
WNW	[281.25 , 303.75]	292.5	0.0%	0.7%	2.1%	2.9%	2.2%	1.1%	9.0%
NW	[303.75 , 326.25]	315	0.0%	0.5%	2.0%	2.1%	1.6%	0.7%	6.9%
NNW	[326.25 , 348.75]	337.5	0.0%	0.5%	1.6%	1.5%	0.9%	0.4%	4.9%
Total	[0 , 360]	TOTAL	0.4%	7.1%	17.1%	17.8%	26.2%	31.4%	100.0%
Other	No Direction	Wind Speed = 0							0.0%

Table A-5: Lake Current Speed and Direction Frequency at PL-North-Intake (Near-Lake-Bed)

Current Direction	Direction Interval (°)	Average Direction (°)	Current Speed (m/s)						
			$0<C_S<0.005$	$0.005≤C_S<0.025$	$0.025≤C_S<0.05$	$0.05≤C_S<0.075$	$0.075≤C_S<0.1$	$C_S≥0.1$	TOTAL
N	[348.75 , 11.25]	0	0.0%	0.7%	1.4%	1.0%	1.3%	0.4%	4.8%
NNE	[11.25 , 33.75]	22.5	0.1%	0.7%	1.2%	1.1%	1.5%	0.8%	5.3%
NE	[33.75 , 56.25]	45	0.0%	0.5%	1.0%	1.1%	2.0%	1.4%	5.9%
ENE	[56.25 , 78.75]	67.5	0.0%	0.3%	0.9%	1.1%	3.1%	1.7%	7.1%
E	[78.75 , 101.25]	90	0.0%	0.3%	0.6%	0.7%	2.7%	3.1%	7.5%
ESE	[101.25 , 123.75]	112.5	0.0%	0.5%	0.6%	0.5%	3.4%	5.2%	10.2%
SE	[123.75 , 146.25]	135	0.0%	0.3%	0.3%	0.3%	3.1%	7.7%	11.7%
SSE	[146.25 , 168.75]	157.5	0.0%	0.3%	0.3%	0.3%	1.8%	2.9%	5.6%
S	[168.75 , 191.25]	180	0.0%	0.2%	0.4%	0.2%	0.9%	0.2%	2.0%
SSW	[191.25 , 213.75]	202.5	0.1%	0.5%	0.9%	0.4%	0.6%	0.1%	2.5%
SW	[213.75 , 236.25]	225	0.0%	0.3%	1.0%	0.9%	0.5%	0.1%	2.8%
WSW	[236.25 , 258.75]	247.5	0.0%	0.5%	1.8%	1.7%	0.8%	0.5%	5.4%
W	[258.75 , 281.25]	270	0.0%	0.8%	2.2%	2.5%	1.8%	0.9%	8.1%
WNW	[281.25 , 303.75]	292.5	0.0%	0.6%	2.3%	3.0%	2.4%	0.8%	9.2%
NW	[303.75 , 326.25]	315	0.0%	0.9%	2.1%	2.2%	1.1%	0.5%	6.8%
NNW	[326.25 , 348.75]	337.5	0.1%	0.6%	1.7%	1.5%	1.1%	0.3%	5.2%
Total	[0 , 360]	TOTAL	0.4%	8.1%	18.6%	18.4%	28.1%	26.5%	100.0%
Other	No Direction	Wind Speed = 0							0.0%

Table A-6: Lake Current Speed and Direction Frequencyat PL-North-Outfall (Near-Surface)

Current Direction	Direction Interval (°)	Average Direction (°)	Current Speed (m/s)						
			$0<C_S<0.005$	$0.005\leq C_S<0.025$	$0.025\leq C_S<0.05$	$0.05\leq C_S<0.075$	$0.075\leq C_S<0.1$	$C_S\geq 0.1$	TOTAL
N	[348.75 , 11.25]	0	0.0%	1.0%	3.1%	1.5%	0.5%	0.1%	6.3%
NNE	[11.25 , 33.75]	22.5	0.1%	1.3%	3.7%	1.0%	0.3%	0.1%	6.4%
NE	[33.75 , 56.25]	45	0.0%	1.3%	3.3%	1.0%	0.1%	0.0%	5.7%
ENE	[56.25 , 78.75]	67.5	0.1%	1.3%	2.8%	1.0%	0.1%	0.0%	5.3%
E	[78.75 , 101.25]	90	0.0%	1.1%	3.6%	1.7%	0.1%	0.0%	6.6%
ESE	[101.25 , 123.75]	112.5	0.1%	1.9%	4.6%	2.5%	0.4%	0.1%	9.6%
SE	[123.75 , 146.25]	135	0.0%	1.6%	4.5%	3.1%	0.7%	0.1%	9.9%
SSE	[146.25 , 168.75]	157.5	0.1%	1.4%	5.0%	2.6%	0.6%	0.1%	9.8%
S	[168.75 , 191.25]	180	0.1%	1.1%	4.0%	1.8%	0.4%	0.2%	7.6%
SSW	[191.25 , 213.75]	202.5	0.1%	1.3%	3.3%	1.3%	0.1%	0.0%	6.1%
SW	[213.75 , 236.25]	225	0.0%	1.0%	1.8%	0.7%	0.1%	0.0%	3.6%
WSW	[236.25 , 258.75]	247.5	0.0%	0.7%	1.8%	0.2%	0.1%	0.0%	2.9%
W	[258.75 , 281.25]	270	0.0%	0.8%	1.6%	0.7%	0.1%	0.0%	3.1%
WNW	[281.25 , 303.75]	292.5	0.1%	0.9%	2.1%	1.2%	0.1%	0.0%	4.4%
NW	[303.75 , 326.25]	315	0.0%	0.9%	2.9%	1.4%	0.3%	0.0%	5.5%
NNW	[326.25 , 348.75]	337.5	0.0%	1.1%	3.5%	1.7%	0.5%	0.1%	7.0%
Total	[0 , 360]	TOTAL	0.8%	18.6%	51.6%	23.6%	4.4%	0.8%	99.9%
Other	No Direction	Wind Speed = 0							0.1%

Table A-7: Lake Current Speed and Direction Frequency at PL-North-Outfall (Mid-Profile)

Current Direction	Direction Interval (°)	Average Direction (°)	Current Speed (m/s)						
			$0<C_S<0.005$	$0.005\leq C_S<0.025$	$0.025\leq C_S<0.05$	$0.05\leq C_S<0.075$	$0.075\leq C_S<0.1$	$C_S\geq 0.1$	TOTAL
N	[348.75 , 11.25]	0	0.0%	0.7%	2.9%	1.4%	0.2%	0.1%	5.4%
NNE	[11.25 , 33.75]	22.5	0.1%	1.5%	3.0%	1.3%	0.1%	0.0%	5.9%
NE	[33.75 , 56.25]	45	0.0%	1.1%	2.5%	0.6%	0.0%	0.0%	4.2%
ENE	[56.25 , 78.75]	67.5	0.0%	1.2%	2.9%	0.5%	0.0%	0.0%	4.6%
E	[78.75 , 101.25]	90	0.0%	1.1%	2.7%	1.1%	0.1%	0.0%	5.1%
ESE	[101.25 , 123.75]	112.5	0.1%	1.7%	3.6%	1.8%	0.1%	0.0%	7.4%
SE	[123.75 , 146.25]	135	0.0%	1.4%	3.9%	2.1%	0.7%	0.1%	8.2%
SSE	[146.25 , 168.75]	157.5	0.0%	1.2%	4.3%	2.7%	1.1%	0.4%	9.6%
S	[168.75 , 191.25]	180	0.0%	1.2%	4.1%	2.5%	0.7%	0.2%	8.8%
SSW	[191.25 , 213.75]	202.5	0.1%	1.6%	3.3%	1.7%	0.5%	0.1%	7.4%
SW	[213.75 , 236.25]	225	0.0%	1.2%	2.7%	1.2%	0.1%	0.1%	5.5%
WSW	[236.25 , 258.75]	247.5	0.0%	1.1%	2.5%	0.7%	0.1%	0.0%	4.4%
W	[258.75 , 281.25]	270	0.0%	1.0%	2.4%	0.9%	0.2%	0.0%	4.5%
WNW	[281.25 , 303.75]	292.5	0.1%	1.4%	2.9%	1.3%	0.2%	0.1%	6.0%
NW	[303.75 , 326.25]	315	0.0%	1.1%	3.4%	1.6%	0.2%	0.1%	6.3%
NNW	[326.25 , 348.75]	337.5	0.1%	0.9%	3.2%	1.9%	0.3%	0.3%	6.6%
Total	[0 , 360]	TOTAL	0.7%	19.3%	50.3%	23.5%	4.7%	1.6%	100.0%
Other	No Direction	Wind Speed = 0							0.0%

Table A-8: Lake Current Speed and Direction Frequency at PL-North-Outfall (Near-Lake-Bed)

Current Direction	Direction Interval (°)	Average Direction (°)	Current Speed (m/s)						
			$0<C_S<0.005$	$0.005\leq C_S<0.025$	$0.025\leq C_S<0.05$	$0.05\leq C_S<0.075$	$0.075\leq C_S<0.1$	$C_S\geq 0.1$	TOTAL
N	[348.75 , 11.25]	0	0.1%	1.1%	2.8%	1.0%	0.1%	0.0%	5.2%
NNE	[11.25 , 33.75]	22.5	0.0%	1.2%	2.6%	0.7%	0.1%	0.0%	4.5%
NE	[33.75 , 56.25]	45	0.0%	0.8%	2.4%	0.5%	0.0%	0.0%	3.7%
ENE	[56.25 , 78.75]	67.5	0.1%	1.2%	2.5%	0.4%	0.0%	0.0%	4.3%
E	[78.75 , 101.25]	90	0.2%	1.3%	2.5%	0.8%	0.0%	0.0%	4.8%
ESE	[101.25 , 123.75]	112.5	0.1%	1.3%	3.8%	1.4%	0.2%	0.0%	6.7%
SE	[123.75 , 146.25]	135	0.0%	1.4%	4.1%	2.2%	0.8%	0.2%	8.7%
SSE	[146.25 , 168.75]	157.5	0.1%	1.5%	4.2%	3.2%	1.5%	0.6%	11.1%
S	[168.75 , 191.25]	180	0.1%	1.2%	3.6%	2.7%	1.1%	0.3%	9.1%
SSW	[191.25 , 213.75]	202.5	0.0%	1.2%	3.5%	1.9%	0.5%	0.1%	7.3%
SW	[213.75 , 236.25]	225	0.0%	1.0%	2.8%	1.3%	0.2%	0.1%	5.5%
WSW	[236.25 , 258.75]	247.5	0.1%	1.0%	2.5%	1.0%	0.1%	0.1%	4.8%
W	[258.75 , 281.25]	270	0.1%	1.2%	2.8%	1.2%	0.2%	0.0%	5.5%
WNW	[281.25 , 303.75]	292.5	0.1%	1.1%	2.9%	1.7%	0.4%	0.1%	6.2%
NW	[303.75 , 326.25]	315	0.1%	1.0%	2.5%	1.9%	0.6%	0.2%	6.2%
NNW	[326.25 , 348.75]	337.5	0.0%	1.3%	3.0%	1.5%	0.4%	0.1%	6.3%
Total	[0 , 360]	TOTAL	1.1%	18.7%	48.5%	23.5%	6.2%	2.0%	100.0%
Other	No Direction	Wind Speed = 0							0.0%

Table A-9: Lake Current Speed and Direction Frequency at PL-South (Near-Surface)

Current Direction	Direction Interval (°)	Average Direction (°)	Current Speed (m/s)						
			$0<C_S<0.005$	$0.005 \le C_S<0.025$	$0.025 \le C_S<0.05$	$0.05 \le C_S<0.075$	$0.075 \le C_S<0.1$	$C_S \ge 0.1$	TOTAL
N	[348.75 , 11.25]	0	0.2%	1.1%	0.7%	0.0%	0.0%	0.0%	2.0%
NNE	[11.25 , 33.75]	22.5	0.2%	2.8%	1.2%	0.0%	0.0%	0.0%	4.4%
NE	[33.75 , 56.25]	45	0.1%	1.8%	2.0%	0.5%	0.2%	0.0%	4.5%
ENE	[56.25 , 78.75]	67.5	0.3%	2.3%	2.6%	1.6%	1.3%	0.8%	8.9%
E	[78.75 , 101.25]	90	0.3%	2.6%	2.1%	1.0%	0.7%	0.4%	7.2%
ESE	[101.25 , 123.75]	112.5	0.2%	2.5%	1.7%	0.1%	0.0%	0.0%	4.6%
SE	[123.75 , 146.25]	135	0.3%	2.0%	1.1%	0.2%	0.0%	0.0%	3.6%
SSE	[146.25 , 168.75]	157.5	0.2%	3.0%	1.8%	0.1%	0.0%	0.0%	5.1%
S	[168.75 , 191.25]	180	0.3%	3.0%	1.0%	0.1%	0.0%	0.0%	4.5%
SSW	[191.25 , 213.75]	202.5	0.3%	5.5%	3.4%	0.5%	0.0%	0.0%	9.7%
SW	[213.75 , 236.25]	225	0.4%	4.5%	4.2%	1.4%	0.1%	0.1%	10.8%
WSW	[236.25 , 258.75]	247.5	0.5%	5.2%	6.1%	1.5%	0.5%	0.4%	14.2%
W	[258.75 , 281.25]	270	0.3%	3.6%	3.7%	0.5%	0.1%	0.0%	8.3%
WNW	[281.25 , 303.75]	292.5	0.5%	4.1%	2.5%	0.1%	0.0%	0.0%	7.2%
NW	[303.75 , 326.25]	315	0.4%	1.6%	0.5%	0.0%	0.0%	0.0%	2.5%
NNW	[326.25 , 348.75]	337.5	0.1%	1.2%	1.0%	0.1%	0.0%	0.0%	2.4%
Total	[0 , 360]	TOTAL	4.5%	46.9%	35.7%	7.9%	3.0%	1.9%	99.9%
Other	No Direction	Wind Speed = 0							0.1%

Table A-10: Lake Current Speed and Direction Frequency at PL-South (Mid-Profile)

Current Direction	Direction Interval (°)	Average Direction (°)	Current Speed (m/s)						
			$0<C_S<0.005$	$0.005\leq C_S<0.025$	$0.025\leq C_S<0.05$	$0.05\leq C_S<0.075$	$0.075\leq C_S<0.1$	$C_S\geq 0.1$	TOTAL
N	[348.75 , 11.25]	0	0.0%	2.1%	0.4%	0.0%	0.0%	0.0%	2.5%
NNE	[11.25 , 33.75]	22.5	0.6%	3.5%	0.6%	0.0%	0.0%	0.0%	4.8%
NE	[33.75 , 56.25]	45	0.0%	2.7%	2.2%	0.4%	0.0%	0.1%	5.5%
ENE	[56.25 , 78.75]	67.5	0.2%	3.0%	3.0%	2.2%	1.0%	0.9%	10.3%
E	[78.75 , 101.25]	90	0.0%	2.3%	1.4%	0.9%	0.4%	0.1%	5.0%
ESE	[101.25 , 123.75]	112.5	0.2%	2.7%	1.0%	0.1%	0.0%	0.0%	4.1%
SE	[123.75 , 146.25]	135	0.3%	2.4%	0.8%	0.0%	0.0%	0.0%	3.4%
SSE	[146.25 , 168.75]	157.5	0.5%	3.3%	0.8%	0.0%	0.0%	0.0%	4.6%
S	[168.75 , 191.25]	180	0.1%	2.5%	1.2%	0.0%	0.0%	0.0%	3.9%
SSW	[191.25 , 213.75]	202.5	0.8%	4.7%	1.9%	0.0%	0.0%	0.0%	7.4%
SW	[213.75 , 236.25]	225	0.1%	4.7%	4.1%	0.8%	0.1%	0.0%	9.9%
WSW	[236.25 , 258.75]	247.5	0.6%	6.2%	6.1%	1.5%	0.7%	0.1%	15.3%
W	[258.75 , 281.25]	270	0.1%	4.7%	5.0%	0.6%	0.0%	0.0%	10.5%
WNW	[281.25 , 303.75]	292.5	0.5%	4.6%	2.1%	0.1%	0.0%	0.0%	7.3%
NW	[303.75 , 326.25]	315	0.2%	2.2%	0.5%	0.0%	0.0%	0.0%	2.9%
NNW	[326.25 , 348.75]	337.5	0.4%	1.9%	0.2%	0.0%	0.0%	0.0%	2.5%
Total	[0 , 360]	TOTAL	4.8%	53.5%	31.3%	6.7%	2.3%	1.2%	99.8%
Other	No Direction	Current Speed = 0							0.2%

Table A-11: Lake Current Speed and Direction Frequency at PL-South (Near-Lake-Bed)

Current Direction	Direction Interval (°)	Average Direction (°)	Current Speed, C_S (m/s)						
			$0<C_S<0.005$	$0.005\le C_S<0.025$	$0.025\le C_S<0.05$	$0.05\le C_S<0.075$	$0.075\le C_S<0.1$	$C_S\ge 0.1$	TOTAL
N	[348.75 , 11.25]	0	0.0%	1.9%	0.2%	0.0%	0.0%	0.0%	2.0%
NNE	[11.25 , 33.75]	22.5	0.9%	2.5%	0.5%	0.1%	0.0%	0.0%	4.1%
NE	[33.75 , 56.25]	45	0.0%	2.5%	1.6%	0.3%	0.0%	0.0%	4.5%
ENE	[56.25 , 78.75]	67.5	0.5%	2.5%	2.8%	1.6%	0.8%	0.8%	8.9%
E	[78.75 , 101.25]	90	0.0%	3.5%	2.1%	0.7%	0.7%	0.1%	7.2%
ESE	[101.25 , 123.75]	112.5	0.5%	2.9%	1.2%	0.1%	0.0%	0.0%	4.6%
SE	[123.75 , 146.25]	135	0.2%	2.4%	1.0%	0.0%	0.0%	0.0%	3.6%
SSE	[146.25 , 168.75]	157.5	0.3%	3.7%	1.2%	0.0%	0.0%	0.0%	5.1%
S	[168.75 , 191.25]	180	0.2%	3.3%	1.0%	0.0%	0.0%	0.0%	4.5%
SSW	[191.25 , 213.75]	202.5	0.8%	5.8%	3.0%	0.1%	0.0%	0.0%	9.7%
SW	[213.75 , 236.25]	225	0.1%	4.7%	5.0%	0.7%	0.3%	0.0%	10.8%
WSW	[236.25 , 258.75]	247.5	0.4%	5.3%	6.9%	1.0%	0.7%	0.0%	14.3%
W	[258.75 , 281.25]	270	0.2%	3.8%	4.0%	0.2%	0.0%	0.0%	8.3%
WNW	[281.25 , 303.75]	292.5	0.6%	5.0%	1.6%	0.0%	0.0%	0.0%	7.2%
NW	[303.75 , 326.25]	315	0.1%	1.9%	0.5%	0.0%	0.0%	0.0%	2.5%
NNW	[326.25 , 348.75]	337.5	0.4%	1.7%	0.3%	0.0%	0.0%	0.0%	2.4%
Total	[0 , 360]	TOTAL	5.2%	53.2%	33.1%	4.8%	2.5%	1.0%	99.7%
Other	No Direction	Current Speed = 0							0.3%