

July 31, 2019

City of Iqaluit
City Hall, P.O. Box 460
Iqaluit, NU X0A 0H0

ISSUED FOR REVIEW
FILE: ENG.GEOP03157-01
Via Email: m.hamp@city.iqaluit.nu.ca

Attention: Matthew Hamp, Director of Public Works and Engineering

Subject: Iqaluit DFO Bathymetric Lake Surveys

This 'Issued for Review' document is provided solely for the purpose of client review and presents our interim findings and recommendations to date. Our usable findings and recommendations are provided only through an 'Issued for Use' document, which will be issued subsequent to this review. Final design should not be undertaken based on the interim recommendations made herein. Once our report is issued for use, the 'Issued for Review' document should be either returned to Tetra Tech Canada Inc. (Tetra Tech) or destroyed.

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was retained by the City of Iqaluit (the City) to conduct bathymetric surveys on two lakes. The two lakes surveyed were Unnamed Lake and Lake Geraldine, approximately 5 km and 1.5 km northeast of Iqaluit, NU, respectively.

The City has historically obtained its fresh water supply from the Lake Geraldine water reservoir. In 2018 a shortage of water in the reservoir was experienced following the spring freshet, requiring the City to supplement the drinking water supply from an additional source. The City's objective is to develop a sustainable long-term water supply. Unnamed Lake has been identified as a possible alternative water supply source. A bathymetric survey is required for the lake to provide an accurate map of lake morphometry and a calculation of potential available water volume. Additionally, a bathymetric survey was requested for Lake Geraldine to assess its current conditions.

The City required the bathymetric surveys to be completed in accordance with Scenario E of Application of the NWT Winter Water Withdrawal Protocol with Bathymetric Profiles of Select Small Lakes in the Mackenzie Delta Region (DFO 2005). Data was collected between July 23 and July 25, 2019.

2.0 EQUIPMENT

Tetra Tech utilized an Ohmex SonarMite single beam acoustic echosounder to complete the bathymetric survey. The SonarMite has a 235 kHz active transducer, a beam width of $\pm 4^\circ$ and a measurement accuracy of ± 2.5 cm. The SonarMite unit employs digital signal conditioning and analysis circuitry to digitally output water depths at a rate of 2 Hz. The water depth measurements are recorded to a field laptop computer.

A Topcon HiperXT real-time kinematic (RTK) GPS system was used to provide positioning information. The GPS base station was positioned on shore for each lake and broadcast positioning correction information. The GPS rover was setup on the boat to receive positioning corrections from the base and integrate corrected positions with the echosounder data as the data was recorded. Given appropriate satellite constellations at the time of data collection, the RTK system typically provides 2 cm horizontal accuracy and 2 cm to 3 cm vertical accuracy.

The bathymetric survey for Unnamed Lake was conducted from a 9.5-foot zodiac with a Yamaha 4 HP outboard motor. The bathymetric survey on Lake Geraldine was conducted from a 12-foot Princecraft aluminum boat with a Yamaha 4 HP outboard motor.

3.0 DATA COLLECTION

The bathymetric survey was carried out by James Mickle, P.Geoph. (AB) of Tetra Tech's Calgary office. Data was collected between July 23 and 25, 2019. Survey support was provided by Qairrulik Outfitting, based in Iqaluit. Lake Geraldine was accessible by truck, while Unnamed Lake was only accessible by ATV. Surveys were carried out using the equipment listed in Section 2.0.

Data was collected with three longitudinal profiles and transverse profiles spaced every 100 m on Unnamed Lake with the location of the profiles optimised to account for the shape of the lake. For Lake Geraldine a single longitudinal profile and transverse lines every 100 m were collected. Based on the shape of both lakes and the paper "Application of the NWT Winter Water Withdrawal Protocol with Bathymetric Profiles of Select Small Lakes in the Mackenzie Delta Region, 2005", it is estimated that the volumes calculated potentially underestimate total volumes by 5% in the case of Unnamed Lake and 10% at Geraldine Lake at the time of the survey. Survey navigation was achieved using a navigation tracking software package that displayed the boat location and track lines in real time for the boat operator.

Three sonar depth calibrations were completed for each lake as part of Tetra Tech's standard Quality Control/Quality Assurance (QA/QC) procedures.

At each lake, ten GPS points were collected using the RTK rover unit along the shoreline to measure elevation of the water level at the time of the survey.

3.1 Unnamed Lake

The bathymetric survey on Unnamed Lake was completed between July 24 and 25, 2019. Data collection tracks for the survey are plotted on Figure 1.

Two small bays can be seen in Figure 1 at the north end and west side of the lake. Tetra Tech was able to access a small portion of the north bay, but the water level was so shallow that the sonar system could not provide depth readings. The west bay was inaccessible due to shallow water depths (<0.5 m). Based on field observations it is assumed that both bays will be isolated from the main water body during winter (frozen) conditions. Therefore, the two bays would not affect the under ice water volume.

3.2 Lake Geraldine

The bathymetric survey on Lake Geraldine was completed on July 23, 2019. Data collection tracks for the survey are plotted on Figure 2.

The southeast arm of Lake Geraldine was inaccessible due to a section of dry land approximately 50 m in length preventing the boat from passing. Extremely rough and rocky terrain was noted on the land around the southeast arm, preventing movement of the boat to that area. Small rocks were also noted protruding from the water in the middle of the southeast arm, so it is assumed that the water depth was minimal. This portion of Lake Geraldine was essentially cut off from the main lake at the time of the survey and thus would not contribute to the immediate water withdrawal capacity of the lake.

Two small islands were present at the time of the survey. These are seen as small gaps in the bathymetry data in Figure 2. Water was extremely shallow (<0.5 m) in the channel between the larger island and the western shore, preventing a data collection track in this channel. Due to the low water level, this channel is expected to freeze to ground in the winter and therefore not affect the under ice water volume.

4.0 DATA PROCESSING

Data processing consisted of the following steps:

- Submitting static GPS base station observation files to the National Resources Canada (NRCAN) precise point positioning (PPP) correction system;
- Applying PPP horizontal and vertical corrections to all positioning information;
- Applying depth corrections to bathymetry data based on sonar depth calibrations;
- Averaging the ten water level elevations recorded for each lake to establish an elevation for each lake surface at the time of the survey (see Section 5.1);
- Digitizing the shoreline from available georeferenced satellite imagery to assign the water surface outline (i.e., 0 m depth contour) at the time of the bathymetric survey;
- Contouring the water depth data using a Kriging algorithm;
- Plotting depth contour results on georeferenced air photos;
- Calculating the lake surface areas using the digitized shoreline; and
- Calculating the required lake volumes using the trapezoidal method of calculation.

4.1 QA/QC

Tetra Tech's QA/QC procedures included conducting sonar depth calibrations in multiple locations on each lake. This was done by manually measuring the lake depth using a weighted tape measure and comparing that number to the depth displayed by the sonar at the same location. Depth calibrations are typically conducted in three locations per lake. Differences between the manually measured depths and the sonar readings are plotted and used to determine what depth corrections are required to be applied to the bathymetric results.

Additionally, crossline consistency is checked as part of the QA/QC procedures. At locations where transverse survey lines intersect longitudinal survey lines, depth values are compared between the two survey passes over the same location. Discrepancies in depth values between the two passes could be indicative of positioning errors. For these surveys, no significant discrepancies between crosslines were noted.

5.0 RESULTS

Survey results for Unnamed Lake and Lake Geraldine are presented in Figures 1 and 2, respectively. Each figure shows a bathymetric colour contour map. A table has been included on each figure summarizing the required information from DFO Protocol for Winter Water Withdrawal in the Northwest Territories. This includes:

- Lake ID;

- Coordinates;
- Surface area;
- Total lake volume;
- Under ice volume;
- Max expected ice thickness value used; and
- Calculated 5% withdrawal volume.

5.1 Vertical Data Positioning

A lake surface elevation has been provided on each figure for the measured CVD28 water elevation at the time of the survey. The absolute accuracy of this elevation measurement is approximately ± 3 cm. Water surface elevations have not yet been compared to LiDAR results, as at the time of this report the LiDAR data had not yet been collected. Once the LiDAR data is available, it is recommended that the Tetra Tech elevations be shifted to match the elevations obtained during the LiDAR program.

This can be achieved by comparing the elevation at a known location in both datasets. While on site, Tetra Tech recorded a 3D point on the eastern side of the dam in a location that can be easily found and surveyed during the LiDAR program. Similarly, points were collected on two distinctive rocks at either end of Unnamed Lake and flagged so that the LiDAR ground crew can find them and record their coordinates. Once collected, the LiDAR elevation at these locations can be compared to Tetra Tech's elevations at the same locations to determine the required elevation shift and thus accurately tie the two datasets together.

Once the water surface elevations have been shifted to match the LiDAR data, a comprehensive above- and below-water elevation contour model can be generated for the region by combining the sonar and LiDAR datasets.

6.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of City of Iqaluit and their agents. Tetra Tech Canada Inc. (operating as Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than City of Iqaluit, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on Use of this Document attached in the Appendix or Contractual Terms and Conditions executed by both parties.

7.0 CLOSURE

We trust this document meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully Submitted,
Tetra Tech Canada Inc.

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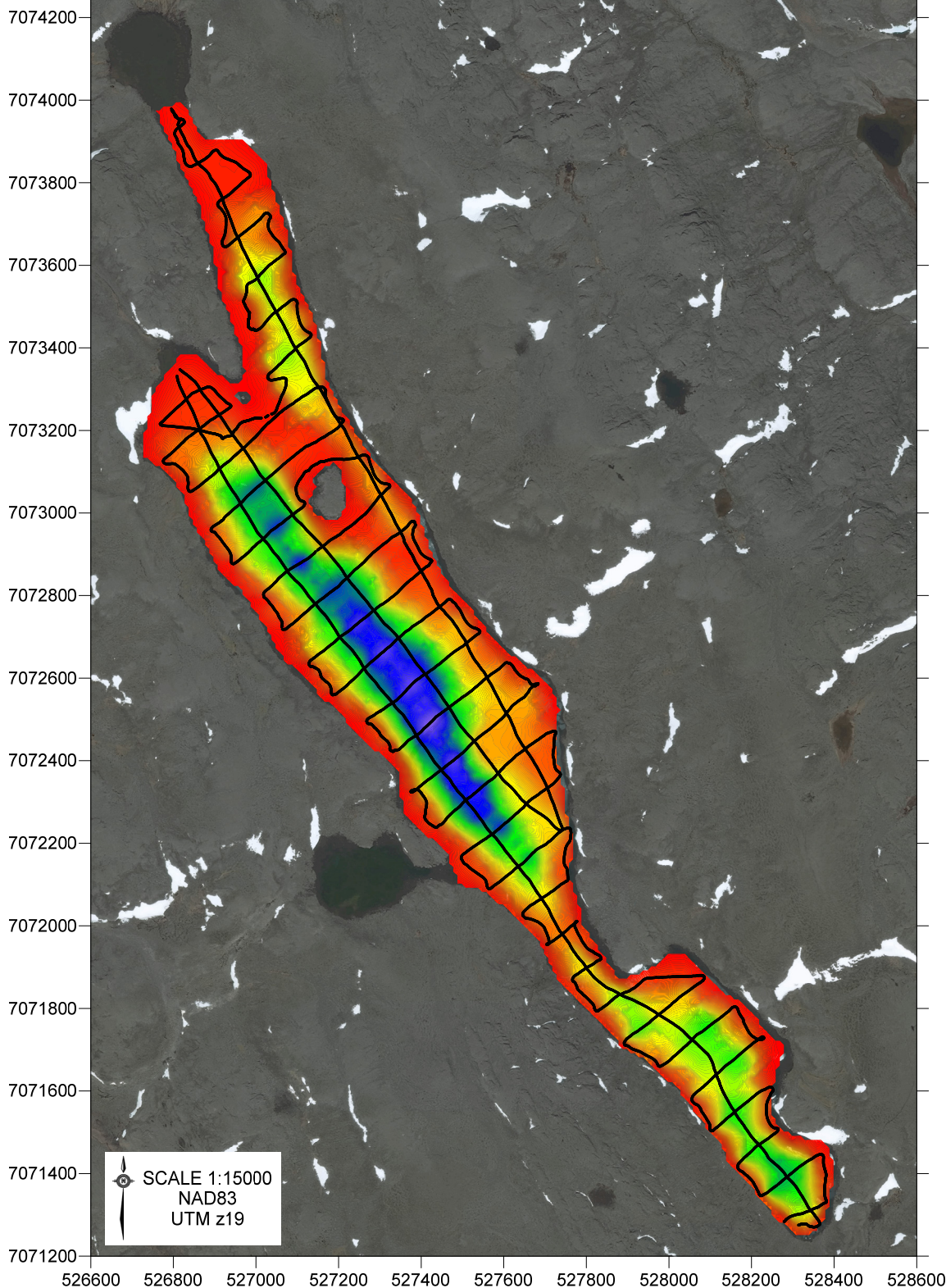
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FIGURES

- Figure 1 Unnamed Lake Bathymetry Depth Results
Figure 2 Lake Geraldine Bathymetry Depth Results

North (m)



Water Depth (m)

Shoreline digitized using Sentinel-2 L1C image from July 23, 2019
 Displayed background image from HERE
 Water level elevation at time of survey 203.32 m in CVD28 datum using HT2_1997 geoid model

LEGEND

Data collection tracks

DFO Lake Summary

Lake ID: Unnamed Lake
Centre Coordinates: 527,432 m E 7,072,564 m N
Surface Area: 911,300 m²
Total Lake Volume: 6,616,900 m³
Under Ice Volume: 4,737,900 m³
Maximum Expected Ice Thickness Value Used: 2.0 m
Calculated 5% Withdrawal Volume: 236,895 m³

CLIENT



IQALUIT DFO BATHYMETRIC LAKE SURVEYS

**Unnamed Lake
 Bathymetry Depth Results**
 Data Collected July 24-25, 2019

PROJECT NO.	DWN	CKD	APVD	REV
ENG.GEOP03157-01	CB	RJM	PIF	0
OFFICE	DATE			
EBA-EDM	July 31, 2019			

Figure 1

APPENDIX A

TETRA TECH'S LIMITATIONS ON USE OF THIS DOCUMENT

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GEOPHYSICAL

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Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

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1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

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While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

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This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to explore, address, or consider and has not explored, addressed, or considered any environmental or regulatory issues associated with the development of the site.

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgemental in nature as to both type and condition. TETRA TECH does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

1.9 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

1.10 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. TETRA TECH does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

1.11 SURFACE WATER AND GROUNDWATER CONDITIONS

Surface and groundwater conditions mentioned in this report are those observed at the times recorded in the report. These conditions vary with geological detail between observation sites; annual, seasonal and special meteorological conditions; and with development activity. Interpretation of water conditions from observations and records is judgmental and constitutes an evaluation of circumstances as influenced by geology, meteorology and development activity. Deviations from these observations may occur during the course of development activities.