IMG-Golder Corporation
Environmental Consulting Inuvik, NT

TECHNICAL MEMORANDUM

DATE September 28, 2012 **PROJECT No.** 11-1320-0001-12

TO Jim Stevens, Director, Mackenzie Valley Highway
GNWT, DOT

FROM Julia Krizan **EMAIL** Julia_Krizan@golder.com

LAKE BATHYMETRY SURVEY FOR THE INUVIK TO TUKTOYAKTUK HIGHWAY

Dear Mr. Stevens,

The Lake Bathymetry Survey (the Survey) for lakes between km 105 and km 120 of the proposed Inuvik to Tuktoyaktuk Highway (the Highway) conducted by IMG-Golder Corporation (IMG-Golder) on behalf of the Government of the Northwest Territories (GNWT), Department of Transportation (DOT) was completed between August 7 and August 9, 2012. The results of the Survey are discussed in this Technical Memorandum.

1.0 INTRODUCTION

GNWT, DOT required the Survey of feasible lakes along the Highway between km 105 and km 120 (Figure 1, Appendix I) to gather lake bathymetric data in support of estimating lake water volumes. Feasible lakes were considered those that are potentially suitable for winter water extraction based on relative size and proximity to the Highway. Estimations of lake water volumes are required for compliance with Fisheries and Oceans Canada's (DFO's) protocol: *DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut* (2010; Appendix II). IMG-Golder was contracted by the GNWT, DOT to complete the Survey along the Highway following the terms of agreement established under Standing Offer Agreement (SOA), reference number SO 050871.

1.1 Rationale

The proposed construction of the northern first stage of the Highway during the winter season will require the development of a winter access road to facilitate ground transportation from the current end of the Highway (at km 120 / Source 177) to suitable gravel borrow sources at approximately km 105 (W. Patrie, GNWT, DOT, pers. comm. July 2012). Winter access road construction will be facilitated by extracting water from ice-covered lakes in close proximity. It is known that excess water extraction from ice-covered waterbodies can impact fish through oxygen depletion, loss in overwintering habitat and/or reduction of littoral habitat (DFO 2010). In order to minimize these impacts and to standardize winter water withdrawal, DFO has developed the DFO Protocol. The DFO Protocol states that total water withdrawal is not to exceed 10% of the total available water as calculated with the following equation (Equation 1; DFO 2010):

Total Volume $_{lake}$ – Ice Volume $_{max\ thickness}$ = Available Water Volume.

For lakes above the tree line (i.e., lakes along the Highway between km 105 and km 120), the maximum expected ice thickness is 2.0 metres (m) and the minimum waterbody depth required for 10% water withdrawal must be at least 3.5 m (i.e., 1.5 m of free water must remain underneath ice cover; DFO 2010).

The Survey was completed pursuant to DFO's protocol (2010) to determine the water volume of feasible lakes along the Highway between km 105 and km 120 to ultimately estimate the total available water volume for winter water withdrawal.

2.0 METHODS

The Survey was completed for lakes between km 105 and km 120 over three days, August 7, 8 and 9, 2012, by a three-person field crew consisting of one field crew lead, one field assistant and one Inuvialuit Wildlife Monitor (Mackenzie Delta Wildlife Monitoring Services). Transportation of the field crew and equipment to the lakes was by helicopter (the boat was transported by helicopter sling to each lake). The Survey included a pre-field map review, overflight and field investigation.

A Northwest Territories Scientific Research License was issued by the Aurora Research Institute (ARI) – License No. 15136; File No. 12 404 803.

An existing Inuvialuit Land Administration (ILA) Land Use License ILA11TN017 was amended to include this Survey.

Pre-field Map Review

The pre-field map review of the Highway was completed to identify four lakes that may be suitable for winter access road construction (Figure 1, Appendix I). These lakes were identified based on relative size and proximity to the Highway, where larger lakes closest to the Highway were considered most suitable.

Field Investigation

The field investigation consisted of a helicopter overflight and bathymetric data collection. The overflight was completed to locate the lakes identified during the pre-field map review and to collect aerial photographs. Observations such as inflow and/or outflow streams and islands were recorded where applicable.

Bathymetric data were collected from four lakes by boat using continuous depth recordings (i.e., at 10 m intervals). The depth recordings were geo-referenced with a Global Positioning System (GPS) inside the bathymetry recorder. The spacing of bathymetric transects was dependent on the size and shape of each lake, as well as the irregularity of the lake bottom. In general, a minimum of two longitudinal transects connecting the two farthest shorelines were completed. Cross transects (i.e., perpendicular to the longitudinal transect) were then completed along the longitudinal transect. Additional transects were run as required to include irregularities in the shape of the lakes, such as fingers or bays.

The naming convention for the lakes was based on their location relative to the proposed Highway. For example, "Lake 105" was named as such because the lake was found at km 105 of the Highway.

Data Analysis

Bathymetric data collected during the Survey were analyzed using Geographic Information System (GIS) software to calculate lake surface area, total lake volume and ice volume (i.e., under ice volume).

Surface area was calculated with the calculate geometry function in ArcGIS using Geogratis® CanVec data (updated on March 1, 2012) that were downloaded in August 2012.

In order to calculate total lake volume, lake depths obtained during the Survey were interpolated with the "Topo to Raster" tool in ArcGIS and with shoreline data from Geogratis® CanVec data (updated on March 1, 2012) that were downloaded in August 2012. After the interpolation, surface smoothing was completed using a three cell radius "mean" filter to calculate a moving average. This was done to remove some of the artefacts created by the initial interpolation. Total lake volume was then calculated by summing up the values of all cells and multiplying the result with the cell area.

Ice volume was calculated for each cell using an ice thickness of 2 m and results were summed up following the same methodology as described above. With that, available winter water volume was calculated using Equation 1 above.

3.0 RESULTS

Bathymetric data were analyzed for four feasible lakes: Lake 105, Lake 106, Lake 119 and Lake 120. Results are provided in Table 1. Units in the table follow DFO (2010) requirements.

Table 1: Lake Data Obtained During Survey

Parameter	Lake ID			
	Lake 105	**Lake 106**	**Lake 119**	**Lake 120**
Coordinates*	579598E / 7675639N	583403E / 7680923N	582924E / 7685495N	580842E / 7687246N
Surface area	829.66 ha	86.63 ha	27.03 ha	903.00 ha
Maximum observed depth	3.4 m	3.2 m	11.1 m	8.0 m
Average depth	1.31 m	1.72 m	6.05 m	2.41 m
Total lake volume	7,885,835.67 m^3	1,346,524.90 m^3	1,192,808.85 m^3	17,667,840.75 m^3
Available winter water volume (under ice)	11,576.78 m^3	30,082.50 m^3	721,723.62 m^3	4,231,093.58 m^3
Max expected ice thickness value used	2.0 m	2.0 m	2.0 m	2.0 m
Calculated 10% allowable withdrawal volume	1,157.68 m^3	3,008.25 m^3	72,172.36 m^3	423,109.36 m^3
Aerial photographs of waterbody	Photographs 1 and 2, Appendix III	Photograph 3, Appendix III	Photographs 4 and 5, Appendix III	Photographs 6 and 7, Appendix III
Bathymetric maps of waterbody	Figure 2, Appendix I	Figure 3, Appendix I	Figure 4, Appendix I	Figure 5, Appendix I

* Datum: NAD 83, Universal Transverse Mercator (UTM) 08W

ha: hectares

m: metres

m^3: cubic metres

In summary, of the four lakes, Lake 120 was found to have the highest 10% allowable withdrawal volume (423,109.36 m^3), followed by Lake 119 (72,172.36 m^3), Lake 106 (3,008.25 m^3) and Lake 105 (1,157.68 m^3).

4.0 ADDITIONAL CONSIDERATIONS

The DFO Protocol (2010) considers lakes above the tree line with a maximum depth less than 3.5 m (without ice cover) to be vulnerable to the effects of winter water extraction. The maximum observed depths of Lake 105 and Lake 106 were just below this threshold (3.4m and 3.2m respectively). Based on the bathymetric data that were collected, these two lakes appear to be relatively shallow flat bottomed lakes. However, as the survey methodology does not produce continuous depth information (10 m intervals), deeper areas may exist that lie between transects and data locations. Further, the survey was conducted at a single point in time in late summer and it is possible that the maximum depth of these lakes may be greater than what was observed during the Survey at different times of the year. The maximum observed depths of Lake 119 (11.1 m) and Lake 120 (8.0 m) are greater than the 3.5 m minimum.

DFO has developed the *Freshwater Intake End-of-Pipe Fish Screen Guideline* (1995) to further mitigate the impacts of water withdrawal. The guideline stipulates that, wherever feasible, water is to be removed from areas of waterbodies greater than 2 m below the ice surface to avoid the removal of oxygenated surface waters, water intakes should be screened with fine mesh of 2.54 mm, and withdrawal is to occur at moderate intake velocities (DFO 1995).

5.0 REFERENCES

Fisheries and Oceans Canada (DFO). 2010. DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut. June 21, 2010.

DFO. 1995. Freshwater Intake End-of-Pipe Fish Screen Guideline. Communications Directorate, Department of Fisheries and Oceans. Ottawa, ON. www.dfo-mpo.gc.ca/Library/223669.pdf; Accessed August 2012.

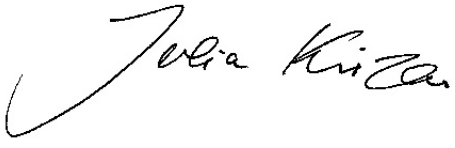
Patrie, W. 2012. Personal communication (email and telephone); July 2012. Government of the Northwest Territories (GNWT), Department of Transportation (DOT).

6.0 CLOSURE

We believe that this Technical Memorandum meets the needs of the GNWT, DOT. Please do not hesitate to contact the undersigned should you have any questions or concerns.

Sincerely,

IMG-GOLDER CORPORATION



Julia Krizan, M.Sc., Ph.D.
Senior Biologist, Office Manager & Director

Grant Clarke, M.A.
Managing Associate, Senior Archaeologist

Attachments:

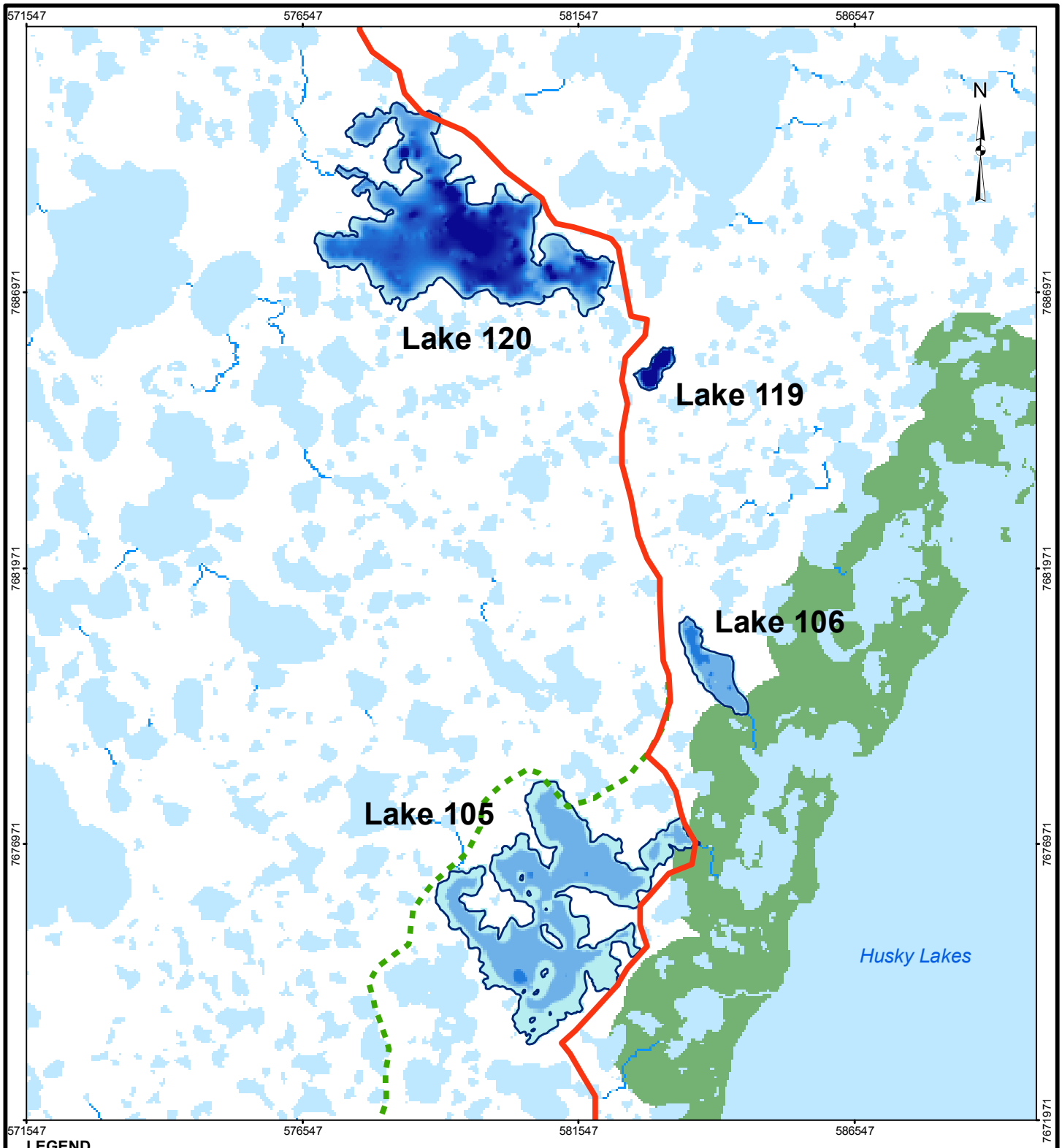
APPENDIX I
Figures

APPENDIX II
DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut

APPENDIX III
Photographs

Appendix I

FIGURES



LEGEND

- PROPOSED ALL-WEATHER ROAD
- PROPOSED RE-ALIGNMENT OF ALL-WEATHER ROAD
- WATERCOURSE
- HUSKY LAKES 1 KM BUFFER ZONE
- WATERBODY

BATHYMETRIC DEPTH (M)

0

11

2 0 2

SCALE 1:100,000 KILOMETRES

REFERENCE

Base Data: obtained from Geogratis® Canvec 1:50,000, August 2012
DATUM: NAD83 PROJECTION: UTM ZONE 9

PROJECT

LAKE BATHYMETRY SURVEY FOR
THE INUVIK TO TUKTOYAKTUK HIGHWAY

TITLE

OVERVIEW OF BATHYMETRIC FINDINGS FROM LAKES SURVEYED, AUGUST 2012

I M G-Golder Corporation
Environmental Consulting Inuvik, NT

PROJECT		11 1320 0001	FILE No.	
DESIGN	KM	5 Sep. 2012	SCALE AS SHOWN	REV. 0
GIS	KM	5 Sep. 2012		
CHECK	JK	28 Sep. 2012		
REVIEW	JK	28 Sep. 2012		

FIGURE: 1

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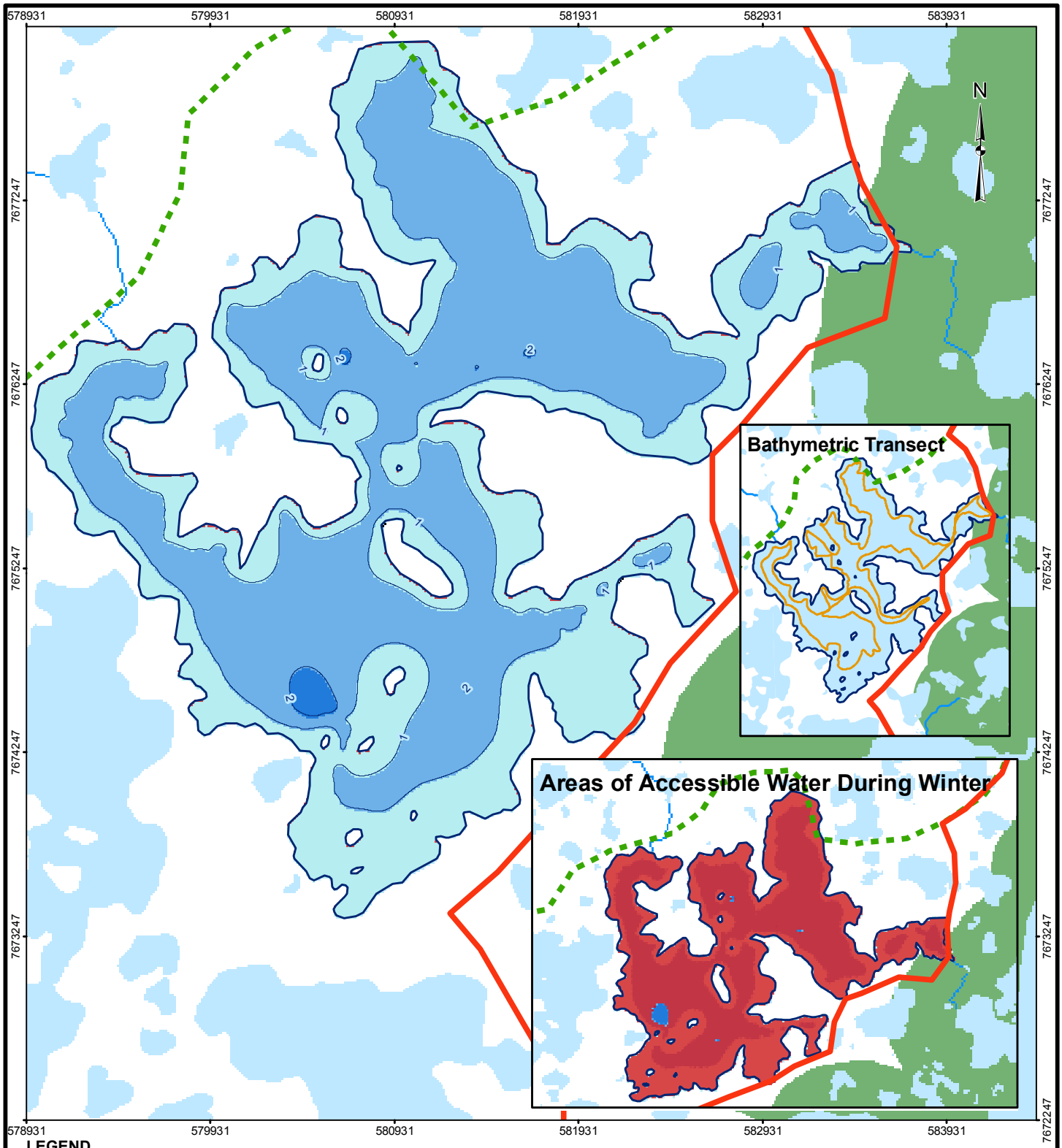

LEGEND

- PROPOSED ALL-WEATHER ROAD
- PROPOSED RE-ALIGNMENT OF ALL-WEATHER ROAD
- LAKE105_TRANSECT
- BATHYMETRY CONTOUR
- WATERCOURSE
- HUSKY LAKES 1 KM BUFFER ZONE
- WATERBODY

BATHYMETRIC DEPTH (M)

0

11

LAKE FROZEN TO BOTTOM

1 0 1

SCALE 1:30,000 KILOMETRES

REFERENCE

Base Data: obtained from Geogratis® Canvec 1:50,000, August 2012
DATUM: NAD83 PROJECTION: UTM ZONE 9

PROJECT

LAKE BATHYMETRY SURVEY FOR
THE INUVIK TO TUKTOYAKTUK HIGHWAY

TITLE

LAKE 105 BATHYMETRY, AUGUST 2012

IMG-Golder Corporation
Environmental Consulting Inuvik, NT

PROJECT		11 1320 0001	FILE No.	
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GIS	KM	5 Sep. 2012		
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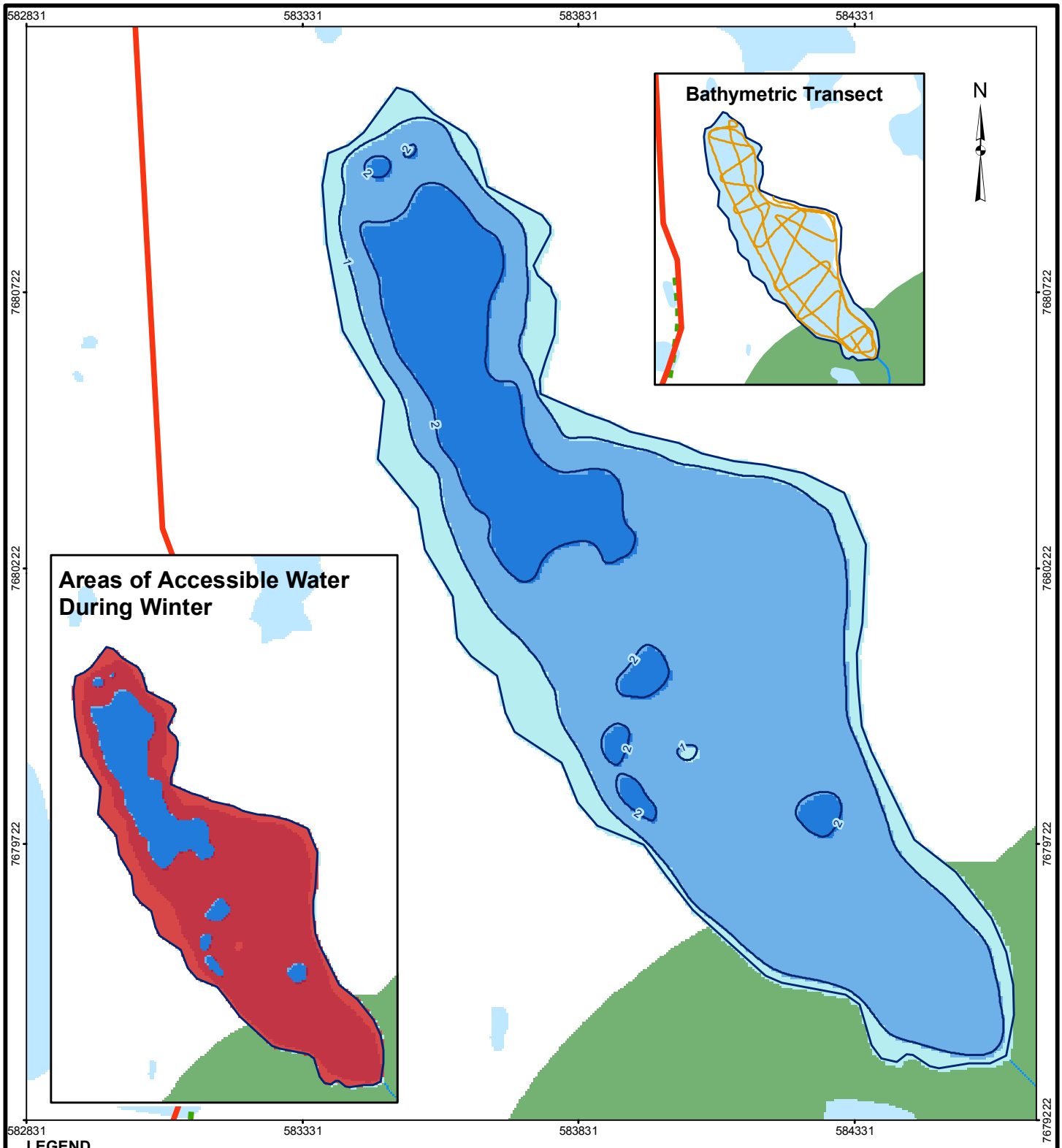

LEGEND

- PROPOSED ALL-WEATHER ROAD
- PROPOSED RE-ALIGNMENT OF ALL-WEATHER ROAD
- LAKE105_TRANSECT
- BATHYMETRY CONTOUR
- WATERCOURSE
- HUSKY LAKES 1 KM BUFFER ZONE
- WATERBODY

BATHYMETRIC DEPTH (M)
0
11
LAKE FROZEN TO BOTTOM

0.25 0 0.25
SCALE 1:10,000 KILOMETRES

REFERENCE

Base Data: obtained from Geogratis® Canvec 1:50,000, August 2012
DATUM: NAD83 PROJECTION: UTM ZONE 9

PROJECT
LAKE BATHYMETRY SURVEY FOR THE INUVIK TO TUKTOYAKTUK HIGHWAY

TITLE
LAKE 106 BATHYMETRY, AUGUST 2012

IMG Golder Corporation
Environmental Consulting Inuvik, NT

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GIS	KM	5 Sep. 2012		
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REVIEW	JK	28 Sep. 2012		

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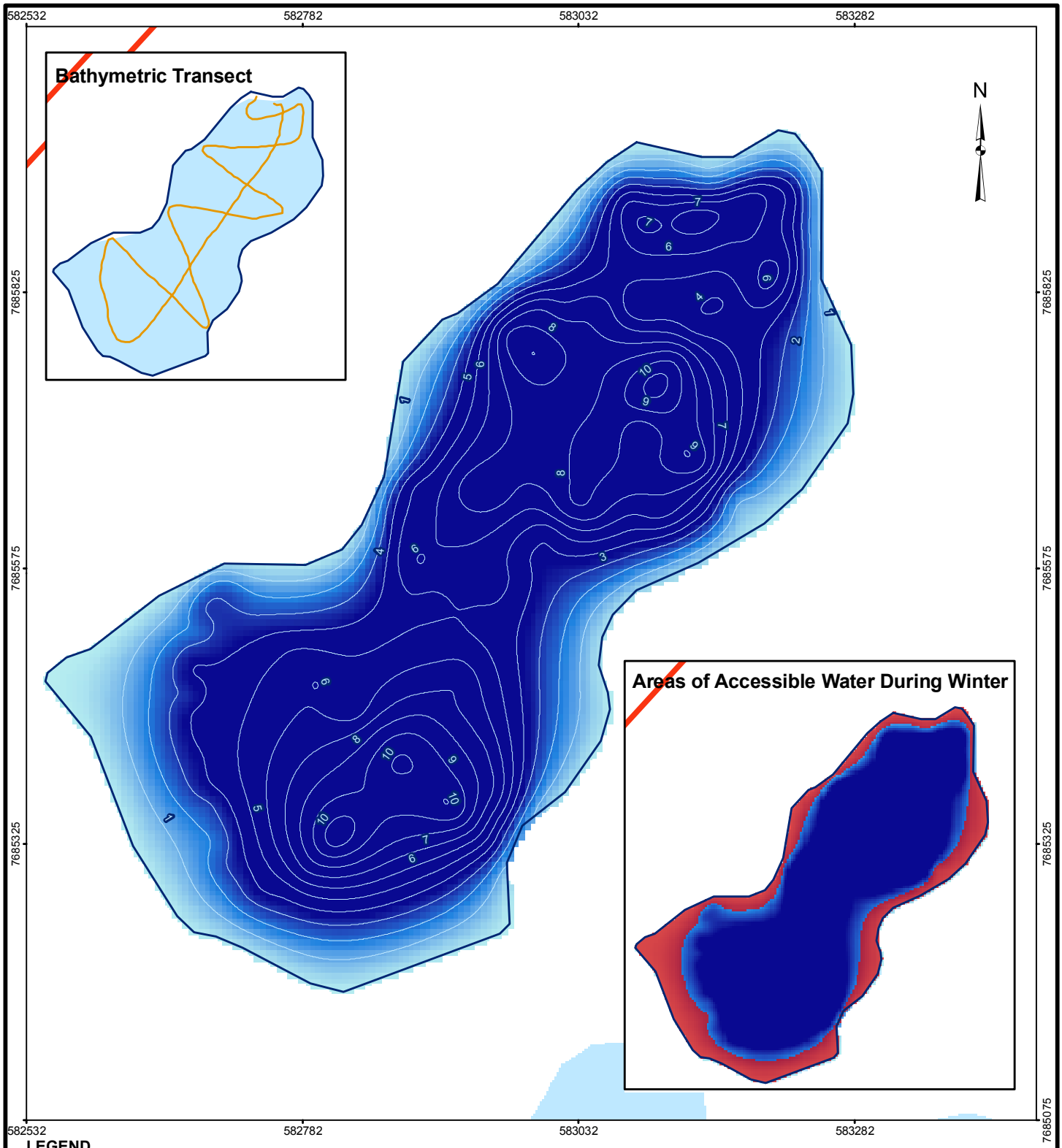

LEGEND

- PROPOSED ALL-WEATHER ROAD
- PROPOSED RE-ALIGNMENT OF ALL-WEATHER ROAD
- LAKE105_TRANSECT
- BATHYMETRY CONTOUR
- WATERCOURSE
- HUSKY LAKES 1 KM BUFFER ZONE
- WATERBODY

BATHYMETRIC DEPTH (M)

0

11

LAKE FROZEN TO BOTTOM

0.1 0 0.1

SCALE 1:5,000 KILOMETRES

PROJECT

LAKE BATHYMETRY SURVEY FOR
THE INUVIK TO TUKTOYAKTUK HIGHWAY

TITLE

LAKE 119 BATHYMETRY, AUGUST 2012

REFERENCE

Base Data: obtained from Geogratis® Canvec 1:50,000, August 2012
DATUM: NAD83 PROJECTION: UTM ZONE 9

IMG-Golder Corporation
Environmental Consulting Inuvik, NT

PROJECT		11 1320 0001	FILE No.	
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FIGURE: 4

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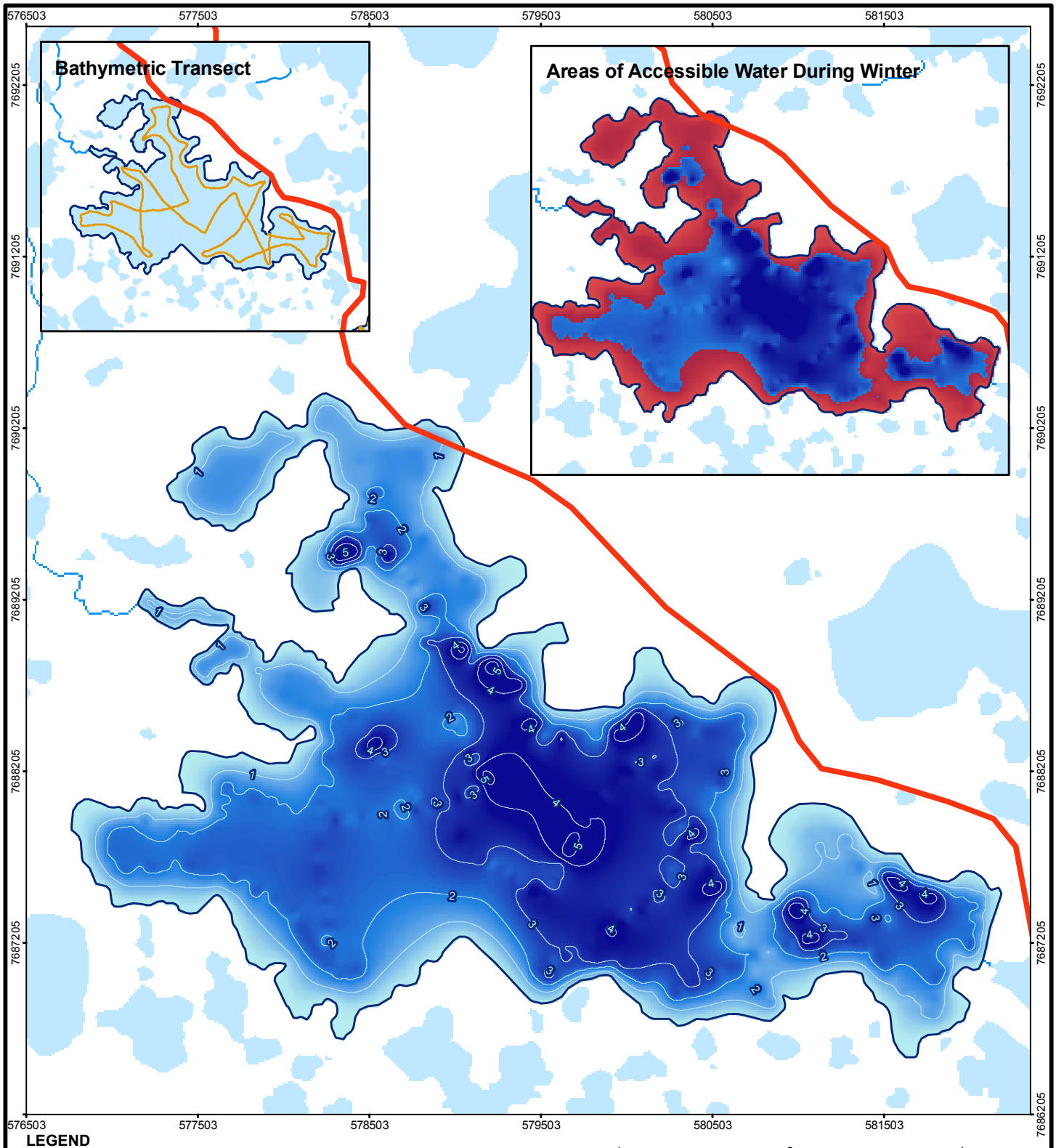

LEGEND

- PROPOSED ALL-WEATHER ROAD
- PROPOSED RE-ALIGNMENT OF ALL-WEATHER ROAD
- LAKE105_TRANSECT
- BATHYMETRY CONTOUR
- WATERCOURSE
- HUSKY LAKES 1 KM BUFFER ZONE
- WATERBODY

BATHYMETRIC DEPTH (M)
0
11
LAKE FROZEN TO BOTTOM

1 0 1
SCALE 1:32,000 KILOMETRES

REFERENCE

Base Data: obtained from Geogratis® Canvec 1:50,000, August 2012
DATUM: NAD83 PROJECTION: UTM ZONE 9

PROJECT
LAKE BATHYMETRY SURVEY FOR
THE INUVIK TO TUKTOYAKTUK HIGHWAY

TITLE
LAKE 120 BATHYMETRY, AUGUST 2012

IMG-Golder Corporation
Environmental Consulting Inuvik, NT

PROJECT		11 1320 0001	FILE No.	
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GIS	KM	5 Sep. 2012		
CHECK	JK	28 Sep. 2012		
REVIEW	JK	28 Sep. 2012		

FIGURE: 5

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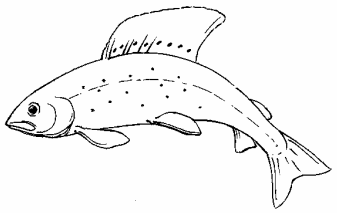
Appendix II

DFO PROTOCOL FOR WINTER WATER WITHDRAWAL FROM ICE-COVERED WATERBODIES IN THE NORTHWEST TERRITORIES AND NUNAVUT



DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut

Rationale

In the Northwest Territories and Nunavut, winter activities such as access road construction, exploratory drilling and camp operations often require large amounts of water. Excessive amounts of water withdrawn from ice-covered waterbodies can impact fish through oxygen depletion, loss of over-wintering habitat and/or reductions in littoral habitat. The potential for such negative impacts to over-wintering fish and fish habitat has made winter water withdrawal a critical issue for Fisheries and Oceans Canada (DFO) in the Northwest Territories and Nunavut. To mitigate impacts to fish from water withdrawal from ice-covered waterbodies, and to provide standardized guidance to water users, including volume limits for certain water source types, DFO has developed this protocol in conjunction with industry and other regulators.

For the purposes of this protocol, a **waterbody** is defined as any water-filled basin that is potential fish habitat. A waterbody is defined by the ordinary high water mark of the basin, and excludes connecting watercourses.

This protocol will **not** apply to the following:

- Any waterbody that is exempted by DFO (e.g. Great Bear Lake, Great Slave Lake, Gordon Lake, and others as and when determined by DFO), and;
- Any waterbody from which less than $100m^3$ is to be withdrawn over the course of one ice-covered period.

In order to establish a winter water withdrawal limit for a given waterbody, the following criteria must be adhered to:

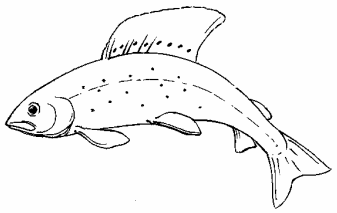
1. In one ice-covered season, total water withdrawal from a single waterbody is not to exceed 10% of the available water volume calculated using the appropriate maximum expected ice thickness provided in Table 1.
2. In cases where there are multiple users withdrawing water from a single waterbody, the total combined withdrawal volume is not to exceed 10% of the available water volume calculated using the appropriate maximum expected ice thickness provided in Table 1. Therefore, consistent and coordinated water source identification is essential.
3. Only waterbodies with maximum depths that are ≥1.5m than their corresponding maximum expected ice thickness should be considered for water withdrawal (Table 1). Waterbodies with less than 1.5m of free water beneath the maximum ice are considered to be particularly vulnerable to the effects of water withdrawal.
4. Any waterbody with a maximum expected ice thickness that is greater than, or equal to, its maximum depth (as determined from a bathymetric survey) is exempt from the 10% maximum withdrawal limit (Table 1).

To further mitigate the impacts of water withdrawal, water is to be removed from deep areas of waterbodies (>2m below the ice surface) wherever feasible, to avoid the removal of oxygenated surface waters that are critical to over-wintering fish. The littoral zone should be avoided as a water withdrawal location. Water intakes should also be properly screened with fine mesh of 2.54 mm (1/10") and have moderate intake velocities to prevent the entrainment of fish. Please refer to the *Freshwater Intake End-of-Pipe Fish Screen Guideline* (DFO, 1995) which is available upon request, or at the following internet address: www.dfo-mpo.gc.ca/Library/223669.pdf.

In order to determine the maximum water withdrawal volume from an ice-covered waterbody, and thereby conform to this protocol, the following information must be provided to DFO for review and concurrence prior to program commencement.

Water Source Identification

1. Proposed water sources, access routes, and crossing locations clearly identified on a map, with geographical coordinates (latitude/longitude and/or UTMs) included.
2. Any watercourse connectivity (permanently flowing and/or seasonal) between the proposed water source and any other waterbody or watercourse.



DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut

3. Aerial photos or satellite imagery of the water sources.
4. Estimated total water withdrawal requirement for work or activity and estimated total water withdrawal per water source (in m^3).

Bathymetric Survey Results

1. For all waterbodies: One longitudinal transect, connecting the two farthest shorelines, is to be conducted regardless of waterbody size. Note: a longitudinal transect may be straight or curved in order to accommodate the shape of a lake (see Figure 1).
2. For waterbodies equal to or less than 1 km in length: a minimum of one longitudinal transect and two perpendicular transects are to be conducted. Perpendicular transects should be evenly spaced on the longest longitudinal transect, dividing the lake into thirds (Figure 1).
3. For lakes greater than 1 km in length: a minimum of one longitudinal transect is to be conducted. Perpendicular transects (minimum of 2) should be evenly spaced on the longest longitudinal transect at maximum intervals of 500 m.
4. Additional transects should be run as required to include irregularities in waterbody shape such as fingers or bays (Figure 1).
5. All longitudinal and perpendicular transects are to be conducted using an accurate, continuous depth sounding methodology, such as open water echo sounding or ground penetrating radar (GPR), that provides a continuous depth recording from one shore to the farthest opposing shore (Figure 1). Any alternative technology should be reviewed by DFO prior to implementing for bathymetric surveys.

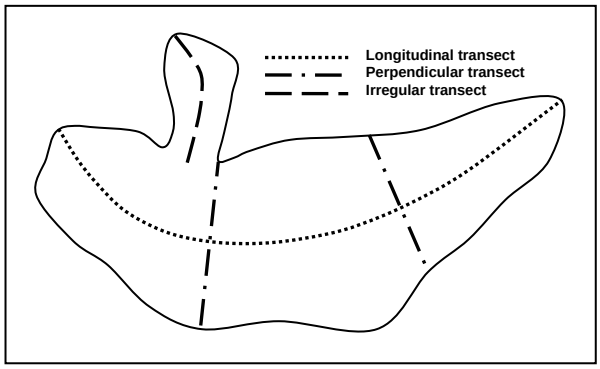
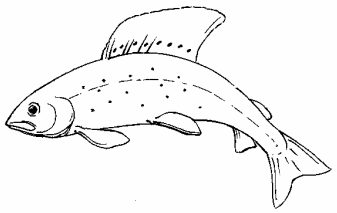


Figure 1. Minimum transect layout for a lake that is less than 1 km in length, with an irregularity.

Volume Calculations

1. Document the methods used to calculate surface area. If aerial photos or satellite imagery were used, provide the date (day/month/year) taken, as surface area may change depending on the time of year. If maps were used, provide the year that they were surveyed.
2. Detail the methods used to determine the total volume of free water, incorporating the relevant bathymetric information.
3. Calculate the available water volume under the ice using the appropriate maximum expected ice thickness, i.e. *Total Volume* $_{lake}$ *– Ice Volume* $_{max\ thickness}$ *= Available Water Volume* (see Table 1 for maximum ice thickness).
4. For programs where ice-chipping is used, the total ice volume to be removed from the waterbody should be converted to total liquid volume and incorporated into the estimate of total water withdrawal requirement per water source.



DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut

Table 1. Maximum expected ice thickness, and corresponding water depth requirements, for different regions in the Northwest Territories.

Area	Maximum Expected Ice Thickness (m)	Minimum Waterbody depth Required for 10% Water Withdrawal (m)
Above the Tree Line	2.0	≥3.5
Below the Tree Line - North of Fort Simpson	1.5	≥3.0
Deh Cho –South of Fort Simpson	1.0	≥2.5

A brief project summary report documenting and confirming total water volume used per water source and corresponding dates should be submitted to DFO within 60 days of project completion. Information should be provided in the following format (this information would also be useful as part of the project description):

Lake ID	number and/or name
Coordinates	latitude and longitude and/or UTM coordinates
Surface area	in ha
Total Lake Volume	in m^3
Under Ice Volume	in m^3 (based on max ice thickness for region)
Max expected ice thickness value used	in m
Calculated 10% Withdrawal volume	in m^3
Total required water volume extracted	in m^3
Aerial photographs of waterbody	PDF format
Bathymetric Map(s) of waterbody	PDF format

Any requests deviating from the above must be submitted to DFO and will be addressed on a site-specific basis.

Beaver and Muskrat

Many species of animals are highly sensitive to water fluctuations. In areas where beaver and muskrat may occur, the appropriate agencies or organizations should be consulted to determine if harmful effects will result from your activities, and whether these effects can be successfully mitigated through modifications to your plans including best management practices.

Please note that adherence to this protocol does not release the proponent of the responsibility for obtaining any permits, licenses or authorizations that may be required.

For more information contact DFO at (867) 669-4915.

Appendix III

PHOTOGRAPHS

Site: Lake 105

Figure 1: View (facing North) of Lake 105 from helicopter (August 8, 2012)

Figure 2: View (facing South) from centre of Lake 105 (August 8, 2012)

Site: Lake 106

Figure 3: View (facing West) of Lake 106 from helicopter (August 7, 2012)

Site: Lake 119

Figure 4: View (facing South) of Lake 119 from helicopter (August 9, 2012)

Figure 5: View (facing north) from centre of Lake 119 (August 9, 2012)

Site: Lake 120

Figure 6: View (facing south-east) of Lake 120 from helicopter (August 9, 2012)

Figure 7: View (facing west) from centre of Lake 120 (August 9, 2012)