1.1 Background

Water that discharges to Jackfish Lake from the Facility is warmer than the water that is withdrawn from the lake when one or more of the power generating systems is operating. Studies have shown that thermal discharges to waterbodies have the potential to affect the aquatic environment; however, most studies have demonstrated that effects tend to be localized, depending on the size of the receiving waterbody (EC 2014). Thermal discharge may result in localized alteration of an organism's physiological and behavioural processes; it may affect primary and secondary production, and cause changes in species composition (EC 2014).

For fish, increased temperatures result in increased rates of metabolism and respiration, as well as increased activity and food consumption (EC 2014). Temperature also affects reproduction, growth, and longevity and can adversely affect species diversity and trophic relationships (Golder 2019a; Spotila et al. 1979).

Thermal discharges from the Facility may result in prolonged and more stable thermal stratification in the lake, which in turn may result in prolonged anoxia at the lake bottom and greater release of the limiting nutrient (phosphorus) and metals from sediments compared to lakes not subject to thermal inputs. Additional internal loads of phosphorus from the sediment to the water column could enhance phytoplankton growth and thereby increase the likelihood of summer algal blooms. In addition, increased temperature can also have an adverse effect when combined synergistically with toxicants (EC 2014). With increasing temperature, toxicity of some contaminants increases (e.g., ammonia; CCME 1999) and the resistance for fish species to disease is lowered.

1.2 Purpose and Scope

The Thermal Plume Study Design objectives, as per Schedule 2, condition 1 in the Water Licence (MVLWB 2019b), are listed in Table 1-1, which provides the locations of where each condition is addressed in this document. The Thermal Plume Study Design includes the development of a thermal model to provide seasonal delineation of the thermal plume and estimate the maximum extent of the thermal plume (Item a in Table 1-1).

Table 1-1: Compliance Table for the Thermal Plume Study Design

Item	Location
a) Seasonal delineation (spring freshet, late summer, late fall, and late under ice) of the thermal plume, include a calculation of maximum extent of plume as a percentage of lake area	Sections 3.0, 4.1, 5.1, 6.1
b) Temperature, dissolved oxygen profiles and any other parameters deemed relevant to the understanding of the thermal plume and the lake stratification	Sections 3.0, 4.2, 5.2, 6.2
c) An assessment of aquatic habitat within the thermal plume zone(s)	Sections 3.0, 4.3, 5.3, 6.3
d) Seasonal chemical characterization at a minimum of one station located outside of the potential plume but situated such that potential influence of inflow(s) can be characterized and one station located at or near the outflow of Jackfish Lake. Station locations and rational to be included	Sections 3.0, 4.2, 5.2, 6.2

1.3 Report Organization

The Thermal Plume Study Design Plan is organized as follows:

- Section 1 – Introduction (background, purpose, and organization of the Thermal Plume Study Design)
- Section 2 – Existing Conditions (existing conditions at the NTPC Jackfish Lake site and existing environmental conditions)

- Section 3 – Study Design Overview (summary of the Thermal Plume Study Design Plan, including rationale, key components, study area, and linkages to other studies for the Facility)
- Section 4 – Field Program (description of field methods, including sampling locations, frequency, timing, and procedures)
- Section 5 – Assessment Approach (description of data analysis and modelling methods to meet the four main objectives of the Thermal Plume Study Design Plan)
- Section 6 – Quality Assurance and Quality Control (description of quality control and quality assurance procedures)
- Section 7 – Reporting (description of reporting requirements for the Thermal Plume Study Design)
- Section 8 – References

2.0 EXISTING CONDITIONS

2.1 Site Conditions

The Facility is located on the northeast shore of Jackfish Lake. The Facility is a critical source of backup power with diesel generators that contribute generation to the North Slave electrical system, including the City of Yellowknife, N'Dilǫ, and Dettah, when required. It is used during periods of peak power demand, during hydroelectric plant maintenance shutdowns, or when hydroelectric power is not available upon loss of the transmission line to the Snare Hydro System. There are three generation plants within the Facility: the CAT Plant (built in 1993), the EMD Plant (built in 1974), and the K-Plant (built in 1969). Each plant has a cooling system for the generators that uses water from Jackfish Lake. The K-Plant has two intakes, and the EMD and CAT Plants each have one intake; each plant also has one discharge pipe.

2.2 Existing Environmental Conditions

The *2018 Environmental Monitoring Report* (Golder 2019b) provides detailed information on water quality, phytoplankton, benthic invertebrates, and fish monitored in 2018 in Jackfish Lake. A brief overview of these monitoring results by component follows:

- **Water quality** – Jackfish Lake is an alkaline lake, with hard water, moderate total dissolved solids (TDS) concentrations, low to moderate concentrations of total suspended solids (TSS), and low sensitivity to acidification. Total phosphorus concentrations in the lake indicate that the lake is eutrophic to hypereutrophic. Concentrations and values of water quality parameters were below Canadian Water Quality Guidelines (CWQGs) for the protection of aquatic life (CCME 1999) (or within the pH CWQG range) with the exception of concentrations of dissolved oxygen (DO), nitrite, and three metals (total arsenic, copper, and zinc). Water quality profile data indicate that Jackfish Lake was thermally stratified in July and August, with near-anoxic conditions at the lake bottom during this period. Nitrate, copper, and zinc concentrations were occasionally above CWQGs; all arsenic concentrations were above the CWQG and have historically been above the CWQG in Jackfish Lake and in the lakes around Yellowknife due to the historical contamination from former gold mines in the area.
- **Phytoplankton** – There was little seasonal or spatial variation in phytoplankton community composition based on relative abundance or biomass in Jackfish Lake and the community was strongly dominated by cyanobacteria, notably *Planktothrix* sp., which is a toxin-producing taxon (Meriluoto et al. 2017).

- **Benthic invertebrates** – The benthic community in Jackfish Lake exhibited low density and richness. The dominant benthic invertebrate taxon in Jackfish Lake was the midge *Chironomus* sp., which is adapted to anoxic conditions (Thorp and Covich 2001) and has a high thermal tolerance limit of greater than 30ºC (EC 2014).
- **Fish** – The fish survey documented three species of fish in Jackfish Lake: Lake Whitefish (*Coregonus clupeaformis*), Northern Pike (*Esox lucius*), and Trout-Perch (*Percopsis omiscomaycus*). The captured Lake Whitefish were mostly adults in good body conditions with full stomachs. Northern Pike adults were also captured but were slender, potentially as a result of limited forage fish in the lake. Tissue concentrations of mercury in Lake Whitefish and Northern Pike were below Canadian Food Inspection Agency guidelines (CFIA 2017), and thermal effects were not observed. Based on the monitoring conducted in 2018, the fish in Jackfish Lake appear to be healthy.

3.0 STUDY DESIGN OVERVIEW

This section provides a summary of the overall study design, detailed field methods and the assessment approach, by component, are provided in Sections 4.0 and 5.0, respectively.

3.1 Study Area

The study area consists of Jackfish Lake and its inflows and outflow. Jackfish Lake is located on the northern end of the city of Yellowknife, immediately southwest of the intersection of Highway No. 3 and the old access to the Ingraham Trail, and approximately 300 m south of the Yellowknife Solid Waste Facility (Figure 3-1). A municipal cemetery is located on the southwest side of the lake.

Inflows to the lake have been observed at two locations in the northwest bay of Jackfish Lake. The lake outlet intermittently drains into a channel that flows into Great Slave Lake, which is approximately 750 m east of Jackfish Lake. The four intake and three discharge pipes for the Facility are located along northeast shore of Jackfish Lake.

LEGEND

- COMMUNITY
- HIGHWAY
- LOCAL ROAD
- MUNICIPAL LANDFILL
- YELLOWKNIFE AIRPORT

0 250 500

1:20,000 METRES

REFERENCE(S)

POPULATED PLACE AND ROAD DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. PUBLIC SECTOR DATASETS MADE AVAILABLE UNDER THE CITY OF YELLOWKNIFE'S OPEN DATA LICENSE V.1. IMAGERY COPYRIGHT © 20170809 ESRI AND ITS LICENSORS. SOURCE: DIGITALGLOBE. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 11 DATUM: NAD 83

CLIENT
NORTHWEST TERRITORIES POWER CORPORATION

PROJECT
JACKFISH WATER LICENCE RENEWAL

TITLE
DEVELOPMENTS SURROUNDING JACKFISH LAKE

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-18
DESIGNED	TL
PREPARED	LB/PS
REVIEWED	KB
APPROVED	DP

PROJECT NO.	CONTROL	REV.	FIGURE
18109589		0	3-1

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3.2 Study Components

Components considered as part of the Thermal Plume Study Design are:

- Thermal modelling (i.e., operational temperature and flux, lake temperature and other inputs, such as flow and water level measurements, that are required to develop a thermal model)
- Water quality (i.e., water quality sampling and field measurements)
- Fish and fish habitat (Aquatic Habitat)

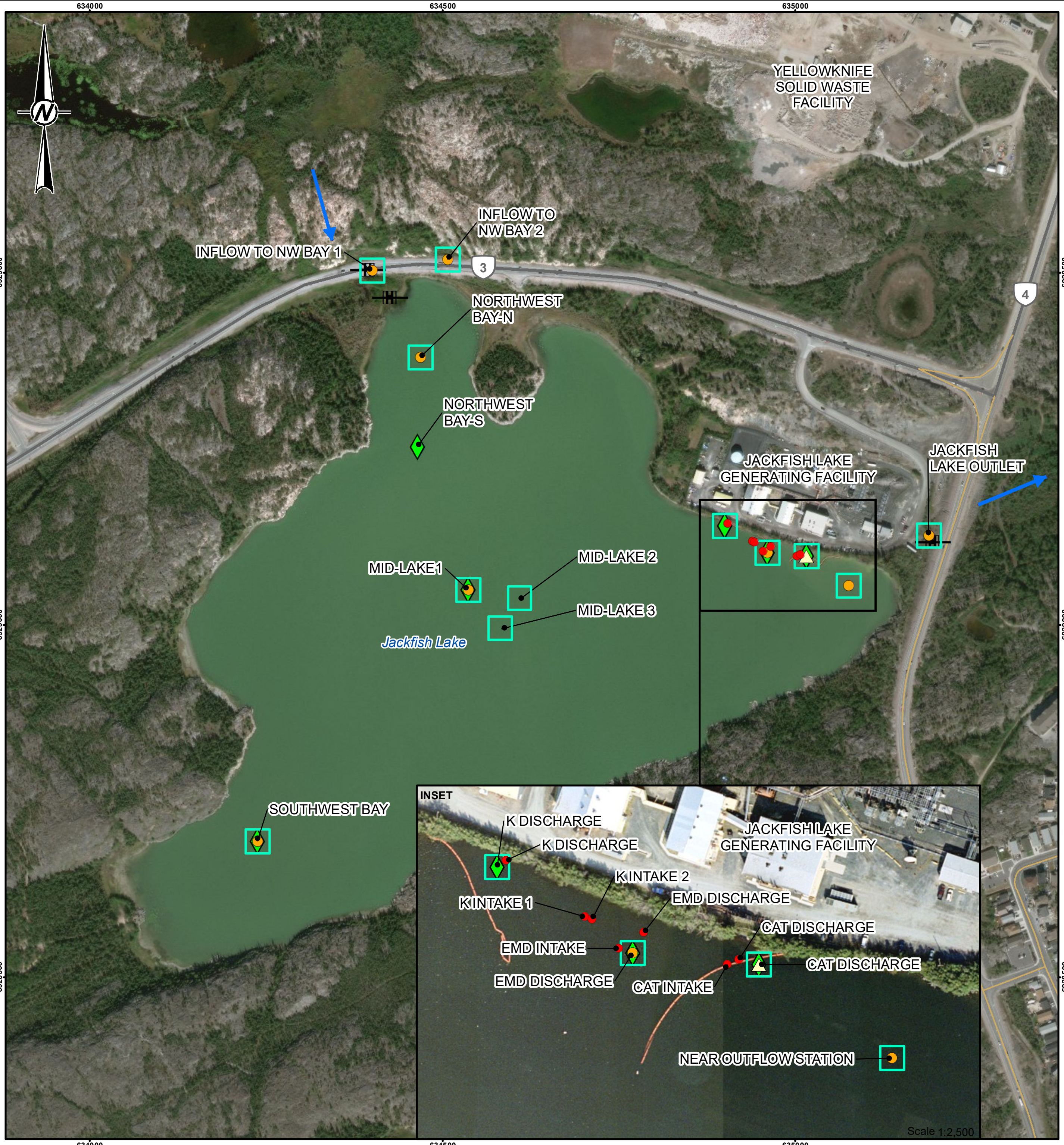
3.3 Sampling Stations

Sampling locations for the Thermal Plume Study Design (Figure 3-2) were selected based on monitoring locations from the 2018 Environmental Monitoring Report (Golder 2019b), feedback from reviewers during the Water Licence application process, and location requirements in the Water Licence (Schedule 2, Condition 1d):

1) a minimum of one station located outside of the potential plume but situated such that potential influence of inflow[s] can be characterized; and
2) one station located at or near the outflow of Jackfish Lake.

The location coordinates and applicable study component for each station are provided in Table 3-1; the proposed monitoring at these stations is summarized as follows:

- Thermistors installed at the intakes and discharges will measure the temperature of the water being circulated through the Facility.
- Temperature loggers that were deployed at the surface and bottom depths in 2018 and maintained and downloaded in 2019 will measure water temperature at three stations in the immediate vicinity of the discharges from the Facility (i.e., K, EMD, and CAT discharges) and at in-lake stations.
- Lake water level monitoring will occur at a location near the Facility discharge, at the same location where it was measured during the 2018 monitoring program (Golder 2019b).
- Water quality samples and field measurements will be collected in the immediate vicinity of the discharges from the Facility (i.e., EMD and K, EMD and CAT discharges), at in-lake stations and watercourse stations to characterize quality in Jackfish Lake and its inflows and outflow.
- Fish habitat mapping will be conducted throughout Jackfish Lake and is described further in Section 4.3.



LEGEND

STATIONS

- TEMPERATURE LOGGER
- THERMISTOR
- WATER QUALITY SAMPLE
- WATER LEVEL
- FIELD WATER QUALITY MEASUREMENTS

- FLOW DIRECTION
- CULVERT
- HIGHWAY
- LOCAL ROAD
- BERM

0 100 200

1:8,000 METRES

NOTE

1. MID LAKE 2 AND 3 WILL BE DETERMINED IN THE FIELD BASED ON DEPTH

REFERENCE(S)

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PROJECTION: UTM ZONE 11 DATUM: NAD 83

CLIENT

NORTHWEST TERRITORIES POWER CORPORATION

PROJECT

JACKFISH WATER LICENCE RENEWAL

TITLE

THERMAL PLUME STUDY DESIGN SAMPLING STATIONS IN JACKFISH LAKE AND ITS INLOFWS AND OUTFLOWS

CONSULTANT

GOLDER

YYYY-MM-DD	2019-12-20
DESIGNED	TL
PREPARED	PS
REVIEWED	KB
APPROVED	DP

PROJECT NO.	CONTROL	REV.	FIGURE
18109589		0	3-2

Table 3-1: Sampling Stations in Jackfish Lake for the Thermal Plume Study Design

Area	Station	UTM Coordinates (NAD 83, Zone 11)		Thermistors[a]	Water Flow	Water Level	Temperature	Water Quality Field Measurements	Water Quality
		Easting	Northing						
Watercourse	Inflow to NW Bay 1[b,c]	634506	6929495	-	x[e]	-	-	x	x
	Inflow to NW Bay 2[b,c]	634507	6929519	-	x[e]	-	-	x	x
Intakes	K Intake 1[c]	634939	6929119	x	x[f]	-	-	-	-
	K Intake 2[c]	634942	6929118	x	x[f]	-	-	-	-
	EMD Intake[c]	634954	6929105	x	x[f]	-	-	-	-
	CAT Intake[c]	635002	6929098	x	x[f]	-	-	-	-
Discharges	K Discharge[c]	634904	6929144	x	x[f]	-	-	-	-
	EMD Discharge[c]	634965	6929112	x	x[f]	-	-	-	-
	CAT Discharge[c]	635007	6929100	x	x[f]	-	-	-	-
In-Lake	Northwest Bay-N	634468	6929380	-	-	-	-	x	x
	Northwest Bay-S	634464	6929253	-	-	-	x	-	-
	Mid-Lake1	634536	6929050	-	-	-	x	x	x
	Mid-Lake 2	TBD[d]	TBD[d]	-	-	-	-	x	-
	Mid-Lake 3	TBD[d]	TBD[d]	-	-	-	-	x	-
	EMD Discharge	634960	6929103	-	-	-	x	x	x
	CAT Discharge	635016	6929098	-	-	x	x	x	-
	K Discharge	634900	6929141	-	-	-	x	x	-
	Southwest Bay	634237	6928693	-	-	-	x	x	x
	Near Outflow	TBD[c]	TBD[c]	-	-	-	-	x	x
Watercourse	Jackfish Lake Outlet[b,c]	635189	6929127	-	x[e]	-	-	x	x

a) Thermistor data may be collected under the Surveillance Network Program.
b) Inflows and outflow of Jackfish Lake will be sampled during water quality sampling events when flow is observed.
c) Approximate location.
d) Location to be determined in the field.
e) Manual water flow measurement.
f) Automatic discharge measurements.
UTM = Universal Transverse Mercator; - = not measured or sampled; TBD = to be determined during first sampling event.

3.4 Schedule

It is anticipated that the Thermal Plume Study Design will be a one-year field study with the final Thermal Plume Study Report due 30 January 2023. Monitoring will begin in late fall (September/October) 2021 and will be completed by early fall 2022. Water quality monitoring and flow measurements will be completed during discrete sampling events, and temperature, water level, and barometric pressure will be measured continuously between late fall 2021 and early fall 2022.

Five sampling events will be completed: late fall 2021 (September/October), late winter 2022 (March/April), during spring freshet 2022 (May/June), early summer 2022 (July), and late summer 2022 (August). These events will capture seasonal differences in temperature and water quality in the lake and fill data gaps to assess the thermal plume within the lake and effects of inflows to Jackfish Lake.

Water quality samples and field water quality measurements will be collected during each of these sampling events. Freshet monitoring will provide data during peak flow conditions. Timing of freshet sampling will depend on when the spring thaw occurs. The summer and fall sampling programs will provide data required for open-water conditions and the winter program will provide data required for under-ice conditions.

Thermistors and temperature loggers will collect continuous temperature data from late fall 2021 to early fall 2022 at the Facility intakes and discharges and in-lake. In addition, a Solinst Levelogger and a Solinst Barologger water level and barometric pressure logger will collect continuous water level information during the same time period. Temperature and water level data logger downloads will occur during each of the sampling events.

3.5 Linkages to Jackfish Lake AEMP

The Thermal Plume Study Design Plan describes a stand-alone study, but the information provided by the study, as reported in the Thermal Plume Study Report, will be used to develop the Aquatic Effects Monitoring Program (AEMP) Design Plan, which is required to be submitted for approval to MVLWB by 30 April 2023 (MVLWB 2021). The field data and modelling results collected as part of the study and the lake data collected in 2018 (Golder 2019b) and 2019 are expected to inform which monitoring components will be required for the AEMP, and suitable monitoring locations and frequency. The results of monitoring and thermal modelling will be used to identify critical timing and areas for future monitoring of temperature and other appropriate parameters, if needed.

4.0 FIELD PROGRAM

This section details the sampling needed to meet the requirements of the Thermal Plume Study Design as set out by the Water Licence and presented in Section 1.2. For the Thermal Modelling component, the field sampling program is based on the needs listed in Section 5.1.

4.1 Thermal Modelling

Water Flow

Manual water flow and water depth measurements within each channel connecting to Jackfish Lake will be collected in late fall (September/October) 2021, late winter (March/April) 2022, during spring freshet (May/June) 2022, early summer (July) 2022, late summer (August) 2022 to capture high and low flow conditions at the inflows and outflow (Tables 3-1 and 4-1).

Manual water flow measurements will be collected following the Water Survey of Canada standard described by Terzi et al. (1994). Velocity and depth measurements used for discharge or flow calculation will be collected using a Sontek Flowtracker Handheld Acoustic Doppler Velocimeter and a top-setting wading rod, or equivalent. Flow and depth measurements will only be collected during each site visit if flow is observed and the connecting channel is ice-free.

NPTC will collect at least hourly intake and discharge temperatures and flows from the EMD, K, and CAT intakes and discharges for the purposes of characterizing operational discharges to the lake throughout the year.

Water Level Data

Two Solinst Leveloggers and a Barologger will be installed at the same location as in 2018 (i.e., near the CAT Discharge [Golder 2019b]) to measure water level and barometric pressure to provide compensated water level data for the thermal model and other analytical purposes (Tables 3-1 and 4-1). Logger accuracy will be verified by collecting confirmatory manual water depth measurements during each site visit, and data downloads will be performed during each water quality field program (i.e., late fall [September/October] 2021, late winter [March/April] 2022, spring freshet [May/June] 2022, early summer [July] 2022, and late summer [August] 2022 to capture high and low flow conditions at the inflows and outflow [Table 3.1]). Water level data will be downloaded in the fall (September/October) 2022 and used in the validation of model results.

Temperature Data

Thermistors

Thermistors were installed in 2018 at all plant intakes and discharges (four intakes and three discharge locations) to measure the temperature of the water being circulated through the Facility (Tables 3-1 and 4-1). Thermistor loggers (RST DT2055 thermistor data logger) were maintained throughout 2018 and 2019 and data have been downloaded. Thermistors will continue to collect data automatically, at 15-minute intervals throughout the year. Thermistor data will be downloaded during each of the five field programs: late fall (September/October) 2021, late winter (March/April) 2022, spring freshet (May/June) 2022, early summer (July) 2022, and late summer (August) 2022. Thermistor data will be downloaded in the fall (September/October) 2022 and used in the validation of model results. The seven thermistors can be accessed and downloaded from a common data logger. The common data logger is mounted on a pole across the roadway from the K-Plant.

Temperature Loggers

Temperature loggers were installed at three stations in the immediate vicinity of the discharges from the Facility (i.e., K, EMD, and CAT discharges) and at two in-lake locations in 2018 (Tables 3-1 and 4-1). HOBO Pendent MX Water Temperature Data Loggers (temperature loggers) were installed near the surface and at the lake bottom at each location.

Temperature loggers will be downloaded during each of the five field programs: late winter (March/April), during spring freshet (May/June), early summer (July), late summer (August), and late fall (September/October). Temperature logger data will be downloaded in the fall (September/October) 2022 and used in the validation of model results. The temperature loggers are Bluetooth-enabled to allow for ease of download. During each program, the mooring device will be slowly retrieved, and the condition and locations of the loggers will be assessed; if loggers have moved more than 25 m from the previous location, the new coordinates will be recorded and the logger will be repositioned to its original location. Logger data will be downloaded using the HOBOmobile application and any maintenance needed to the logger set-up will be rectified at the time of logger download or noted for follow-up if time does not permit addressing the maintenance at the time. The date and time of temperature logger download will be recorded with the serial number and position on the mooring (i.e., surface or bottom). The available memory will also be checked; if memory is low after downloading, the memory will be cleared and the temperature logger will be re-started. Any temperature loggers found not to be functioning will be removed and replaced with a pre-launched HOBO Pendant logger.

The existing temperature logging locations within the lake are sufficient for the purposes of collecting the necessary data to validate the model with in-lake data during ice free months. Operational data (hourly discharge rates and temperatures) are also required to characterize thermal heat waste from the Facility to validate the model.

Table 4-1: Proposed Flow, Temperature, and Water Level Monitoring Stations to Support the Thermal Modelling

Component	Station	Sample Type	Frequency/Duration	Rationale
Flows	Inflow to NW Bay 1	Watercourse - lake inflow; manual flow measurements	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Measurements collected with intention to capture high and low flow conditions at inflows
	Inflow to NW Bay 2	Watercourse - lake inflow; manual flow measurements	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Measurements collected with intention to capture high and low flow conditions at inflows
	Outflow	Watercourse - lake outflow; manual flow measurements	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Measurements collected with intention to capture high and low flow conditions at outflows
	EMD, CAT, and K Intake and Discharge Point	Logger	Automatic level data (15 to 60-minute intervals) recorded throughout entire year	Cooling water intake and discharge flows
Lake level	CAT Discharge - In lake	Level logger	Automatic level data (15 to 60-minute intervals) recorded throughout entire year	Measurements of water level and barometric pressure to provide required lake level data for modelling and other analytical applications
Temperature	Northwest Bay	Lake - multi-depth in-lake temperature loggers	Automatic temperature data at 15-minute intervals throughout the year	Identify changing temperature gradient over time
	Mid Lake 1	Lake - multi-depth in-lake temperature loggers	Automatic temperature data at 15-minute intervals throughout the year	Identify changing temperature gradient over time
	EMD Discharge - In lake	Lake - multi-depth in-lake temperature loggers	Automatic temperature data at 15-minute intervals throughout the year	Characterize thermal plume, and identify changing temperature gradient over time during non-operational conditions
	CAT Discharge - In lake	Lake - multi-depth in-lake temperature loggers	Automatic temperature data at 15-minute intervals throughout the year	Characterize thermal plume, and identify changing temperature gradient over time during non-operational conditions
	K Discharge - In lake	Lake - multi-depth in-lake temperature loggers	Automatic temperature data at 15-minute intervals throughout the year	Characterize thermal plume, and identify changing temperature gradient over time during non-operational conditions
	Southwest Bay	Lake - multi-depth in-lake temperature loggers	Automatic temperature data at 15-minute intervals throughout the year	Identify changing temperature gradient over time
	EMD, CAT, and K Intake and Discharge Point	Thermistor temperature logger	Automatic temperature data at 15-minute intervals throughout the year	Characterize hourly cooling water intake and discharge temperatures

Note: Periodic manual measurements are required to verify no issues with logger drift/accuracy

4.2 Water Quality

Water quality monitoring will be completed at three locations where inflows to and the outflow from Jackfish Lake have been observed and nine locations in Jackfish Lake. Water quality sampling stations were selected to characterize water quality in inflows to Jackfish Lake (and their influence on lake water quality), within the potential thermal plume, in the outflow of Jackfish Lake, and in an area of Jackfish Lake least likely to be influenced by observed inflows or the thermal plume (Table 4-2, Figure 3-2). Water quality samples and field measurements will be collected during late fall (September/October) 2021, late winter (i.e., immediately before ice-breakup in March/April) 2022, spring freshet (May/June) 2022, early summer (July) 2022, and late summer (August) 2022. When possible, programs will be timed with cooling water discharges (i.e., when one or more of the power plants are operating). Monitoring will be completed at all water quality stations during each field program, with the exception of the watercourse stations which will not be monitored if flow is not observed (Table 4-2).

Table 4-2: Proposed Water Quality Monitoring Stations in Jackfish Lake and Jackfish Lake Inflows and Outflows

Station	Sample Type	Frequency/Duration	Rationale
Inflow to NW Bay 1	Watercourse - surface sample and surface field measurement	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Characterize water quality in inflows to lake
Inflow to NW Bay 2	Watercourse - surface sample and surface field measurement	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Characterize water quality in inflows to lake
Northwest Bay	Lake - bottom and mid-depth sample and field measurement profile	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Characterize influence of inflows on in-lake water quality, outside of the potential thermal plume, and identify vertical differences in water quality in the water column
Mid Lake 1	Lake - bottom and mid-depth sample and field measurement profile	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Characterize water quality at a deep location in the lake, and identify vertical differences in water quality in the water column
Mid Lake 2	Lake - field measurement profile	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Provide additional field profile information for DO and temperature at deep locations
Mid Lake 3	Lake - field measurement profile	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Provide additional field profile information for DO and temperature at deep locations
EMD Discharge - In lake	Lake - bottom and mid-depth sample and field measurement profile	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Characterize water quality in the potential thermal plume and identify vertical differences in water quality in the water column
CAT Discharge - In lake	Lake - field measurement profile	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Provide additional field profile information for DO and temperature in the potential thermal plume
K Discharge - In lake	Lake - field measurement profile	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Provide additional field profile information for DO and temperature in the potential thermal plume
Southwest Bay	Lake - bottom and mid-depth sample and field measurement profile	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Characterize water quality least influenced by discharges or observed inflows
Near Outflow – In lake	Lake - bottom and mid-depth sample and field measurement profile	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Characterize lake water quality near the outflow and identify vertical differences in water quality in the water column
Outflow	Watercourse - surface sample and surface field measurement	Late Fall, Late Winter, Spring Freshet, Early Summer, Late Summer	Characterize water quality in the outflow from lake

Notes: Bottom samples will be collected 1 m above lake bottom, surface samples, and surface field measurements will be collected approximately 30 cm below the water or ice surface, and water quality field measurement profiles will be collected at 1-m intervals.
Parameters to be collected during field measurements are water temperature, dissolved oxygen (concentration and percent saturation), pH, and specific conductivity.

Water Quality Field Measurements

Profiles or surface measurements of field water quality will be collected at all stations during each program (assuming flow is present at watercourse stations) and prior to collecting water quality samples. Field water quality measurements within Jackfish Lake will be collected as vertical profile measurements recorded at 1-metre depth intervals throughout the water column using a handheld multi-parameter water quality meter. Secchi depth and total water depth will be measured at each profile location. At watercourse stations, surface field measurements will be collected approximately 30 cm under the water surface. The profile or surface measurements will consist of:

- water temperature (°C)
- pH
- DO (milligrams per litre [mg/L] and percent saturation)
- specific conductivity (microsiemens per centimetre [µS/cm])

Additional field information such as station name and location coordinates, total depth, and weather conditions will be recorded.

Water Quality Samples

During each program, samples will be collected at five lake stations at the mid-depth and bottom (1 m above the lake bottom) of the water column of each station using a Teflon Kemmerer sampler and three watercourse stations by directly filling bottles provided by the laboratory. Lake samples will be poured from the Kemmerer sampler into sample bottles provided by the laboratory. If more than one volume of the sampler is required to fill the bottle suite, the bottles will be filled by splitting the sample from each Kemmerer volume equally between the bottles. Water from the Kemmerer sampler (for lake samples) or extra laboratory-grade bottle (for watercourse samples) will also be used to measure turbidity in the field using a turbidity meter; turbidity measurements will be based on the average of three readings from the turbidity meter.

Samples with dissolved parameters will be filtered and preserved according to laboratory instructions. Prior to transport to the analytical laboratory, samples will be stored in coolers and kept cool with ice packs. Analysis request and chain-of-custody forms will be used to request the analysis and track samples, respectively.

All water quality samples will be sent to a Canadian Association for Laboratory Accreditation Inc. (CALA) accredited laboratory for analysis of routine parameters, major ions, nutrients, and total and dissolved metals:

- Routine parameters (hardness, total alkalinity, specific conductivity, TDS, TSS, turbidity, pH)
- Major ions (fluoride, chloride, sulphate, calcium, potassium, magnesium, sodium)
- Nutrients (total and dissolved phosphorus, nitrate, nitrite, total ammonia, total nitrogen, reactive silica, dissolved organic carbon)
- Total and dissolved metals (aluminum, antimony, arsenic, barium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, thallium, uranium, and zinc)

The analyses of petroleum hydrocarbons (i.e., benzene, toluene, ethylbenzene, and fractions F1 to F4 of total petroleum hydrocarbons) completed for samples collected during the 2018 environmental monitoring program indicated concentrations of these parameters were below detection limits (Golder 2019a). Therefore, a subset of samples are proposed for further hydrocarbon analyses to confirm the 2018 results. Bottom samples from Northwest Bay and Near the Outlet (In-lake) will be sent to a CALA accredited laboratory for analysis of:

- Oil and grease (hexane extractable)
- Total petroleum hydrocarbons (F1, F2, F3, F4 Canadian Council of Ministers of the Environment [CCME] fractions)
- Benzene, toluene, ethylbenzene, xylene (BTEX)

4.3 Fish and Fish Habitat

To refine predictions of effects to fish habitat and better understand effects on fish use from changes in water quality detected as part of future monitoring of the thermal plume, a detailed sonar survey will be completed in Jackfish Lake to map the habitat in the lake and specifically near the discharges to better understand fish use of the area. Sidescan sonar methods will map depths and benthic habitat (substrates) around the diffusers and throughout the lake, providing high-resolution images to map vegetation and rocky shoals intersected by the extent of the thermal plume. All data will be recorded digitally onboard a vessel. The study design will include transects spaced every 25 m, plus a littoral transect running parallel to the shoreline around the lake where depths are approximately 1 m. The field crew may adjust survey effort where needed to better map complex habitat features identified while navigating the lake. This data will supplement that previously collected in 2019. The resulting fish habitat map (based on depth and substrate) will then be compared to the results from the thermal modelling to determine the potential effects on fish habitat (see Section 5.3).

5.0 ASSESSMENT APPROACH

This section details the data analysis and modelling approach to meet the requirements of the Thermal Plume Study Design as set out in by the Water Licence and presented in Section 1.2.

5.1 Thermal Modelling

Several lake processes are relevant to the fate and behaviour of thermal discharges in Jackfish Lake. The most relevant of these processes include:

- **Circulation and hydrodynamics:** Lake circulation and wind-driven currents dictate the rate at which temperature plumes are advected and dispersed and ultimately, influences thermocline development and timing of turnover events.
- **Ice formation:** ice cover can substantially reduce advection and mixing within reservoir waters for a large period of the year, allowing thermoclines to develop during winter stratification periods. Ice formation also limits heat exchange between the lake and atmosphere ultimately affecting the water temperature under ice.
- **Temperature stratification:** the establishment of thermoclines occurs in response to seasonal variations in temperature. The more pronounced a temperature gradient becomes, the greater the potential for it to impede vertical mixing. It has been assumed that chemical inputs are insignificant, and therefore, stratification driven by chemistry gradients is not considered to be a relevant lake process which could affect the fate of thermal plumes.

- **Water and heat balance:** the balance of inputs, including direct precipitation, and potentially, watercourse inflows, as well as losses through surface evaporation and outflows, drive the lake water balance and determine lake-wide residence time. Atmospheric heating/cooling effects ultimately drive the heat balance within a body of water and dictate the rate at which cooling, or heating of a waterbody occurs. Heat exchange between the lake and atmosphere directs both the long-term (e.g., seasonal) and short-term (e.g., diurnal) thermal characteristics of the lake and any point in time.

The spatial and temporal delineation of thermal plumes within this environmental context will be assessed through the development of a hydrothermal (hydrodynamic and thermodynamic) model of Jackfish Lake that will simulate the physical processes affecting heat accumulation, dissipation, and transfer resulting from atmospheric and operational influences. The hydrothermal model will allow lake temperatures to be predicted in the absence of operations to facilitate comparison against lake temperatures under operational conditions. This is a suitable approach for delineating the thermal plume, as it allows the absolute and relative effects of operational conditions on lake temperatures to be distinguished form atmospheric heating effects and quantified for the periods of interest. Measured field data will be used to verify model performance under operational conditions; however, field data do not necessarily provide information on what the lake temperatures would be in the absence of operations.

A number of outputs to quantify and characterize the magnitude and aerial extent of thermal discharges in the lake, while ensuring these can be distinguished from atmospheric heating influences, will be produced for the Thermal Plume Study Report. Both seasonally representative, as well as event-based (e.g., peak operational loading and/or specific weather conditions) surface delineations and profiles will be delivered with specific focus on characterizing operational effects during late fall (September/October) 2021, late winter (i.e., immediately before ice-breakup in March/April) 2022, spring freshet (May/June) 2022, early summer (July) 2022, and late summer (August) 2022.

5.1.1 Model Benchmarking

A 3D model will be used to integrate the lake processes outlined above and to enhance the characterization of thermal plume fate and behaviour. An abridged hydrodynamic and thermodynamic lake model will be used, using the MIKE 3 Flexible Mesh (MIKE3 FM) platform.

MIKE3 FM is a hydrodynamic modelling platform that combines a number of computational components in either 2D or 3D environments including, but not limited to, hydrodynamics, thermodynamics, advective transport, water quality, sediment and mud transport, and spectral wave attenuation. Only two of these components will be necessary for the purposes of simulating the hydrodynamics and thermodynamics of Jackfish Lake, but the flexibility of this platform can easily be extended to other components for other future investigations, if ever required.

MIKE3 FM is recognized as one of the leading, if not the premiere, computational platforms for replicating and investigating lake hydrodynamic and thermodynamic behaviour and is capable of providing highly accurate information to address current, as well as, potential future questions regarding operational effects on the lake. It combines all the relevant physical process underlying thermal plume fate within one platform, avoiding the need to produce overly conservative outcomes associated with more simplistic computational approaches. The MIKE3 FM software package also includes animation and/or graphical output functions which, together with post-processing tools, will maximize the informational value of the model results for a variety of technical and non-technical audiences.

An abridged approach to using MIKE3 FM model will be used because it precludes detailed model calibration, yet quantifies model accuracy and retains the capability to allows lake processes to be represented in an integrated fashion in order to provide a more precise examination of thermal plume delineations under the range of varying seasonal, meteorological, and operational conditions.

5.1.2 Data Requirements

The required data types and anticipated data sources are summarized below and in Table 5-1.

- Lake morphology and environment – bathymetry, lake inflows and outflows, temperature profiles, and water levels will be sourced from Golder (2019b), where available, and be supplemented with monitoring data acquired during the 2021-2022 field program (Section 4.1).
- Local meteorology – weather data pertinent to heat exchange with Jackfish Lake and/or the characterization of inflows during 2021 and 2022 will be sourced from Environment and Climate Change Canada's Yellowknife A Climate Station (Station ID 2204101).
- Operational conditions – inflow and outflow temperatures for each cooling water system at between a 15-minutely and hourly frequency will be provided by NTPC, as well as discharge and intake volumes. In addition to these operational data, an understanding of the intake and discharge configurations (depth, port sizes, horizontal and vertical orientation, and locations) is required to achieve suitable representation within the model and will be provided by NTPC.

Table 5-1: Data Requirements for the Thermal Modelling Approach

Data Type	Data Requirement	Potential Sources for Information	Possible Issues or Data Gaps	Activities Available to Address Potential Data Gaps
Bathymetry	Lake bathymetry data	Bathymetric survey data collected in 2018 (Golder 2019b)	Limited spatial resolution in area around discharges may slightly limit plume definition in this area	Collect additional bathymetry data and integrate into the model if preliminary results suggest this is required; however, this is not currently expected to be necessary to address the regulatory information request received
Meteorology	Hourly historical and/or existing climate data	Nearby meteorological station: Yellowknife A Meteorological Station ID (2204101)	Potential for gaps in 2020 data (i.e. extreme weather events, failure of monitoring stations) could affect ability to develop seasonal characterization	Use available data and augment missing periods with typical seasonal data from other years, if necessary
Ice cover	Dates of ice-on and ice-off and ice thickness	Provided by NTPC	NTPC staff to record dates of ice cover	Estimate ice cover using available literature and/or using one of the methods recommended by USACE (2002) Acquire local snowmobile association measurements of ice-thickness

Table 5-1: Data Requirements for the Thermal Modelling Approach

Data Type	Data Requirement	Potential Sources for Information	Possible Issues or Data Gaps	Activities Available to Address Potential Data Gaps
Watercourse inflows and outflow	Level logger data and spot flow measurements	2021-2022 field program (Section 4.1)	Sufficiency of flow, sufficiency of water level and flow measurements	Develop high-level water balance of upstream basin to estimate daily inflows for 2020 and 2021, using Environment and Climate Change Canada water budget information for Yellowknife, if necessary and available. Use 2020 and 2021 lake level records to estimate outflows combined with survey control invert elevation at outlet. Disregard inflow and outflow representation if field team suggest that inflows are insignificant.
In-lake water temperatures	Temperature logger data	2021-2022 field program (Section 4.1)	-	-
Temperature profiles	Field water quality measurements	2021-2022 field program (Section 4.2)	Temperature profile information could be temporally restricted (i.e. lack of under-ice data available)	Retain just deep location temperature loggers during ice-cover period and download in spring 2021. Assume model validation for open water period justifies use of model for ice-cover period.
Intake/Discharge Temperatures	Thermistor logger data	2021-2022 field program (Section 4.1)	-	-
Operational Data	Hourly operational flows (flux) Hourly delta or outflow temperature for each discharge	Provided by NTPC	Faulty instrumentation Incomplete records	No suitable work-around.
Intake/Discharge Configuration	Geographical location, depth, diameter and orientation of intake channel and discharge pipes	Design drawings provided by NTPC	Drawings not available or obsolete	Deploy field team during nonoperational conditions to collect key measurements.

\- = Not applicable

5.1.3 Hydrodynamic/Thermodynamic Model Development

The hydrodynamic model of Jackfish Lake will be developed in MIKE3 FM to resolve the physical processes governing the behaviour of the lake-atmosphere interactions and thermal plumes. The following sections describe a step by step approach to setup the hydrodynamic/thermodynamic model.

Mesh Development and Optimization

A 3D computational domain of the lake will be created in MIKE Zero (the external data processing interface provided in MIKE). Available bathymetric data (XYZ format) will be used in MIKE Mesh Generator to create the domain using a flexible mesh (FM) format to optimize resolution around areas of increased hydrodynamic complexity (if suitable data coverage exists) while minimizing spatial resolution and associated computational implications in less important areas (e.g., the computational mesh size will be optimized to reduce model run time while maintaining the necessary spatial resolution in the model). It is currently anticipated that a fine mesh size will be used in the vicinity of the site and along the shoreline (to capture nearshore processes), and a coarser mesh size will be defined for the remainder of the domain.

Given the shallow nature of the lake (average water depth of 5.0 m and maximum water depth of 7.8 m [Golder 2019b]), and the relatively small range of water level fluctuations (0.64 m [Golder 2019b]), the vertical resolution of the model will likely be represented using solely sigma layers (e.g., depth-integrated layers that each represent a vertical fraction of the water column at any given point). This modelling approach provides variable thickness of layers based on the total depth of the water column, with increased resolution at the surface where the thermal exchange between water and atmosphere occurs.

Once the required data are defined in the MIKE Mesh Generator, the computational mesh will be smoothed and interpolated using a Natural Neighbour method (Sibson 1980). After the interpolation, the MIKE Mesh Analyze tool will be used to identify and improve mesh elements to optimize model run times.

Model Parameters

Development of the hydrodynamic model will be primarily based on the following model parameters:

- **Eddy Viscosity:** The effective applied shear stress in the momentum equations contains the laminar stress and Reynolds Stress (turbulence). Eddy viscosity will be used to calculate the Reynolds component of the applied shear stress. Horizontal eddy viscosity will be defined as a function of current velocity using the Smagorinsky formulation (1963).
- **Bed Resistance (Manning's *n*):** Bed resistance will be determined using an evaluation of bed morphology and sediment characteristics throughout the reservoir and associating a Manning's roughness value, *n*, to that area.
- **Wind Forcing:** Generally, wind is the most important force generating localized flow variances in quasi-static systems, in particular in relatively shallow systems like Jackfish Lake.
- **Ice Coverage:** For the purposes of this study, no explicit formulation of ice thickness will be developed to simulate ice cover. Instead, ice coverage will be represented in a binary manner to express its lakewide presence or absence, thereby limiting or fully considering, respectively, atmospheric influences on lake hydrodynamics and thermodynamics.

Boundary Conditions

Circulation of water within lake-wide models are typically partially influenced by boundary conditions although the extent to which this influence is likely to apply at Jackfish Lake is questionable due to the limited volume and frequency of inflows and outflows to and from the lake (Golder 2019b). A water level boundary will be used to represent the outflow from the lake, and a source boundary condition will be used to represent intermittent inflows to the lake from the northwest portion of the basin, if inflows and outflows from the lake are deemed meaningful throughout the year. Alternatively, if not deemed meaningful to the lake water and heat balance, these inflows may simply be disregarded as model parameters.

Meteorological Integration

Hydrodynamic and thermodynamic responses are principally influenced by meteorological functions, which in turn affect lake circulation and mixing processes. Successful integration of meteorological parameters requires adjustment to a number of variables including the light extinction coefficient, transfer coefficients for heating and cooling, sensitivity of shear to wind speed and friction, among others. A small allowance has been made to allow for integration and adjustment of these variables with the hydrodynamic module to improve the accuracy of results.

Initial Conditions

As a dynamic model, initial background conditions are required to start the computation. The initial conditions of the hydrodynamic model will include the average water level for Jackfish Lake and an average of recorded water temperatures corresponding to the first simulation timestep. Once the computation commences, the boundary conditions drive the model and the initial values are replaced with computed values. To encourage initial computation stability, a suitable warm-up period (of up to a few weeks) will be incorporated in the model simulations.

5.1.4 Model Validation

Once the hydrodynamic model is configured, validation will involve comparing predicted and observed water temperatures at key locations within the lake graphically and numerically to provide a visual indicator of model performance and coefficient of determination (r^2) and Root Mean Squared Error (RMSE) metrics.

Production Simulations, Post-Processing of Results, and Reporting

Production simulations for the 2021-2022 calendar year will be conducted using the validated model to simulate two operational conditions:

- Measured Operational Conditions – corresponding to the operational output documented by NTPC and recorded at one or more temperature loggers in 2021 and 2022.
- Non-Operational Conditions – corresponding to hypothetical environmental conditions in the absence of documented operations.

By comparing these two conditions, the absolute effects of operational conditions (e.g., extent of discharge plume throughout lake, temperature increase attributed to operations) and relative effects (e.g., increase in water temperature attributed to operational versus atmospheric heating) can be quantified for each time step and presented in cartographic, graphic, and tabular forms.

The *median* and *maximum* extent of the thermal plume will be calculated and provided as maps for each seasonal period of interest (i.e., late fall [September/October] 2021, late winter [i.e., immediately before ice-breakup in March/April] 2022, spring freshet [May/June] 2022, early summer [July] 2022, and late summer [August] 2022). For characterizing median extents, modelled water temperatures at each of the 3D model nodes within the lake will be extracted for, and compared between, 1) the Measured Operational Conditions and 2) the Non-Operational Conditions to identify the physical extent of the thermal discharge plume to an aerial delineation extent of 1°C. For characterizing maximum extents, the timestep associated with the maximum thermal plume for each season will be identified. The following figures will subsequently be produced for each seasonal condition:

- Contour plots showing the median water temperatures at lake **surface** under Measured Operational Conditions.

- Contour plots showing the median water temperatures at lake **bottom** under Measured Operational Conditions.
- Contour plots showing the median and maximum water temperature difference (Delta T) between Measured Operational Conditions and Non-Operational Conditions at lake **surface**.
- Contour plots showing the median and maximum water temperature difference (Delta T) between Measured Operational Conditions and Non-Operational Conditions at lake **bottom**.

Calculations corresponding to the median and maximum plume delineation during each seasonal condition depicted on the above figures will be provided on each map. A calculation of the median and maximum extent of the plume as a percentage of the lake area for each of these seasonal conditions will be provided.

5.2 Water Quality

The Jackfish Lake water quality data will be tabulated and compared to CWQGs (CCME 1999). Parameter-dependent CWQGs (i.e., total ammonia, aluminum, cadmium, copper, lead, nickel, and zinc) will be calculated for each sampling event and for each sampling station based on individual sample parameter values.

Water quality data from Jackfish Lake and its inflows and outflow will be plotted to qualitatively review spatial and seasonal patterns in Jackfish Lake and differences between inflow, outflow, and lake water quality. In addition, parameters will be reviewed further to assess the potential for watercourse inflows to influence water quality in Jackfish Lake if they meet two criteria during one or more field programs:

- concentrations are 20% higher in the inflows relative to Southwest Bay station (located farthest from the inflows)
- concentrations are 20% higher at the Northwest Bay station (located closest to the inflows) relative to other stations in Jackfish Lake

A difference of 20% was selected to identify parameters for further review because concentrations that are within 20% of each other are not considered notably different (Section 6.2).

Seasonal profiles at either 1-m intervals (for field parameters) or mid and bottom depths (for routine parameters, nutrients, metals, and hydrocarbons) will be plotted to assess water quality differences within the water column. If field programs when stratification occurs (e.g., summer programs) coincide with cooling water discharges from the Facility or occur immediately after, a qualitative assessment of the potential effect of cooling water discharge on lake stratification will be completed. For this assessment, temperature profiles and concentration profiles of parameters with vertical gradients (e.g., DO and selected nutrients and metals) will be compared for time periods with and without cooling water discharge. Water quality data collected during the 2018 and 2019 water quality monitoring programs may be used in the assessment to expand the dataset over multiple years.

5.3 Fish and Fish Habitat

Spatially-explicit depth data (i.e., with XY coordinates) collected during the sonar survey of Jackfish Lake will be processed and analyzed in a geographic information system (GIS). Spatially-explicit substrate images will be processed (e.g., using SonarTRX) prior to mapping and analyses in GIS. The proposed analyses will generate an updated table describing storage (m^3) per elevation (or depth; m) for Jackfish Lake, combined with an updated characterization of oxythermal habitat for Lake Whitefish per ice-covered (winter) and open-water (summer) seasons using updated results from the thermodynamic model. The outputs will supplement information generated from previously collected bathymetry data in 2019. The updated map of fish habitat (based on depth and substrate) will then be compared to the results from the thermal modelling to determine the potential effects on fish habitat. The environmental assessment of suitable habitat for fish (i.e., the distribution of fish) will consider a benchmark oxygen concentration of 3 mg/L or greater, and a temperature range of 10°C to 14°C (as per Christie and Regier 1988). Other temperature criteria derived from a review of the literature will also be applied to the results of thermodynamic model as they related to reproduction and survival endpoints.

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance (QA) refers to plans or programs encompassing internal and external management and technical practices designed to ensure that data of known quality are collected, and that such collections match the intended use of those data (EC 2012). Quality control (QC) is an internal aspect of quality assurance. It includes the techniques used to measure and assess data quality and the remedial actions to be taken when QC assessment criteria are not met. The QA/QC procedures ensure that field sampling, laboratory analyses, data entry, data analysis, and report preparation produce technically sound and scientifically defensible results.

The QA/QC procedures for the Thermal Plume Study Design will apply to the following program components:

- field program (e.g., staff training, procedures and responsibilities, technical procedures, and specific work instructions to field crews)
- sample collection (e.g., equipment calibration and cleaning; avoidance of cross contamination; duplicate samples; field, travel, and equipment blanks)
- documentation (e.g., field logs, labelling, chain of custody)
- sample handling and shipping
- sample analysis (e.g., assessment of data quality and decision rules for acceptance/rejection, data entry, manipulations, and analyses)
- model validation, simulation, processing, and reporting
- report preparation

6.1 Thermal Modelling

Quality assurance and quality control procedures are applied to all stages of the modelling process. All modelling inputs, setup files, and result files will be independently reviewed. Readily available automated post-processing routines minimize the potential for transcription errors.

As part of routine practices for field operations, the following QA procedures will be completed on the temperature loggers:

- Duplicate HOBO Pendant temperature data loggers will be installed at mid-depth at a single in-lake station to verify repeatability of logged values.
- Temperature data collected using a handheld multi-parameter water quality meter will be compared to temperatures measured by the in-lake temperature data loggers.

The data downloaded from the temperature loggers will be checked for validity and completion. The recorded temperatures will be compared to expected ranges and checked to ensure that logging period was complete.

6.2 Water Quality

Quality assurance and quality control procedures are applicable to field methods, laboratory analyses, and data validation. As part of routine practices for field methods related to water quality monitoring, the following QA procedures will be completed:

- A pre-field meeting with the field crew and the project/task manager will be held before the field work to discuss the purpose of the field program, specify the roles of crew members, address questions regarding the specific work instructions, and discuss equipment needs, field logistics, and contingency plans.
- Calibrations will be performed on water quality multi meters at the beginning of each day to maintain accuracy of the field data; multi meters will only be used if calibration was successful (i.e., calibration criteria ranges were met). End-of-day checks on multi meter calibration will be completed to evaluate potential drift in the calibration during the field program. Records of calibration and end-of-day checks will be reviewed if unexpected field readings were measured.
- Winkler titrations will be completed daily to assess the accuracy of DO measurements.
- During field work, field data will be recorded according to established field record-keeping procedures.
- Surface water samples will be collected by experienced personnel following standard methods, best practices, and specific laboratory requirements.
- Field data will be checked at the end of the sampling event for completeness and accuracy.
- Temperature data collected using a handheld multi-parameter water quality meter will be compared to temperatures measured by the in-lake temperature data loggers.
- Samples will be tracked and documented using chain-of-custody forms; receipt of samples by the analytical laboratory will be confirmed. Field crews will be responsible for managing sample shipment to the analytical laboratory. Prior to sample shipment, field crews will confirm the following:
  - All required samples were collected and accounted for prior to shipping.
  - Chain-of-custody and analytical request forms were completed and correct.
  - Proper bottle labelling and documentation procedures were followed.

As part of the QA/QC for the field programs, a series of QC samples will be collected during each sampling event. Specifically, these include:

- duplicate surface water samples to assess variability introduced during sample collection, sample handling, and laboratory analytical procedures
- equipment blank samples to assess potential contamination due to sample equipment
- field blank to assess potential contamination during sample collection
- travel blanks to determine if any contamination may have occurred during transportation, storage, or analysis.

A duplicate sample and an equipment blank will be collected and prepared, respectively, during each sampling program. A travel or a field blank will be prepared during each sampling program, alternating between programs.

The QC samples will account for at least approximately 10 percent (%) of the samples collected in each sampling event. The QC samples will be submitted "blind" to the laboratory and will be analyzed for the same set of parameters as the collected water samples.

A CALA accredited analytical laboratory will be used for the analysis of water samples. Under CALA's accreditation program, performance evaluation assessments are conducted for laboratory procedures, methods, and internal QC. Therefore, the analytical data reported by these laboratories are expected to be reliable. One member of the water quality monitoring team will be designated as the laboratory liaison for water quality to streamline communications with the laboratory.

Laboratory and relevant field data (i.e., those data associated with samples) will be transferred electronically into the Golder's Environmental Quality Information System (EQuIS) to avoid transcription errors associated with manual data entry. A multi-step validation process, as described in the *2018 Environmental Monitoring Report* (Golder 2019b), will be used to assess the quality of the analytical results from the laboratory and the field data collected in Jackfish Lake. The steps in the data management system will involve the review of:

- laboratory-stated qualifiers
- detection limits compared to project standard detection limits
- sample holding time exceedances
- detectable concentrations in blank samples
- differences in duplicate sample concentrations
- dissolved and total concentrations (i.e., the dissolved concentration should be lower than the total concentration of the same parameter in the same sample)
- units compared to units outlined in laboratory quote
- proofing sheets

6.3 Fish and Fish Habitat

The QA/QC procedures are designed such that all field sampling, data entry, data analyses, and report preparation produce technically sound and scientifically defensible results. Field staff will be knowledgeable of fish habitat requirements, data recording, and sonar equipment operations. Equipment will be calibrated as part of routine QA/QC for field operations. Specific work instructions outlining each field task in detail will be provided to the field personnel by the task manager and reviewed prior to the start of the field program. Data will be checked at the end of each field day for completeness and accuracy. Data recorded digitally will be downloaded and backed up as a specific QA/QC measure. Tables containing summary data will be reviewed and values verified by a second person.

7.0 REPORTING

7.1 Thermal Plume Study Report Schedule and Requirements

The Thermal Plume Study Report will be issued on or before 30 January 2023 (MVLWB 2021). The field program is anticipated to be completed by fall (September/October) 2021. The Thermal Plume Study Report will document how the four main objectives of the Thermal Plume Study Design plan (Section 1.2) have been met and will contain the required information outlined in Schedule 2, condition 2 (MVLWB 2019b):

a) Maps illustrating the extent of the thermal plume and any seasonal changes documented;

b) Graphical representation of the thermal profile and applicable water quality data;

c) Identification of the worse-case thermal plume scenario of the four seasonal conditions identified in Schedule 1, item 1a;

d) Discussion of results and potential impacts to the aquatic ecosystem in Jackfish Lake and recommendations to inform the Aquatic Effects Design Report; and

e) Tabular summaries of all data and information generated under the Thermal Plume Delineation Study, in Excel format.

7.2 Thermal Plume Study Report Content

The Thermal Plume Study Report will provide all of the data collected as part of the Thermal Plume Study Design. The report will document field and assessment methods used in the Thermal Plume Study Design and will make recommendations for monitoring as part of the AEMP. A summary of the most important results will be communicated in a plain language summary that will be presented at the front of the Thermal Plume Study Report.

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https://golderassociates.sharepoint.com/sites/126316/project files/6 deliverables/03_thermal plume study design_v2.1_may2021/jackfish lake thermal plume study design_v2.1.docx

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