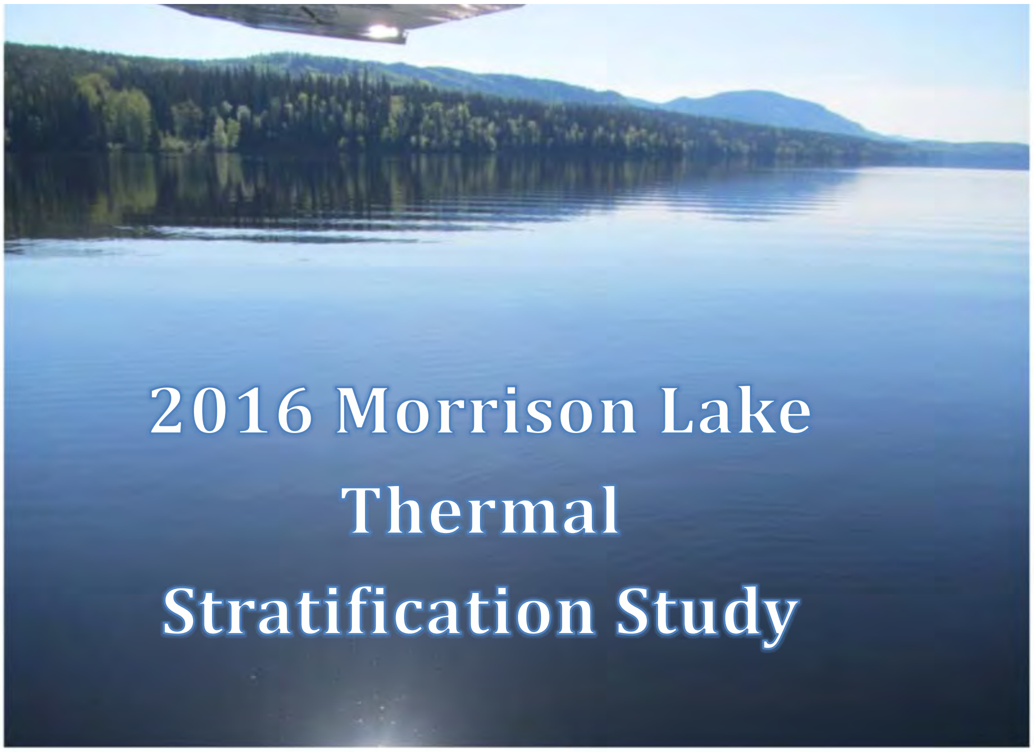

2016 Morrison Lake Thermal Stratification Study

Prepared For

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Prepared By

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Glossary of Terms

Dimictic lake – a lake that has two annual periods of free mixing water.

Epilimnion – the top most layer in a thermally stratified lake.

Euphotic zone – the uppermost layer of a body of water that receives sufficient light to allow photosynthesis.

Hypolimnion – the deepest layer in a thermally stratified lake.

Monolimnion –the lowest layer in a chemically stratified lake.

Meromictic – a lake that is chemically stratified.

Metalimnion – the transitional layer between the epilimnion and hypolimnion in a thermally stratified lake.

1 Introduction

This report is submitted to Pacific Booker Minerals (PBM) in response to PBM's request to obtain additional baseline data on Morrison Lake. The work conducted during the summer and fall of 2016 is contained in this report and a final report is envisioned once a full year of data has been obtained from Morrison Lake.

Baseline data for the project has been collected over the period of 2001 to 2011 according to the approved Terms of Reference. The scope of data collection was developed and coordinated with the BC Environmental Assessment Office.

Water quality sampling was conducted at five sites on Morrison Lake, at multiple depths (surface, thermocline and bottom). A depth profile including in situ measurements of temperature profiles to confirm stratification, pH, dissolved oxygen, total dissolved solids, conductivity and oxidation reduction potential was conducted. Water sampling included sampling during freshet (Ice-Off) which confirmed that the lake turns over. A bathymetric survey was conducted in 2008.

This report is intended to bring forth the thermal stratification data for Morrison Lake over a one-year time frame. In addition to Morrison Lake, the lake inlet (Tahlo Creek) and the lake outlet temperatures were also collected over a year-long time frame which will assist with understanding the lake's mixing patterns over a year-long timeframe. Profiles for lake conductivity, pH, and dissolved oxygen reported as percent saturation and mg/L were also collected.

2 Previous Relevant Work

In order to put this report into context, a brief description of how the mine will be operated and how effluent discharges will be managed will be summarized. A brief review of the EA effects assessment for the lake and the input from two experts in lake mixing will then be summarized. The purpose of these reviews is to provide an understanding of how the information acquired in this study could be used for future effects assessments.

Figure 1 presents the proposed configuration of the mine along with the proposed diffuser location. The centre of the ore body to be mined is approximately 500 m to the east of Morrison Lake. The open pit would eventually be up to 273 m deep. Mine life for the project while milling at 30,000 tonnes per day would be roughly 21 years. A tailings storage facility (TSF) would be located roughly 3 km to the north of the open pit. Pacific Booker Minerals has committed to line the TSF in order to minimize or eliminate any seepage from this facility. The open pit and TSF would be operated as a zero discharge facility during the mine life. Once the ore body is exhausted, excess water from the tailings impoundment and surface run-off would be diverted into the open pit. A high density lime treatment plant would be constructed to treat effluent prior to discharge at depth into Morrison Lake. The main uncertainty with this plan revolves around seepage rates into the open pit. If high seepage rates occur, a water treatment plant and the associated discharge pipe into Morrison Lake may have to be established early in the mine life.

Klohn Crippen Bergen conducted the initial effects assessment of effluent discharges into Morrison Lake. Water chemistry, initial dilution zones and the potential effects that discharges may have on phytoplankton, zooplankton and ultimately the fishery was assessed. Dr. Greg Lawrence from UBC provided a mixing model for a single port diffuser in the deepest section of the northern basin in Morrison Lake. Modelling calculations indicated that all parameters would meet provincial water quality guidelines outside of the initial dilution zone (assuming 100-fold dilution). The calculated cadmium concentration marginally met the BC Water Quality Guidelines but the guidelines for cadmium were subsequently reviewed and increased by roughly an order of magnitude (MOE 2015). With 100-fold dilution at the diffuser, all parameters would comfortably meet the various BC Water Quality Objectives.

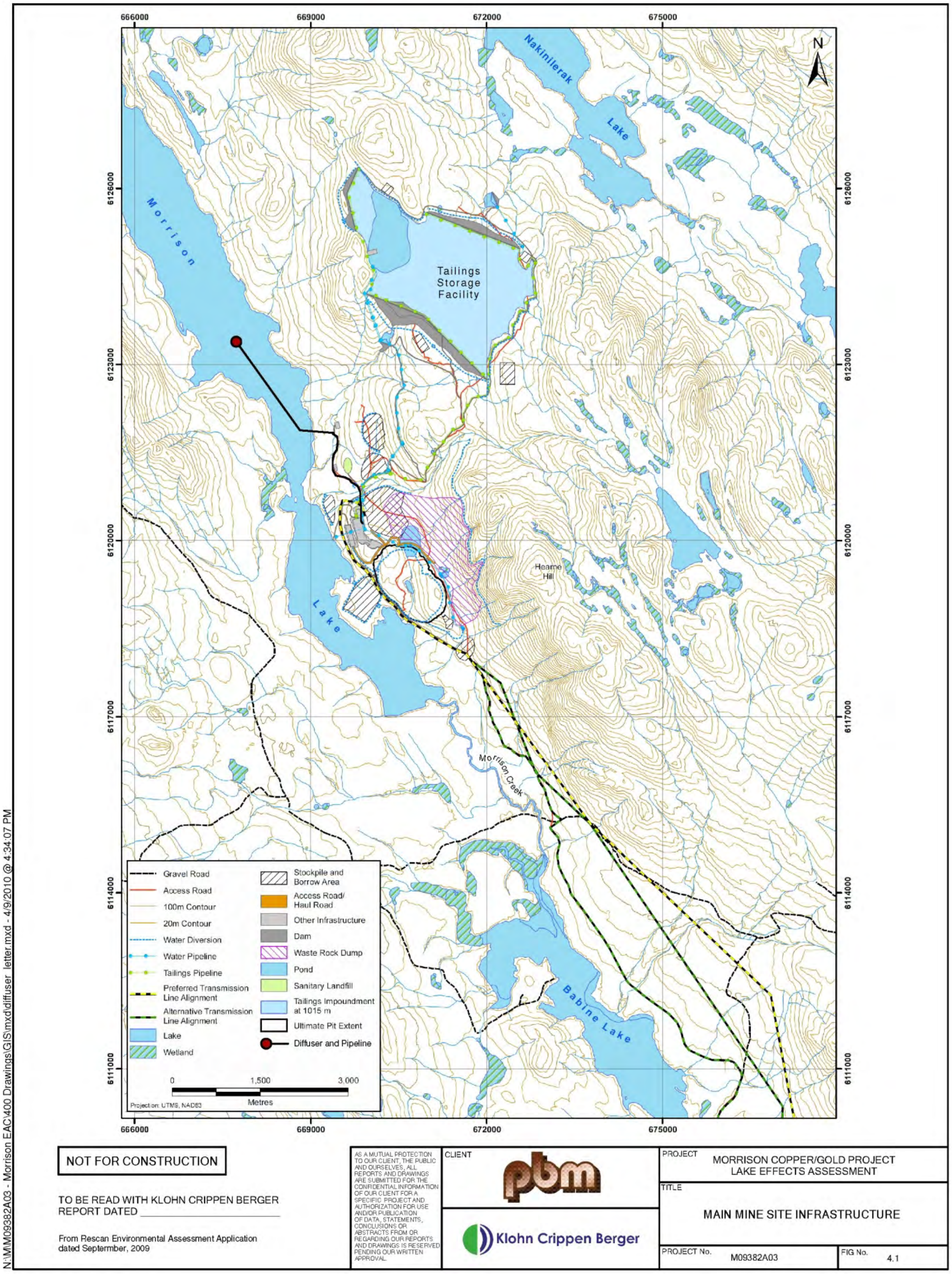

Figure 1 Proposed configuration of Morrison Copper/Gold mine.

The EAO hired an independent reviewer to further assess the diffuser design and estimate the subsequent water quality. Concerns were raised by reviewers about the notion of 'hot spots' due to incomplete mixing and/or causing the lake to become meromictic in nature. In meromictic lakes a layer below the hypolimnion become permanently stratified due to its increased density which is typically chemically induced (monlimnion). The open pit at Island Copper on the northern tip of Vancouver Island is a meromictic lake which was generated when salt water from the sea was used to flood the pit at the end of mine life. Much less dense freshwater now exists on top of the saline waters and wind in the area is of insufficient strength to mix the entire water column.

The independent reviewer selected by the EAO was Dr. Bernard Laval who also teaches at UBC in the faculty of civil engineering. Dr. Laval's assessment brought forward the concern that a single port diffuser placed in the hypolimnion might generate sufficient energy to penetrate the thermocline and result in un-natural currents. This could be especially problematic during the fall when weak stratification would allow the warmer water to rise to surface delaying the seasonal freezing of the lake. It was suggested that the single port could be slanted slightly to eliminate the 'falling fountain' mixing scenario and to also prevent warmer currents of water from surfacing in the lake. Mixing of 100 fold was thought to be easily achieved using this slight modification.

All of the mixing calculations were made based on a relatively limited amount of stratification data from the lake. The information collected in this study provides ample data to further assess the mixing regimes that would occur if a diffuser were to be installed in Morrison Lake.

3 Methods and Materials

In this section, the materials and methods used to collect the additional data from the lake are presented. Additionally, temperature readings are being collected at the inlet (Tahlo Creek) and at the bridge crossing over Morrison Creek (outlet).

3.1 Location

In order to obtain better information for lake mixing calculations, six stations were established on or near Morrison Lake. Onset Hobo Tidbit data loggers were installed at the lake inlet (Tahlo Creek), at the bridge crossing the Morrison River and on four thermistor chains in the lake basin. Figure 2 presents the locations for Tahlo Creek, Thermistor Chain #1 and Thermistor Chain #2. Figure 3 shows the locations of Thermistor Chains #2 through #4. Thermistor Chain #2 is in the deepest part of the northern basin and this is where the proposed outfall would be situated. The lake outlet site is roughly 2.5 km downstream from the lake outlet and under a bridge that crosses Morrison Creek (Figure 4).

Annual thermal stratification of dimictic lakes is influenced by solar input, the amount of mixing from winds and from the temperature of creeks flowing into the lake. If the creek temperature is lower than the lake surface, the creek input will drop to a level where the influent is neutrally buoyant. This is the primary reason why Tahlo Creek is being monitored.

Four thermistor chains were established along the length of Morrison Lake. Two chains were installed in the northern basin with one of the chains being located over the area where the diffuser would be established. The third station was established at the narrows where a shallow shelf separates the two lake basins. The fourth thermistor chain was established in the deepest part of the southern basin. The final temperature monitoring station was established at the bridge that crosses Morrison Creek. This station was established here to supplement historic readings and due to its ease of access.

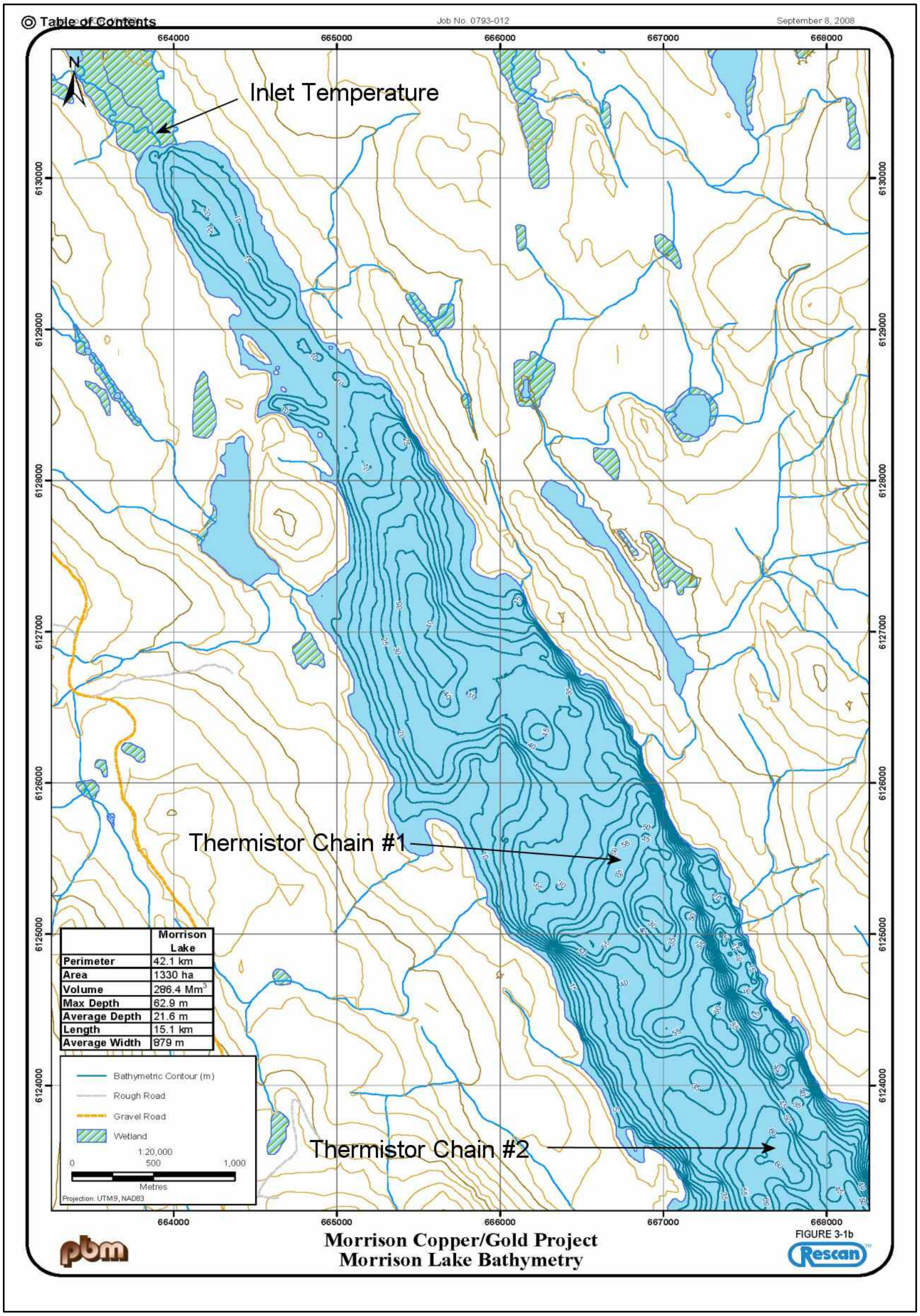

Figure 2 Bathymetric map with temperature monitoring stations on northern basin.

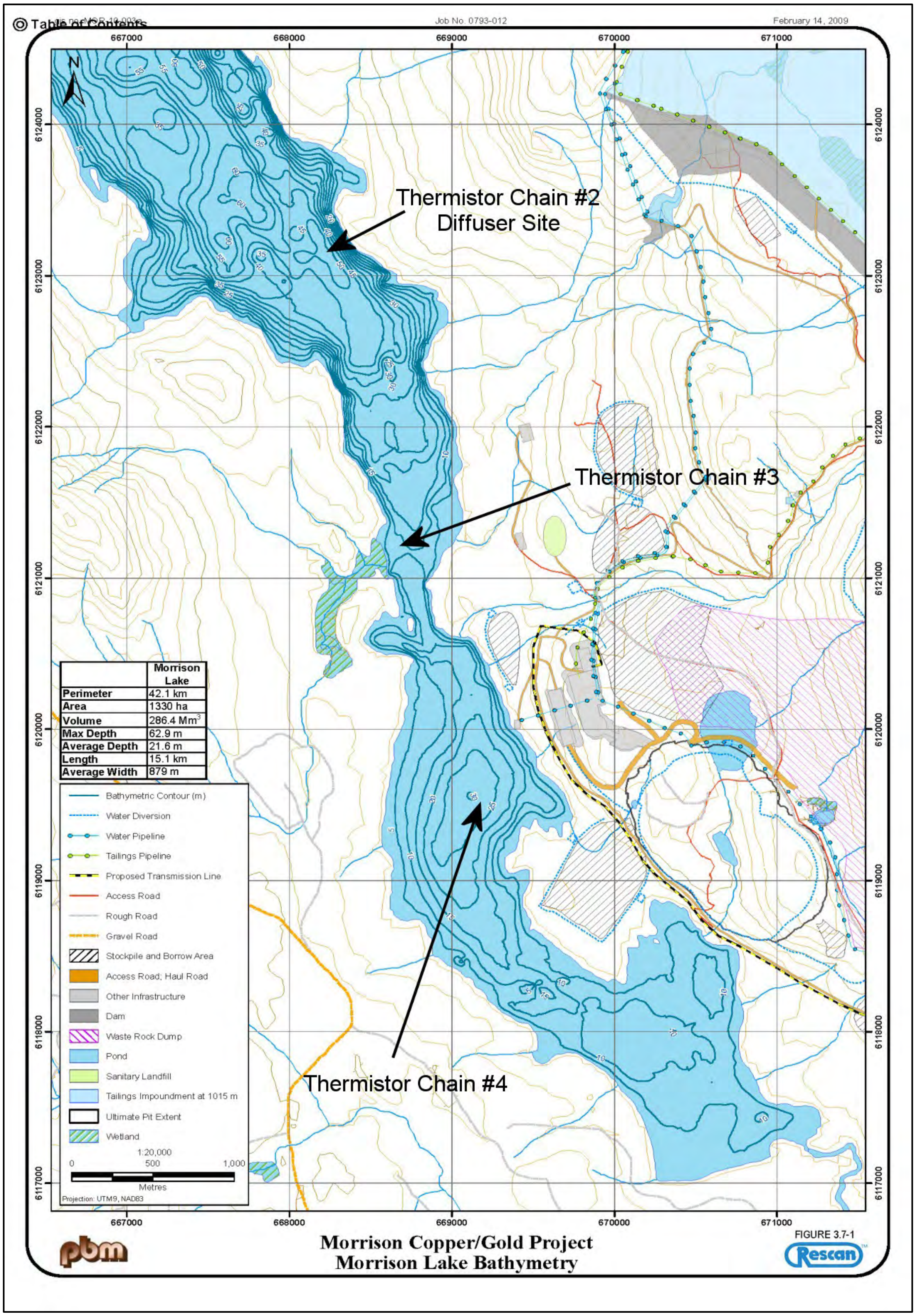

Figure 3 Bathymetric map and temperature monitoring stations on southern basin.

Figure 4 Goggle Earth map of temperature monitoring stations on and near Morrison Lake.

3.2 Onset Tidbit Temperature Loggers

The Onset Tidbit data loggers are self-contained temperature recording devices that can be offloaded using a data logging shuttle. Figure 5 shows the size of the Tidbit data loggers and Figure 6 is a picture of the hand-held shuttle. The shuttle allows Tidbit data to be downloaded in the field and the data can then be exported into an excel spreadsheet for data management and manipulation.

The Tidbits are accurate to within ±0.21 °C over a temperature range of 0 °C to 50 °C. The data loggers were all programmed to take temperature readings once every 6 hours. The two Tidbits placed in the creeks were tethered to shore and anchored to the creek bed with small weights.

The creeks were completely mixed at the temperature monitoring stations so they would be representative of the creek temperature.

Thermistor chains consist of Tidbits that were zap-strapped to depths below the surface of the lake. The line was kept afloat with a small white buoy and a blue foam block. The line was anchored into place using a 5 kg dumb-bell.

Figure 5 Onset Tidbit temperature data logger.

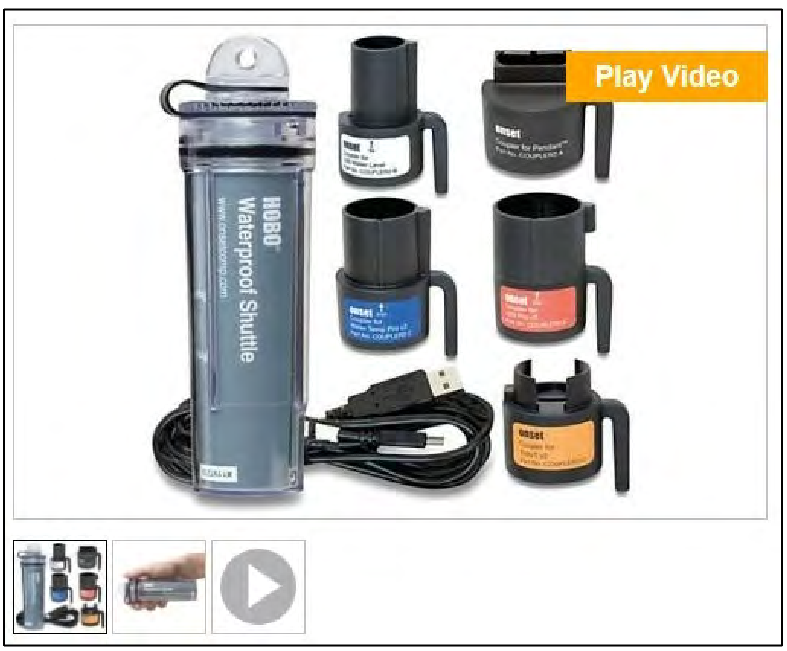

Figure 6 Onset waterproof shuttle used to download Tidbits.

Table 1 presents the depths at which the Tidbits were secured on each of the thermistor chains.

Table 1 Depths of Tidbits on thermistor chains in Morrison Lake.

	Depth (m)									
Station	0.5	2.5	5	10	15	20	25	30	40	50
1	✓		✓	✓	✓	✓	✓	✓	✓	✓
2	✓		✓	✓	✓	✓	✓	✓	✓	✓
3	✓	✓	✓							
4	✓		✓	✓	✓	✓	✓	✓		

3.3 YSI Sonde

In addition to collecting temperature data with the Tidbits, a YSI Sonde was rented from Hoskin Scientific to measure conductivity, dissolved oxygen, pH and temperature and profiles. The Sonde was deployed four times over 2016 while installing or downloading the Tidbits. Figure 7 shows the Sonde and Figure 8 shows the data logger associated with the Sonde.

Figure 7 YSI EXO Sonde.

Figure 8 Data logging unit used in conjunction with EXO Sonde.

Two different sondes were in Hoskins' rental fleet and both units measured temperature, specific conductivity, dissolved oxygen (both % saturation and mg/L), pH and depth. One of the sondes also measured tds and redox potential (ORP). Each of the units was used twice over the season for a total of four sets of sonde casts. Confirmation of calibration was conducted by Hoskin Scientific prior to sending the probes into the field.

3.4 Data Collection Schedule

Four routine trips and one trouble shooting trip were conducted over the spring/summer of 2016. On the first trip (May 15th) a float plane was chartered from Smithers and the 4 thermistor chains were installed in the lake. Sonde casts were also conducted at each of the stations. A Tidbit was not installed at the inlet of the lake due the plane's poor maneuverability in shallow water. Access to the bridge station was also unachievable with the float plane.

The second trip was conducted on June 20th. On this trip and subsequent trips, Lloyd Hooper from Tuki Lodge was contracted to boat across Babine Lake to the wharf at head of Morrison Arm. From there a vehicle was taken to the bridge site and then to Morrison Lake. Boats associated with the Tuki Lodge guide outfitting operation in the area were then used to download the Tidbit data and conduct the Sonde casts. On this trip a Tidbit was installed at the Tahlo Creek station (main inlet to Morrison Lake).

The third trip occurred on August 16th. Four Sonde casts occurred and all of the Tidbits were downloaded. Once the Tidbit data was examined upon return to Smithers, it became apparent that several of the Tidbits had a time-stamp problem with resulted in data being collected once every two days rather than once every 6 hours.

A trouble shooting trip occurred on August 28th where the problem was rectified. No Sonde casts were conducted on this trip. It was fortuitous that this extra trip was scheduled as the Tidbit that was positioned in Tahlo Creek had been broken off. Sockeye salmon were actively spawning in the area and it was apparent from all of the tracks and the beaten down sedge in the area that grizzly bears were actively fishing in this area. A bear apparently had become entangled in the string attached to the Tidbit and had snapped it. The Tidbit from the 50 m depth from Station #1 was re-positioned in the area. The subsequent installation did not have string going into mid-stream so the risk of future disruption by bears was eliminated.

The final trip of the season occurred on October 23rd. Four Sonde casts occurred and all of the Tidbits were downloaded. GPS readings of the float locations were taken to assist with thermistor chain re-location in the spring. It is anticipated that an additional trip will occur in 2017 to collect the winter's data from the Tidbits. This will generate a full year's worth of data on lake temperature as requested by the Section 17 Order.

4 Results

In the following sections, data collected from the Tidbits and the Sondes will be presented largely through the use of graphics. The raw data can be used to conduct additional mixing modelling if deemed necessary.

4.1 Tidbit Data

Figure 9 presents the temperature data collected in Tahlo Creek. The missing data is from where the grizzly bear broke away the initial Tidbit. Temperatures through the summer seemed to fluctuate between 15 and 22 °C. Sockeye spawning started in mid-August and the temperate data is missing during that time period. Once data was being collected as of August 26th, temperatures remained at or below 15 °C.

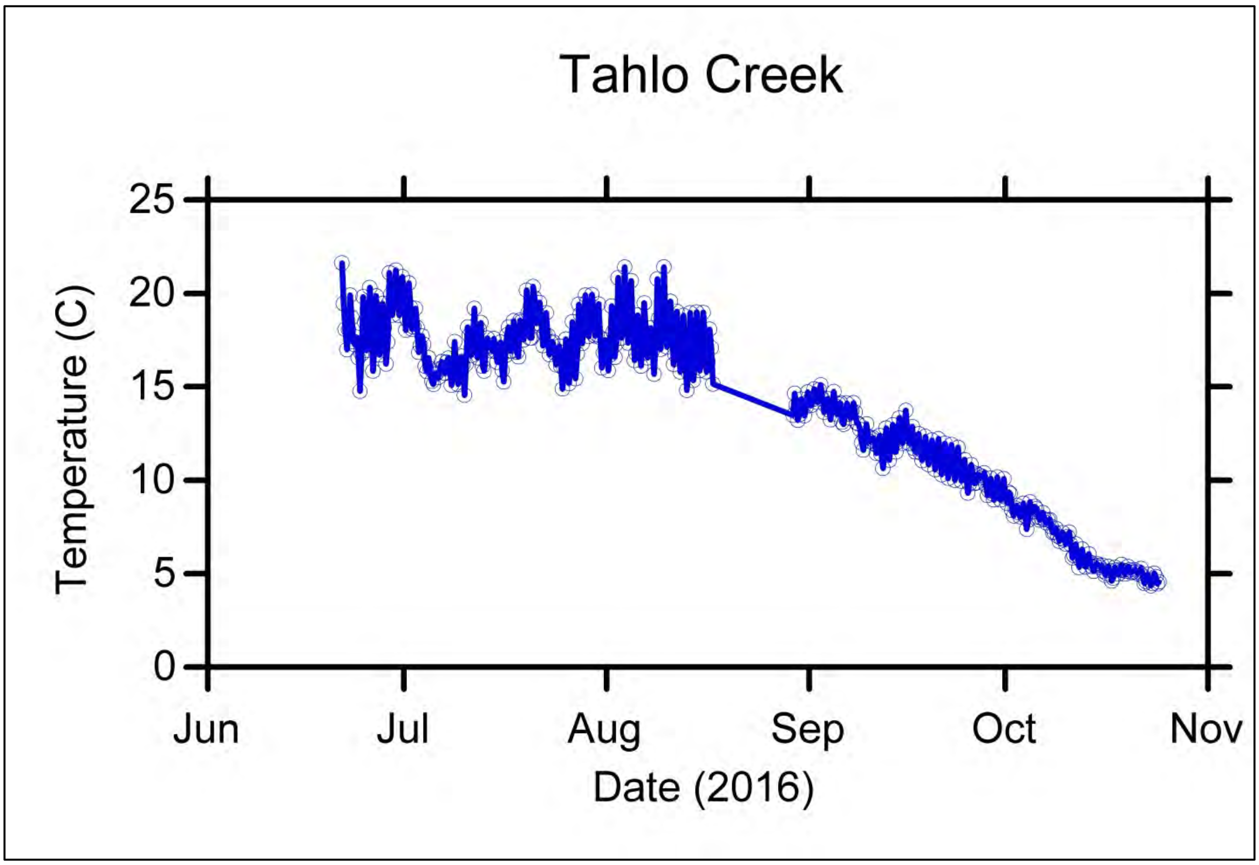

Figure 9 Temperature data from Tahlo Creek.

Figure 10 presents the 2016 Tidbit temperature data from Morrison Lake Station #1. This is the most northerly station in Morrison Lake. Thermal stratification had already begun in mid-May with the epilimnion beginning to establish itself somewhere between the 5 and 10 m depth. The strength of stratification continued to develop and appears to be fairly well pronounced by mid-June. The stratification continued persisted until October. It appears that a mixing event took place in mid-September when the 10 m depth reading approached 15 ºC. Mixing events such as these would be caused by wind. Heat loss occurred from mid-September until early October – heat radiated from the water body, mixing from winds and cold precipitation landing on the lake contribute to heat loss and the resulting degradation of the epilimnion. By late September, it appears that a storm event started to mix the 15 m water into the epilimnion. Complete mixing of the water column (turn-over) of the lake had not occurred by late October. As of late October, the lake was weakly stratified with epilimnetic waters being around 7 ºC and hypolimnetic waters being around 5 ºC. Maximum water density is at 4 ºC, and it is anticipated that winter readings in the lake will drop to that level through the majority of the water column.

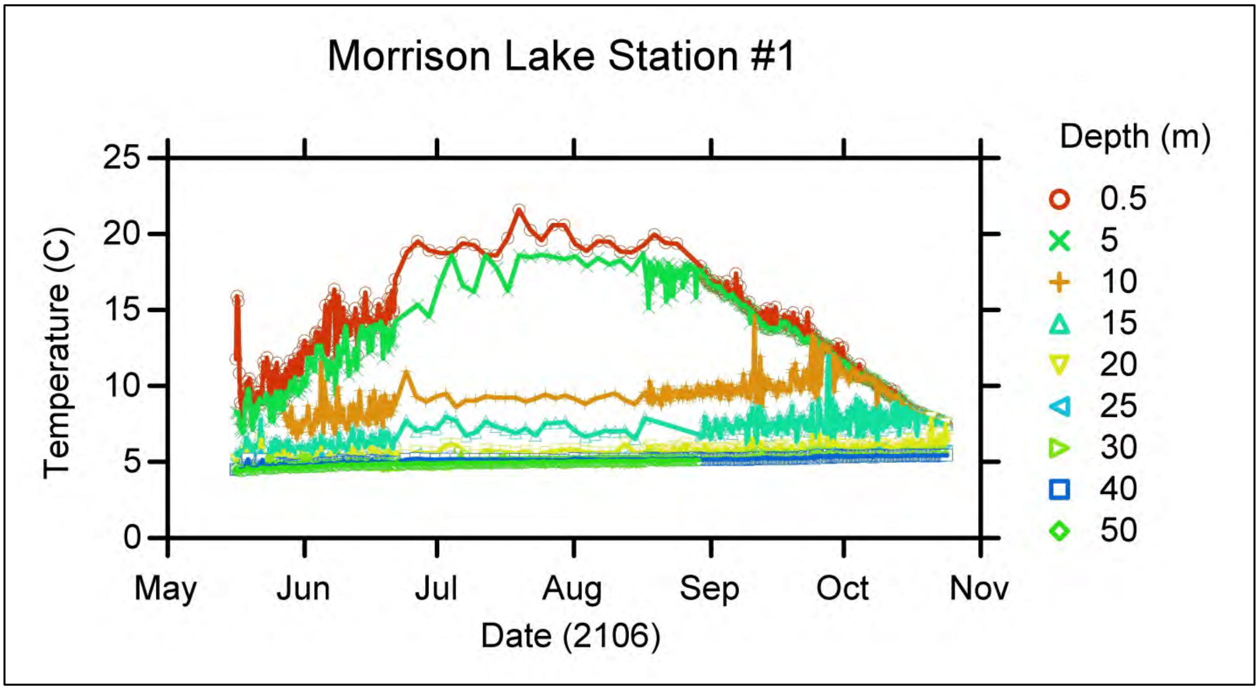

Figure 10 Temperature data from Station #1 thermistor chain.

Figure 11 presents the temperature data collected at Station #2 in Morrison Lake. The temperatures are very similar to those found at Station #1 with the exception of the readings presented by the 5 m Tidbit. A possible rationale for these higher temperatures is presented later in this section. Similar to Station #1, a strong thermocline appears to exist between the 5 and 10 m Tidbits and stratification begins in early June and continues through to October.

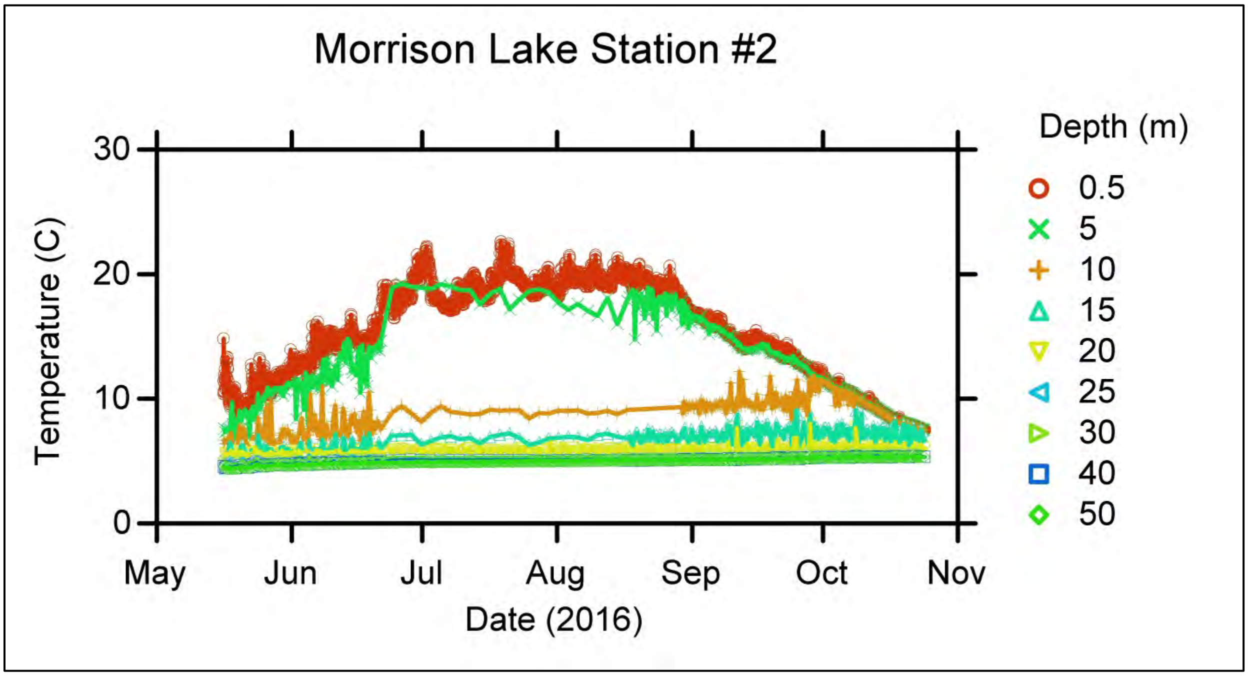

Figure 11 Temperature data from Station #2 thermistor chain.

Station #3 was established in the narrows between the north and south basin of Morrison Lake. Total depth at this station is approximately 7 m and this shelf would prevent hypolimnetic waters from being discharged from the north basin during periods of stratification. Figure 12 presents the temperature data from this station. As can be seen in Figures 9 and 10, the hypolimnetic water temperature rarely exceeds 10 ºC during any point during the year. The temperature data collected at Station #3 is consistently above 10 ºC from June through to October indicating that hypolimnetic waters from the north basin are not discharged during this time period.

Figure 13 presents the temperature data collected from the deepest portion of the south basin of Morrison Lake (Station #4). Similar to the north basin, a strong thermocline exists somewhere between the 5 and 10 m depth for the time period of mid-May through to October.

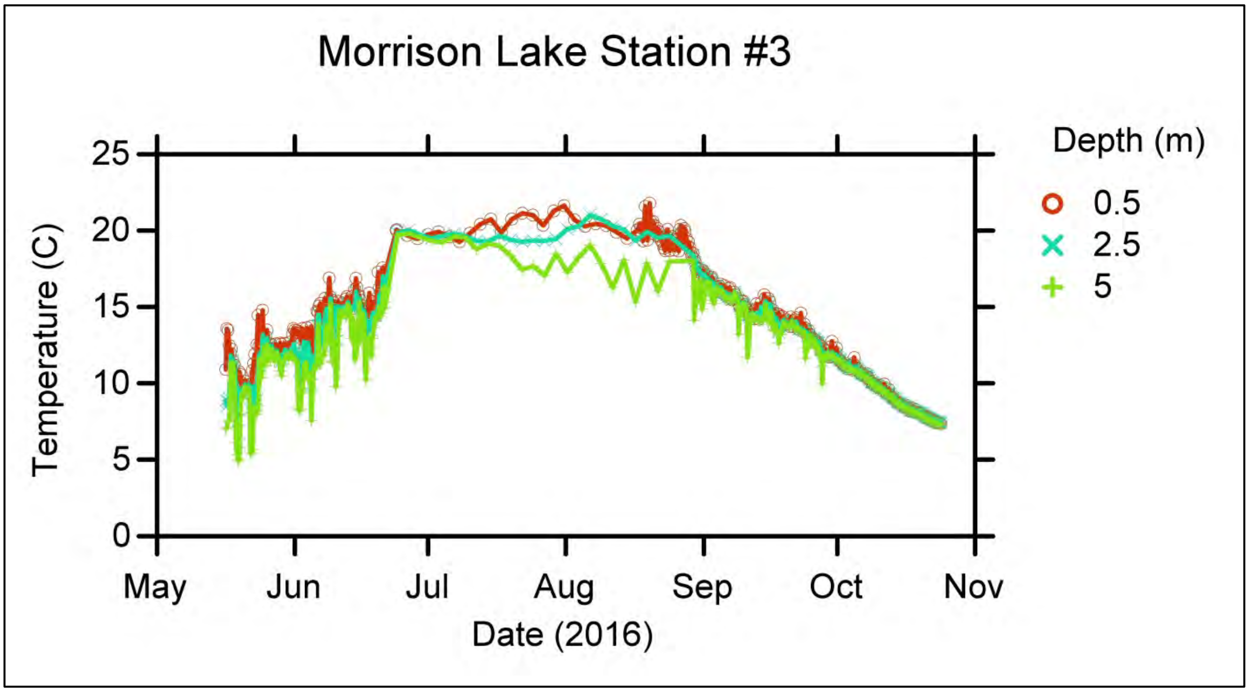

Figure 12 Temperature data from Station #3 thermistor chain.

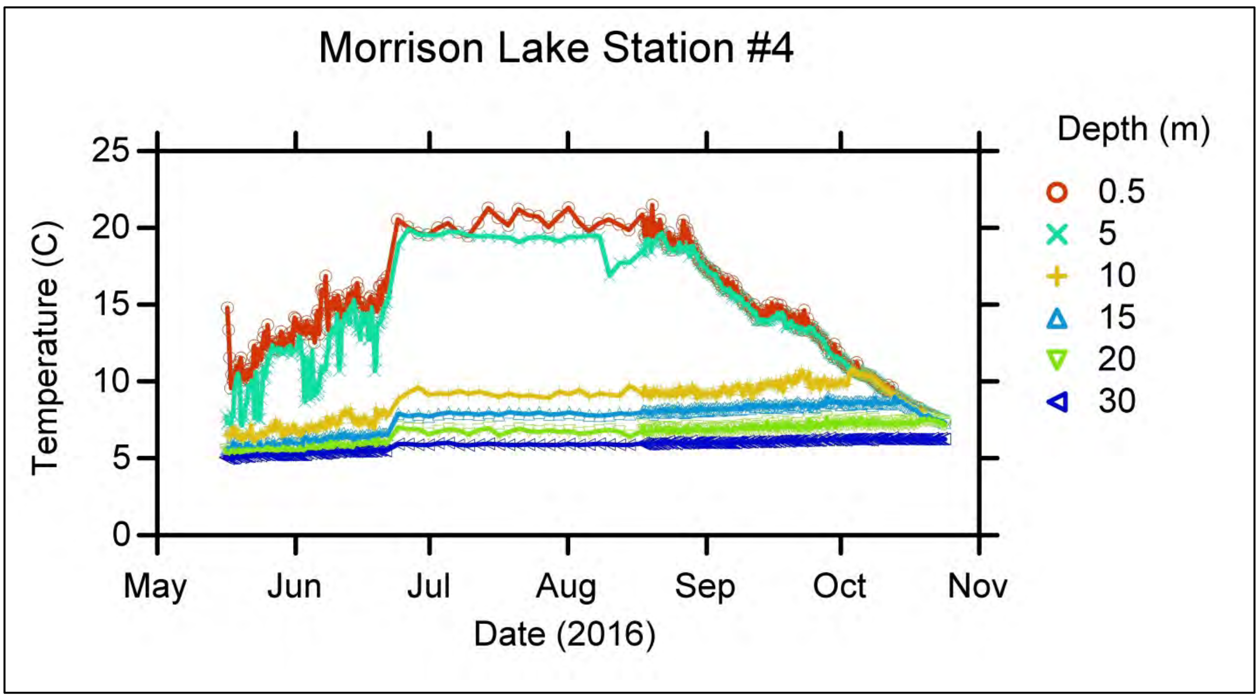

Figure 13 Temperature data from Station #4 thermistor chain.

Morrison Lake outlet temperatures are presented in Figure 14. As discussed above, this station is underneath the bridge that crosses Morrison Creek approximately 2.5 km downstream from the lake. The downward slope of temperatures staring in September reflects the epilimnetic temperatures found in the south basin of Morrison Lake.

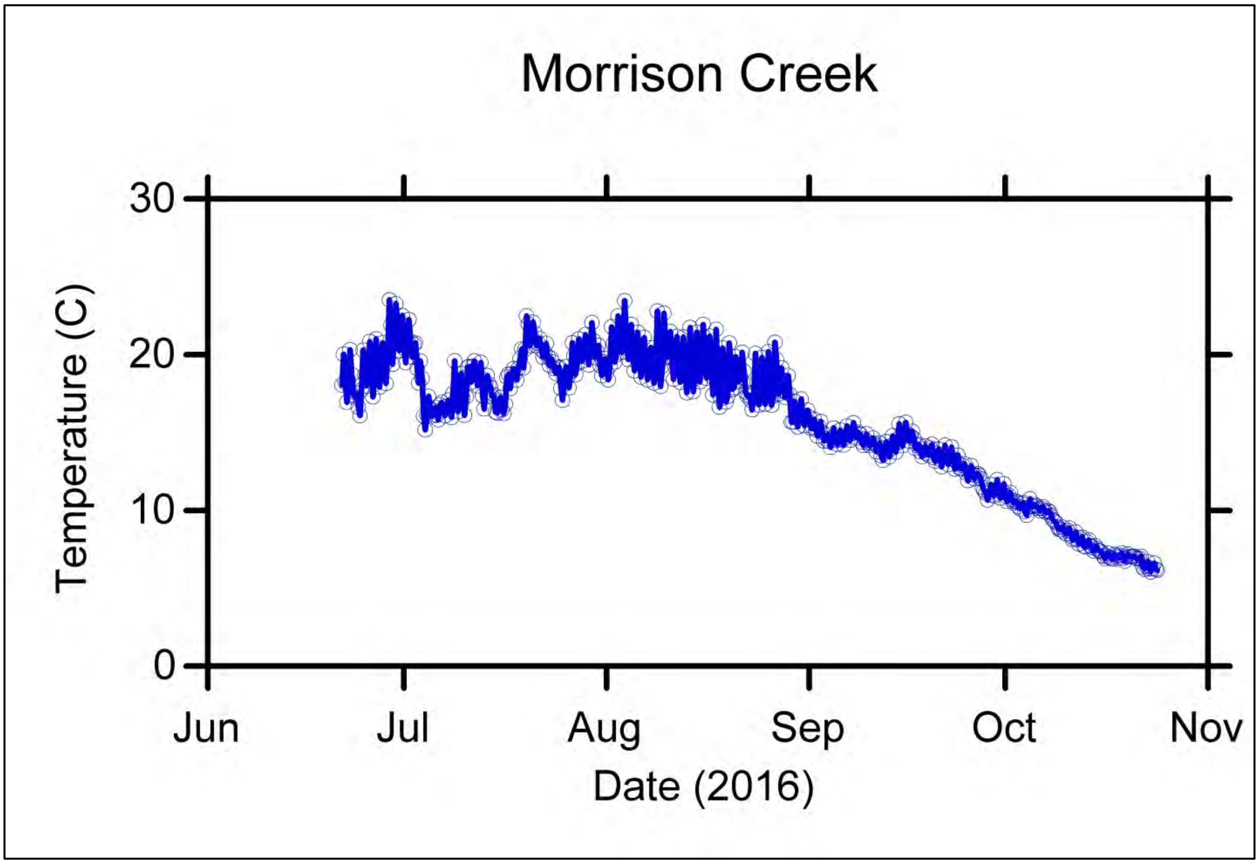

Figure 14 Temperature readings from Morrison Creek.

Figure 15 presents superimposed temperature data from Tahlo and Morrison Creeks. The data shows that the discharge at the outlet of Morrison Lake is slightly warmer than its primary inlet – Tahlo Creek. During the summer months of stratification, the lake would act as a warming basin. During the fall when cooler creek inlet temperatures are being experienced, the lake is likely acting as a heat sink which is slowly releasing some of its energy.

The final graph to be presented using the Tidbit data shows the lake inlet temperature and how it relates to the Station 1 thermistor chain (Figure 16). Creek inflows are generally cooler than the surface waters. The period from mid-June to early July, the creek temperature exceeded that of the lake surface. If the solids content in the creek were elevated, this lens of water could have submerged into the lake rationalizing the anomaly noted in Figure 11. From early July until late September, neutral buoyancy for the inflow would be reached within the epilimnion (i.e. <10 m depth). From that time period forward, the temperature of Tahlo Creek is lower than the temperature found at the 15 m depth. This plunging inflow would help destabilize the thermocline that was established over the summer. The lake was weakly stratified during the October 23rd trip (Figures 10 through 13) and likely became isothermal and turned over completely prior to the lake freezing which typically occurs in early December. Recovery of the Tidbit data in the spring of 2017 will confirm the timing of this event.

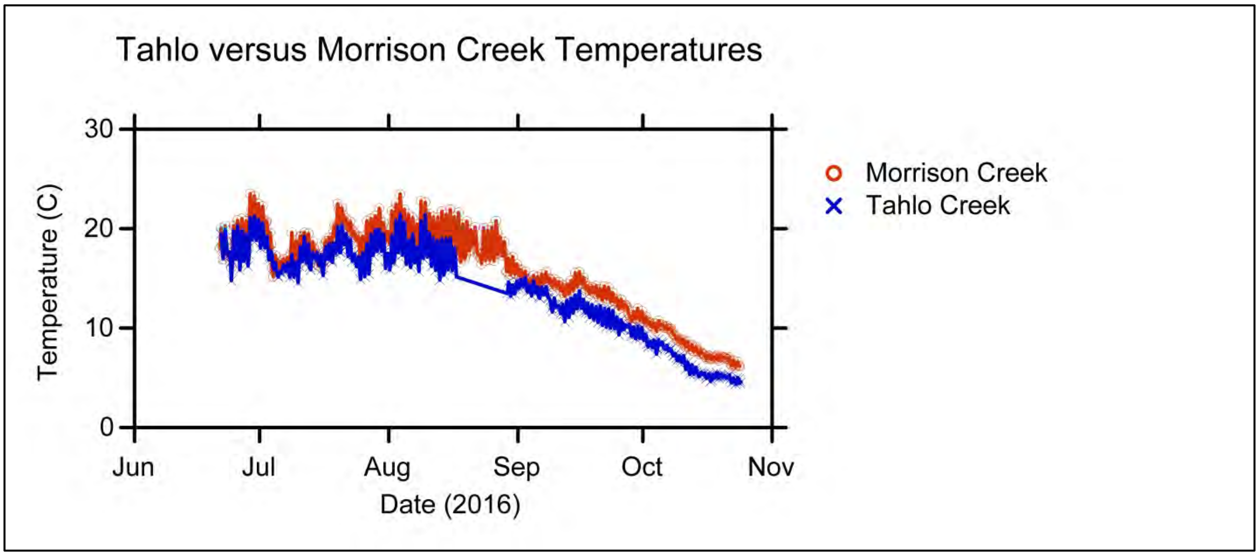

Figure 15 Superimposed temperature data from Tahlo and Morrison Creeks.

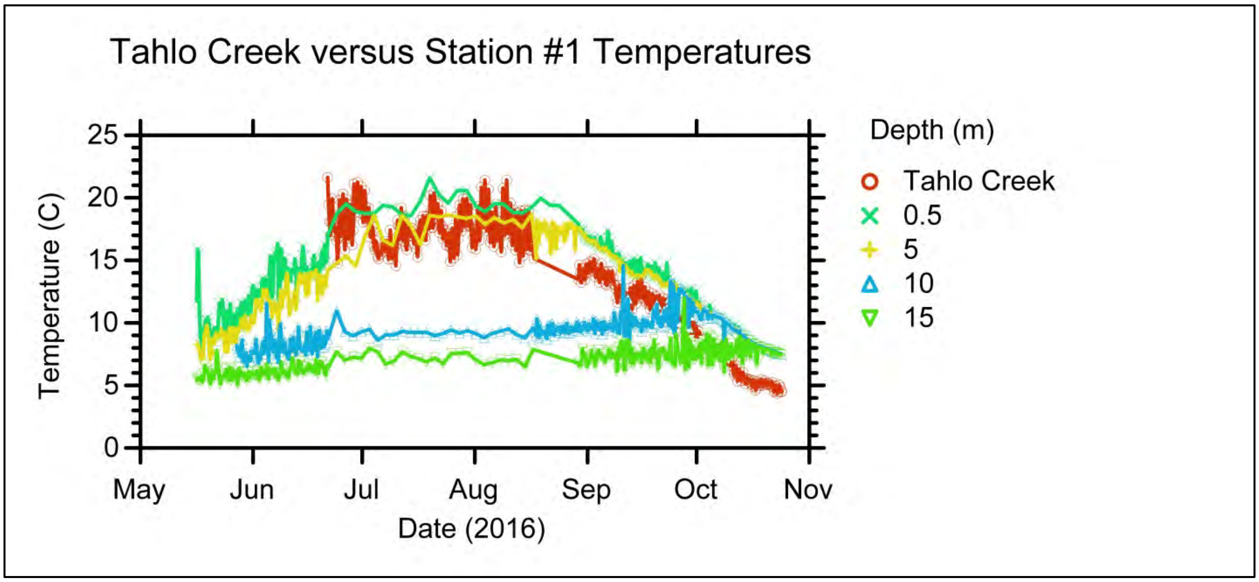

Figure 16 Tahlo Creek versus Station #1 temperature data.

4.2 Sonde Data

In this section, data from the four sets of Sonde casts will be presented. Parameters that will be discussed include temperature, specific conductivity, pH and dissolved oxygen.

4.2.1 Temperature

The seasonal progression of the thermocline development at station 1 can be seen in Figure 17. By May, the top 1 m of water was approaching 10 ^{o}C whereas the majority of the water column at depths greater than 20 m were around 4.5 ^{o}C. By June 20th, surface temperatures exceeded 15 ^{o}C and a relatively strong thermocline was developing around the 7 m mark. By August 20th, the top 3 m of Morrision Lake was above 19 ^{o}C. A second significant temperature change occurred at 5.5 m. A temperature drop from 14.2 ^{o}C down to 12.6 ^{o}C occurred within a half meter interval. The final level of significant stratification occurred at 13.5 m where a temperature drop of 1.18 ^{o}C occurred over a depth of 16 cm. Stability index calculations can be made for these various levels of stratification to determine how much energy would be required to mix these layers. For the sake of this report, the eplimnion could be classified as the 0 to 5.5 m, the metalimnion from the 5.5 to the 13.5 m level and the hypolimnion extending from the 13.5 m level down to the bottom.

During the October 23rd Sonde cast, it was interesting to note that the top metre of water was colder than the water below it. This would be due to heat loss and/or cold precipitation landing on the lake. The colder layer would begin to fall through the lower water causing mixing. Once lakes become weakly stratified in the fall, wind from autumn storms normally mix waters to the bottom of the lake causing the fall turn-over.

Once ice covers the lake, mixing from wind can no longer occur. An inverse stratification is always established because water colder than 4 ^{o}C becomes less dense. This inverse stratification may extend a meter or two below the ice, with the remainder of the water column being unstratified.

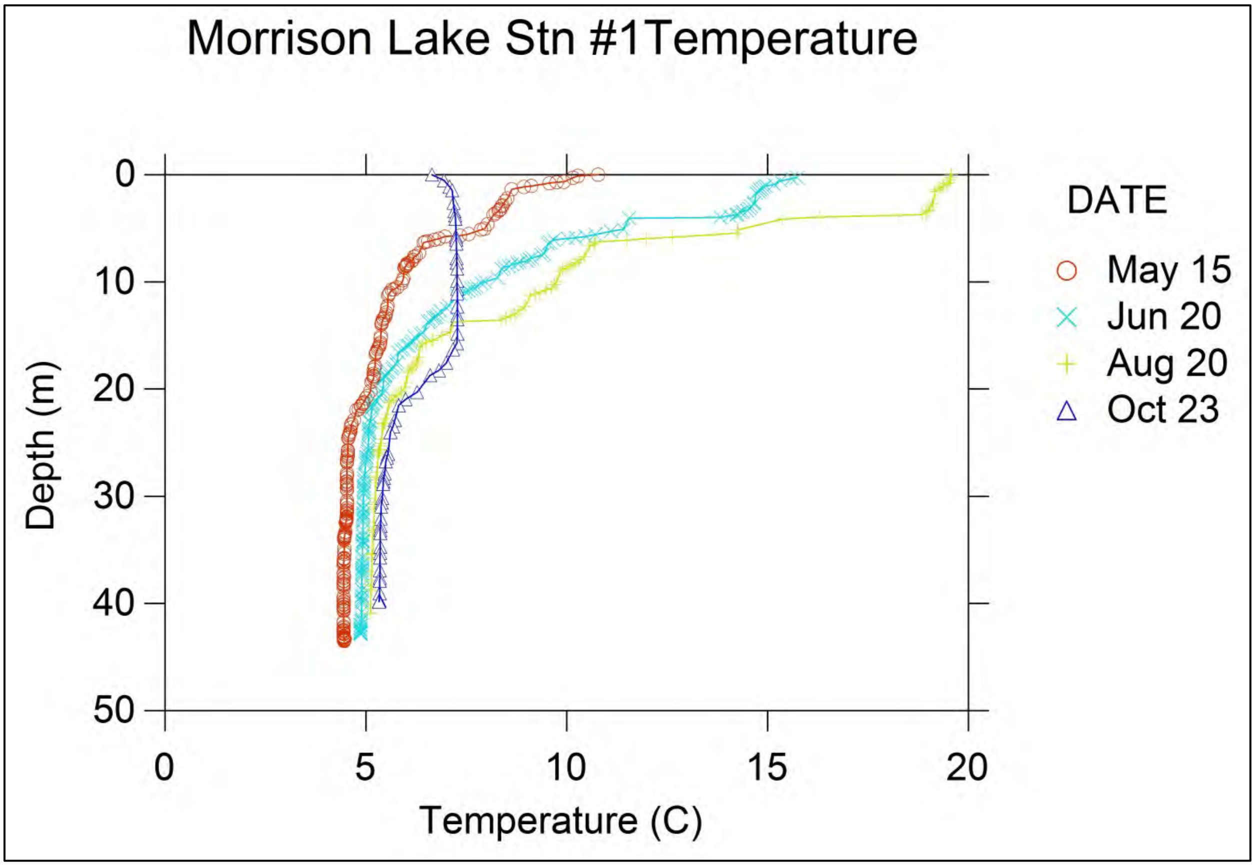

Figure 17 Station #1 temperature profiles.

Figure 18 presents the temperature data from Station #2. This is the proposed location of the diffuser. The stratification at this station is virtually identical to what occurred at Station #1. Station 2 is slightly more central in the northern basin, so it may receive more energy from wind mixing due to the increased fetch. The hypolimnion again remains relatively constant around 15 m throughout the period of stratification.

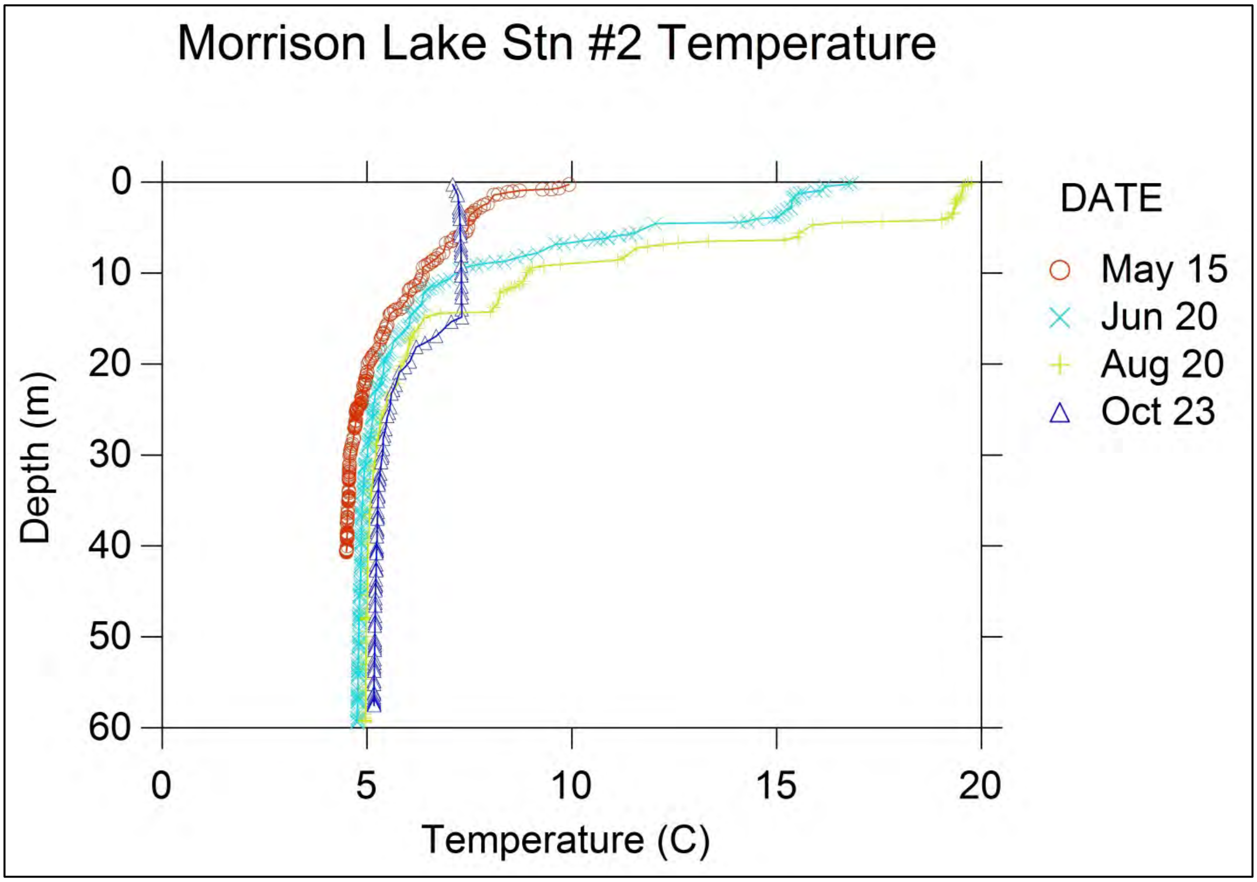

Figure 18 Station #2 temperature profiles.

Figure 19 presents the temperature data from Station #3. This is the shallow bench that separates the north basin from the south. Water flows from the north basin to the south basin then to Morrison Creek and subsequently into Babine Lake.

During the May cast, thermal stratification had begun, but lower cooler water existed below the 2 m depth. Rivers discharging water from such lakes discharge the warm waters from the surface of the lake. During the strongest periods of stratification, epilimentic waters at this Station ranged in depth from approximately 5 to 6.5 m. This layer of water would be moving from the north basin to the south and then subsequently to Morrison Creek. The stratification here is very similar to what was experienced in the north basin of the lake.

Figure 20 presents the temperature data from Station #4 which is the south basin of Morrison Lake. This basin is about 1/3 the size of the north basin and is somewhat more sheltered from winds. It appears that this basin may be slightly warmer than the northern basin.

Figue 21 presents the Sonde temperature data with all four casts superimposed by date. Thermal profiles are very similar across the lake with Station #4 having slightly warmer temperatures during the October cast.

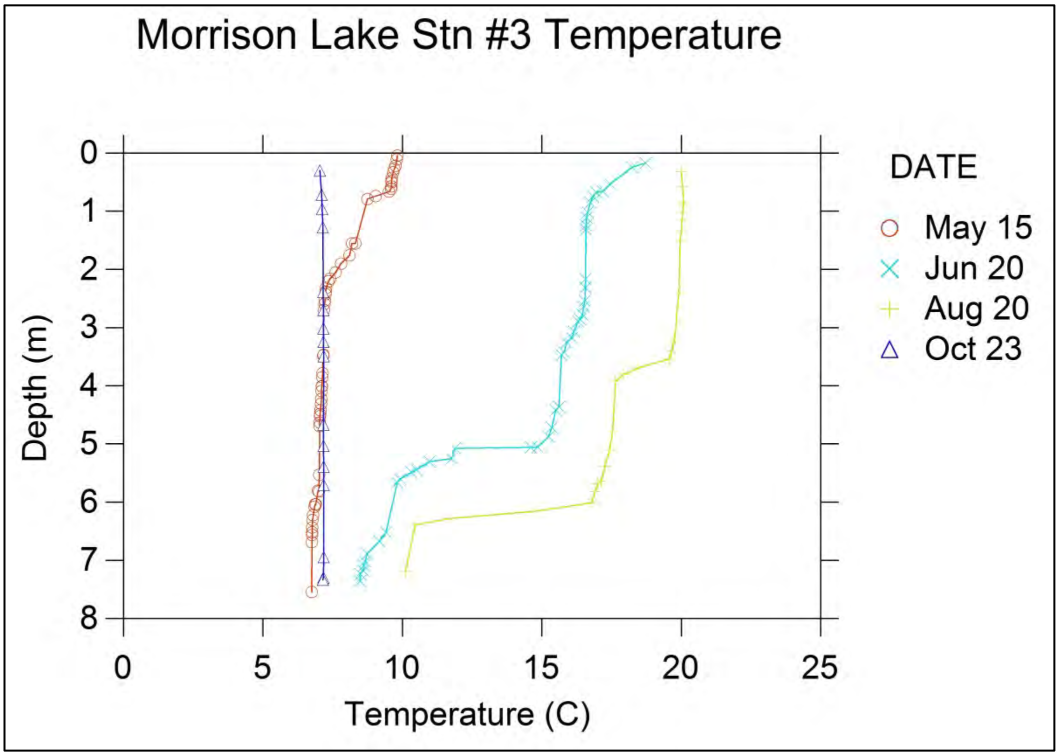

Figure 19 Station #3 temperature profiles.

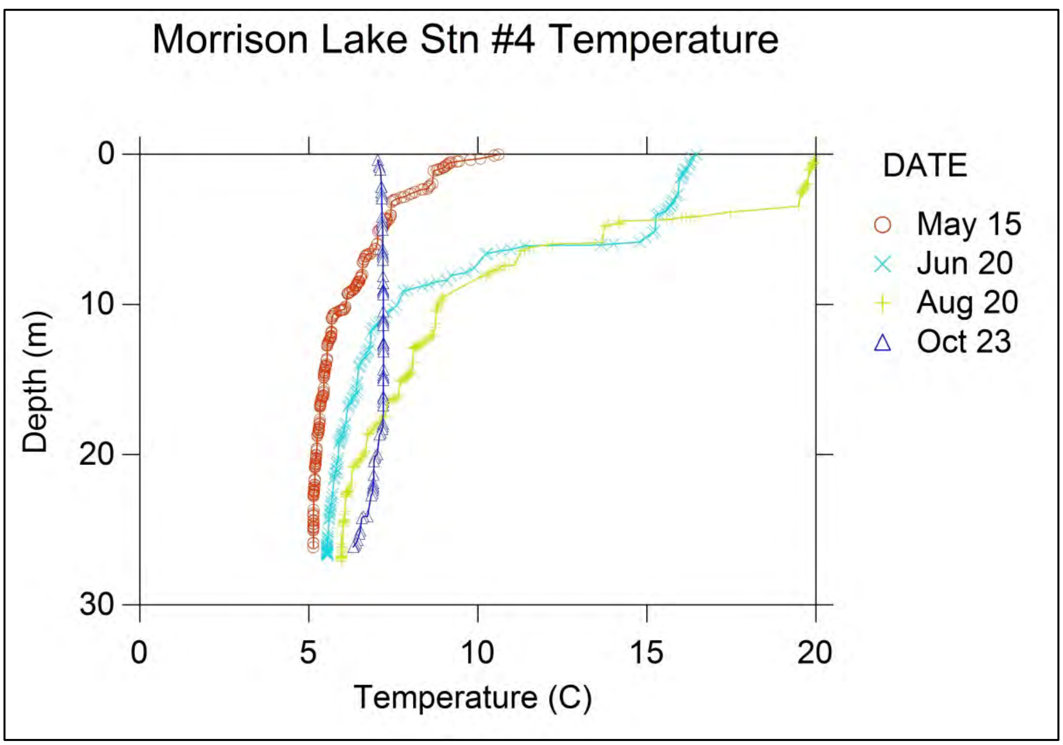

Figure 20 Station #4 temperature profiles.

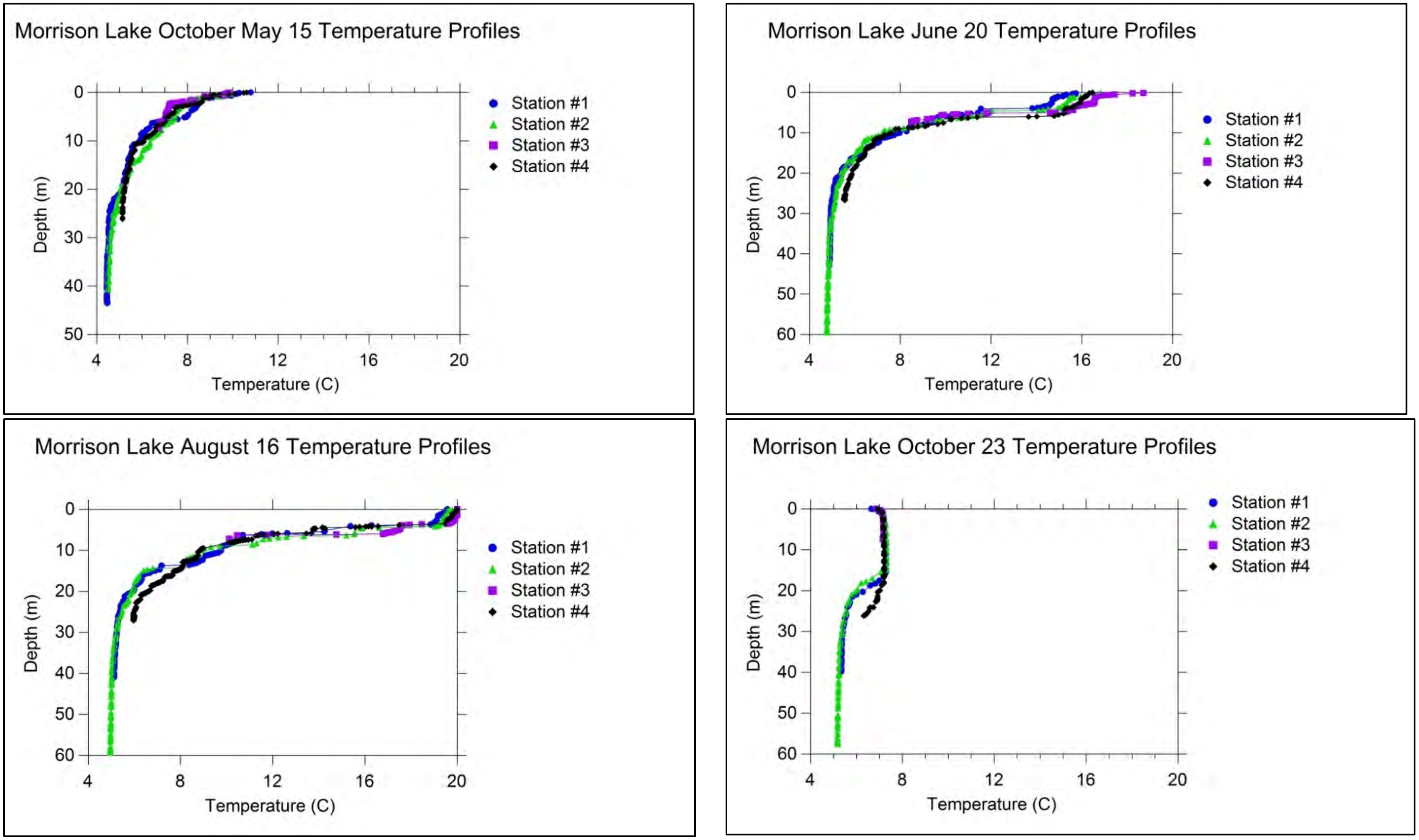

Figure 21 Temperature profiles from all Stations shown by date.

4.2.2 Specific Conductivity

Conductivity is a simple and accurate measurement of how much current a solution allows to flow between two electrodes. This measurement is typically used as a surrogate for the amount of total dissolved solids that are found in a solution. Conductivity is sensitive to temperature with a typical increase of about 2% per degree Celsius (Wetzel, 1983). Specific conductivity is corrected for this temperature function. The conductivity of groundwater is always greater than surface water due to the dissolution of salts as water passes through bedrock and/or soils.

Figure 22 presents the specific conductivity data from the four sets of Sonde casts that were conducted on Morrison Lake in 2016. Virtually off the data readings fell between 55 and 70 uS/cm. The south basin (Station #4) had slightly higher specific conductivity that the north basin and without good chemistry data, it is hard to decipher why this is occurring. On theory is that groundwater inflows from the nearby mineralized orebody may be a contributing factor.

During periods of stratification, the thermocline had increased conductivity which may have been due to the breakdown of organic matter and the subsequent release of inorganic salts at this layer. Strong thermoclines can act as a boundary layer and settling salts and organic matter can be supported by the denser water below the thermocline. The increased conductivity at the thermocline is especially evident during the August 16th Sonde cast.

4.2.3 pH

Figure 23 presents the pH data that was collected from the four sets of Sonde casts conducted on Morrison Lake in 2016. The majority of the readings were at pH 7 ± 0.5. The May and October profiles on Station #4 are definite outliers. In discussion with the Hoskin Scientific technician, he indicated that the pH probes are often slow to equilibrate in relatively low conductivity solutions. The time stamps of the casts were examined and on both of the outlier casts, Station #4 was the first station surveyed. pH is a measurement of the activity of the hydrogen ion, and the storage solutions are of very high ionic strength. The instrument's calibration is checked every time prior to shipment, so the calibration should be accurate.

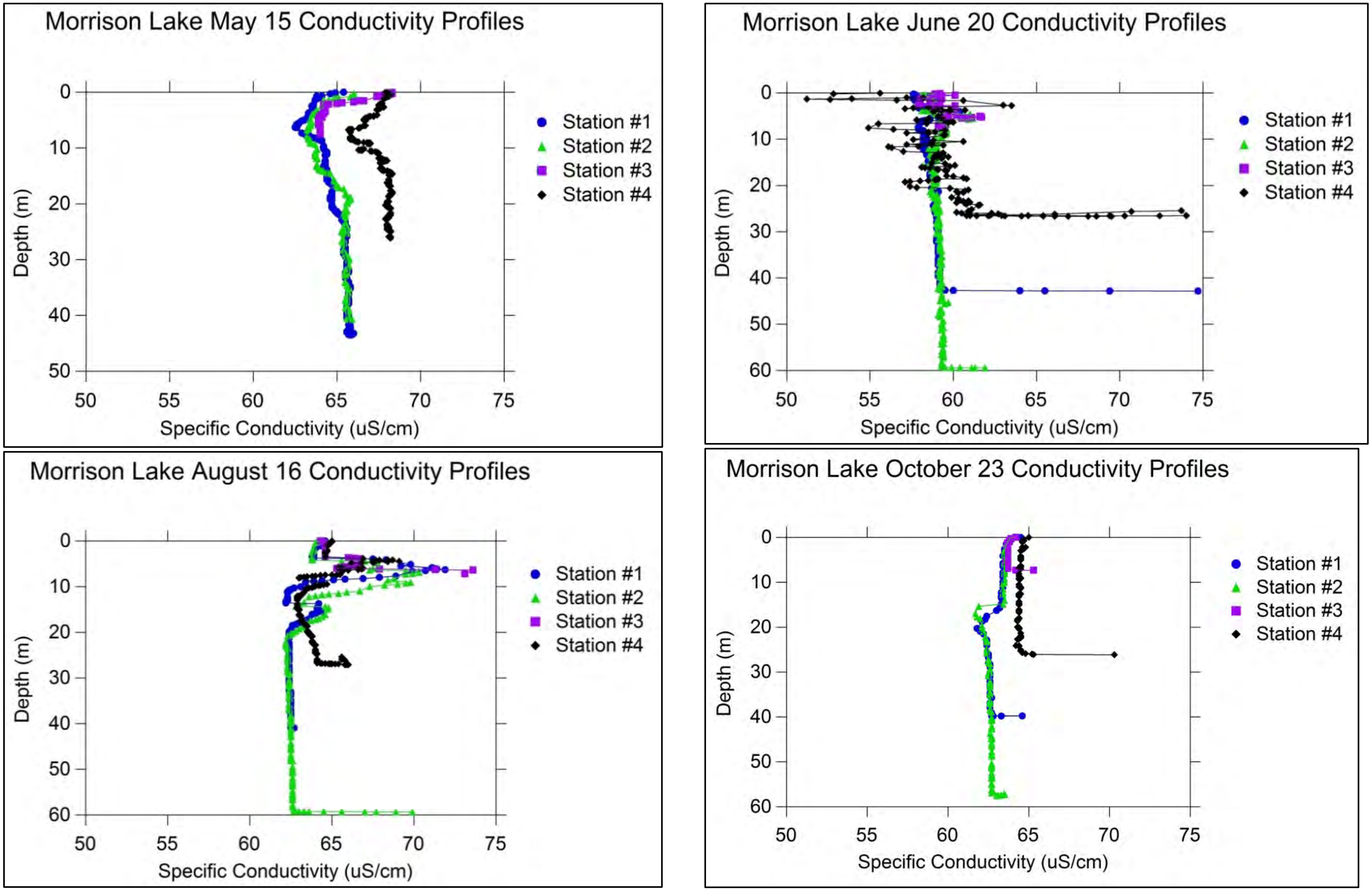

Figure 22 Conductivity plots for Morrison Lake by date.

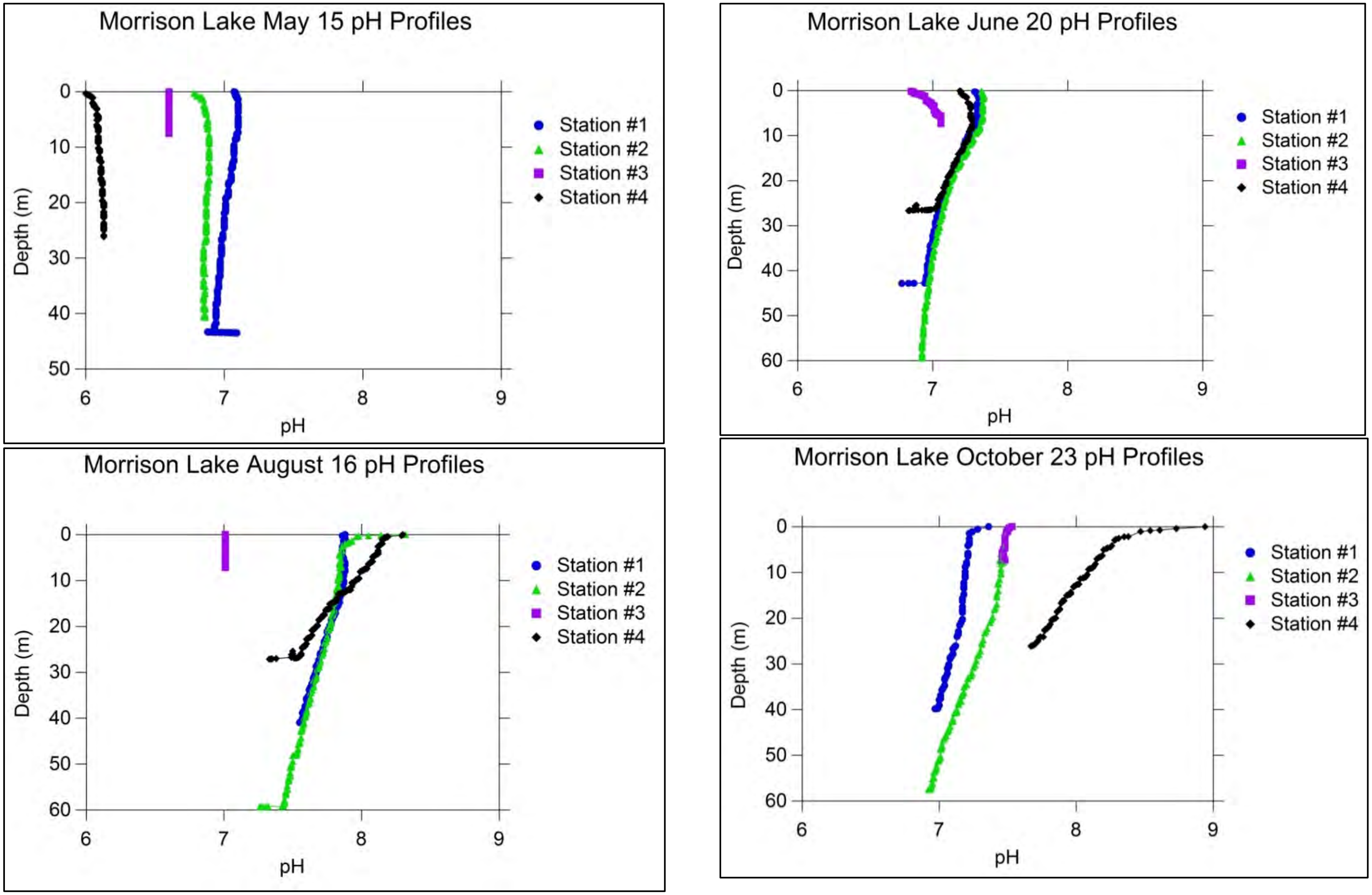

Figure 23 pH plots for Morrison Lake by date.

4.2.4 Dissolved Oxygen

The dissolved oxygen cycle in lakes is controlled by atmospheric diffusion into the water (wind and subsequent breaking waves), by photosynthesis and by biological respiration and decomposition. In highly productive lakes, the consumption of oxygen due to the oxidation of organic matter can cause lakes to go anoxic. Morrison Lake does not have enough primary productivity to cause this problem, so it remains inhabitable by fish and aquatic organisms throughout the year.

Figure 24 is a plot of the dissolved oxygen profiles that were obtained in Morrison Lake during 2016. During periods of stratification a slight reduction in the concentration of dissolved oxygen is evident at the thermoclines (June 20 and August 16 plates). This reduction is likely due to the breakdown or organic matter that has settled onto the thermocline. As was briefly discussed earlier, the difference in water density at the thermocline tends to briefly support material as it settles to the bottom of the lake.

The solubility of gasses in water is a function of temperature. Percent solubility of dissolved oxygen corrects for the temperature and provides insight into seasonal biological processes in the lake. Figure 25 displays the percent dissolved oxygen saturation data collected from the 2016 Sonde casts on Morrison Lake. Dissolved oxygen saturation levels of over 90% occurred in the euphotic zone during periods of thermal stratification. This would have been caused by photosynthesis because strong winds were not observed during any of these trips. A reduction in dissolved oxygen saturation occurred in the metalimnion, with the lowest levels occurring in the hypolimnion. The consumption of oxygen in these layers would be due to the breakdown of organic matter.

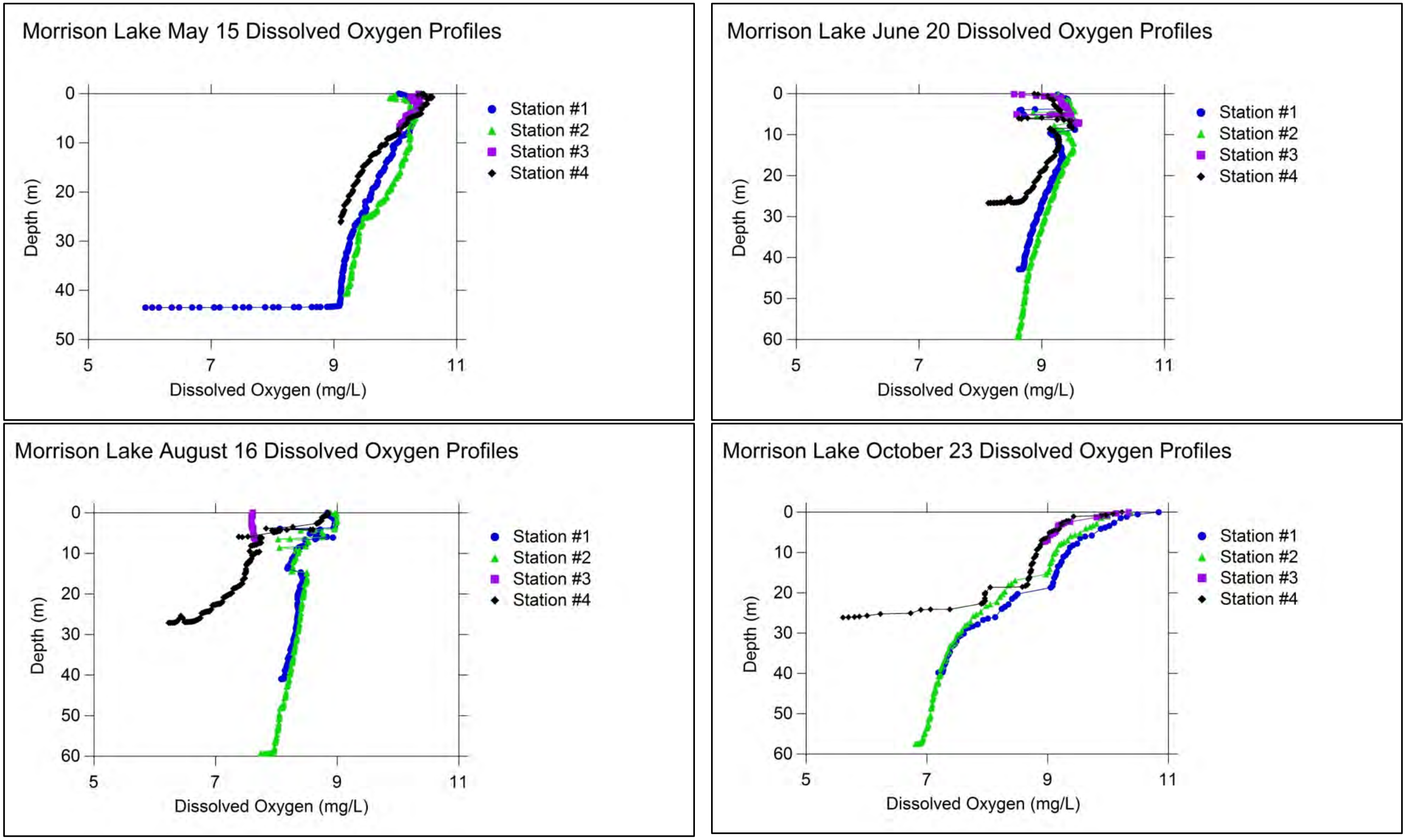

Figure 24 Dissolved oxygen plots for Morrison Lake by date.

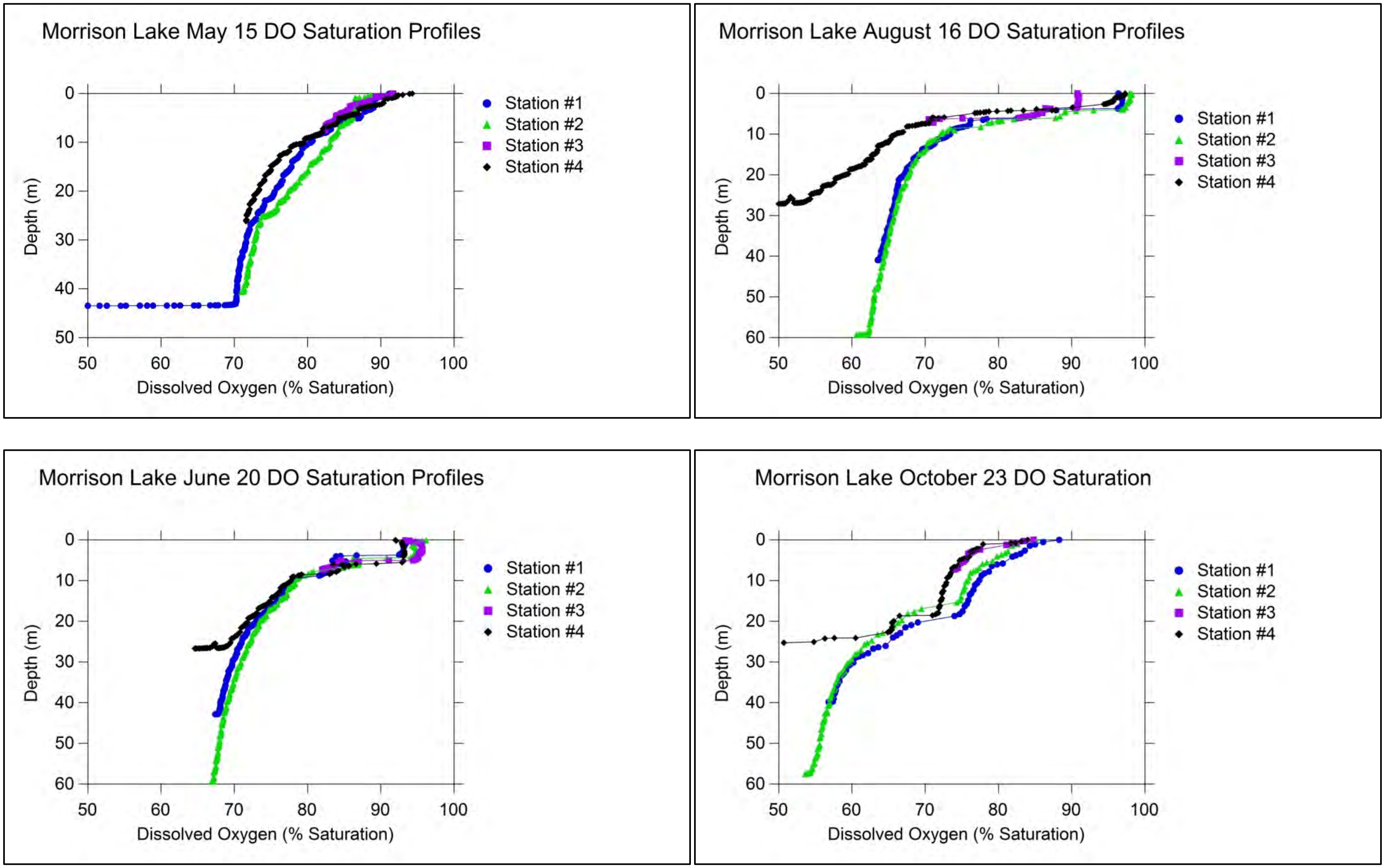

Figure 25 Dissolved oxygen percent saturation for Morrison Lake by date.

4.2.5 Station #2 – Proposed Diffuser Location

In this section, temperature, conductivity, dissolved oxygen and dissolved oxygen saturation graphs are presented for Station #2 which is the proposed location for the diffuser outfall (Figure 26).

The top of the hypolimnion appears to remain at the 15 to 20 m level throughout the period of stratification. Specific conductivity does increase during the period of strongest stratification and is likely due to the decomposition of organic matter and the subsequent release of salts. Dissolved oxygen is not limiting for aquatic organisms during any time period monitored. The lowest levels of dissolved oxygen in the hypolimnion occurred in October which can be explained by the oxidation of organic matter through the growing season. Dissolved oxygen concentrations would become uniform through the water column after the fall turn-over.

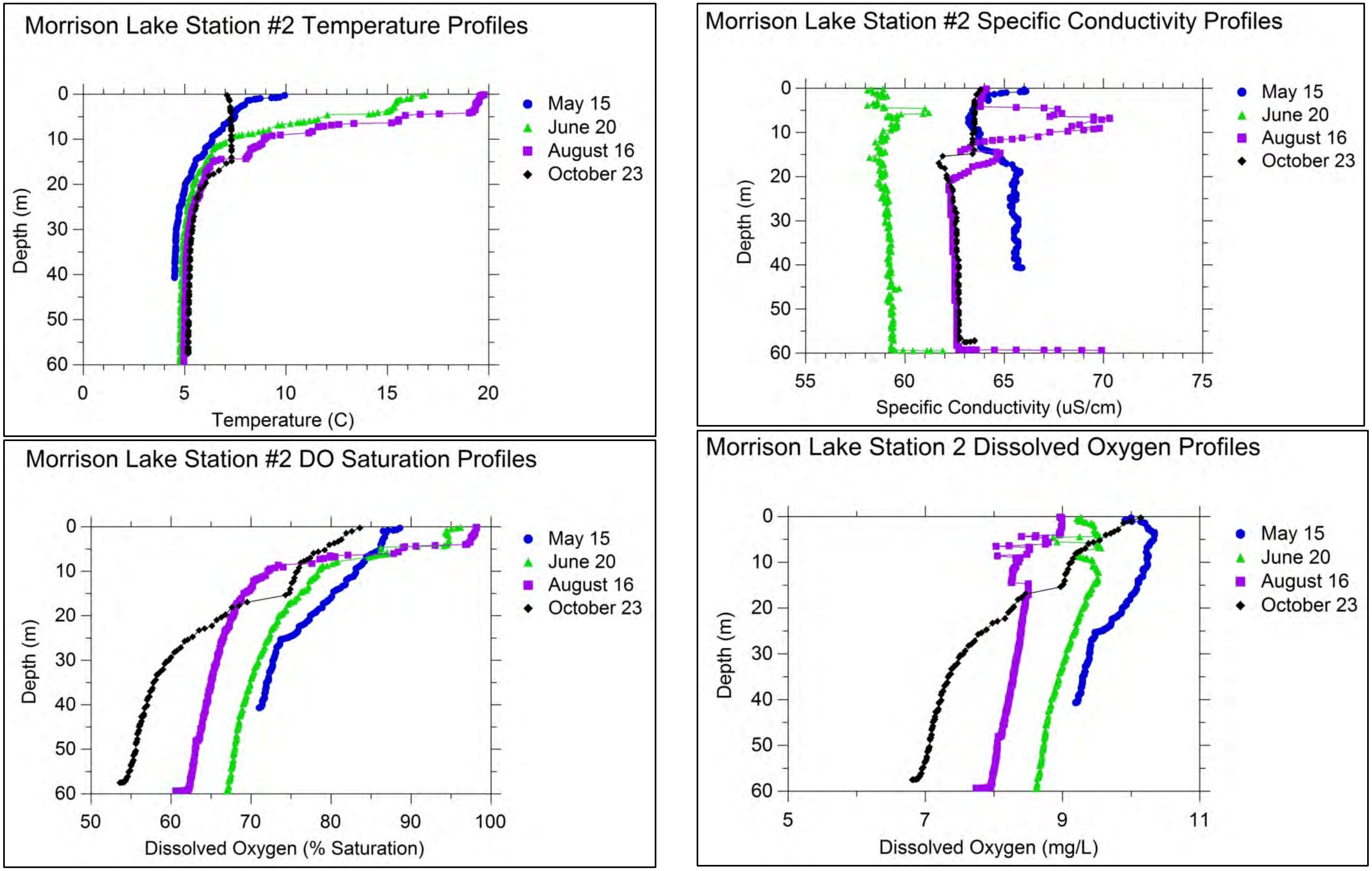

Figure 26 Temperature, conductivity and dissolved oxygen profiles at Station #2.

5 Discussion and Conclusions

This report confirms that Morrison Lake is a typical dimictic lake with stratification beginning in the spring, strengthening through the summer and then breaking down through the fall. Four thermistor chains were installed along the lake. In addition, lake inlet and outlet temperatures will be monitored for a year to document lake turn-over events in the spring and fall. Data presented in this report cover the stratification period from mid-May of 2016 through to the end of October. A final report will be presented in June once a full year of data has been collected.

The data collected confirm several of the assumptions made by Dr. Lawrence in his diffuser mixing model. First, the north and south basins are isolated during the summer stratification period. Secondly, approximating the top of the hypolimnion to be around 15 m for the sake of diffuser dilution calculations is reasonable.

Specific conductivity will be a critical parameter to monitor prior to and once effluent is being discharged to the hypolimnion. This parameter could be used to monitor and track mixing at and near the diffuser once the treated effluent is being discharged. The instantaneous conductivity data could be used to establish a water quality monitoring program to check metal concentrations in the water column. A multi-port diffuser could be established which would maximize the mixing and reduce the risk of generating un-natural currents in the lake as suggested by Dr. Laval.

The discharge of treated effluent to the depths of a lake may generate more of perception problem than biological effect. Permit discharge limits will be established and continuously monitored at the treatment plant discharge point prior to entering the discharge pipe. Effluent at that point will be required to meet all provincial and federal standards. Discharging the treated effluent into the hypolimnion where very limited biological activity occurs is preferable to discharging to surface waters. Metal complexation with organic matter in the hypolimnion and the subsequent settling of these colloids would remove these metals from the food chain. Benthic invertebrate activity in the deep basins of Morrison Lake are likely very limited.

Once a full year of data has been collected, it is suggested that lake inlet, lake outlet and Stations #2 and #4 Tidbits be left in to continue data collection. The extra Tidbits can be placed at 1 m intervals down to the 20 m level on the two thermistor chains to collect higher resolution data on the thermal stratification and subsequent destratification in the epi- and metalimnion. Collection of that information twice a year would be adequate for additional lake stratification information.

The final observation is that during the EA and Lake Effects Assessment process, no attention was given to the fact that the pit like will likely become meromictic over time. Island Copper was a large porphyry copper mine which was flooded with sea water on closure. Surface fertilization in the pit was used to increase algae production. The algae was used to sequester metals and eventually settled into the depths which are anoxic. In this anoxic zone, high levels of sulphates are reduced to metal-sulphide complexes which are relatively insoluble and readily precipitate into the sediments. Such a treatment system may have applicability at the proposed mine pit once is has been flooded.

6 References Cited

Ministry of Environment, 2015. Ambient water quality guidelines for cadmium – technical report. 114 pp.

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