Memorandum

Date:	August 12th, 2015		
Project Name:	Fish Lake Hydrology Study: Igloolik	Project #:	OTT-00227772-A0
Subject:	Technical Memo		
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Distribution:	Bhabesh Roy		

1. Introduction

The over-winter water requirements for the Hamlet of Igloolik are provided from a man-made reservoir situated adjacent to the airport. This reservoir is replenished from a lake, often referred to as South Lake, located 1.7 km to the south. In the spring of 2015 there was a shortfall in water availability from the reservoir. In response water was taken from Fish Lake, which is located across Turton Bay, as illustrated in Figure 1 (attached). The Department of Community and Government Services (CGS) of the Government of Nunavut (GN) has retained **exp** Services Inc. **(exp**) to examine the ongoing capability of Fish Lake to supply water to meet the long term requirements of Igloolik. This assessment does not examine the capabilities of providing storage or truck-fill operations at Fish Lake. The following memorandum provides a summary of this review, which includes:

- A review of related studies;
- Delineation of the water source watershed;
- Definition of 30 year water requirements for the community;
- An examination of climatic data; and,
- An estimate of the watershed yield.

2. Background Information and Related Studies

2.1 General

Limited information is available regarding the behaviour of northern watersheds. Experience gained in southern Canada must be applied with great caution, as the difference in climates leads to fundamental differences in the nature of runoff from northern watersheds. Many Arctic locations experience relatively low amounts of annual precipitation, and much of this precipitation falls as snow. This snowfall accumulates over the winter, making available in the spring much of the over-winter precipitation as runoff.

Guidance has been sought from previous investigations and publications. These sources of guidance include:

- Rankin Inlet
  - Design of Pipeline System to Augment Natural Replenishment of Nipissar Lake, FSC Engineers and Architects, December 15, 2010.
  - Nipissar Lake Volume Study and Environmental Variable Study, FSC Engineers and Architects, April 20, 2011
- Water Supply Facility Operation and Maintenance (O&M) Plan, Hamlet of Rankin Inlet, Nuna Burnside, December 2008, revised April 2010.

- Iqaluit
  - City of Iqaluit Raw Water Supply and Storage Review, Trow Associates, April 2004.
- Resolute Bay
  - Operations and Maintenance Manual for Resolute Bay Water and Sewer System, Underwood McLelland and Associates
  - Char Lake Pump House Design Brief, **exp** Services Inc., November, 2012.
  - Technical Memorandum on Char Lake Hydrology Study, **exp** Services Inc., August 25, 2014.
- Draft CSA standard S503, Community drainage system planning, design and maintenance in northern communities.
- Nunavut Bureau of Statistics
  - Nunavut Population Projections.
- Annual reports submitted to the Nunavut Water Board

2.2 Rankin Inlet

Investigations have been undertaken regarding the ability of Nipissar Lake to meet the water demands of the community. As a result of these assessments, an overland pipeline was installed to supplement the water volume available from the watershed to Nipissar Lake. The following has been drawn from the reviewed documents.

- The report dealing with the design of the pipeline system (FSC December 15, 2010) provides the following:
  - Average water resupply to Nipissar Lake as 311,789 m^3.
  - Current water consumption of 469 litres per capita per day (lpcd) leads to an annual requirement of 427,791 m^3.
- The Nipissar Lake Volume Study (FSC April 2010) reports the following:
  - Average annual snowfall is 128.7 mm and average annual precipitation is 305.4 mm.
  - Nipissar Lake is capable of providing an estimated maximum demand 311,789 m^3 without continued depletion.
- The Water Supply Facility O&M Plan (Nuna Burnside, April 2010) report provides the following:
  - The area of the watershed draining to Nipissar Lake is 323 ha.
  - An annual precipitation rate of 297.2 mm and an annual evapotranspiration rate of 200 mm are reported.
  - Net recharge to the lake is estimated at 314,000 m^3.

The following observations and conclusions are drawing from the information reviewed for Rankin Inlet.

- Climatic conditions in Rankin Inlet vary from those that arise in Igloolik.
- Both FSC and Nuna Burnside provide similar estimates of annual watershed yield to Nipissar Lake.
- Annual runoff of 314,000 m^3 from a watershed of 323 ha indicates an annual runoff of 97 mm.

2.3 Iqaluit

In response to a concern for the sustainability of the community water supply, the City of Iqaluit commissioned a study to examine the ability of the watershed for Lake Geraldine to support the demands of the City. This investigation made use of stream flow data from monitoring stations of the Apex (1973 to 1995) and the Sylvia Grinnell (1971 to 1999) Rivers. Among other matters this report provides the following:

- The average ratio of annual runoff to annual precipitation for the Apex River was calculated as between 0.467 and 1.038, with an average of 0.772.
- The average ratio of annual runoff to annual precipitation for the Sylvia Grinnell River was calculated as between 0.790 and 1.070, with an average of 0.898.
- Recognizing the risks that can arise from overestimation of annual runoff, the estimate of watershed yield was based upon an assumed ratio of annual runoff to annual precipitation of 60%.
- The watershed of Lake Geraldine is reported as 385 ha. The 1:100 year return low watershed yield estimate is 485,000 m^3.

2.4 Resolute Bay

The Operations and Maintenance Manual for the existing water and sewer system provides an estimate of the Char Lake drainage area of 4.40 km^2 (440 ha).

The Design Brief reports that the Char Lake water supply must be capable of supporting an ongoing demand of 4.06 litres per second, or 129,000 m^3 per year.

The review of the sustainability of Char Lake estimates the yield from the 425 ha watershed for the lowest observed annual precipitation as 166,000 m^3.

2.5 Draft CSA Standard S503

The CSA standard S503 provides guidance regarding collection, conveyance, detention and discharge of excess surface water in the form of overland flow. The following are noted from the standard:

- Included among the exclusions, “Watershed level drainage planning.” Thus, the guidance from this standard is not directly applicable to the estimation of watershed yield to Fish Lake.
- Various sources of topographic data including the National Topographic System (NTS) in the scale of 1:50,000 are suggested.
- Section 4.7.2.2 of the draft standard notes, “Freshet, or spring thaw, may comprise the majority of a community’s runoff for the entire year. During this time of year icing may be more likely. Information on spring freshet and runoff rates can be found in the annex.” A review of the annex did not identify this information.
- Flow estimation is focused around determining the peak rate of runoff arising from a single event.
- The Rational Method is presented as a tool to estimate flows. The discussions of the Rational Method note that conventional runoff coefficients are not appropriate for spring runoff conditions where runoff can approach 100% when the ground is frozen.

In summary, although the draft standard is not directly applicable to the investigation of watershed yield into Fish Lake, the comments regarding topographic data sources and intensity of runoff during spring freshet provide useful guidance.

2.6 Nunavut Bureau of Statistics

The Nunavut Population Projections provides projections of the population for all of the communities of Nunavut to the year 2035. The population in Igloolik at the end of this period is estimated as 2,721. The population projection data can be extrapolated to provide an estimate to the end of the planning period in 2045.

2.7 Nunavut Water Board

The annual reports for the Water Licence, as found in the Public Registry of the Nunavut Water Board, were reviewed. The annual consumption, as provided in these reports, is as follows.

Table 1: Historic Annual Water Consumption

Year	Annual Consumption (L)
2012	51,227,919
2013	53,096,725
2014	55,085,387

2.8 Summary

The following may be drawn from the various sources that were reviewed.

- All of the annual precipitation provides some contribution to the recharge of Fish Lake. Spring runoff represents a large portion of annual runoff.
- The estimates of watershed yield prepared in 2003 for Iqaluit incorporated a ratio of annual runoff to annual total precipitation of 0.60. The calculated average values of this ratio for the Apex and Sylvia Grinnell Rivers were 0.772 and 0.898 respectively.
- The following table summarizes the estimated watershed area and yield for Rankin Inlet, Iqaluit and Resolute Bay

Table 2: Summary of Watershed Yields for Communities in Nunavut

Community	Watershed Area (ha)	Estimated Annual Yield (m^3)	Runoff (mm)	Comment
Rankin Inlet	323	311,789	97	32% of annual average precipitation
Iqaluit	385	485,000	126	60% of 1:100 low precipitation
Resolute Bay	425	166,000*	39	50% of lowest observed annual precipitation

* Based upon lowest observed total annual precipitation for the period 1948 to 2011.

- The estimated population in Igloolik at the end of 2035 is 2,721.
- The following table summarizes current per capita water consumption, based upon the water licence annual reports.

Table 3: Historical Per Capital Daily Consumption

Year	Population	Annual Consumption (L)	Per Capital Daily Consumption (L)
2012	1,906	51,227,919	73.6
2013	1,952	53,096,725	74.5
2014	2,007	55,085,387	75.2

3. Watershed Assessment

3.1 Introduction

The assessment of watershed yield for Fish Lake will advance on the following basis:

- The potential for Fish Lake to meet the long term needs of the community will be determined.
- The water source must be capable of meeting the needs of a population at the end of a 30 year planning horizon.
- Estimates of water source recharge must be conservative, especially in view of the essential nature of a sustainable water supply.

3.2 Fish Lake Watershed

Data Gathering

The following data sources were identified:

- Government of Nunavut digital topographic mapping of the Hamlet of Igloolik.
- National Topographic System Mapping in the scale of 1:50,000 (Sheet 47-D/7).
- Google Earth images of Igloolik Island.

Data Review

The GN mapping in the scale of 1:2,000 does not provide coverage of Fish Lake or the watershed to Fish Lake.

The 1:50,000 mapping provides full coverage of Igloolik Island, including the watershed draining into Fish Lake. This mapping by Natural Resources Canada, which was produced in July 2010, incorporates confirmations of the road network in 2006 and the hydrographic network in 2002. This mapping is felt to be appropriate for the delineation of the watershed to Fish Lake. The watercourse and contour information from this mapping was the principal data source for the development of the estimate of the watershed limits.

Google Earth images have been reviewed to confirm the watershed limits.

Findings

The attached Figure 1 depicts the limits of the watershed draining to Fish Lake. This watershed has an area of 469 ha. The surface area of Fish Lake is 106 ha.

3.3 Community Water Supply Requirements

An estimate of the long-term (30 year) water requirements has been developed.

The Nunavut Municipal Infrastructure Capital Standards and Criteria (April, 2012) direct that water consumption be calculated based upon historical use, or a minimum of 90 lpcd. It should be noted that this is described as the minimum demand and the allowance of 90 lpcd does not include an allocation for non-residential uses including commercial, institutional or industrial water use.

The criteria provided in the Water and Sewage Facilities Capital Program Standards and Criteria, published by MACA, GNWT in July 1993 provide a design value for average residential water consumption (RWU) for communities with trucked water and sewer services of 90 lpcd. These criteria direct an adjustment to provide for other water uses including institutional and commercial consumption. The following formula is recommended for communities with populations between 2,000 and 10,000.

Total Community Consumption = RWU x [-1.0 + (.323 ln(Population)]

For the long term planning horizon (30 years) and a population of 3,145 a community wide average per capita water consumption of 144 Lpcd is estimated. This in turns leads to an average day water requirement of 165,000 litres. On an annual basis this represents a requirement of 165,000 m^3 in the year 2045.

It is noted that, based upon annual reporting to the Water Board, current unit water consumption is approximately 75 lpcd. This is significantly lower than both the minimum demand provided in Capital Standards and Criteria and the criteria of MACA, GNWT. This variation between reported and predicted demand is the result of a list of issues including delivery system capabilities, building water tanks size and average household population. It is likely that there will be improvements, over the long term, in these factors that constrain water use. In that the purpose of this evaluation is to estimate long term water demands, the water consumption estimates, as provided by the MACA, GNWT formula will be assumed.

3.4 Climatic Data

Climate data from Environment Canada provides information for 2 stations in Igloolik, the airport and the research centre. This data takes the following forms.

- Canadian Climate Normals 1981-2010 for both stations.
- Monthly summaries for the Igloolik Research Institute for the period 1977 to 2002.
- Monthly summaries for Igloolik Airport for the period 1984 to 2007.

Canadian Climate Normals

The following table summarizes the data provided from the Canadian Climate Normals

Table 4: Canadian Climate Normals

Station	Rainfall (mm)	Snowfall (cm)	Total Precipitation (mm)
Airport	86.9	136.2	222.4
Research Institute	101.3	173.3	274.8

It is noted that there is a significant variation in the Normals reported for the Airport and the Research Institute. It is further noted that these sites are separated by approximately 1 km. The resolution of this variation falls outside the scope of this investigation.

Monthly Observations

Monthly summaries of rainfall, snowfall and total precipitation have been obtained for the Airport and Research Institute stations. The following table summarizes information regarding the extent and completeness of this data.

Table 5: Available Precipitation Data

Station	Period	Years with Incomplete Data	Period of Useable Data
Airport	1984 to 2007	1984 to 1988, 2001, 2007	17 years
Research Institute	1977 to 2003	1977, 1978, 1984, 1997, 2003	22 years

The following table summarizes information extracted from the monthly data.

Table 6: Summary of Precipitation Data

	Airport	Research Institute
Total Precipitation (mm)		
• Mean	228.2	283.2
• Minimum	165.9	194.3
• Maximum	362.4	399.3
• Standard Deviation	55.3	57.8
• Years of useable data	17	22
Total snowfall (cm)		
• Mean	138.2	177.5
• Minimum	99.7	126.4
• Maximum	231.6	252.6
• Standard Deviation	40.9	39.7
• Years of useable data	17	22

As an initial observation it is noted that there are significant differences between the observations at the Airport and those at the Research Institute. The stations are separated by a short distance, and it is very likely that they share the same climate. The variation between the observations at these stations is probably the result of local conditions at each station. Without an assessment of each station by a specialist in the siting of meteorological instruments it is impossible to present an opinion regarding the comparative validity of the observations at each site.

It must be recognized that ongoing access to a reliable supply of water is essential for the habitability of a community. Thus, conservative assumptions regarding watershed inputs are appropriate. On this basis the data for the airport will be used in this assessment.

3.5 Fish Lake Watershed Yield Estimate

There is little definitive data, aside from the watershed area, available for Igloolik. Previous assessments of some watersheds in Nunavut have assumed that 50% to 60% of annual total precipitation appears as runoff. For the purpose of this estimate of watershed yield it will be assumed that runoff will represent 40% of annual total precipitation.

The estimate of watershed yield is based upon the following assumptions.

- Watershed area 469 ha
- Minimum annual total precipitation 166 mm
- Ratio of annual yield to annual total precipitation 40%

Based upon the above assumptions the watershed yield to Fish Lake is estimate to total 311,000 m^3. No evaporation data is available for either climate data station in Igloolik. Lake evaporation data for Resolute Bay is reported as 8.2 mm. This allowance, applied to the surface area of Fish Lake of 106 ha leads to an annual loss of 8,700 m^3. This reduces the net quantity of water available to the community to 302,000 m^3 annually. This estimated watershed yield exceeds projected community consumption of 165,000 m^3 in 2045 by a margin of 1.8 times.

3.6 Anecdotal Observations

No anecdotal information has been obtained regarding the current behaviour Fish Lake. There is good value in reviewing the ongoing behaviour of this waterbody with members of the community.

4. Bathymetric Survey

Bathymetric information was provided by CGS and is shown on the attached figure. A total of 48 points were provided including depths and coordinates. One point when plotted was outside the boundary of the lake, and therefore it has been assumed the coordinate was recorder incorrectly. This point has been removed from the information presented.

The information provided din not include a surveyed edge of the lake and the maximum depth that was available to be recorded was 8 feet. Therefore the depths of the portions of the lake greater than 8 feet is unknown. As the information provided is not complete, comments on the available storage of the lake is not possible.

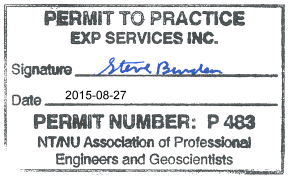
5. Summary

The principal findings of this assessment may be summarized as follows.

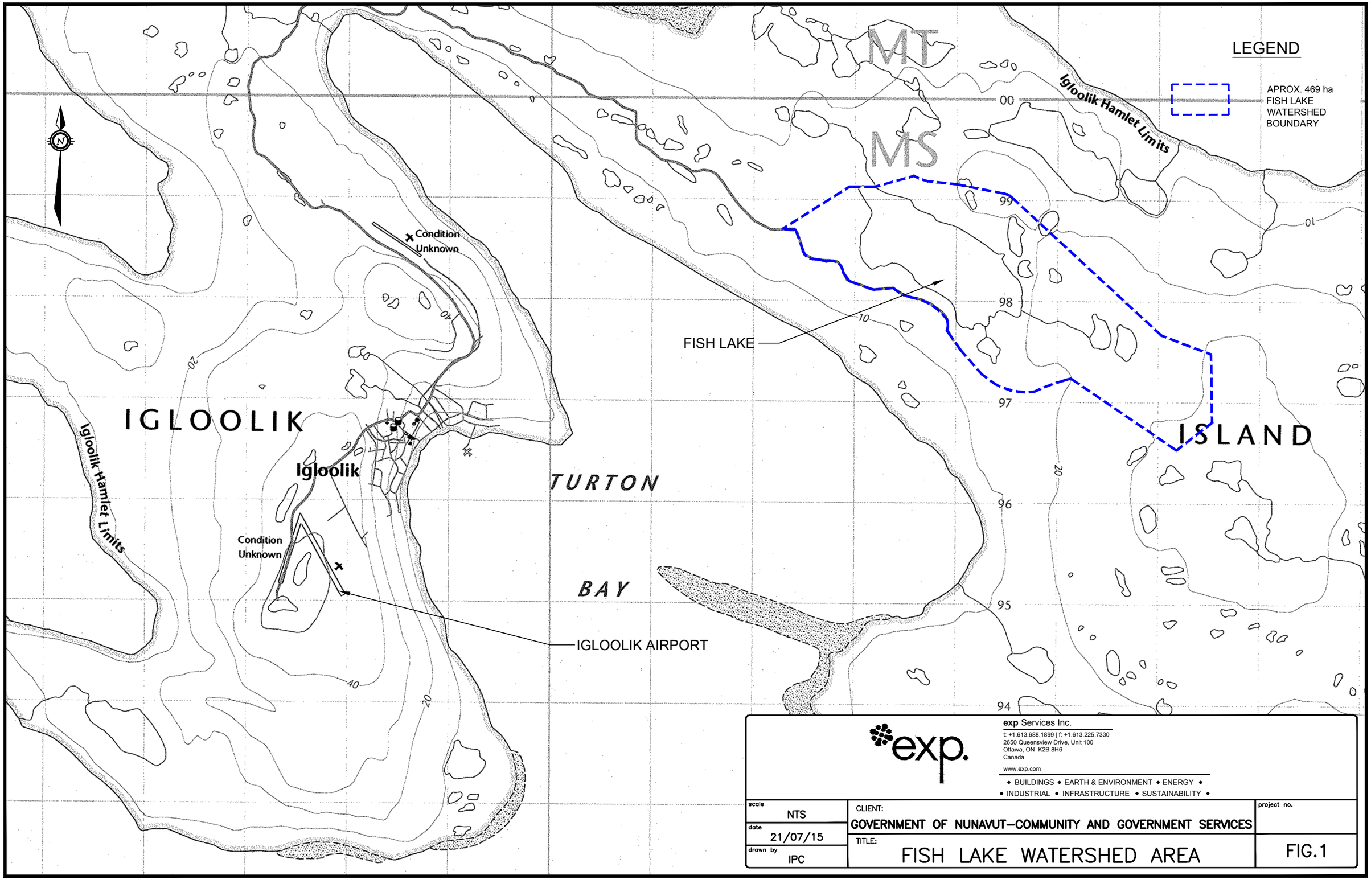
1. The 2004 assessment of the water source for Iqaluit determined the ratio of annual runoff to precipitation to be between 0.7 and 0.9, based on stream flow measurements. The assessment of the sustainability of Lake Geraldine as a water source for Iqaluit was advanced on the basis of a ratio of runoff to precipitation of 60%.
2. The estimated population at the end of the 30 year planning horizon is 3,145.
3. Annual water consumption at the end of a 30 year planning horizon is estimated to total 165,300 m^3.
4. The area of the watershed draining to Fish Lake has been estimated as 469 ha. The surface area of Fish Lake is estimated at 106 ha.
5. Precipitation data has been identified for 2 climatic stations in Igloolik. Significant differences were noted for the data for these stations.

6. In view of the essential nature of access to a water supply for ongoing habitability of a community conservative estimates of potential precipitation have been assumed. On this basis the analysis has been conducted using data from the Airport climatic station.
7. The lowest observed total annual precipitation is reported as 166 mm.
8. A watershed yield estimate has been developed based upon annual runoff of 40% of total annual precipitation. This assumption is based upon experience in other communities.
9. An allowance of lake evaporation has been developed based upon data obtained for Resolute Bay.
10. Runoff, net of evaporation from Fish Lake, is estimated at 302,000 m^3.
11. Estimated runoff exceeds community water demands at the end of the planning period (2045) by a factor of approximately 1.8.
12. Ongoing monitoring of Fish Lake should be implemented should this lake be selected as a water source for the community. Annual confirmation of replenishment of the lake will both assure an ongoing supply to the community and provide an opportunity for a timely response should demand exceed resupply.
13. The bathymetric information provided by CGS did not include sufficient information to determine the depth and therefore the capacity of Fish Lake.
14. This assessment of the Fish Lake watershed has not examined the suitability of Fish Lake as over-winter water storage. Thus, issues such as capability to contain the required volume, losses to ice cover, and changes in water quality due to formation of the ice cover have not been examined.

Sincerely,
exp Services Inc.



Steven Burden, P.Eng.
Senior Manager
Infrastructure Services



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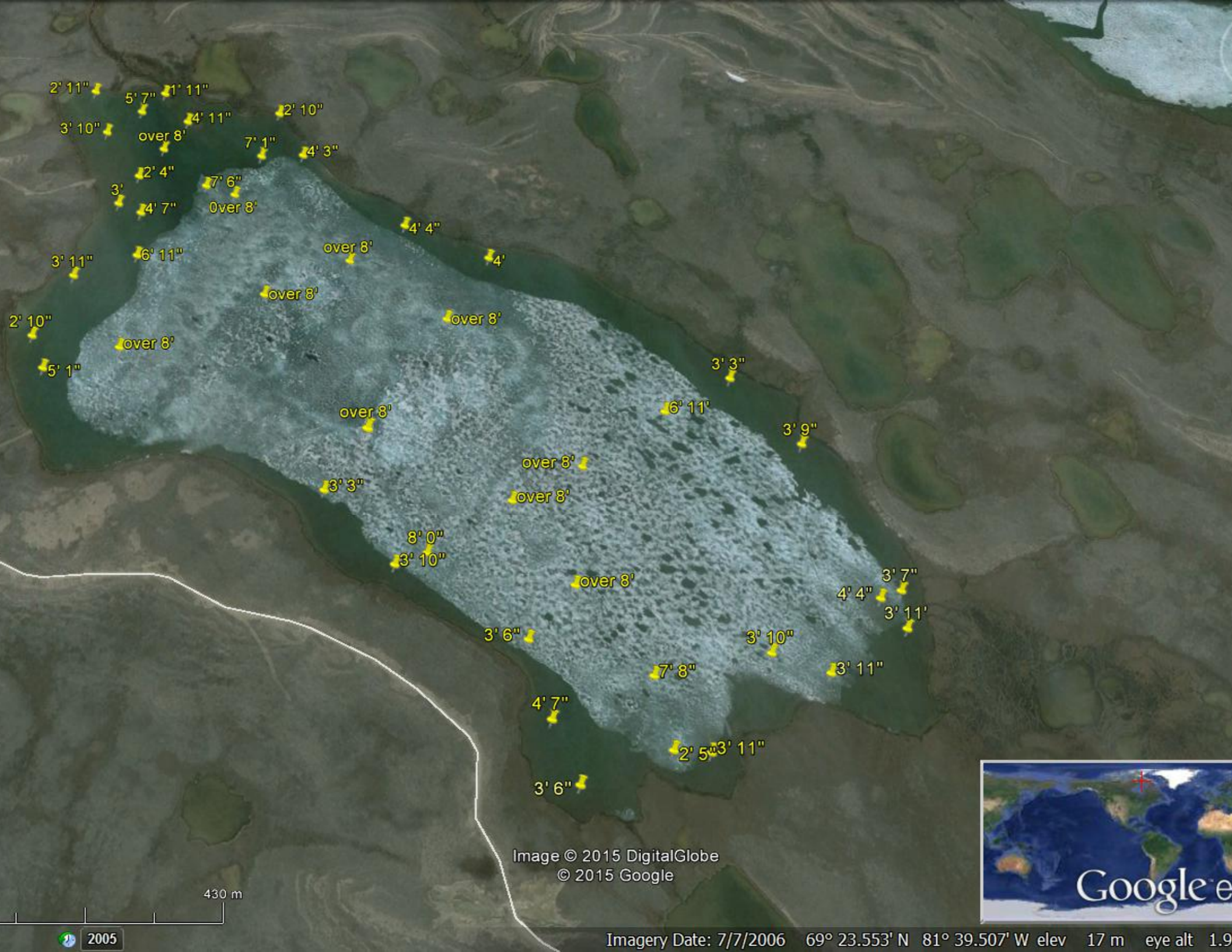
scale: NTS	CLIENT: GOVERNMENT OF NUNAVUT–COMMUNITY AND GOVERNMENT SERVICES	project no.
date: 21/07/15	TITLE: FISH LAKE WATERSHED AREA	FIG.1
drawn by: IPC		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