TECHNICAL MEMORANDUM

DATE 18 September 2020 **Project No.** 20142970

TO Mathew Miller, Senior Environmental Licensing Specialist, Northwest Territories Power Corporation

CC Kevin Rattray, Project Manager

FROM Allison Humphries, Senior Water Quality Specialist and Justine Crowe, Aquatic Biologist **EMAIL** ahumphries@golder.com

WATER QUALITY AND WATER TEMPERATURE DATA SUMMARY, JACKFISH LAKE, 2019 TO 2020

1.0 INTRODUCTION

The Northwest Territories Power Corporation (NTPC) owns and operates the Jackfish Lake Generating Facility (Jackfish Facility), located on the northeast shore of Jackfish Lake in Yellowknife, Northwest Territories (NT) (Figure 1-1). The Jackfish Facility provides electricity to the North Slave communities of Yellowknife, Behchokǫ̀, Dettah and Ndilǫ when the demand exceeds the capacity of the Snare and Bluefish Hydroelectric facilities, or during planned outages.

The Facility's cooling systems and the water withdrawal from Jackfish Lake were previously regulated under Water Licence N1L1-1632 (MVLWB 1995). NTPC prepared a Water Licence renewal application for the Facility and submitted it to the Mackenzie Land and Water Board (MVLWB) on 25 February 2019. On 27 September 2019, the MVLWB recommended that the new Water Licence (MV2019L1-0001; the Water Licence) be approved by the Government of Northwest Territories Minister of Environment and Natural Resources. The Water Licence was signed by the Minister and issued on 18 October 2019 (MVLWB 2019).

In 2018, in-lake and Facility intake and discharge water temperature and water quality monitoring were completed to support the Water Licence application, and to support subsequent monitoring expected to be required under the current Water Licence (Golder 2018). The Surveillance Network Program (SNP) in the current Water Licence does not require in-lake monitoring but does require monitoring of flow and water temperatures in the intakes and discharges of the Facility's cooling system (MVLWB 2019). The Water Licence also requires that NPTC develop and implement a Thermal Plume Delineation Study Design, which includes monitoring temperatures and water quality in Jackfish Lake (MVLWB 2019). Upon completion of the Thermal Plume Delineation Study, the Water Licence requires that NTPC develop and implement an Aquatic Effects Monitoring Program (AEMP) Design Plan (MVLWB 2019).

This technical memorandum provides a description of the 2019 and 2020 (up to August 2020) environmental monitoring program for water temperature and water quality measurements in Jackfish Lake and the results of the program. Sampling frequency and station locations are described in Section 2. Field methods, quality assurance (QA) and quality control (QC) practices and results are provided for water temperature and water quality in Sections 3 and 5, respectively.

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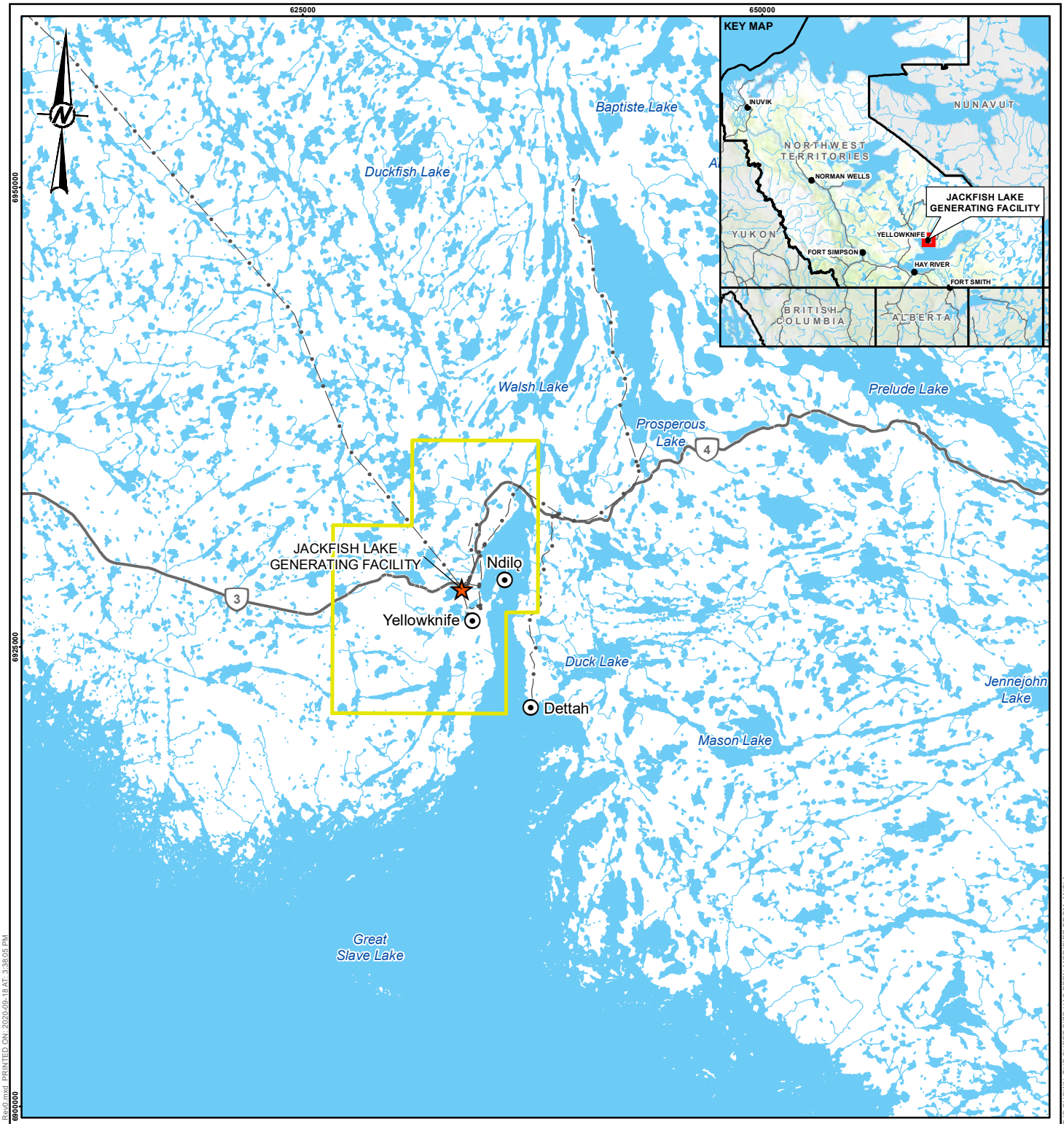
1.1 Location and Facility

Jackfish Lake is located on the northern end of Yellowknife, immediately southwest of the intersection of Highway 3 and the former access to the Ingraham Trail, and approximately 300 m south of the Yellowknife Solid Waste Facility (Figure 1-1). Flow from lake outlet drains toward Yellowknife Bay of Great Slave Lake, approximately 750 m east of Jackfish Lake. The topography throughout the area is similar and typical of the Precambrian Shield. Lakes and ponds are frequent in the area and vary in size and depth. Jackfish Lake, which was formerly known as Stock Lake, is located in an area of low rocky hills which are sparsely covered with black spruce, popular, and birch (Roberge and Gillman 1986). The lake has a surface area of approximately 0.6 km^2 (Baker 1987).

The diesel generating units at the Jackfish Facility are only utilized when there is an instantaneous loss of hydro supply (outage or planned maintenance), a shortage of hydro generating capacity or there is a diminished supply of hydro due to low water inflows. Lake water is used to cool the generators in the system. The Jackfish Facility has three different diesel power plants; the CAT Plant, EMD Plant and the K-Plant (Figure 1-2). Each plant has an engine cooling system that circulates cooling water from Jackfish Lake. K-Plant has two intakes, and EMD Plant and CAT Plant each have one intake; each plant has one discharge pipe. With all pumps running, the Jackfish Facility raw water pumps have the capacity to cycle through and discharge water at a rate of 0.58 m^3/s. Based on 2016 rates, the mean annual discharge from the Jackfish Facility to Jackfish Lake was 0.47 m^3/s of water (NTPC 2019).



LEGEND

- PROJECT LOCATION
- COMMUNITY
- ACTIVE TRANSMISSION LINE
- HIGHWAY
- WATERCOURSE
- WATERBODY
- YELLOWKNIFE MUNICIPAL BOUNDARY

0 5 10

1:300,000 KILOMETRES

REFERENCE(S)

BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA AND GNWT, © 2005 GOVERNMENT OF CANADA WITH PERMISSION FROM INDIAN AND NORTHERN AFFAIRS CANADA. PUBLIC SECTOR DATASETS MADE AVAILABLE UNDER THE CITY OF YELLOWKNIFE'S OPEN DATA LICENSE V.1. TOPOGRAPHIC MAP © ESRI AND ITS LICENSORS. USED UNDER LICENSE, ALL RIGHTS RESERVED.
DATUM: NAD 83 PROJECTION: UTM ZONE 11

CLIENT
NORTHWEST TERRITORIES POWER CORPORATION

PROJECT
JACKFISH LAKE ENVIRONMENTAL MONITORING

TITLE
REGIONAL LOCATION OF JACKFISH LAKE

CONSULTANT
GOLDER

YYYY-MM-DD	2020-09-18
DESIGNED	JC
PREPARED	AA
REVIEWED	AH
APPROVED	DP

PROJECT NO.	CONTROL	REV.	FIGURE
20142970	4000-4020	0	1-1

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25mm

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PATH: I:\2020\20142970\Mapping\Products\WaterQuality\20142970_Fig1-1_Regional_Location_Revised_PRINTED ON: 2020-09-18 AT: 3:38:05 PM

REFERENCE(S)
AERIAL PHOTO PROVIDED BY CLIENT, 2018.

CLIENT
NORTHWEST TERRITORIES POWER CORPORATION

PROJECT
JACKFISH LAKE ENVIRONMENTAL MONITORING

TITLE
JACKFISH LAKE GENERATING STATION 2019 AND 2020

CONSULTANT
GOLDER

YYYY-MM-DD	2020-09-18
DESIGNED	JC
PREPARED	AA
REVIEWED	AH
APPROVED	DP

PROJECT NO.	CONTROL	REV.	FIGURE
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2.0 ENVIRONMENTAL MONITORING OVERVIEW

2.1 Objectives

The overall objectives of the 2019 and 2020 Jackfish Lake environmental monitoring program were to continue collection of environmental monitoring data to build an environmental dataset for the lake to inform analysis of the potential effects of the cooling system water discharges on Jackfish Lake. The temperature data from 2019 and 2020 may also be used to meet, in part, the SNP requirements for monitoring temperatures in the intakes and discharges. The 2019 and 2020 water temperature and field water quality profiles also provide supplementary in-lake data for the Thermal Plume Study and to support development of the AEMP Design Plan.

2.2 Components

Monitoring in 2019 and 2020 can be divided into two components:

- Water Temperature (Section 3)
- Water Quality (Section 4)

2.3 Sampling Locations

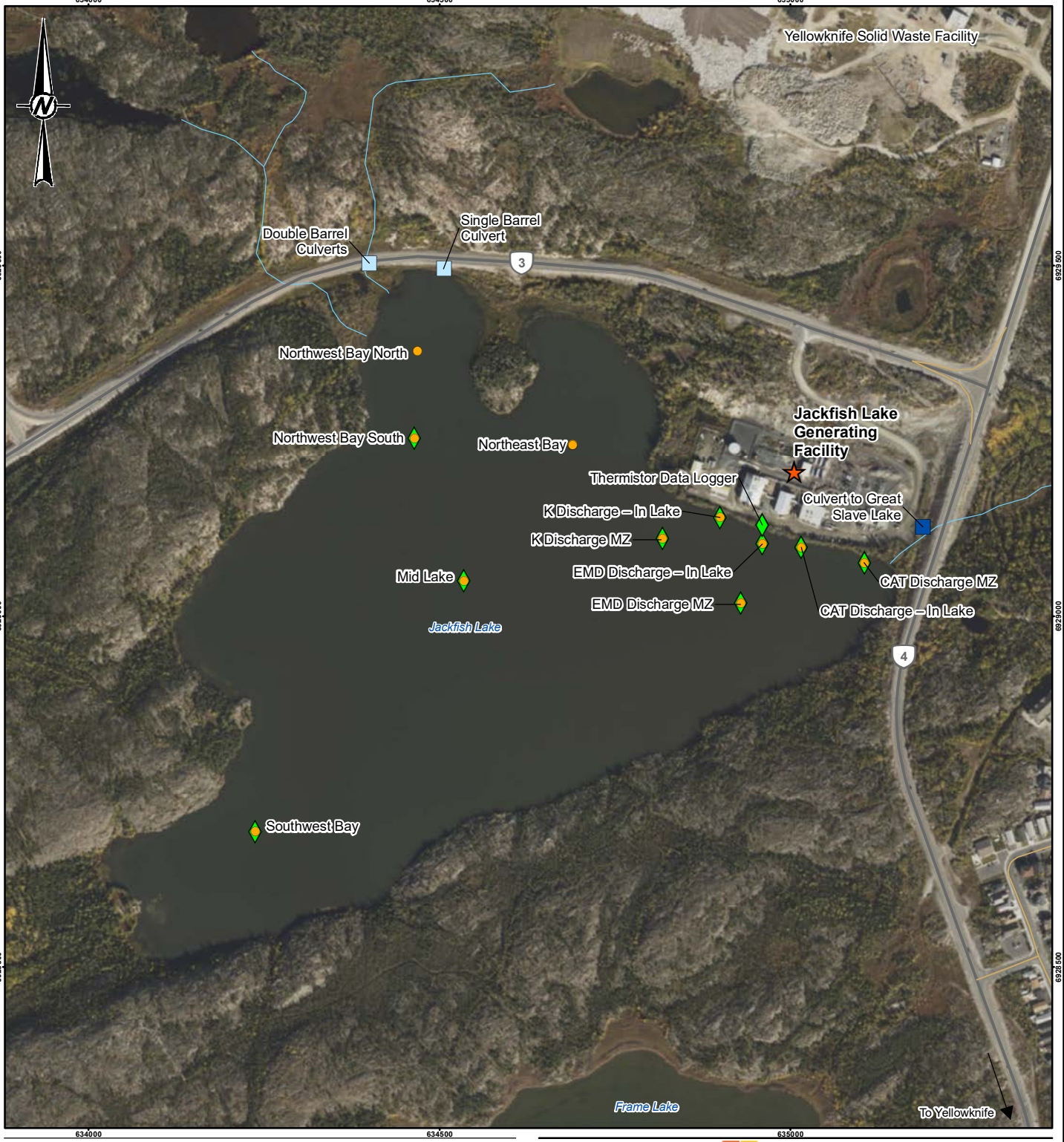
Water temperature and water quality sampling locations that were selected in 2018 (Golder 2019) were retained for monitoring in 2019 and 2020. Three additional water temperature and water quality monitoring locations (i.e., K Discharge MZ, EMD Discharge MZ, and CAT Discharge MZ in Table 2-1), which are 100 m out from each of the three plant discharge lines, were added in 2019. The monitoring stations for water temperature and water quality are shown in Figure 2-1 and are described in Table 2-1.

Table 2-1: 2019 and 2020 Environmental Monitoring Stations, Jackfish Lake and Facility

Station	UTM Coordinates (NAD 83, Zone 11)		Monitoring Activity			
	Easting	Northing	Temperature Logger Download	Thermistor Download	Water Quality Profile	Temperature Logger Location Check
K Discharge – In Lake	634900	6929141	✓	-	✓	✓
EMD Discharge – In Lake	634960	6929103	✓	-	✓	✓
CAT Discharge – In Lake	635016	6929098	✓	-	✓	✓
K Discharge MZ	634818	6929110	✓	-	✓	✓
EMD Discharge MZ	634930	6929018	✓	-	✓	✓
CAT Discharge MZ	635106	6929076	✓	-	✓	✓
K and EMD	634917	6929104	-	-	✓	-
EMD and CAT	634982	6929082	-	-	✓	-
Mid-Lake	634535	6929050	✓	-	✓	✓
Northwest Bay South	634464	6929253	✓	-	✓	✓
Southwest Bay	634237	6928693	✓	-	✓	✓
Northwest Bay North	634468	6989378	-	-	✓	-
Northeast Bay	634690	6929244	-	-	✓	-
Thermistor Data Logger[(a)]	634960	6929130	-	✓	-	-

(a) Thermistor data logger is the download point for the seven thermistors on the discharges and intakes of K Plant, EMD Plant and CAT Plant.

UTM = Universal Transverse Mercator; ✓ = monitoring is required at station; - = sampling not applicable to station.



LEGEND

- PROJECT LOCATION
- INFLOW CULVERT
- OUTFLOW CULVERT
- TEMPERATURE DATA LOGGER
- WATER QUALITY
- HIGHWAY
- LOCAL ROAD
- WATERCOURSE

0 200 400

1:8,000 METRES

REFERENCE(S)

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PROJECTION: UTM ZONE 11 DATUM: NAD 83

CLIENT
NORTHWEST TERRITORIES POWER CORPORATION

PROJECT
JACKFISH LAKE ENVIRONMENTAL MONITORING

TITLE
2019 AND 2020 JACKFISH LAKE ENVIRONMENTAL MONITORING STATIONS

CONSULTANT
GOLDER

YYYY-MM-DD	2020-09-18
DESIGNED	JC
PREPARED	AA
REVIEWED	AH
APPROVED	DP

PROJECT NO.	CONTROL	REV.	FIGURE
20142970	4000-4020	0	2-1

2.4 Monitoring Schedule

Dates for monitoring activities for each component are provided in Table 2-2. Temperature data collected in Jackfish Lake and the intakes and discharges are collected continuously and downloaded during each monitoring event. Data from June 2019 to August 2020 are included in this report; however, plots of temperature include data from the 2018 monitoring programs for completeness. To capture seasonal variability in water quality field measurements in Jackfish Lake, four monitoring events were conducted for water quality in 2019 and 2020: spring, summer, and fall in 2019 and late winter in 2020 (Table 2-2).

Table 2-2: 2019 and 2020 Environmental Monitoring Sampling Schedule, Jackfish Lake

Sampling Events	Dates	Monitoring Activity	
		Water Temperature Logger Download	Water Quality Field Profile Measurements
2019 Spring Field Program	6 and 7 June 2019	✓(a)	✓
2019 Summer Field Program	14 and 15 August 2019	✓	✓
2019 Fall Field Program	26 and 27 September 2019	✓	✓
2020 Winter Field Program	11 and 12 March 2020	✓(b)	✓(b)
2020 Spring Field Program	16 July 2020	-(c)	-
2020 Summer Field Program	11 August 2020	✓	-

(a) Temperature data loggers installed at CAT MZ, EMD MZ, K MZ stations.
(b) Profiles and temperature logger downloads were only able to be collected from stations with thicker ice (Northwest Bay South, Northwest Bay North, Mid Lake, Northeast Bay, Southwest Bay) due to health and safety concerns with thin ice conditions in proximity to the discharge area.
(c) Relocation of loggers which had moved, data was not downloaded.
UTM = Universal Transverse Mercator; ✓ = monitoring completed during sampling event; - = monitoring activity not applicable to sampling event.

3.0 WATER TEMPERATURE

3.1 Introduction

Instrumentation to record temperatures at the cooling water intakes and discharges, and throughout Jackfish Lake, were installed in March 2018 and have operated continuously since installation, except for instances of instrument failure (Golder 2019). Instrumentation originally installed in 2018 was replaced when damaged or found to malfunction. Three additional temperature monitoring stations located 100 m from each of the discharges were installed in 2019 and monitored in 2019 and 2020 (Section 2.3).

3.2 Methods

3.2.1 Water Temperature Monitoring

Water temperature at the plant intakes and discharges were measured using RST Instruments 3K negative temperature coefficient thermistors[1], which were installed on the grate of each intake and the end of pipe of each discharge pipe, for a total of seven thermistors. These thermistors are connected to one data logger (referred to as the thermistor data logger). Thermistors were originally installed on 14 March 2018; additional details related to installation of these thermistors are included in Golder (2019). The thermistor data logger was installed on 9 April 2018.

[1] Sensor accuracy for a RST 3K negative temperature coefficient thermistor is ±0.1°C from 0° to 75°C

Water temperature within Jackfish Lake was measured using multiple self-contained temperature dataloggers suspended vertically in the water column at each in-lake temperature monitoring station and were set using an anchor, steel cable, and buoy as described by Golder (2019), with a pole buoy and flag also attached to the cable for stations that freeze in ice during the winter (i.e., all stations except for: K Discharge – In Lake, EMD Discharge – In Lake and CAT Discharge – In Lake).

Three additional in-lake water temperature monitoring stations were established 100 m from the end of the discharge pipe of each generating plant on 6 and 7 June 2019: K Discharge MZ, EMD Discharge MZ and CAT Discharge MZ). These stations were assembled using the same approach used in 2018 (Golder 2019), with three temperature data loggers (HOBO Pendant MX Water Temperature Data Loggers[2] distributed along its depth. Temperature data loggers were positioned 1.2 m to 1.4 m below the water surface, 1.0 m to 1.1 m above the lake bottom, and approximately at mid-depth. Extra length was included in the construction of the thermistors strings to allow for seasonal increases to lake water level and to prevent wave action from lifting anchors from the lake bed. On 11 August 2020 all of the in-lake temperature loggers were changed to the same type and model (HOBO Pendant MX Water Temperature Loggers[2]) for consistency between all stations and also to avoid data gaps due to equipment failure from other older temperature logger models.

Table 3-1: In-Lake Temperature Monitoring Station Lengths and Data Logger Positions, 2019

In-Lake Monitoring Station	Total String Length (m)	Data Logger Depth from Buoy (m)			
		Top	Middle	Middle2	Bottom
K Discharge MZ	7.9	1.2	4.0	-	6.9
EMD Discharge MZ	8.2	1.3	4.1	-	7.1
CAT Discharge MZ	6.4	1.4	3.4	-	5.4
K Discharge - In Lake[(a)]	2.50	0.20	0.90	-	1.50
EMD Discharge - In Lake[(a)]	5.00	0.30	2.50[(b)]	-	4.00
CAT Discharge - In Lake[(a)]	3.40	0.40	1.90	-	2.55
Mid-Lake[(a)]	8.54	1.00	3.37	5.54	7.54
Northwest Bay South[(a)]	8.50	1.00	4.25	-	7.50
Southwest Bay[(a)]	5.60	1.00	2.80	-	4.60

(a) Originally presented by Golder (2019) and lengths and data logger positions are unchanged.
(b) A data logger was installed at the same depth in duplicate as a quality assurance/quality control measure.
- = logger was not installed at this position.

After the ice was off of the lake in 2019 and 2020, in-lake temperature loggers were downloaded and each string was repositioned to account for drifting of the stations due to wind/ice break-up. Data were also downloaded from the thermistor data logger. After ice-off, in-lake temperature data logger and thermistor logger downloads were paired with water quality field programs (Table 2-2) so data collection was completed at the same time.

Prior to freeze up of Jackfish Lake, on 26 and 27 September 2019, each of the nine in-lake temperature stations and the thermistor data logger were visited. Data were downloaded, and coordinates of loggers were checked to confirm that in-lake temperature stations would overwinter in the correct location. Stations were marked with a flagged buoy to facilitate their location in March 2020.

[2] Sensor accuracy for the Onset “HOBO MX2204” is ±0.25°C from -20° to 0°C, ±0.2°C from 0° to 70°C

Stations near the Jackfish Facility do not completely freeze up during winter months due to the warmer water from the diffuser. This causes ice conditions near the facility to be thin and dangerous and personnel trained in ice rescue are required to conduct the field work. The winter field program was originally planned to occur in December 2019, however due to a lack of availability of personnel trained in ice rescue or Ice Rescue Technician supervisor and extreme cold weather days, the program was delayed until the following year in March 2020. During the winter field program on 11 and 12 March 2020, data from the in-lake temperature data loggers were downloaded from three stations that were under ice (Mid-Lake, Northwest Bay South, and Southwest Bay). These three temperature data logger strings were accessed by drilling a hole using an auger adjacent to the flagged buoy and using a hook to pull the string above the ice. Six in-lake temperature monitoring stations near the Jackfish Facility (K Discharge MZ, EMD Discharge MZ, CAT Discharge MZ, K Discharge-In Lake, EMD Discharge-In Lake, and CAT Discharge-In Lake) were in open water during the winter program. The six stations in open water were not visited during the March winter program because trained personnel in ice rescue continued to be unavailable and training was not possible due to the COVID-19 pandemic.

Instrumentation for temperature monitoring, including in-lake temperature data logger strings and thermistors, remains installed and recording in Jackfish Lake for future use (e.g., for the Thermal Plume Delineation Study) by NTPC.

3.3 Data Analysis

3.3.1 Water Temperature

Data from in-lake temperature data loggers were compiled into a spreadsheet. Data points that were non-representative of lake temperature (e.g., before initial installation and when loggers are pulled from the lake for data downloads) were identified and removed from the compiled dataset. Data from the thermistor data logger were compiled in the same manner. From this compilation, plots of temperatures within Jackfish Lake and at the intakes and discharges were generated.

3.4 Quality Assurance/Quality Control

The QA/QC measures taken for the temperature work included following specific work instructions (SWIs) and manufacturers recommendations for installation and operation of the equipment, installing a duplicate in-lake data logger for temperature (i.e., at EMD discharge mid-depth), inspecting the data loggers during each download, comparing hand-held measurements to in-lake logger measurements, and examining the data for suspect or invalid data. The duplicate data logger showed minimal differences in temperature readings (Figure 3.1). Alterations and re-locations of the in-lake instrumentation were needed on multiple occasions to accommodate local weather effects in 2019 and 2020 including high wind, ice break-up and heavy rains that created high water levels. Some data exclusions and gaps were noted; however, data were generally acceptable for use.

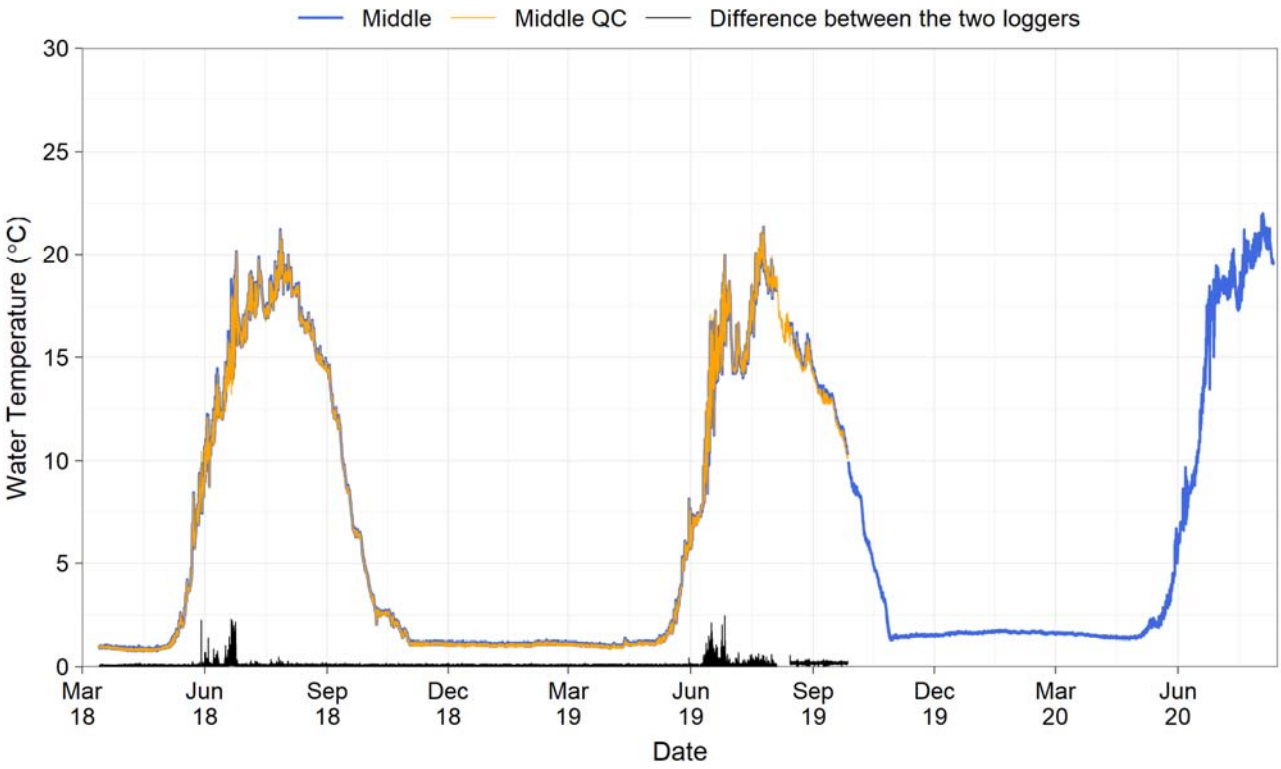

Figure 3-1: Quality Control Plot Comparing Temperatures from In-lake Data Logger to Duplicate, April 18 to August 20

3.5 Results

Summary plots of continuous water temperature data are presented in Section 3.5.1 for the Jackfish Facility intakes and discharges and Section 3.5.2 for in-lake locations. Compiled thermistor and in-lake temperature logger data have been provided digitally to NTPC.

3.5.1 Intake and Discharge Temperatures

Three temperature plots for the intakes and discharges are provided:

- Figure 3.2 shows temperatures separately for the intakes to and discharges from each plant from April 2018 to August 2020.
- Figure 3.3 shows temperatures for the intakes to and discharges together from each plant from April 2018 to August 2020.
- Figure 3.4 shows the temperature difference between the intakes and discharges of each plant from April 2018 to August 2020

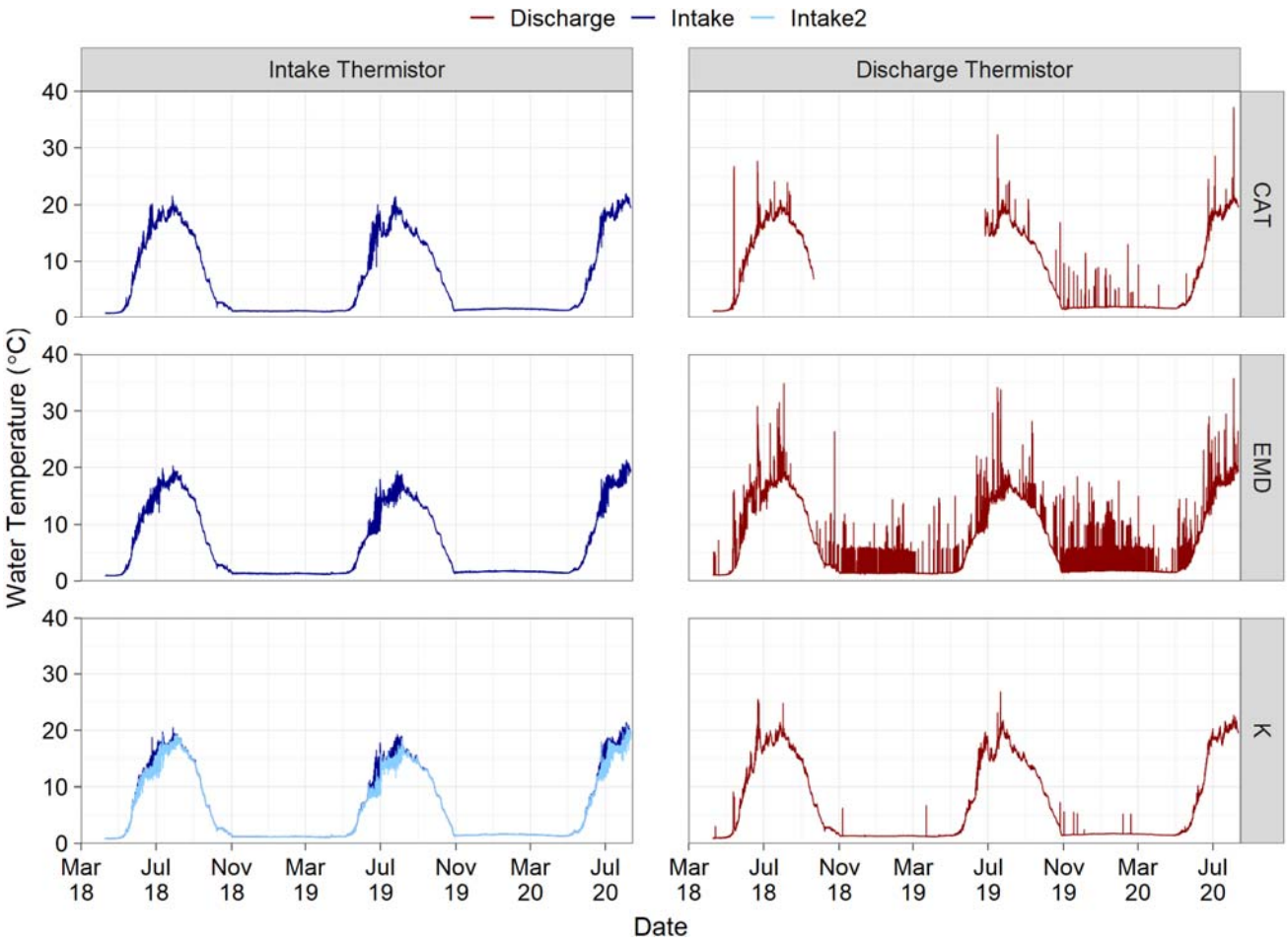

Figure 3-2: Water Temperature in the Individual Intakes and Discharges of each Plant, April 2018 to August 2020

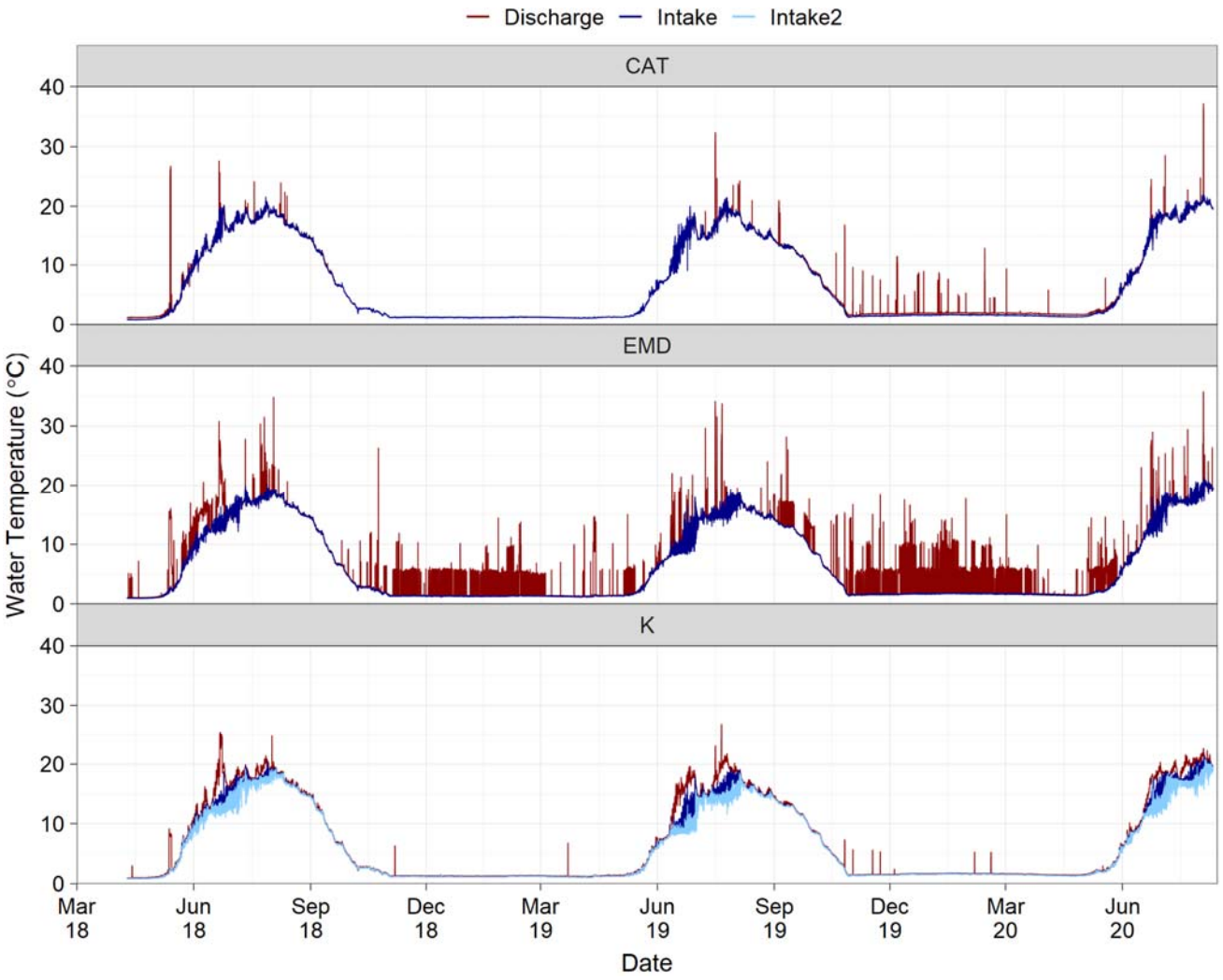

Figure 3-3: Water Temperature in Both Intakes and Discharges of each Plant, April 2018 to August 2020

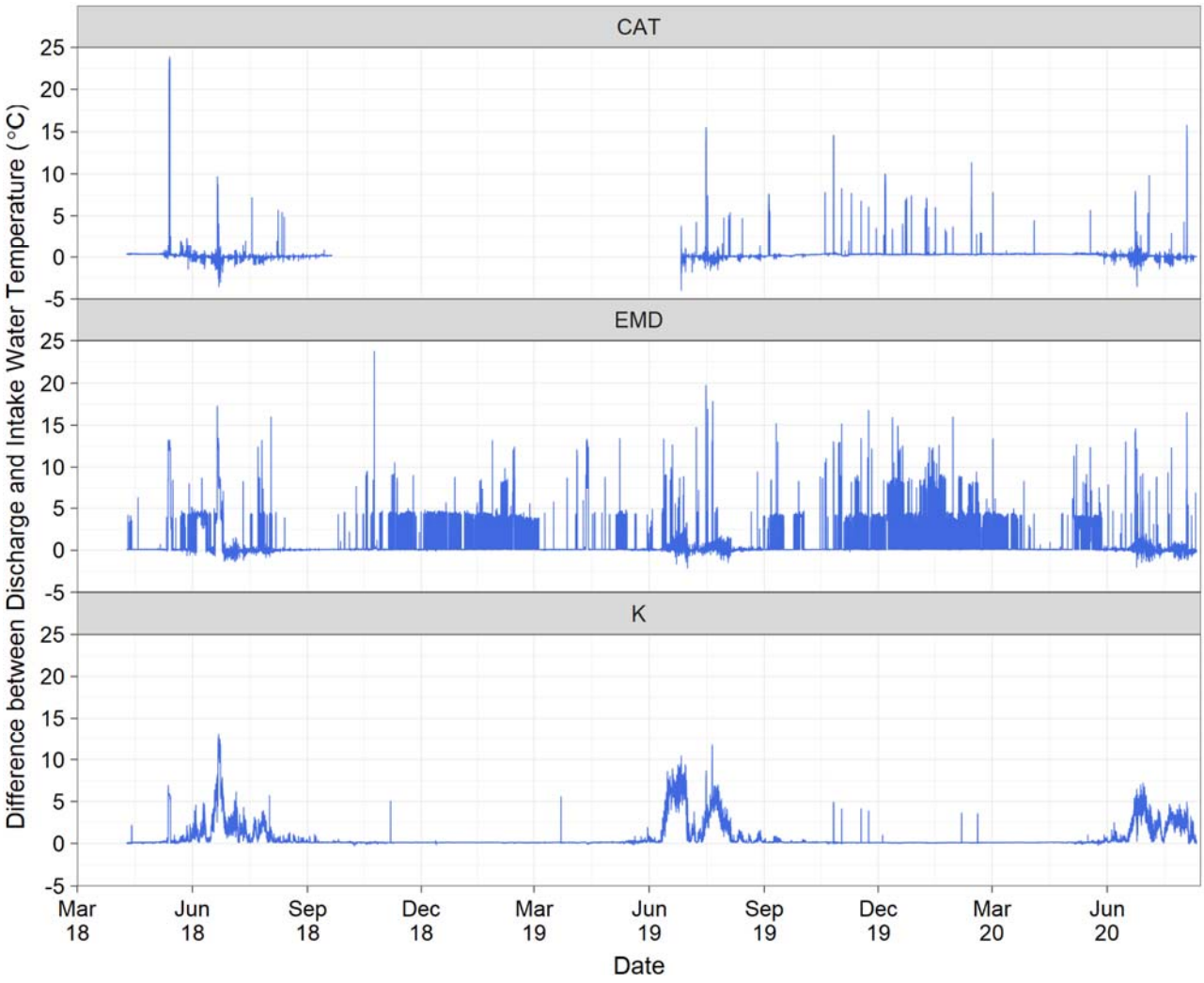

Figure 3-4: Difference in Water Temperature between Intakes and Discharges of each Plant, April 2018 to August 2020

3.5.2 In-Lake Temperatures

Three temperature plots for the in-lake monitoring locations are provided:

- Figure 3.5 shows temperatures for each sampling depth and location separately in Jackfish Lake from April 2018 to August 2020.
- Figure 3.6 shows temperatures for different depths at each sampling location in Jackfish Lake from April 2018 to August 2020.
- Figure 3.7 shows temperatures for each sampling depth from April 2018 to August 2020.

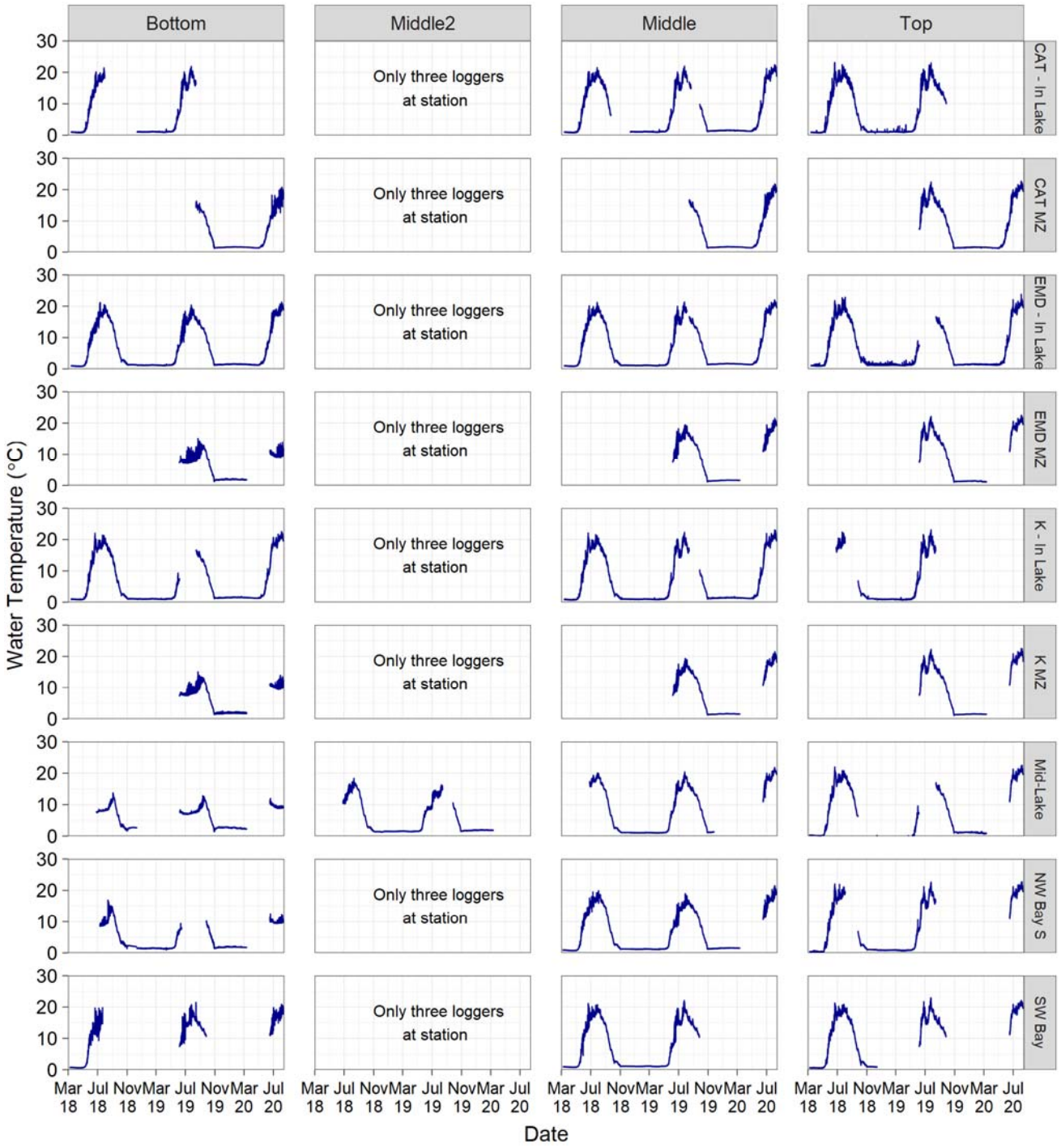

Figure 3-5: Water Temperatures at Different Depths for each Station in Jackfish Lake, April 2018 to August 2020

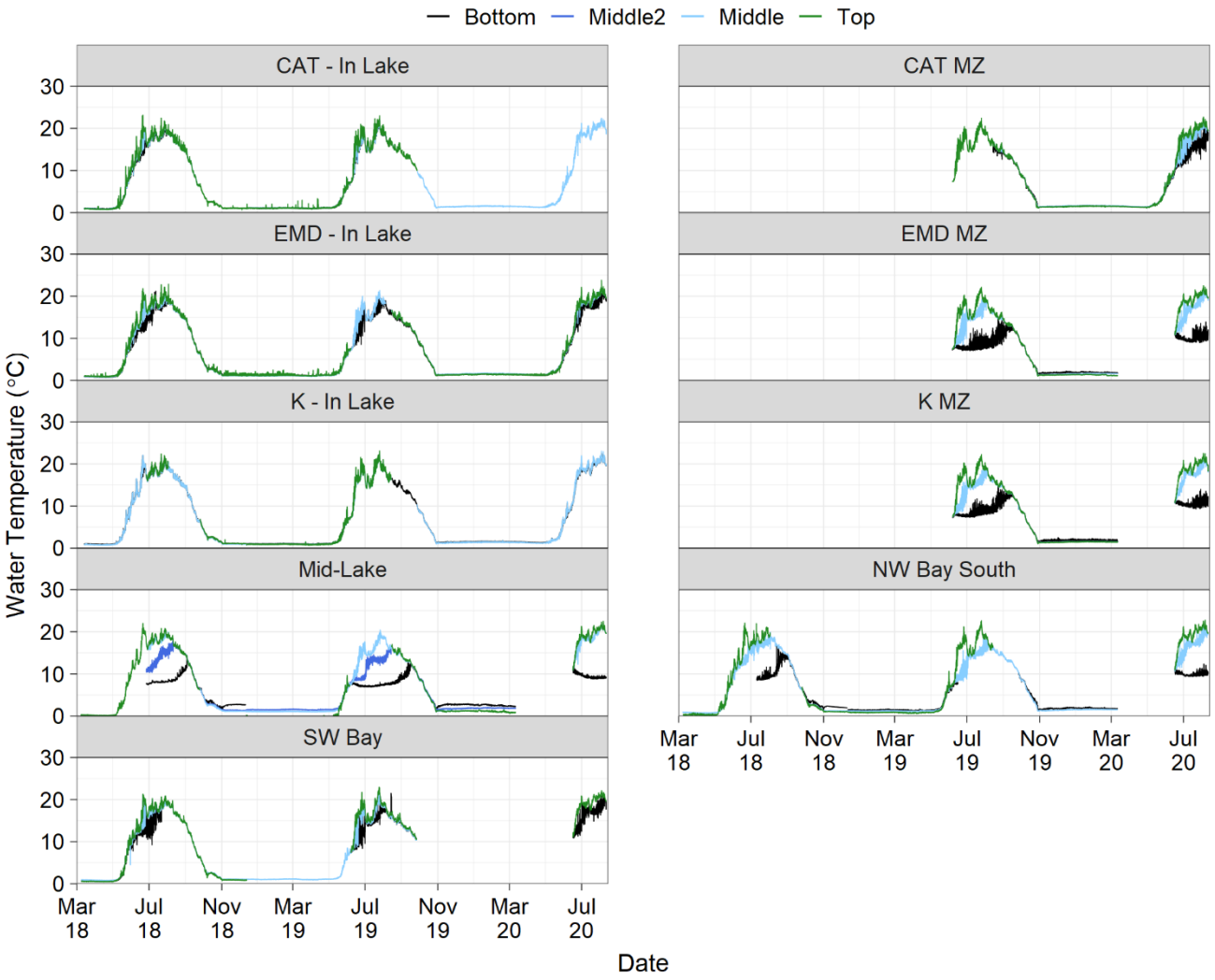

Figure 3-6: Water Temperatures at each Jackfish Lake Station from April 18 to August 2020

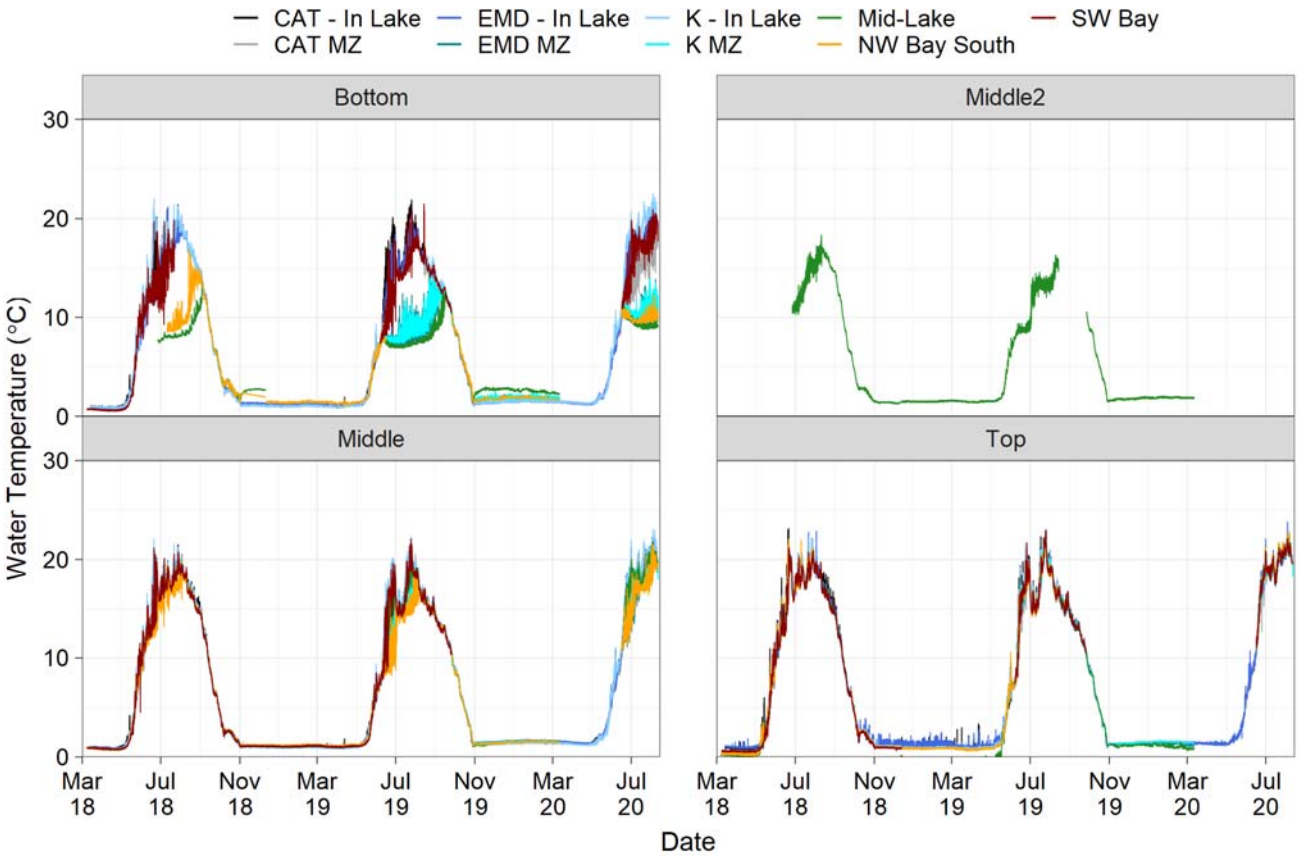

Figure 3-7: Water Temperatures in Jackfish Lake at Different Sampling Depths, April 2018 to August 2020

4.0 WATER QUALITY

4.1 Introduction

In-situ water quality field profile measurements were completed in Jackfish Lake in 2019 and 2020. A detailed description of the field methods used to collect the water quality data in 2019 and 2020 is provided in Section 4.2. A summary of QA/QC measures completed for the program are provided in Section 4.3 and results, including QA/QC results, are provided in Section 4.4 (Tables 4-1 to 4-4).

4.2 In-Situ Water Quality Field Methods

Three water quality monitoring events were completed in Jackfish Lake in 2019 (June, August, and September) and one in 2020 (March). Each monitoring event required one to two days to complete. Monitoring was completed at 13 stations in Jackfish Lake after ice break-up (early-June), summer (Mid-August), fall (late-September) in 2019 (Figure 2-1, Tables 2-1 and 2-2). In-situ water quality monitoring was completed at 13 stations in Jackfish Lake during each visit in 2019 (Figure 2-1, Table 2-1, Table 2-2). The winter program was delayed to March 2020 due to health and safety reasons (Section 3.2.1) and only five under ice stations were visited during the winter program (Mid-Lake, Northwest Bay North, Northwest Bay South, Northeast Bay, and Southwest Bay).

Field in-situ profile measurements were recorded at 1-m depth intervals using a handheld multi-parameter water quality meter (SmarTROLL, AquaTroll) to record:

- depth (m)
- water temperature (°C)
- pH
- dissolved oxygen (DO; as mg/L and% saturation)
- specific conductivity (microsiemens per centimetre [µS/cm])

Total water depth and Secchi depth was also measured at each water quality station. Secchi depth was not collected during the 2020 winter program because only under-ice stations were accessible.

4.3 Quality Assurance/Quality Control Summary

The QA/QC measures taken for collecting water quality field measurements included following SWIs and standardized technical procedures in the field, calibrating and maintaining the equipment as per manufacturer's instructions and technical procedures, performing calibration checks at the end of the day and reviewing data for transcription errors or unexpected or inconsistent results.

Prior to each field program, handheld multiparameter water quality meters were calibrated daily to ensure accuracy of readings. A same-day post-field parameter check was performed at the end of each field day to detect if the probes were experiencing drifting during the field programs.

Water quality field profiles were conducted prior to temperature logger downloads to avoid mixing up the water column by retrieving the moorings. Profile readings were only collected while the meter was being lowered. At the first station visited each day, the multiparameter meter was allowed to stabilize at the first depth for 10 minutes before collecting profile measurements even if values appeared to stabilize sooner. After the profile was completed at each station, the multiparameter meter was brought back to a depth of 1m and allowed to stabilize to compare the initial values at the first depth. A second profile measurement was collected if the values were different by more than:

- 0.5 pH unit for pH
- 1.5 mg/L for dissolved oxygen
- 10 µS/cm for specific conductivity
- 1°C for temperature

If the criteria were not met after the second profile, the data were qualified because the probe may have not fully stabilized prior to collecting the measurement.

The water quality data from field data sheets were entered into Excel spreadsheets and a 20 to 30% QA/QC transcription check was conducted by a different person. Data were also reviewed for inconsistent results between stations within each monitoring event or unexpected or unusual results (e.g., temperatures below 0°C or values above or below typical values for Jackfish Lake) and qualified or invalided if there was sufficient evidence to do so (e.g., based on calibration checks or issues with stabilization of the probe).

4.4 Results

4.4.1 Water Quality

In-situ field profile water quality measurements are presented in Tables 4-1 to 4-4. Qualified data were limited to specific conductivity data as noted in Tables 4-1 to 4-4. Specific conductivity measurements collected on 6 and 7 June 2019 and 26 September 2019 were qualified due to calibration issues with the conductivity probe and inconsistent measurements during the monitoring event (e.g., conductivity was consistently higher during one day compared to another). The remaining qualified specific conductivity data were qualified because the probe did not fully stabilize prior to taking the measurement. Two pH measurements collected at Mid Lake on 11 March 2020 were invalidated because they were unusually high (greater than 9) for Jackfish Lake and the probe did not stabilize prior to collecting the measurement. Measurements of pH were not collected on 12 March 2020 due to issues with the pH probe.

Table 4-1: Water Quality Field Measurements in Jackfish Lake, June 2019

Station	Date	UTM: NAD83, Zone 11V, Easting	Northing	Ice Thickness [m]	Secchi Depth [m]	Total Depth (m)	Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Dissolved Oxygen [% Sat]	pH	Specific Conductivity [µS/cm]
K Discharge-In Lake	07-Jun-19	634898	6929141	-	0.3	2	1	7.4	11.4	97	8.0	524
EMD Discharge-In Lake	07-Jun-19	634963	6929112	-	0.3	4.2	1	7.3	12.1	102	8.0	523
							2	7.3	12.1	102	8.0	523
							3	7.3	12.0	102	8.0	523
CAT Discharge-In Lake	07-Jun-19	635017	6929099	-		2.7	1	7.4	11.3	95	8.0	523
							2	7.3	11.3	95	7.9	523
K Discharge MZ	06-Jun-19	634825	6929112	-	0.3	7.6	1	7.4	10.9	93	7.9	467
							2	7.4	10.9	93	7.9	467
							3	7.4	10.9	92	7.9	467
							4	7.3	10.8	92	7.9	467
							5	7.3	10.7	91	7.9	467
							6	7.3	10.7	90	7.9	467
							7	7.2	10.6	90	7.9	467
EMD Discharge MZ	06-Jun-19	634933	6929014	-	0.3	8.1	1	7.3	10.9	93	7.9	467
							2	7.3	10.9	93	7.9	467
							3	7.3	10.9	93	7.9	467
							4	7.3	10.9	93	7.9	467
							5	7.3	10.9	93	7.9	467
							6	7.3	10.9	93	7.9	467
							7	7.3	10.9	92	7.9	467
CAT Discharge MZ	06-Jun-19	635100	6929061	-	0.3	6	1	7.2	10.9	92	7.9	467
							2	7.2	10.8	91	7.9	467
							3	7.1	10.7	90	7.9	467
							4	7.1	10.7	90	7.9	468
							5	7.1	10.6	90	7.9	468
K+EMD	07-Jun-19	634917	6929098	-	0.3	7.2	1	7.4	12.5	106	8.1	523
							2	7.4	12.4	105	8.0	523
							3	7.4	12.4	105	8.0	522
							4	7.3	12.3	104	8.0	523
							5	7.3	12.3	104	8.0	523
							6	7.3	12.3	104	8.0	523
EMD+CAT	07-Jun-19	634980	6929078	-	0.3	7.2	1	7.3	11.4	96	8.0	523
							2	7.3	11.3	96	8.0	523
							3	7.3	11.3	95	8.0	523
							4	7.3	11.3	95	8.0	523
							5	7.3	11.2	95	8.0	523
							6	7.3	11.1	94	8.0	523
Mid-Lake	06-Jun-19	634542	6929047	-	0.3	8.5	1	7.6	11.1	95	8.0	467
							2	7.6	11.2	95	8.0	467
							3	7.6	11.1	95	8.0	467
							4	7.6	11.2	95	8.0	467
							5	7.6	11.1	95	8.0	467
							6	7.6	11.1	94	8.0	466
							7	7.6	11.1	94	8.0	466
							8	7.6	11.1	94	7.9	467
Northwest Bay North	07-Jun-19	634467	6929331	-	0.3	5.9	1	7.4	12.5	106	8.1	523
							2	7.4	12.4	105	8.0	522
							3	7.4	12.1	102	8.0	522
							4	7.3	11.7	99	7.9	522
							5	7.2	11.1	93	7.8	524
Northwest Bay South	06-Jun-19	634463	6929238	-	0.3	8.0	1	7.5	12.0	102	8.0	466
							2	7.6	12.0	102	8.0	466
							3	7.6	12.0	102	8.0	466
							4	7.6	11.9	102	8.0	466
							5	7.6	12.0	102	8.0	466
							6	7.6	12.0	102	8.0	466
							7	7.5	11.6	99	8.0	466
Northeast Bay	07-Jun-19	634690	6929243	-	0.3	7.6	1	7.4	12.7	108	8.1	523
							2	7.4	12.6	107	8.0	523
							3	7.4	12.6	107	8.0	523
							4	7.4	12.6	106	8.0	523
							5	7.4	12.6	107	8.0	523
							6	7.4	12.5	106	8.0	523
							7	7.3	12.0	101	7.9	523
Southwest Bay	06-Jun-19	634229	6928639	-	0.3	4.4	1	7.7	11.5	98	8.1	466
							2	7.7	11.4	98	8.1	465
							3	7.7	11.4	97	8.1	466

Notes: % Sat = percent dissolved oxygen saturation; µS/cm = microsiemens per centimetre; - = no data collected.

<--Data are qualified due to inconsistent measurements of specific conductivity between 6 and 7 June 2019, which was likely due to calibration issues with the probe.

Table 4-2: Water Quality Field Measurements in Jackfish Lake, August 2019

Station	Date	UTM: NAD83, Zone 11V, Easting	Northing	Ice Thickness [m]	Secchi Depth [m]	Total Depth (m)	Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Dissolved Oxygen [% Sat]	pH	Specific Conductivity [µS/cm]
K Discharge-In Lake	14-Aug-19	634899	6929142	-	1.2	1.9	0.3	16.6	9.7	103	8.7	541
							1	16.6	9.7	102	8.7	541
EMD Discharge-In Lake	14-Aug-19	634964	6929133	-	1.2	4.1	0.3	16.5	9.5	100	8.7	542
							1	16.5	9.5	100	8.7	542
							2	16.4	9.3	97	8.7	541
							3	16.3	9.2	97	8.6	541
							4	16.2	8.7	91	8.6	542
CAT Discharge-In Lake	14-Aug-19	635019	6929096	-	1.2	3.9	0.3	16.8	9.5	101	8.7	542
							1	16.7	9.5	100	8.7	541
							2	16.6	9.5	100	8.7	541
							3	16.4	9.2	97	8.6	540
K Discharge MZ	14-Aug-19	634828	6929116	-	1.2	7.3	0.3	16.5	9.7	102	8.7	541
							1	16.6	9.7	102	8.7	542
							2	16.5	9.6	101	8.7	541
							3	16.4	9.4	98	8.7	541
							4	16.3	9.1	95	8.6	541
							5	16.2	8.7	90	8.6	542
							6	14.7	0.5	4	7.8	543
							7	12.0	0.0	0	7.3	544
EMD Discharge MZ	14-Aug-19	634936	6929017	-	1.2	7.7	0.3	16.5	9.6	101	8.7	542
							1	16.5	9.6	101	8.7	542
							2	16.5	9.5	100	8.7	542
							3	16.5	9.4	99	8.7	541
							4	16.4	9.4	99	8.7	542
							5	16.3	9.0	94	8.6	541
							6	14.7	1.9	18	8.1	542
							7	11.7	0.0	0	7.4	542
CAT Discharge MZ	14-Aug-19	635102	6929064	-	1.2	6	0.3	16.5	9.4	99	8.6	542
							1	16.5	9.4	98	8.6	542
							2	16.5	9.3	98	8.6	541
							3	16.4	9.2	97	8.6	541
							4	16.3	9.1	96	8.6	542
							5	16.3	9.0	95	8.6	542
K+EMD	15-Aug-19	634919	6929102	-	1.2	6.5	0.3	16.4	9.4	98	8.6	484
							1	16.5	9.4	99	8.6	484
							2	16.4	9.4	99	8.6	484
							3	16.4	9.4	98	8.6	484
							4	16.4	9.3	98	8.6	484
							5	16.2	8.6	89	8.5	484
							6	14.8	1.6	17	8.0	484
EMD+CAT	15-Aug-19	634984	6929080	-	1.3	6.6	0.3	16.5	9.4	99	8.6	484
							1	16.5	9.5	99	8.6	484
							2	16.5	9.5	100	8.6	484
							3	16.5	9.5	99	8.6	484
							4	16.4	9.4	99	8.6	484
							5	16.3	9.0	94	8.6	484
							6	5.1	2.9	29	8.1	483
Mid-Lake	14-Aug-19	634.546	6929038	-	1.3	8.2	0.3	16.9	9.8	104	8.7	541
							1	16.8	9.8	104	8.7	541
							2	16.7	9.8	104	8.7	541
							3	16.6	9.8	103	8.7	541
							4	16.4	8.7	91	8.6	541
							5	16.0	7.9	82	8.5	541
							6	15.4	4.7	44	8.2	540
							7	12.1	0.2	2	7.5	533
							8	9.6	0.0	0	7.0	588
Northwest Bay North	15-Aug-19	634467	6929380	-	1.5	5.2	0.3	16.5	9.3	97	8.6	485
							1	16.5	9.3	97	8.6	485
							2	16.4	9.2	96	8.6	484
							3	16.3	8.4	88	8.5	485
							4	16.2	8.3	87	8.5	485
							5	16.1	7.8	81	8.5	484
Northwest Bay South	14-Aug-19	634469	6929242	-	1.3	7.5	0.3	16.8	9.8	104	8.7	542
							1	16.7	9.8	103	8.7	540
							2	16.6	9.7	103	8.7	541
							3	16.4	9.3	98	8.7	541
							4	16.3	9.1	95	8.7	541
							5	16.1	7.8	81	8.5	542
							6	14.7	0.6	6	8.0	542
							7	12.0	0.0	0	7.3	541
Northeast Bay	15-Aug-19	634691	6929240	-	1.3	6.8	0.3	16.6	9.5	99	8.6	484
							1	16.5	9.4	99	8.7	484
							2	16.5	9.4	99	8.7	484
							3	16.5	9.4	99	8.7	484
							4	16.3	8.6	90	8.6	484
							5	16.1	7.6	79	8.5	485
							6	14.7	0.8	9	8.0	485
Southwest Bay	14-Aug-19	634228	6928638	-	1.3	4.0	0.3	16.7	9.7	103	8.7	540
							1	16.6	9.7	102	8.7	540
							2	16.4	9.4	99	8.7	541
							3	16.3	9.4	99	8.7	541

Notes: % Sat = percent dissolved oxygen saturation; µS/cm = microsiemens per centimetre; - = no data collected.

<--Data are qualified due to inconsistent measurements of specific conductivity between 14 and 15 August 2019, which was likely due to calibration issues with the probe.

Table 4-3: Water Quality Field Measurements in Jackfish Lake, September 2019

Station	Date	UTM: NAD83, Zone 11V, Easting	Northing	Ice Thickness [m]	Secchi Depth [m]	Total Depth (m)	Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Dissolved Oxygen [% Sat]	pH	Specific Conductivity [µS/cm]
K Discharge-In Lake	26-Sep-19	634900	6929139	-	0.4	1.9	0.3	10.3	9.1	83	7.9	477
							1	10.3	9.0	82	7.9	477
							2	10.3	8.7	79	7.8	477
							3	10.2	8.7	79	7.8	477
							4	10.2	8.7	79	7.8	477
EMD Discharge-In Lake	27-Sep-19	634966	6929110	-	0.4	5.9	0.3	10.5	9.2	84	7.8	448
							1	10.2	9.0	81	7.8	449
							2	10.0	9.0	81	7.8	447
							3	9.8	9.1	81	7.8	448
							4	9.8	9.1	81	7.8	448
							5	9.8	9.0	80	7.8	448
CAT Discharge-In Lake	27-Sep-19	635026	6929094	-	0.4	4.9	0.3	9.8	9.0	80	7.8	448
							1	9.8	9.0	80	7.8	448
							2	9.8	9.0	80	7.8	448
							3	9.8	9.0	80	7.8	448
							4	9.8	8.9	80	7.8	449
K Discharge MZ	26-Sep-19	634820	6929113	-	0.4	7.3	0.3	10.2	9.0	82	7.9	477
							1	10.2	9.0	82	7.9	477
							2	10.2	8.9	81	7.9	477
							3	10.2	8.9	81	7.9	477
							4	10.2	8.9	81	7.9	477
							5	10.2	8.9	81	7.9	477
							6	10.2	8.6	78	7.8	477
							7	10.2	8.3	76	7.8	477
EMD Discharge MZ	26-Sep-19	634935	6929015	-	0.4	7.6	0.3	10.3	9.0	82	7.9	477
							1	10.3	9.0	82	7.9	477
							2	10.3	9.0	82	7.9	477
							3	10.3	9.0	82	7.9	477
							4	10.3	9.0	82	7.9	477
							5	10.3	9.0	82	7.9	477
							6	10.3	8.9	81	7.9	477
							7	10.3	9.9	81	7.9	477
CAT Discharge MZ	27-Sep-19	635102	6929063	-	0.4	5.7	0.3	9.7	9.0	80	7.8	448
							1	9.7	9.1	81	7.8	448
							2	9.7	9.0	80	7.8	448
							3	9.7	8.9	80	7.8	447
							4	9.7	8.9	79	7.8	448
							5	9.7	8.9	79	7.8	448
K+EMD	27-Sep-19	634918	6929102	-	0.4	7.1	0.3	9.9	9.1	82	7.8	448
							1	9.9	9.1	81	7.8	448
							2	9.9	9.1	81	7.8	448
							3	9.9	9.0	81	7.8	448
							4	9.9	9.0	81	7.8	448
							5	9.8	9.0	80	7.8	448
							6	9.8	8.9	80	7.8	448
							7	9.8	8.0	71	7.5	443
EMD+CAT	27-Sep-19	634982	6929079	-	0.4	6.8	0.3	9.6	9.3	83	7.9	448
							1	9.8	9.2	82	7.9	448
							2	9.8	9.1	81	7.8	448
							3	9.8	9.1	82	7.8	448
							4	9.8	9.1	82	7.8	448
							5	9.8	9.2	82	7.8	448
							6	9.7	9.1	81	7.8	448
Mid-Lake	26-Sep-19	634536	6929049	-	0.4	8	0.3	10.2	8.8	80	7.8	477
							1	10.3	8.8	80	7.8	477
							2	10.3	8.8	80	7.8	477
							3	10.3	8.8	80	7.8	477
							4	10.2	8.7	80	7.8	477
							5	10.2	8.7	79	7.8	477
							6	10.2	8.7	79	7.8	477
							7	10.2	8.6	78	7.8	477
Northwest Bay North	26-Sep-19	634467	6929380	-	0.4	5.6	0.3	10.1	8.9	81	7.9	478
							1	10.2	8.8	80	7.8	478
							2	10.2	8.8	80	7.8	478
							3	10.2	8.9	81	7.8	477
							4	10.1	8.8	80	7.8	477
							5	10.1	8.5	77	7.8	477
Northwest Bay South	26-Sep-19	634468	6929233	-	0.4	7.5	0.3	10.2	9.0	81	7.8	477
							1	10.2	9.9	81	7.8	477
							2	10.2	8.8	80	7.8	477
							3	10.2	8.8	80	7.8	477
							4	10.2	8.8	80	7.8	477
							5	10.2	8.6	78	7.8	477
							6	10.2	8.4	77	7.8	477
							7	10.1	8.4	76	7.8	476
Northeast Bay	26-Sep-19	634689	6929244	-	0.4	7.2	0.3	10.2	9.3	85	7.9	477
							1	10.2	9.3	84	7.9	477
							2	10.2	9.1	83	7.9	477
							3	10.2	9.1	83	7.9	477
							4	10.2	8.8	80	7.9	477
							5	10.2	8.6	78	7.8	477
							6	10.2	8.6	78	7.8	477
							7	10.0	8.0	73	7.8	476
Southwest Bay	26-Sep-19	634233	6928638	-	0.4	4	0.3	10.1	9.1	83	7.8	477
							1	10.1	9.1	83	7.8	477
							2	10.1	9.0	82	7.8	477
							3	10.0	8.9	81	7.8	477
							4	9.9	8.2	73	7.7	470

Notes: % Sat = percent dissolved oxygen saturation; µS/cm = microsiemens per centimetre; - = no data collected.

Table 4-4: Water Quality Field Measurements in Jackfish Lake, March 2020

Station	Date	UTM: NAD83, Zone 11V, Easting	Northing	Ice Thickness [m]	Secchi Depth [m][a]	Total Depth (m)	Effective Water Depth [m][b]	Temperature [°C]	Dissolved Oxygen [mg/L]	Dissolved Oxygen [% Sat]	pH	Specific Conductivity [µS/cm]
Mid-Lake	11-Mar-20	634527	6929048	0.6	-	7.8	0.3	0.4	8.8	62	9.4 X[c]	558
							1	1.1	8.7	63	9.1 X[c]	577
							2	1.4	8.7	63	9.0	572
							3	1.5	8.5	62	8.9	571
							4	1.6	8.5	62	8.8	570
							5	1.6	8.6	63	8.7	569
							6	1.7	8.6	63	8.7	569
Northwest Bay North	12-Mar-20	634469	6929381	0.75	-	4.8	0.3	1.2	8.3	59	-[d]	560
							1	1.4	8.3	59	-[d]	558
							2	1.5	8.3	59	-[d]	556
							3	1.5	8.3	59	-[d]	556
							4	1.5	8.2	59	-[d]	556
Northwest Bay South	11-Mar-20	634458	6929226	0.6	-	7	0.3	0.5	8.5	60	8.9	588
							1	1.0	8.7	62	8.9	579
							2	1.3	8.7	63	8.8	575
							3	1.5	8.7	63	8.8	573
							4	1.5	8.7	63	8.7	572
							5	1.6	8.6	63	8.7	571
							6	1.6	8.6	63	8.7	570
Northeast Bay	12-Mar-20	634689	6929245	0.65	-	6.7	0.3	1.0	8.4	59	-[d]	564
							1	1.3	8.3	59	-[d]	559
							2	1.4	8.2	59	-[d]	558
							3	1.5	8.4	60	-[d]	557
							4	1.5	8.3	59	-[d]	557
							5	1.5	8.2	58	-[d]	556
Southwest Bay	12-Mar-20	634234	6928639	0.65	-	3.6	0.3	0.6	8.7	61	-[d]	566
							1	1.0	8.8	62	-[d]	564
							2	1.4	8.7	62	-[d]	560

Notes: % Sat = percent dissolved oxygen saturation; µS/cm = microsiemens per centimetre; - = no data collected; X = invalidated data.
Measurements of pH were not collected on 12 March 2020 due to an issue with the probe.
(a) Secchi Depth was not collected at under ice stations.
(b) Effective water depth is the total depth minus the ice depth.
(c) pH values were invalidated because they were unusally high and the probe did not stabilize prior to taking the measurement.
(d) Measurements of pH were not collected on 12 March 2020 due to an issue with the probe.
<--Data are qualified because the probe have not stabilize prior to taking the measurement.

5.0 CLOSURE

We trust the above meets your needs, if you have any questions or concerns, please do not hesitate to contact the undersigned.

Golder Associates Ltd.

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AH/DP/al

https://golderassociates.sharepoint.com/sites/126316/project files/6 deliverables/2019_2020 jackfish lake tech memo_wq and temp/ntpc wq tech memo 2019-20.docx

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