Hamlet of Qikiqtarjuaq – Hydrological Desktop Study

Nunavut

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Submitted By:
EXP
1133 Regent Street, Suite 300
Fredricton, NB E3B 3Z2
t: +1.506.452.9000

Date Submitted:
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Prepared by

Chris Keung, P.Eng., MASc.
Municipal Engineer

Boris Allard, FEC, P.Eng.
Project Manager, Senior Engineer

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1 Introduction

1.1 Overview

EXP was retained by SBL Services Inc. (SBL) to complete a coarse-resolution hydrological and water-balance desktop study for the Hamlet of Qikiqtarjuaq to determine if the existing water source (Tulugak River) and watershed is sustainable to provide enough water to meet the current and future needs for the community over a 20- and 40-year horizon.

It is anticipated that this initial desktop study will be used to develop a more comprehensive field program to further investigate the flow characteristics and regime of the Tulugak River.

1.2 Objectives

Arctic community water supply systems have several components that are vulnerable to changing conditions such as capacity of the existing water infrastructure (water storage, distribution, treatment) and variability in streamflow. The main objective of this study is to complete a hydrological and water balance study to assess the suitability of the community's current source watershed and its ability to provide enough water to meet the current and future needs of the community over a 20- and 40-year horizon to the year 2044 and 2064, respectively. The specific tasks of this study include:

- Review of existing background information.
- Climate characterization and potential impacts on water supply from climate change.
- Summary of the hydrologic regime of the system.
- Water balance study considering the ecologic characteristics of the source. This includes defining any regulatory requirements that may impact water use volumes.
  - Watershed characterization and coarse resolution analysis to characterize annual watershed yield versus expected water use of the community and accounts for annual municipal water supply usage, population growth and potential impacts of climate change.
- Review of existing discharge and stream flow data for the Tulugak River water source.
- Recommendations on if the current water source will be sustainable for the community for a 20- and 40-year horizon.
- Note that this desktop study does not include any field investigations.

Based on the Hamlet's current Type B Water Licence (# 3BM-QIK1924), EXP understands that the Hamlet's freshwater supply is the Tulugak River (also referred to as the Kuruluk River). Water from the river is piped with a gravity fed system to the surface water storage reservoir during times when the river is not frozen and experiencing peak flow events (typically between late June through July). The water storage reservoir is located approximately 2.2 km from the Hamlet and filled late each summer to store the community's annual water supply.

Note that no field program is included in this current scope to physically characterize the Tulugak River. If required, an additional field program would be required to collect site-specific data of the Tulugak River (flow rates, installation of flow gauges, timing dates of flow/melt period, topographic survey, water quality analysis, etc.).

2 Previous Hydrological Investigations

2.1 Hydrological Analysis of Municipal Source Water Availability in the Canadian Arctic Territory of Nunavut (Hayward, J., Johnston, L., Jackson, A. and Jamieson, R., 2020)

A desktop study in 2020 provides a screening level vulnerability assessment of municipal drinking water supplies for the communities in Nunavut with consideration to climate change, population growth, and infrastructure changes. Water balance models were used to predict the annual water yield for each watershed using historical and projected climate data. The study only focuses on the ability of the source watershed to supply annual water volumes and did not include an analysis of storage infrastructure or seasonal water availability. Findings from the study include:

- Overall increasing trends in evapotranspiration (22 out of 24 Nunavut communities included in the study)
- Statistical precipitation trends for Qikiqtarjuaq were inconclusive due to limited data availability
- Based on the worst-case scenario of 50-year return period minimum precipitation and maximum evapotranspiration (ET), the following vulnerability threat levels were identified for historical, 2016-2040 and 2041-2070 timelines:
    - Qikiqtarjuaq
        - Water shortage vulnerability for the current water source (Tulugak River) was considered low for all three timeline scenarios (historical, 2016-2040 and 2041-2070)
        - Tulugak River watershed area was estimated as 2,400 ha (24,000,000 m^2)
- Most influential factor regarding water supply vulnerability threat levels appears to be the size of the source watershed

2.2 Water Resources Development for High Arctic Communities (Suk, 1975)

A Master's thesis from McMaster University in 1975 titled "Water Resources Development for High Arctic Communities" included a field campaign that measured the flow rates and discharge of the Tulugak River (referred to as Kuruluk River in the report) in Qikiqtarjuaq (formerly called Broughton Island) over the 1974 season. Findings from this document will be discussed in Section 5 of the report.

2.3 Water Survey of Canada – Tulugak River, Qikiqtarjuaq (1975 to 1983)

Between 1975 and 1983, the Water Survey of Canada monitored and recorded daily discharge for the Tulugak River (aka Kuruluk River) near Qikiqtarjuaq (Station 10EU001 – 67° 33' 40" N, 63° 58' 54" W). This information has been reviewed and will be discussed in Section 5 of the report.

3 Background

3.1 Community and Existing Water Supply System

3.1.1 Qikiqtarjuaq

The Hamlet of Qikiqtarjuaq is located at 67°33’ N latitude and 64°02’ W longitude on Broughton Island in Nunavut, off the east side of Baffin Island. The community is located within the continuous permafrost zone. The municipal boundary covers an area of approximately 130 km^2 and is within the Arctic Cordillera terrestrial ecozone (Figure 3-1).

Figure 3-1: Qikiqtarjuaq and Terrestrial Ecozones of Canada

The Tulugak River, which runs next to the community, is the main drinking water source for the Hamlet of Qikiqtarjuaq (Figure 3-2). The river’s name is interchangeably referred to as Kuruluk River. The river is typically frozen from October to May each year.

A water storage reservoir designed with a usable capacity of 31,500 m^3 is located next to the Tulugak River, approximately 2.2 km from the Hamlet. The reservoir is filled during months when the river is not frozen. The refill period is estimated to be between the start of June until the end of August when the river has sufficient flow volumes and depth. The current Type “B” Water License (3BM-QIK1924) allows for a maximum water usage for all purposes of 37,500 m^3 per year, or up to 299 m^3 per day for filling of the reservoir. Water is transferred by gravity from the intake location to the reservoir via a 300 mm dia. HDPE pipe (275 m in length). It is understood that the area near the intake has been dammed to promote higher water levels at the intake. The reservoir is lined with a potable grade geomembrane liner system.

In the 2019 Water License Inspection Form, it was noted that there is a suspected leak in the liner of the reservoir, as the outer walls appeared to be slumping and leaking water from the north wall of the reservoir. Once the reservoir hits 22 meters full, the leak of the water reservoir was observed to begin.

From the reservoir, water is transferred by a submersible pump to the treatment/truck fill building directly adjacent to the reservoir.

Figure 3-2: Map of Qikiqtarjuaq and Tulugak River

3.2 Methodology

3.2.1 Catchment and Basin Physiography

This study focuses on a coarse-resolution analysis to characterize annual watershed yield versus expected water use of the community and accounts for annual municipal water supply usage, population growth and potential impacts of climate change.

3.2.2 Watershed Delineation

A Digital Terrain Model (DTM) was created using contour information downloaded from the Government of Nunavut, Community Government Services, Planning and Lands Division website. The contours, available in 1 m increments, were interpolated (ESRI ArcGIS) to create a Digital Terrain Model with a grid cell size of 2 m. Catchment Modeling software available in the Global Mapper GIS software package were used to derive both catchments and drainage/drainage traces from the DTM. This algorithm uses a D8 model featuring flow direction, flow accumulation, and depression filling parameters. All data have been rendered using the UTM Zone 20 NAD83(CSRS) coordinate system.

3.2.3 Water Supply Modelling

3.2.3.1 ***Water Balance Formulation***

Water budgets (as volumes) were computed on an annual basis assuming steady conditions with respect to storage within the watershed. Water volumes are removed (losses) from the watershed through community water usage and evapotranspiration (ET). Water volumes are recharged (inputs) into the watershed through annual precipitation.

The change in annual storage volume equation (water balance) within a watershed is given as:

$$\Delta S = \frac{(P - ET)}{1000} \times Area_w - U$$

Where:

- ΔS = change in annual storage volume (m^3/year)
- P = annual total precipitation as rain or snow (mm/year)
- ET = annual evapotranspiration rate (mm/year)
- $Area_w$ = catchment area of the watershed (m^2)
- U = annual water usage of the community (m^3/year)

If $\Delta S > 0$, precipitation (input) exceeds ET and water use (losses) in the watershed and the annual net balance is positive.

If $\Delta S < 0$, precipitation does not exceed ET and water use in the watershed and the annual net balance is negative.

This approach assumes no cross-boundary sub-surface water flow and treats one drainage basin. Each drainage basin is a single unit and recognizes no ET spatial distribution within the basin.

Percolation due to groundwater is assumed to be negligible due to underlain permafrost. The equation above assumes that the entirety of the precipitation entering the watershed experiences evapotranspiration.

Underestimation of precipitation due to snow undercatch and water losses due to sublimation were not accounted for in the calculation. Actual basin snow amounts are usually larger than measured values (at weather stations) which suffer from gauge undercatch and thus the use of snow gauge data was deemed as a conservative approach for this study. Estimates for snow undercatch can range from 10% to 75% depending on gauge type and wind conditions. Sublimation losses have not been characterized. Characterization of these processes requires detailed meteorological data.

3.2.3.2 ***Population Projections, Daily Water Consumption and Annual Water Use Rates***

Population projections for the Hamlet of Qikiqtarjuaq up to 2035 have been provided by the Nunavut Bureau of Statistics (2014). The average population growth rate of 0.04% from 2014 to 2035 was used to project populations to the design horizon year of 2064. The 2016 Stats Canada Census population was 598 and the 2021 was 593 – a 0.8% decrease. If projected, the decreasing Stats Canada Census percentage results in a lesser population at the horizon years than the projected Nunavut Bureau populations, thus the Nunavut Bureau of Statistics population projections are considered conservative for the assessment.

Note that based on the above information, the population is not expected to change significantly over the course of the study period.

The 2020 Nunavut Draft Guideline Document "Water Treatment Plant Design" and Standardized Treatment Train (SWTT) guideline states a minimum per capita average day water consumption rate of 120 litres per capita per day (lpcd) for water treatment plant design for truck fill communities.

Annual historical water use records were reviewed between 1994-2023 to determine the actual recorded average daily consumption. Note that complete records were missing for the years 1998, 2007, and 2008. For the Hamlet of Qikiqtarjuaq between 1994-2023, average daily consumption was recorded as 97.8 lpcd. The maximum recorded average daily demand occurred in 2022 and was 120.1 lpcd. Water demand data is provided in Appendix D. Historical recorded daily demands for the Hamlet are typically lower than the design value of 120 lpcd. **Thus, the design value**

of 120 lpcd has been used as a conservative value to estimate the annual water use rates for the water balance calculations. Population projections and projected annual water use rates for Qikiqtarjuaq to 2064 using the 120 lpcd assumption are provided in Table 3-1.

Table 3-1: Qikiqtarjuaq Population Projections and Projected Annual Water Use Rates

Year	Population	Projected Water Use (m^3/year) *		Year	Population	Projected Water Use (m^3/year) *
2021	560	24,528		2043	585	25,617
2022	564	24,703		2044	585	25,627
2023	568	24,878		2045	585	25,638
2024	572	25,054		2046	586	25,648
2025	575	25,185		2047	586	25,658
2026	578	25,316		2048	586	25,669
2027	580	25,404		2049	586	25,679
2028	585	25,623		2050	587	25,689
2029	586	25,667		2051	587	25,699
2030	586	25,667		2052	587	25,710
2031	586	25,667		2053	587	25,720
2032	585	25,623		2054	587	25,730
2033	585	25,623		2055	588	25,740
2034	584	25,579		2056	588	25,751
2035	583	25,535		2057	588	25,761
2036	583	25,546		2058	588	25,771
2037	583	25,556		2059	589	25,782
2038	584	25,566		2060	589	25,792
2039	584	25,576		2061	589	25,802
2040	584	25,587		2062	589	25,813
2041	584	25,597		2063	590	25,823
2042	585	25,607		2064	590	25,833

** Water use based on design value of 120 lpcd*

3.2.3.3 *Meteorology / Precipitation Data*

Historical data was downloaded from the Environment and Climate Change Canada website to calculate annual total precipitation at a given weather station:

- Total precipitation includes the input of snowfall and rainfall
- Only 12 years of climate data was used for Qikiqtarjuaq during the periods of 1971-2023 and have been summarized in Table 3-2 and attached in Appendix B.

- At many of the weather stations near Qikiqtarjuaq, there are significant gaps in the collected data and concerns about the accuracy of measurements. If a yearly dataset had 60 days or more of missing data, this dataset was omitted.

- Minimum, maximum, median, average, 3-year low, 5-year low, 10-year low and 3-year high values (mm/year) were calculated using the complete precipitation datasets.

It should be noted that the precipitation data sets specific for Qikiqtarjuaq contain significant gaps and/or appear to contain questionable data points. Thus, Qikiqtarjuaq precipitation data has been challenging to ascertain and/or interpret with accuracy. As a comparison, the Hamlet of Pangnirtung (173 km away from Qikiqtarjuaq) has more available and continuous weather records compared to the Qikiqtarjuaq weather stations and thus, has been used as a point of reference in interpreting the available data sets. It should be noted that there is large variability in local weather patterns and data from nearby stations do not always reflect conditions in the vicinity.

Table 3-2 compares the Environment and Climate Change climate datasets for both communities. Table 3-3 compares the mean precipitation from compiled historical Environment and Climate Change Canada data and two Climate Reports for Auyuittuq National Park. Annual average for Iqaluit has also been included for reference.

Table 3-2: Summary of Estimated Total Annual Precipitation (Snow + Rain) for Qikiqtarjuaq and Pangnirtung

	Qikiqtarjuaq Annual Total Precipitation (mm/year)	Pangnirtung Annual Total Precipitation (mm/year)
Minimum (mm/year)	83	212
Maximum (mm/year)	392	585
Median (mm/year)	176	352
Mean (mm/year)	203	341
3-year low average	101	219
5-year low average	122	226
10-year low average	186	258
3-year high average	343	515
5-year high average	294	469

Table 3-3. Qikiqtarjuaq, Pangnirtung and Iqaluit Annual Precipitation Comparison

	Qikiqtarjuaq (Annual)	Pangnirtung (Annual)	Iqaluit (Annual)
Annual Precipitation at Selected Locations on Baffin*	305 mm	395 mm	N/A
Daily Historical Climate Data (Annual Average)**	203 mm	341 mm	404 mm
Annual Precipitation - Auyuittuq National Park ***	288 mm	395 mm	N/A

** Masterton J.M, & Findlay B.F. (1976) The Climate of Auyuittuq National Park, Baffin Island, NWT*
*** Environment and Climate Change Canada Historical Climate Data – Compiled by EXP*
****Seidel (1987) The Climate of Auyuittuq National Park Reserve: A Review, NWT*

Referencing Table 3-2 and Table 3-3, it should be noted that the following assumptions have been used:

- In comparing Qikiqtarjuaq and Pangnirtung data sets from various sources, there appears to be a general trend that annual precipitation totals in Qikiqtarjuaq are less than in Pangnirtung (see Table 3-2 and Table 3-3). The three datasets from Table 3-3 that included both Pangnirtung and Qikiqtarjuaq (Broughton Island) show that Pangnirtung receives over 90 mm more precipitation annually. This is corroborated by the Climate of Auyuittuq National Park report which states that Pangnirtung has both greater annual precipitation and greater amounts of winter precipitation than Broughton Island (Qikiqtarjuaq).
- The 2016 Qikiqtarjuaq data point was omitted due to the unreasonably low precipitation data collected (51 mm). In the same year, Pangnirtung recorded 308 mm, indicating that the 2016 dataset for Qikiqtarjuaq is likely erroneous.
- Two other years of Qikiqtarjuaq data (2022 and 1973) both had abnormally low precipitation values of 87 mm and 83 mm. The accuracy and validity of these data points is questionable. However, since there was not sufficient data at Pangnirtung to compare these years, this data was conservatively included in the analysis.

Climate Datasets (1951-1980) are available for select communities on Baffin Island in the Climate of Auyuittuq National Park Reserve Report (1987). The summarized monthly data of the precipitation values for Broughton Island are given in Table 3-4, below.

Table 3-4: Mean monthly rainfall, snowfall, and precipitation for Broughton Island 1951-1980 (Environment Canada) *

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	-	-	-	-	0.4	5.4	12.1	15.5	4.0	0.3	-	-	37.7
Snowfall (mm)	11.1	9.4	5.9	14.7	32.8	23.0	6.4	8.9	32.9	53.9	37.1	13.9	250.0
Total Precipitation (mm)	11.1	9.4	5.9	14.7	33.2	28.4	18.2	24.4	37.0	54.3	37.1	13.9	287.6

**Seidel (1987) The Climate of Auyuittuq National Park Reserve: A Review, NWT*

3.2.3.4 ***Precipitation Projections for Water Balance Calculations***

Snow and rainfall contribute to the precipitation inputs for the water balance calculations. It is assumed that raw water extraction only occurs from the start of June until the end of August. Hence, rainfall that occurs from September onwards is not available to the watershed and is omitted from the available inputs.

Based on the Environment Canada Report "The Climate of Auyuittuq National Park Reserve" (Seidel, 1987), the following assumptions have been used to estimate the available total precipitation for the water balance studies:

- 87% of the total annual precipitation occurs as snowfall. It is assumed that the entire portion of snowfall is available and provides positive inputs into the watershed as snowmelt
- The remaining 13% of the total annual precipitation occurs as rainfall between June and September
- Based on the Auyuittuq National Park Report, it is assumed that for Qikiqtarjuaq, approximately 89% of the rainfall occurs before September (i.e. months of June, July and August).

The precipitation available to the Tulugak River watershed has been estimated based on these assumptions and is summarized in Table 3-5 below.

Table 3-5: Summary of Estimated Available Precipitation for Tulugak River Water Balance Studies

	Annual Total Precipitation (mm/year)	Annual Snowfall (mm/year) *	Annual Rainfall (mm/year) **	Available Rainfall for Extraction (mm/year) ***	Total Inputs for Calculations (mm/year) ****
Minimum (mm/year)	83	72	11	10	82
Maximum (mm/year)	392	341	51	45	387
Median (mm/year)	176	153	23	20	174
Mean (mm/year)	203	176	26	23	200
3-year low average	101	88	13	12	99
5-year low average	122	106	16	14	121
10-year low average	186	161	24	21	183
3-year high average	343	298	45	40	338
5-year high average	294	256	38	34	290

* 87% of total precipitation
** 13% of total precipitation
*** rainfall occurring before September = 89% of annual rainfall
**** Total Inputs = Annual Snowfall + Available Rainfall for Extraction

3.2.4 Evapotranspiration

Evapotranspiration (ET) is the primary mechanism for water loss from a watershed underlain by permafrost. However, sparse data is available regarding actual ET rates for the study community of Qikiqtarjuaq and for the Arctic geography as a whole.

For this assignment, a literature review was completed using past research that investigated annual ET in geographies above 60°N latitude and specifically for the terrestrial ecozones of the Arctic Cordillera and the Northern Arctic. This information includes ET data for intermittent river and ephemeral stream systems. These values have been listed in Table 3-6 below.

Table 3-6: Reported Annual ET Rates (mm/year) in Arctic Environments

Location	Lat (°N)	Long (°W)	Year	Reported Annual ET Rate (mm/year)	Reference Paper
Cape Dorset, NU	64.2	76.5	2016	63	1
Naujaat, NU	66.5	86.2	2016	65	2
Resolute, NU	74.7	95.0	1978 (July 1 - Aug 31)	61	3
			1979 (July 1 - Aug 26)	52	
			1976 (May - Sept)	39	
			1978 (May - Sept)	46	
Axel Heiberg Island, NU	79.8	91.3	1969 (June 20 - Aug 31)	85	5
			1970 (June 1 - Aug 14)	86	
			1972 (June 28 - Aug 22)	82	
McMaster River Basin, Cornwallis Island, NU	75.1	95.1	1976-1981	30-51	3
Ellesmere Island, NU	80.8	72.7	1975 (July 6 - Aug 17)	27	3
Heather Creek, Ellesmere Island, NU	80.0	84.5	1990-1991	86	4
Hot Weather Creek, Ellesmere Island, NU	80.0	84.5	1997	56	5
Devon Island, NU	76.0	85.0	1972-1974	81	4
Bathurst Island, NU	75.7	98.7	2008-2010, 2012	103	4
Melville Island, NU	74.9	109.5	2007-2009	81	4
Ross Point, Melville Island, NU	74.0	107.0	1986	43	4

[1] Centre for Water Resource Studies (2017). Wetland Treatment Area Study in Cape Dorset, Nunavut. Dalhousie University, Halifax, NS, January 2017.
[2] Centre for Water Resource Studies (2017). Wetland Treatment Area Study in Naujaat, Nunavut. Dalhousie University, Halifax, NS, January 2017.
[3] Kane, D.L., Gieck, R.E., & Hinzman, L.D. (1990). Evapotranspiration from a Small Alaskan Arctic Watershed. *Nordic Hydrology, 21, 253-272.*
[4] Young, K.L., Lafrenière, M.J.m Lamoureux, S.F., Abnizova, A. & Miller, E.A. (2015). Recent multi-year streamflow regimes and water budgets of hillslope catchments in the Canadian High Arctic: evaluation and comparison to other small Arctic watershed studies. *Hydrology Research, 46(4), 533-550.*
[5] Young, K.L. & Woo, M.K. (2004). Queen Elizabeth Islands: water balance investigations. *Northern Research Basins Water Balance, 290, 152-163.*

Minimum, maximum, median, average and 3-year high annual ET values for the water balance study have been calculated using these literature values and have been presented in Table 3-7, below.

Table 3-7: Calculated ET Values Used for Water Balance Calculations

ET Parameter	ET (mm/year)
Minimum ET	27
Maximum ET	103
Median ET	63
Average ET	65
3-year high ET	86

As a comparison, in a study completed by Wang et al. (2013), mean annual ET values were modeled for the 15 ecozones in Canada over the period of 1979-2008. In both the Arctic Cordillera and northern Arctic ecozones, mean annual ET values were noted to be less than 100 mm/year.

ET rates greatly decrease with increasing latitude because of the decrease of solar irradiance and air temperature. The annual surface irradiance in the Northern Arctic is approximately 2500 MJ•$m^{-2}yr^{-1}$ which is almost 60% less than communities in the south (Wang et al., 2015). Typically, communities further south (below 60°N latitude) experience higher ET values, which illustrates that the chosen ET values for the Northern Arctic communities are appropriate for the conservative approach applied for the purposes of this screening study.

3.2.4.1 Water Balance Scenarios

For the water balance calculations, fifteen (15) scenarios were analyzed. Taking a conservative approach, the fifteen analyzed scenarios use below average values for precipitation (inputs) and above average values for evapotranspiration (losses). The worst-case would be represented as Scenario 1, with minimum precipitation and maximum ET.

Table 3-8: Scenarios for Water Balance Calculations

Scenario No.	Precipitation Scenario	ET Scenario
1	minimum	maximum
2	minimum	3-year high (average)
3	minimum	average
4	3-year low (average)	maximum
5	3-year low (average)	3-year high (average)
6	3-year low (average)	average
7	5-year low (average)	maximum
8	5-year low (average)	3-year high (average)

9	5-year low (average)	average
10	10-year low (average)	maximum
11	10-year low (average)	3-year high (average)
12	10-year low (average)	average
13	median	maximum
14	median	3-year high (average)
15	median	average

4 Results

4.1 Qikiqtarjuaq – Tulugak River

4.1.1 Watershed Delineation

The catchment/watershed area for Tulugak River is shown in Figure 4-1 on the next page.

Table 4-1 presents the delineated watershed area for the Tulugak River Area.

Table 4-1: Tulugak River Delineated Watershed Areas

Water Source	Watershed Area (m^2)	Watershed Area (km^2)	Watershed Area (ha)
Tulugak River	24,640,000	24.64	2,464

4.1.2 Water Balance and Water Source Assessment

The results showing the amount of potential annual runoff for the Hamlet of Qikiqtarjuaq are presented in Table 4-2.

Table 4-2: Qikiqtarjuaq - Tulugak River Potential Runoff Analysis

Scenario No.	Precipitation Scenario	ET Scenario	Precipitation (mm/year)	Estimated ET (mm/year)	Potential Runoff (mm/year)
1	minimum	maximum	82	103	-21
2	minimum	3-year high	82	86	-4
3	minimum	average	82	65	17
4	3-year low	maximum	99	103	-4
5	3-year low	3-year high	99	86	13
6	3-year low	average	99	65	34
7	5-year low	maximum	121	103	18
8	5-year low	3-year high	121	86	35
9	5-year low	average	121	65	56
10	10-year low	maximum	183	103	80
11	10-year low	3-year high	183	86	97
12	10-year low	average	183	65	118
13	Median	maximum	174	103	71
14	Median	3-year high	174	86	88
15	Median	average	174	65	109

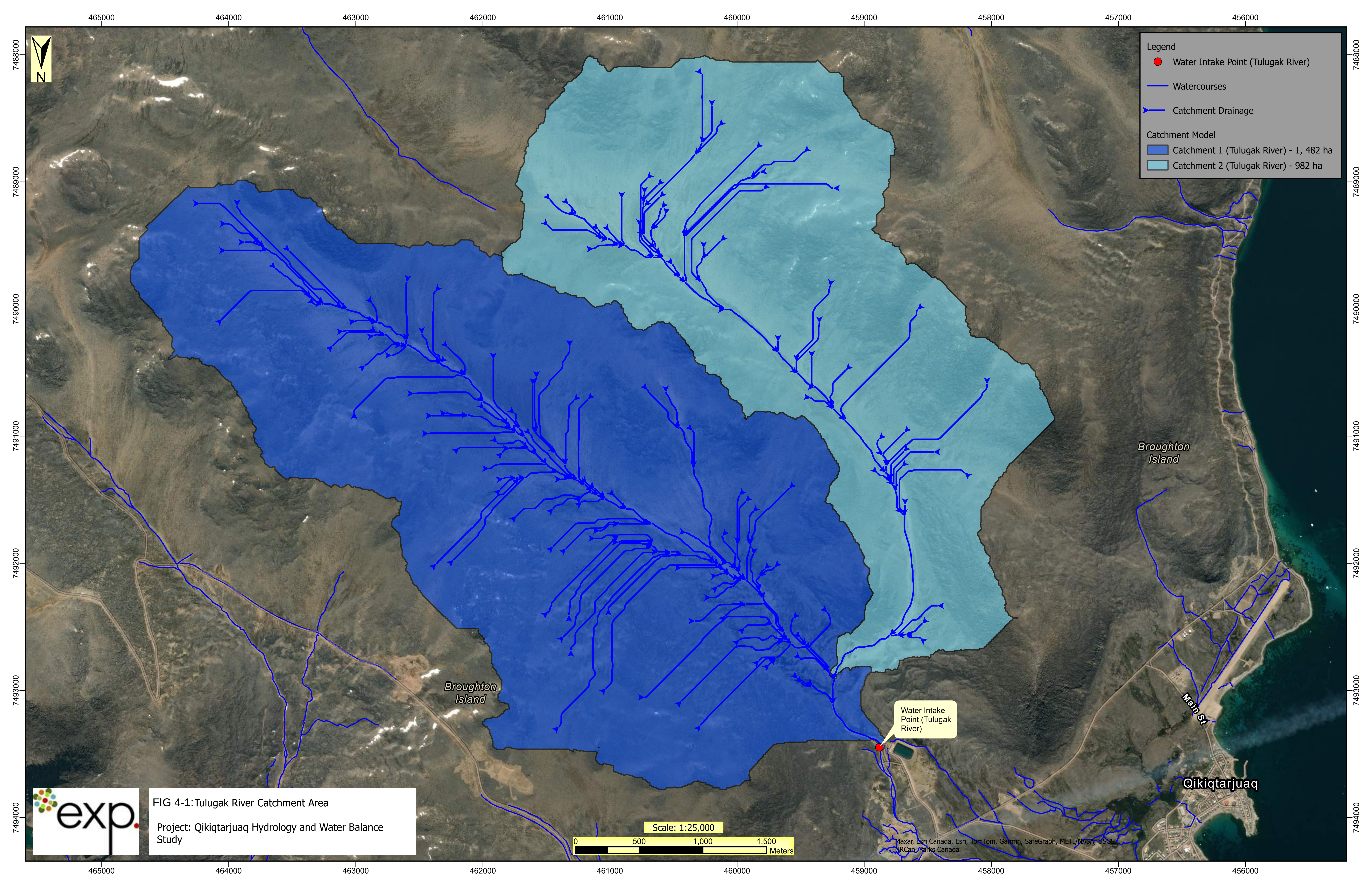

FIG 4-1: Tulugak River Catchment Area

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The results of the water balance analysis for the Tulugak River watershed are presented in Table 4-3.

If the annual precipitation volume is greater than or equal to the annual losses (annual ET plus community water use), the water supply sufficiently meets the needs of the community. Based on the assessment, in scenarios 1, 2 and 4, the annual precipitation experienced over the Tulugak River watershed does not sufficiently meet the community's future water supply needs for the 20- or 40-year horizons.

Table 4-3: Qikiqtarjuaq - Tulugak River Water Balance Analysis

QIKIQTARJUAQ			TULUGAK RIVER		
Scenario No.	2044 Water Use (m^3/year)	2064 Water Use (m^3/year)	Runoff Volume (m^3/year)	2044 ΔS > 0	2064 ΔS > 0
1	25,627	25,833	-519,616	NO	NO
2	25,627	25,833	-100,736	NO	NO
3	25,627	25,833	416,704	YES	YES
4	25,627	25,833	-89,725	NO	NO
5	25,627	25,833	329,155	YES	YES
6	25,627	25,833	846,595	YES	YES
7	25,627	25,833	434,888	YES	YES
8	25,627	25,833	853,768	YES	YES
9	25,627	25,833	1,371,208	YES	YES
10	25,627	25,833	1,967,880	YES	YES
11	25,627	25,833	2,386,760	YES	YES
12	25,627	25,833	2,904,200	YES	YES
13	25,627	25,833	1,740,349	YES	YES
14	25,627	25,833	2,159,229	YES	YES
15	25,627	25,833	2,676,669	YES	YES

5 Discussion

5.1 Hydrologic Regime

The Tulugak River watershed is associated with snowfall and snowmelt-generated runoff, which characterizes an Arctic nival regime streamflow. The Tulugak River catchment was calculated at approximately 24,640,000 m^2 (24.64 km^2 or 2,464 ha). The river has a long river channel length of about six miles, with large areas of mud and near stagnant water. The hilly areas are rocky with little vegetation, while the flat areas and foothills are covered with mosses and lichens (Suk, 1975).

These nival regimes are characterized by very low or negligible winter flows (typically from October to early May). Snowmelt represents the major source of runoff with additional inputs from rainfall during the summer months. Evapotranspiration is the main hydrological loss and is apparent for a couple of months after snowmelt until soil moisture declines. Evapotranspiration is greatest following the snowmelt (typically around late June/early July) and decreases substantially throughout the summer except for lesser events caused by precipitation.

Runoff ratio, the ratio between runoff and precipitation, are typically high for polar deserts, oases and glacierized basins (Young and Woo, 2004). In the late spring/summer, high solar radiation causes rapid snowmelt where a large portion of the annual runoff flow occurs within a few weeks period (can typically be in the order of greater than 80%). It is expected that flows (and peak flow) will lag the initial snowmelt event as integrated channel networks are established by collecting runoff from upstream hillslopes and valleys. Year-to-year variability in peak flow can be substantial and timing and duration of the melt season depends on the rainfall events (intensity and duration), weather and end-of-winter snow conditions. After snowmelt, flow generally declines. The presence of permafrost at shallow depths prevents infiltration and limits storage capacity.

Limited field data is available for the Tulugak River. However, the Water Survey of Canada investigated flow and discharge rates for the river over a nine-year period of 1975-1983. This information has been reviewed and is discussed in Section 5.2.5 below.

5.2 Qikiqtarjuaq

5.2.1 Water Balance Scenarios and Outcomes

Based on the water balance assessment, under three of fifteen scenarios, the Tulugak River water source and watershed does not provide sufficient water quantities, where the community is experiencing either minimum precipitation and/or maximum ET.

Precipitation data specific for Qikiqtarjuaq contain significant gaps and/or appear to contain questionable data points. In the analysis, two abnormally low precipitation values of 87mm in 2022 and 93mm in 1973 were included in the analysis for conservativism. However, the accuracy and validity of these data points is questionable. **If these data points are omitted from the analysis, under all fifteen scenarios, the Tulugak River water source and watershed provides sufficient water quantities to meet the community's current and future water supply needs.**

The catchment area of the Tulugak River watershed is relatively large at approximately 24,640,000 m^2 (24.64 km^2 or 2,464 ha). In general, any net-positive annual runoff within the Tulugak River catchment will provide sufficient water supply for the community's water supply needs. Based on watershed catchment area, a minimal net positive annual runoff of 1.1mm would be sufficient to meet the 2064 annual water demand for the community (25,833 m^3).

In a study investigating vulnerability levels of municipal drinking water supplies for the communities in Nunavut, Hayward et al. (2020), it was stated that the most influential factor regarding water supply vulnerability threat levels appears to be the size of the source watershed. The same study noted a low-level water supply vulnerability threat for Qikiqtarjuaq based on the worst-case scenario assessment (minimum precipitation and maximum ET scenario).

As discussed previously, the maximum ET rate used in the water balance assessment is likely overestimated (conservative) as seasonal recharge caused by snow melt occurs over a short period in the summer and is substantial enough to produce a flowing stream – this short duration of flow reduces the amount of time that the runoff is exposed to evapotranspiration and is represented by the high runoff ratio (ratio between runoff and precipitation) that is seen in polar deserts. During the cold season, precipitation storage is in the form of snow and ice and undergoes negligible evapotranspiration.

It is noted that the existing water storage reservoir has a usable design capacity of 31,500 m^3. The projected 2064 annual water demand for the community is 25,833 m^3 (i.e. population of 590 persons in 2064 with a water consumption rate of 120 Lpcd). Based on this preliminary information, expansion of the reservoir may not be required in the near future. However, further investigation is required to confirm geometric storage volumes for the existing reservoir accounting for ice thicknesses and confirming storage requirements over summer/winter periods.

5.2.2 Climate Change Considerations

It is well documented that anticipated climate change impacts include a general warming of ambient air temperature and increases in precipitation volumes over most of the Arctic region. Changing patterns also include increasing precipitation percentages occurring as rainfall vs. snow which will subsequently influence runoff patterns and water budgets.

The presence of permafrost is important in Arctic hydrology as it influences infiltration, runoff and groundwater storage and flow. Increases in air temperature results in permafrost degradation and increases the active (thaw) layer – this leads to increased infiltration, larger groundwater storage and flows, and changes to spring runoff and melt timing. Additionally, as the permafrost thaws, different settlement and ponding can occur leading to the introduction of new hydrological pathways and significantly alter drainage networks and distribution of surface/groundwater flows. Ice content that is typically frozen has the potential to increase streamflow by providing additional inputs (Lemmen et al., 2008 & Spence et al., 2020).

The Geological Survey of Canada (Ednie & Smith, 2015) noted that mean annual permafrost temperatures at 15 m depth in the nearby community of Pangnirtung were measured at -5.2°C in 2008 and -4.9°C in 2012. Since 2008, ground temperatures have followed the warming trends observed with increasing air temperatures.

As ambient air temperatures increase, ET rates experienced by watersheds are likely to increase due to larger amounts of radiation input, longer evaporation seasons as the snowmelt will begin earlier and increases in vegetation cover (Young and Woo, 2004).

5.2.3 Water Licence

The current Type B Water Licence #3BM-QIK1924 for the Municipality of Qikiqtarjuaq was issued on September 20, 2019 and expires on September 19, 2024. The Water Licence states the following:

- The current Water Licence permits a water extraction volume of up to 37,500 m^3 per year, or up to 299 m^3 per day for filling of the reservoir.
- As part of the current licence, the Hamlet is required to install a flow meter at the Tulugak River and measure water uptake from the source.

The Water Survey of Canada has flow and discharge information for the Tulugak River for the period of record between 1975 – 1983 (see Section 5.2.5 below). However, it is our understanding that no additional related field work has been completed since 1983.

5.2.4 Previous Flow and Discharge Information for Tulugak River (1975 – 1983)

In the 1970's, McMaster University (Suk, 1974) completed an investigation in collaboration with the Water Survey Branch of Environment Canada that included monitoring streamflows and discharge rates for the Tulugak River.

Following the initial investigation, the water level recorders and station were taken over by the Water Survey of Canada and used to monitor the Tulugak River (referred to as Kuruluk River) over the period between 1975 and 1983.

Hydrological discharge rates for the Tulugak River were reviewed for this period and are summarized in Table 5-1 and Figure 5-1 below (Appendix C). Total estimated annual river discharge volumes (m^3) were calculated based on the cumulative recorded daily flows during the monitoring years. In most years, early and late season flows were not recorded and thus, it is expected that the actual discharge volumes are higher than estimated volumes due to gaps in the datasets. Only the years 1982 and 1983 are considered complete data sets.

Table 5-1: Historical Tulugak River Discharge Monitoring (1975-1983)

Year	Start Date	End Date	Mean Daily Discharge (m^3/s)	Maximum Daily Discharge (m^3/s)	Total Estimated Annual River Discharge (m^3)
1975	6/23/1975	8/31/1975	0.20	1.25	1,182,038
1976	6/23/1976	9/10/1976	1.19	6.14	8,248,176
1977	7/10/1977	9/27/1977	0.43	3.79	2,974,666
1978	7/11/1978	9/5/1978	3.44	4.36	2,673,994
1979	7/14/1979	9/30/1979	1.18	6.16	8,061,466
1980	6/26/1980	9/30/1980	0.31	4.33	1,645,834
1981	7/28/1981	9/21/1981	0.28	1.00	1,343,434
1982	6/1/1982	9/30/1982	0.69	6.60	6,106,838
1983	6/1/1983	9/30/1983	1.18	6.84	11,089,267

The year-to-year variability in the timing and magnitude of the peak flows between 1975-1983 is quite large. In general, measurable flows begin in mid-June and peaks sometime in late June / July. Flows tend to decrease starting in the month of September although there are apparent peaks in various years likely due to rainfall events.

The projected water extraction volume in 2064 for the community of Qikiqtarjuaq is approximately 25,833 m^3. This equates to only about 0.5% of the total annual discharge of the Tulugak River (assuming a total annual discharge of 6,000,000 m^3 for the Tulugak River – an underestimation of the smaller of the complete data sets). From a water quantity perspective, the extraction volume required by the community is negligible compared to the estimated annual discharge of the Tulugak River and thus, the volume extracted is not expected to be a concern.

It should be noted that these findings have been based on best-available information provided for the Tulugak River and surrounding watershed. This is a limited dataset that is 40-50 years old. Site conditions have likely changed, and thus, an up-to-date field monitoring program should be established to update discharge rates and streamflows accordingly.

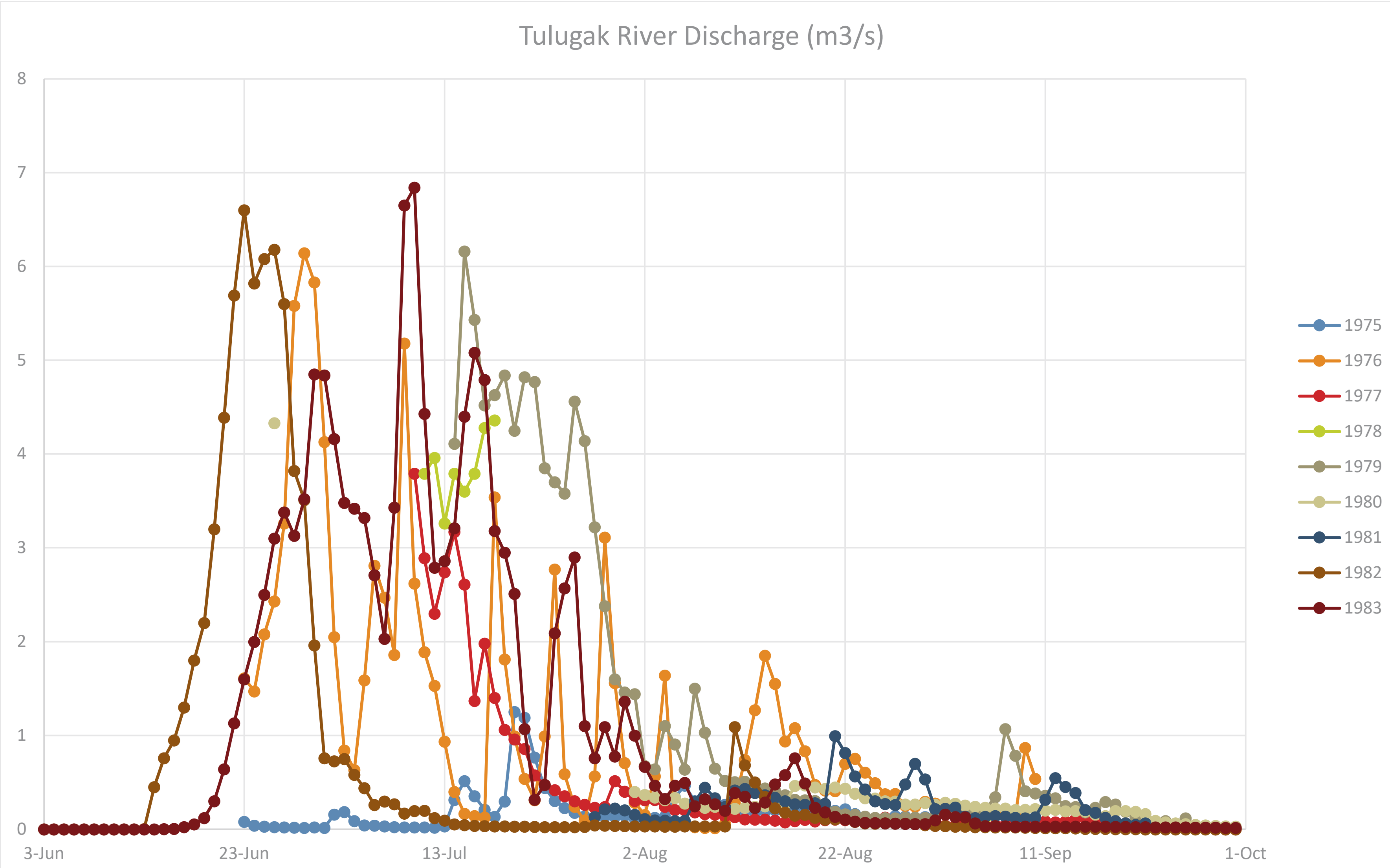

Figure 5-1: Tulugak River Discharge Rates (1975-1983)

5.2.5 Recommendations for Future Studies

The flow regime for the Tulugak River requires further investigation. The findings from this report have been based on best-available information provided for the Tulugak River which is over 40 years old. A future study would be required to ultimately detail discharge volume/velocity, drawdown rates, erosion, sedimentation, water quality, and variability of discharge into the Tulugak River. Recommendations for future studies include:

- Installation of flow gauges and levels to monitor the Tulugak River during flow periods including at the intake structure
  - Hydrograph development of the Tulugak River
    - Timing dates of flow/melt period
    - Impact of rain events in generating peak flows
    - Pattern and duration, magnitude of peak to low flows, shape of hydrograph peak
  - Ongoing monitoring of precipitation and ET rates for the Tulugak River watershed
  - Flow depths along the river and at the intake structure
- Additional topographic survey of the Tulugak River water basin
- Additional water quality sampling – recommend weekly sampling during the flow season to understand the temporal water quality fluctuations and sediment transport that occur over the flow period and to confirm optimal dates for raw water collection
- Further investigations related to permafrost monitoring
  - potential impacts on hydrological patterns
  - impacts on potential flood mitigations

6 Limitations of Water Balance Analysis

Results from this analysis should be considered high-level and coarse resolution. This desktop study provides a screening level assessment of the drinking water supplies for the Hamlet of Qikiqtarjuaq with consideration to climate change, population growth, and existing water infrastructure. This study focuses solely on water quantity and does not comment on water quality.

There are a number of limitations based on poor data availability and quality of the data. Precipitation data specific for Qikiqtarjuaq contain significant gaps and/or appear to contain questionable data points. If a yearly climate dataset had two or more months of missing data, this climate dataset was omitted from the water balance analysis. Discharge and flow information for Tulugak River is outdated and over 40 years old.

Evapotranspiration (ET) characteristics of the studied watersheds are also extremely limited – no field data for measured evapotranspiration rates was available at any of the sites. A literature review was completed to estimate ET rates in similar Arctic environments but there is still a high degree of uncertainty in the quality of this historical data. Variations in environmental conditions, plant community composition, soil freeze/thaw and micro-topographical features have a significant influence on ET rates. There is a large spatial and temporal variability in geomorphic and climatic drivers of evapotranspiration which makes it difficult to predict ET rates in the absence of any field data. As precipitation and ET are the main sources of water inputs and losses, any variation or error in these values could significantly alter the results of the water modeling assessments.

Underestimation of precipitation due to snow undercatch and water losses due to sublimation were not accounted for in the calculation. Actual basin snow amounts are usually larger than measured values (at weather stations) which suffer from gauge undercatch and thus the use of snow gauge data was deemed as a conservative approach for this study. Estimates for snow undercatch can range from 10% to 75% depending on gauge type and wind conditions. Sublimation losses have not been characterized. Characterization of these processes requires detailed meteorological data.

In general, there is a lack of field studies detailing the hydrological regime and hydrological features that affect recharge (streams, glaciers, flows through the active layer) at the study sites.

To improve the accuracy of future studies, it is recommended to conduct additional field studies to provide more complete and site-specific climate information, evapotranspiration rates and flow rates and water levels for major streams and channels. Future studies must consider the potential impacts of climate change and also flooding risks for the community of Qikiqtarjuaq.

7 Conclusions

Based on the water balance assessment, under twelve of fifteen scenarios, the Tulugak River water source and watershed provides sufficient water quantities to meet the community's current and future water supply needs to the year 2064 (projected annual water usage for Qikiqtarjuaq in 2064 is approximately 25,833 m^3).

It should be noted that precipitation data specific for Qikiqtarjuaq contain significant gaps and/or appear to contain questionable data points. In the analysis, two abnormally low precipitation values of 87mm in 2022 and 93mm in 1973 were included in the analysis for conservativism. However, the accuracy and validity of these data points is questionable. **If these data points are omitted from the analysis, under all fifteen scenarios, the Tulugak River water source and watershed provides sufficient water quantities to meet the community's current and future water supply needs.**

Note that based on the Nunavut Bureau population projections, the population of Qikiqtarjuaq is not expected to change significantly over the course of the study period (i.e 560 persons in 2021 to 590 persons in 2064). If population trends or census data change, this would impact water balance scenarios and would require the analysis to be re-evaluated.

The catchment area of the Tulugak River watershed is relatively large at approximately 26,640,000 m^2 (26.24 km^2 or 2,464 ha) and any net-positive annual runoff (>1.1mm) for the Tulugak River watershed will provide sufficient water supply to meet the community's needs.

EXP reviewed the limited dataset that documented the discharge and flow rates of the Tulugak River between 1975-1983. The year-to-year variability in the timing and magnitude of the peak flows for the Tulugak River between 1975-1983 is quite large. In general, measurable flows begin in mid-June and peak sometime in July/early August. Flows tend to decrease starting in the month of September although there are apparent peaks in various years likely due to rainfall events.

The projected water extraction volume in 2064 for the community of Qikiqtarjuaq is approximately 25,833 m^3. This equates to only about 0.5% of the total annual discharge of the Tulugak River (assuming a total annual discharge of 6,000,000 m^3 for the Tulugak River). From a water quantity perspective, the extraction volume required by the community is negligible compared to the estimated annual discharge of the Tulugak River and thus, the volume extracted is not expected to be a concern.

It should be noted that these findings have been based on best-available information provided for the Tulugak River and surrounding watershed. This is a limited dataset that is 40-50 years old. Site conditions have likely changed, and thus, future field studies are recommended.

Recommendations for future studies include:

- Installation of flow gauges and levels to monitor the Tulugak River during flow periods including at the intake structure
  - Hydrograph development of the Tulugak River
    - Timing dates of flow/melt period
    - Impact of rain events in generating peak flows
    - Pattern and duration, magnitude of peak to low flows, shape of hydrograph peak
  - Ongoing monitoring of precipitation and ET rates for the Tulugak River watershed
  - Flow depths along the river and at the intake structure
- Additional topographic survey of the Tulugak River water basin

- Additional water quality sampling – recommend weekly sampling during the flow season to understand the temporal water quality fluctuations and sediment transport that occur over the flow period and to confirm optimal dates for raw water collection
- Further investigations related to permafrost monitoring
  - potential impacts on hydrological patterns
  - impacts on flood mitigations

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Appendix A – Watershed Delineation Map (Tulugak River)

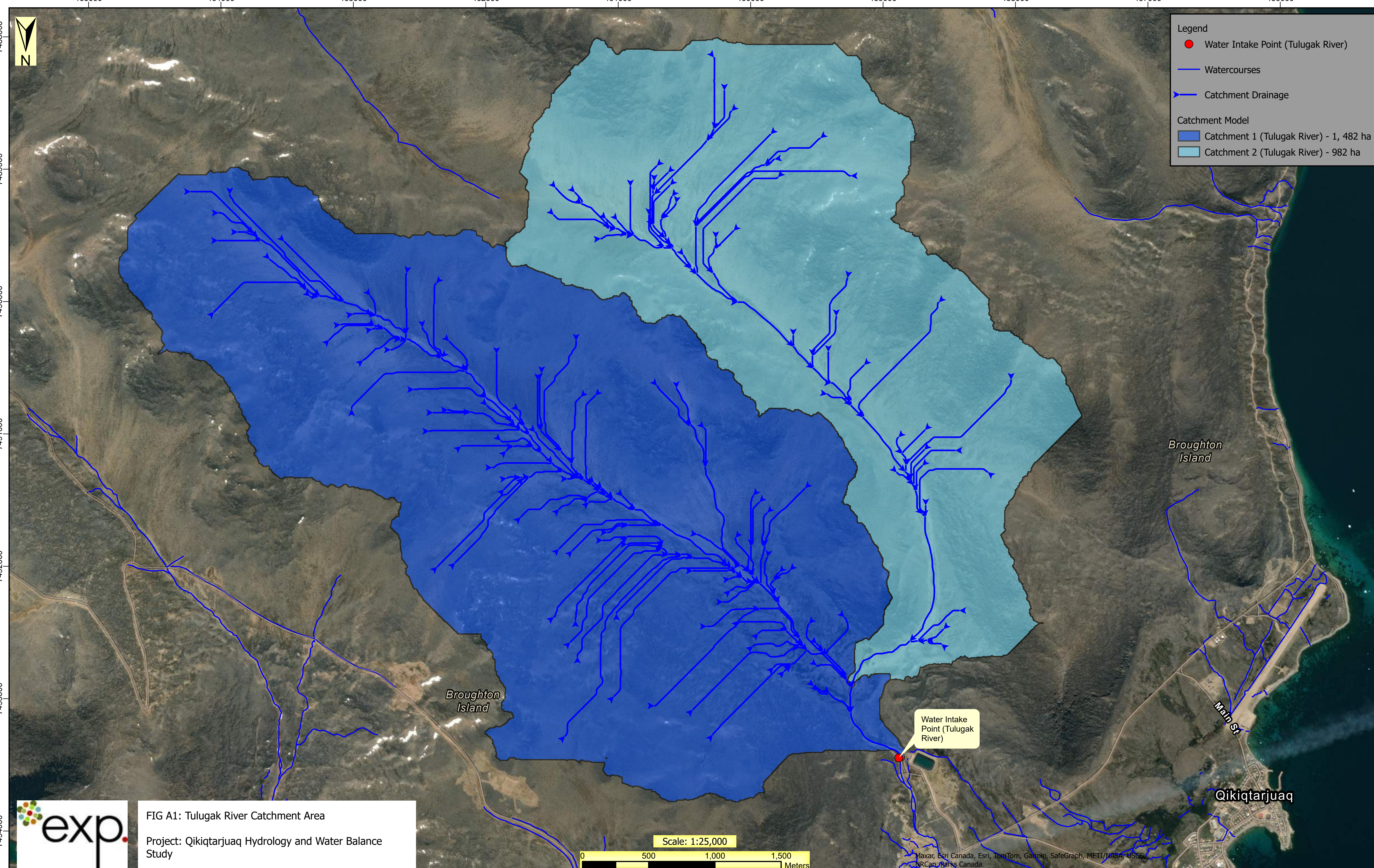

FIG A1: Tulugak River Catchment Area

Project: Qikiqtarjuaq Hydrology and Water Balance Study

Appendix B – Water Balance Calculations and Precipitation Data (Qikiqtarjuaq)

Qikiqtarjuaq Historical Precipitation Data			
Station Name	BROUGHTON VILLAGE (1971-1974)	QIKIQTARJUAQ A (1994 - 2013)	QIKIQTARJUAQ A (2013-2024)
Climate ID	2400574	2400572	2400577
Longitude	-64.03333333	-64.03138889	-64.03166667
Latitude	67.55	67.54583333	67.54666667

Year	Annual Precipitation (mm/yr)	Used for Analysis (Y or N)	Comments	MISSING DATA	TRACE: VALUE IS 0	# Days in Year		# DAYS NO DATA
1971	188.4	N	Over 60 days missing	0	37	214	151	188
1972	74.9	N	Over 60 days missing	2	72	305	60	134
1973	83.1	Y		0	42	365	0	42
1974	162.4	N	Over 60 days missing	0	48	304	61	109
1994	0	N	Over 60 days missing	30	0	61	304	334
1995	0	N	Over 60 days missing	85	11	365	0	96
1996	51	N	Over 60 days missing	52	22	336	29	103
1997	0	N	Over 60 days missing	118	8	365	0	126
1998	11	N	Over 60 days missing	126	34	365	0	160
1999	50	N	Over 60 days missing	53	51	365	0	104
2000	68	N	Over 60 days missing	91	43	366	-1	133
2001	58.4	N	Over 60 days missing	89	62	365	0	151
2002	7.2	N	Over 60 days missing	115	37	365	0	152
2003	83	N	Over 60 days missing	77	72	365	0	149
2004	192	N	Over 60 days missing	0	114	366	-1	113
2005	365.9	N	Over 60 days missing	12	71	365	0	83
2006	331.6	Y		0	50	365	0	50
2007	244.4	Y		3	29	365	0	32
2008	392.2	Y		21	2	349	16	39
2009	304.2	Y		0	4	364	1	5
2010	493.5	N	Over 60 days missing	0	89	331	34	123
2011		N	Over 60 days missing			0	365	365
2012		N	Over 60 days missing			0	365	365
2013	196.2	Y		12	15	357	8	35
2014	172.1	Y		12	7	347	18	37
2015	132.7	Y		5	6	353	12	23
2016	51.9	N	CONSIDERED OUTLIER	5	6	325	40	51
2017	94.3	N	Over 60 days missing	3	0	269	96	99
2018	153.6	N	Over 60 days missing	5	0	301	64	69
2019	180.2	Y		3	0	365	0	3
2020	142.8	Y		6	0	366	-1	5
2021	103.1	N	Over 60 days missing	8	0	289	76	84
2022	86.6	Y		3	0	365	0	3
2023	166.8	Y		2	0	365	0	2
2024		N	Over 60 days missing			114	251	251

Year	Annual Precipitation (mm/yr)
1971	
1972	
1973	83.1
1974	
1994	
1995	
1996	
1997	
1998	
1999	
2000	
2001	
2002	
2003	
2004	
2005	
2006	331.6
2007	244.4
2008	392.2
2009	304.2
2010	
2011	
2012	
2013	196.2
2014	172.1
2015	132.7
2016	
2017	
2018	
2019	180.2
2020	142.8
2021	
2022	86.6
2023	166.8
2024	

		FOR CALCULATIONS			
(mm/year)	Total Precip	Snowfall (87%)	Rainfall (13%)	89% of Rainfall	Total
Minimum (mm/year)	83.1	72.297	10.8	9.61467	81.91167
Maximum (mm/year)	392.2	341.214	51.0	45.37754	386.5915
Median (mm/year)	176.2	153.2505	22.9	20.380555	173.6311
Mean (mm/year)	202.7	176.38525	26.4	23.45721083	199.8425
3-year low average	100.8	87.696	13.1	11.66256	99.35856
5-year low average	122.4	106.488	15.9	14.16168	120.6497
10-year low average	185.5	161.4008182	24.1	21.46445364	182.8653
3-year high average	342.7	298.12	44.5	39.64653333	337.7665
5-year high average	293.7	255.5364	38.2	33.983404	289.5198

QIKIQTARJUAQ - WATER BALANCE AND VOLUME CALCULATIONS 2044

2044 - 20 YR HORIZON			***QIKIQTARJUAQ***			**Kuruluk River- Watershed Area** 24,640,000 ***m2***		
Scenario No.	**Precipitation Scenario**	**ET Scenario**	**Precipitation (mm/year)**	**Estimated ET (mm/year)**	**Potential Runoff (mm/year)**	**runoff (m3/year)**	**2044 Annual Water Use (m3/year)**	**ΔS > 0**
1	minimum	maximum	82	103	-21	-519,616	25,627	NO
2	minimum	3-year high	82	86	-4	-100,736	25,627	NO
3	minimum	average	82	65	17	416,704	25,627	YES
4	3-year low	maximum	99	103	-4	-89,725	25,627	NO
5	3-year low	3-year high	99	86	13	329,155	25,627	YES
6	3-year low	average	99	65	34	846,595	25,627	YES
7	5-year low	maximum	121	103	18	434,888	25,627	YES
8	5-year low	3-year high	121	86	35	853,768	25,627	YES
9	5-year low	average	121	65	56	1,371,208	25,627	YES
10	10-year low	maximum	183	103	80	1,967,880	25,627	YES
11	10-year low	3-year high	183	86	97	2,386,760	25,627	YES
12	10-year low	average	183	65	118	2,904,200	25,627	YES
13	Median	maximum	174	103	71	1,740,349	25,627	YES
14	Median	3-year high	174	86	88	2,159,229	25,627	YES
15	Median	average	174	65	109	2,676,669	25,627	YES

WATER USE (2044) 25,627

QIKIQTARJUAQ - WATER BALANCE AND VOLUME CALCULATIONS 2046

2064 - 40 YR HORIZON			***QIKIQTARJUAQ***			**Kuruluk River- Watershed Area** 24,640,000 ***m2***		
Scenario No.	**Precipitation Scenario**	**ET Scenario**	**Precipitation (mm/year)**	**Estimated ET (mm/year)**	**Potential Runoff (mm/year)**	**runoff (m3/year)**	**2044 Annual Water Use (m3/year)**	**ΔS > 0**
1	minimum	maximum	81.9	103	-21.1	-519,616	25,833	NO
2	minimum	3-year high	81.9	86	-4.1	-100,736	25,833	NO
3	minimum	average	81.9	65	16.9	416,704	25,833	YES
4	3-year low	maximum	99.4	103	-3.6	-89,725	25,833	NO
5	3-year low	3-year high	99.4	86	13.4	329,155	25,833	YES
6	3-year low	average	99.4	65	34.4	846,595	25,833	YES
7	5-year low	maximum	120.6	103	17.6	434,888	25,833	YES
8	5-year low	3-year high	120.6	86	34.6	853,768	25,833	YES
9	5-year low	average	120.6	65	55.6	1,371,208	25,833	YES
10	10-year low	maximum	182.9	103	79.9	1,967,880	25,833	YES
11	10-year low	3-year high	182.9	86	96.9	2,386,760	25,833	YES
12	10-year low	average	182.9	65	117.9	2,904,200	25,833	YES
13	Median	maximum	173.6	103	70.6	1,740,349	25,833	YES
14	Median	3-year high	173.6	86	87.6	2,159,229	25,833	YES
15	Median	average	173.6	65	108.6	2,676,669	25,833	YES

WATER USE (2064) 25,833

Appendix C – Tulugak River Discharge and Flow Data (1975-1983)

TULUGAK RIVER DISCHARGE 1975-1983 LATITUDE 67°33'40" N
STATION # 10EU001 LONGITUDE 63°58'54" W

Date	Date	Instantaneous Flow (m3/s)
6/23/1975	23-Jun	0.079
6/24/1975	24-Jun	0.04
6/25/1975	25-Jun	0.028
6/26/1975	26-Jun	0.025
6/27/1975	27-Jun	0.022
6/28/1975	28-Jun	0.019
6/29/1975	29-Jun	0.017
6/30/1975	30-Jun	0.022
7/1/1975	1-Jul	0.017
7/2/1975	2-Jul	0.159
7/3/1975	3-Jul	0.184
7/4/1975	4-Jul	0.088
7/5/1975	5-Jul	0.042
7/6/1975	6-Jul	0.04
7/7/1975	7-Jul	0.031
7/8/1975	8-Jul	0.024
7/9/1975	9-Jul	0.022
7/10/1975	10-Jul	0.021
7/11/1975	11-Jul	0.02
7/12/1975	12-Jul	0.018
7/13/1975	13-Jul	0.031
7/14/1975	14-Jul	0.314
7/15/1975	15-Jul	0.515
7/16/1975	16-Jul	0.354
7/17/1975	17-Jul	0.21
7/18/1975	18-Jul	0.133
7/19/1975	19-Jul	0.297
7/20/1975	20-Jul	1.25
7/21/1975	21-Jul	1.19
7/22/1975	22-Jul	0.767
7/23/1975	23-Jul	0.442
7/24/1975	24-Jul	0.303
7/25/1975	25-Jul	0.227
7/26/1975	26-Jul	0.176
7/27/1975	27-Jul	0.139
7/28/1975	28-Jul	0.13
7/29/1975	29-Jul	0.136
7/30/1975	30-Jul	0.133
7/31/1975	31-Jul	0.144
8/1/1975	1-Aug	0.116

TULUGAK RIVER DISCHARGE 1975-1983 LATITUDE 67°33'40" N
STATION # 10EU001 LONGITUDE 63°58'54" W

8/2/1975	2-Aug	0.108
8/3/1975	3-Aug	0.122
8/4/1975	4-Aug	0.136
8/5/1975	5-Aug	0.34
8/6/1975	6-Aug	0.467
8/7/1975	7-Aug	0.3
8/8/1975	8-Aug	0.215
8/9/1975	9-Aug	0.215
8/10/1975	10-Aug	0.263
8/11/1975	11-Aug	0.218
8/12/1975	12-Aug	0.198
8/13/1975	13-Aug	0.181
8/14/1975	14-Aug	0.19
8/15/1975	15-Aug	0.204
8/16/1975	16-Aug	0.212
8/17/1975	17-Aug	0.218
8/18/1975	18-Aug	0.229
8/19/1975	19-Aug	0.19
8/20/1975	20-Aug	0.167
8/21/1975	21-Aug	0.198
8/22/1975	22-Aug	0.215
8/23/1975	23-Aug	0.164
8/24/1975	24-Aug	0.13
8/25/1975	25-Aug	0.113
8/26/1975	26-Aug	0.108
8/27/1975	27-Aug	0.142
8/28/1975	28-Aug	0.136
8/29/1975	29-Aug	0.122
8/30/1975	30-Aug	0.13
8/31/1975	31-Aug	0.125
6/23/1976	23-Jun	1.61
6/24/1976	24-Jun	1.47
6/25/1976	25-Jun	2.08
6/26/1976	26-Jun	2.43
6/27/1976	27-Jun	3.26
6/28/1976	28-Jun	5.58
6/29/1976	29-Jun	6.14
6/30/1976	30-Jun	5.83
7/1/1976	1-Jul	4.13
7/2/1976	2-Jul	2.05
7/3/1976	3-Jul	0.841
7/4/1976	4-Jul	0.631
7/5/1976	5-Jul	1.59
7/6/1976	6-Jul	2.81

7/7/1976	7-Jul	2.47	
7/8/1976	8-Jul	1.86	
7/9/1976	9-Jul	5.18	
7/10/1976	10-Jul	2.62	
7/11/1976	11-Jul	1.89	
7/12/1976	12-Jul	1.53	
7/13/1976	13-Jul	0.934	
7/14/1976	14-Jul	0.399	
7/15/1976	15-Jul	0.167	
7/16/1976	16-Jul	0.142	
7/17/1976	17-Jul	0.125	
7/18/1976	18-Jul	3.54	
7/19/1976	19-Jul	1.81	
7/20/1976	20-Jul	0.991	
7/21/1976	21-Jul	0.538	
7/22/1976	22-Jul	0.311	
7/23/1976	23-Jul	0.991	
7/24/1976	24-Jul	2.77	
7/25/1976	25-Jul	0.589	
7/26/1976	26-Jul	0.241	
7/27/1976	27-Jul	0.096	
7/28/1976	28-Jul	0.566	
7/29/1976	29-Jul	3.11	
7/30/1976	30-Jul	1.56	
7/31/1976	31-Jul	0.708	
8/1/1976	1-Aug	0.283	
8/2/1976	2-Aug	0.153	
8/3/1976	3-Aug	0.566	
8/4/1976	4-Aug	1.64	
8/5/1976	5-Aug	0.062	
8/6/1976	6-Aug	0.042	
8/7/1976	7-Aug	0.024	
8/8/1976	8-Aug	0.015	
8/9/1976	9-Aug	0.014	
8/10/1976	10-Aug	0.059	
8/11/1976	11-Aug	0.28	
8/12/1976	12-Aug	0.739	
8/13/1976	13-Aug	1.27	
8/14/1976	14-Aug	1.85	
8/15/1976	15-Aug	1.55	
8/16/1976	16-Aug	0.937	
8/17/1976	17-Aug	1.08	
8/18/1976	18-Aug	0.833	
8/19/1976	19-Aug	0.473	

8/20/1976	20-Aug	0.416
8/21/1976	21-Aug	0.408
8/22/1976	22-Aug	0.699
8/23/1976	23-Aug	0.753
8/24/1976	24-Aug	0.606
8/25/1976	25-Aug	0.493
8/26/1976	26-Aug	0.374
8/27/1976	27-Aug	0.377
8/28/1976	28-Aug	0.252
8/29/1976	29-Aug	0.244
8/30/1976	30-Aug	0.294
8/31/1976	31-Aug	0.275
9/1/1976	1-Sep	0.224
9/2/1976	2-Sep	0.193
9/3/1976	3-Sep	0.178
9/4/1976	4-Sep	0.153
9/5/1976	5-Sep	0.176
9/6/1976	6-Sep	0.173
9/7/1976	7-Sep	0.17
9/8/1976	8-Sep	0.142
9/9/1976	9-Sep	0.867
9/10/1976	10-Sep	0.538
7/10/1977	10-Jul	3.79
7/11/1977	11-Jul	2.89
7/12/1977	12-Jul	2.3
7/13/1977	13-Jul	2.74
7/14/1977	14-Jul	3.17
7/15/1977	15-Jul	2.61
7/16/1977	16-Jul	1.37
7/17/1977	17-Jul	1.98
7/18/1977	18-Jul	1.4
7/19/1977	19-Jul	1.06
7/20/1977	20-Jul	0.96
7/21/1977	21-Jul	0.858
7/22/1977	22-Jul	0.575
7/23/1977	23-Jul	0.473
7/24/1977	24-Jul	0.419
7/25/1977	25-Jul	0.354
7/26/1977	26-Jul	0.3
7/27/1977	27-Jul	0.263
7/28/1977	28-Jul	0.229
7/29/1977	29-Jul	0.238
7/30/1977	30-Jul	0.515
7/31/1977	31-Jul	0.402

TULUGAK RIVER DISCHARGE 1975-1983 LATITUDE 67°33'40" N
STATION # 10EU001 LONGITUDE 63°58'54" W

8/1/1977	1-Aug	0.303
8/2/1977	2-Aug	0.311
8/3/1977	3-Aug	0.314
8/4/1977	4-Aug	0.241
8/5/1977	5-Aug	0.207
8/6/1977	6-Aug	0.204
8/7/1977	7-Aug	0.181
8/8/1977	8-Aug	0.164
8/9/1977	9-Aug	0.159
8/10/1977	10-Aug	0.139
8/11/1977	11-Aug	0.13
8/12/1977	12-Aug	0.108
8/13/1977	13-Aug	0.105
8/14/1977	14-Aug	0.105
8/15/1977	15-Aug	0.093
8/16/1977	16-Aug	0.076
8/17/1977	17-Aug	0.088
8/18/1977	18-Aug	0.102
8/19/1977	19-Aug	0.085
8/20/1977	20-Aug	0.099
8/21/1977	21-Aug	0.105
8/22/1977	22-Aug	0.099
8/23/1977	23-Aug	0.105
8/24/1977	24-Aug	0.102
8/25/1977	25-Aug	0.105
8/26/1977	26-Aug	0.125
8/27/1977	27-Aug	0.116
8/28/1977	28-Aug	0.099
8/29/1977	29-Aug	0.071
8/30/1977	30-Aug	0.065
8/31/1977	31-Aug	0.054
9/1/1977	1-Sep	0.04
9/2/1977	2-Sep	0.042
9/3/1977	3-Sep	0.051
9/4/1977	4-Sep	0.045
9/5/1977	5-Sep	0.042
9/6/1977	6-Sep	0.042
9/7/1977	7-Sep	0.048
9/8/1977	8-Sep	0.057
9/9/1977	9-Sep	0.079
9/10/1977	10-Sep	0.099
9/11/1977	11-Sep	0.085
9/12/1977	12-Sep	0.074
9/13/1977	13-Sep	0.085

9/14/1977	14-Sep	0.11
9/15/1977	15-Sep	0.122
9/16/1977	16-Sep	0.079
9/17/1977	17-Sep	0.051
9/18/1977	18-Sep	0.04
9/19/1977	19-Sep	0.028
9/20/1977	20-Sep	0.011
9/21/1977	21-Sep	0.008
9/22/1977	22-Sep	0.008
9/23/1977	23-Sep	0.008
9/24/1977	24-Sep	0.008
9/25/1977	25-Sep	0.006
9/26/1977	26-Sep	0.003
9/27/1977	27-Sep	0.002
9/28/1977	28-Sep	0
9/29/1977	29-Sep	0
9/30/1977	30-Sep	0
7/11/1978	11-Jul	3.79
7/12/1978	12-Jul	3.96
7/13/1978	13-Jul	3.26
7/14/1978	14-Jul	3.79
7/15/1978	15-Jul	3.6
7/16/1978	16-Jul	3.79
7/17/1978	17-Jul	4.28
7/18/1978	18-Jul	4.36
9/5/1978	5-Sep	0.119
7/14/1979	14-Jul	4.11
7/15/1979	15-Jul	6.16
7/16/1979	16-Jul	5.43
7/17/1979	17-Jul	4.52
7/18/1979	18-Jul	4.63
7/19/1979	19-Jul	4.84
7/20/1979	20-Jul	4.25
7/21/1979	21-Jul	4.82
7/22/1979	22-Jul	4.77
7/23/1979	23-Jul	3.85
7/24/1979	24-Jul	3.7
7/25/1979	25-Jul	3.58
7/26/1979	26-Jul	4.56
7/27/1979	27-Jul	4.14
7/28/1979	28-Jul	3.22
7/29/1979	29-Jul	2.38
7/30/1979	30-Jul	1.6
7/31/1979	31-Jul	1.46

TULUGAK RIVER DISCHARGE 1975-1983 LATITUDE 67°33'40" N

STATION # 10EU001 LONGITUDE 63°58'54" W

8/1/1979	1-Aug	1.44
8/2/1979	2-Aug	0.676
8/3/1979	3-Aug	0.641
8/4/1979	4-Aug	1.1
8/5/1979	5-Aug	0.905
8/6/1979	6-Aug	0.637
8/7/1979	7-Aug	1.5
8/8/1979	8-Aug	1.03
8/9/1979	9-Aug	0.649
8/10/1979	10-Aug	0.517
8/11/1979	11-Aug	0.504
8/12/1979	12-Aug	0.508
8/13/1979	13-Aug	0.469
8/14/1979	14-Aug	0.437
8/15/1979	15-Aug	0.413
8/16/1979	16-Aug	0.365
8/17/1979	17-Aug	0.315
8/18/1979	18-Aug	0.311
8/19/1979	19-Aug	0.303
8/20/1979	20-Aug	0.245
8/21/1979	21-Aug	0.187
8/22/1979	22-Aug	0.16
8/23/1979	23-Aug	0.154
8/24/1979	24-Aug	0.136
8/25/1979	25-Aug	0.123
8/26/1979	26-Aug	0.119
8/27/1979	27-Aug	0.118
8/28/1979	28-Aug	0.126
8/29/1979	29-Aug	0.125
8/30/1979	30-Aug	0.123
8/31/1979	31-Aug	0.143
9/1/1979	1-Sep	0.179
9/2/1979	2-Sep	0.172
9/3/1979	3-Sep	0.169
9/4/1979	4-Sep	0.177
9/5/1979	5-Sep	0.211
9/6/1979	6-Sep	0.343
9/7/1979	7-Sep	1.07
9/8/1979	8-Sep	0.784
9/9/1979	9-Sep	0.406
9/10/1979	10-Sep	0.382
9/11/1979	11-Sep	0.358
9/12/1979	12-Sep	0.331
9/13/1979	13-Sep	0.25

9/14/1979	14-Sep	0.237
9/15/1979	15-Sep	0.182
9/16/1979	16-Sep	0.231
9/17/1979	17-Sep	0.293
9/18/1979	18-Sep	0.265
9/19/1979	19-Sep	0.186
9/20/1979	20-Sep	0.129
9/21/1979	21-Sep	0.038
9/22/1979	22-Sep	0.037
9/23/1979	23-Sep	0.087
9/24/1979	24-Sep	0.061
9/25/1979	25-Sep	0.118
9/26/1979	26-Sep	0.03
9/27/1979	27-Sep	0.023
9/28/1979	28-Sep	0.02
9/29/1979	29-Sep	0.018
9/30/1979	30-Sep	0.018
6/26/1980	26-Jun	4.33
8/1/1980	1-Aug	0.399
8/2/1980	2-Aug	0.368
8/3/1980	3-Aug	0.34
8/4/1980	4-Aug	0.311
8/5/1980	5-Aug	0.334
8/6/1980	6-Aug	0.275
8/7/1980	7-Aug	0.249
8/8/1980	8-Aug	0.229
8/9/1980	9-Aug	0.24
8/10/1980	10-Aug	0.223
8/11/1980	11-Aug	0.22
8/12/1980	12-Aug	0.23
8/13/1980	13-Aug	0.242
8/14/1980	14-Aug	0.247
8/15/1980	15-Aug	0.274
8/16/1980	16-Aug	0.27
8/17/1980	17-Aug	0.463
8/18/1980	18-Aug	0.469
8/19/1980	19-Aug	0.446
8/20/1980	20-Aug	0.43
8/21/1980	21-Aug	0.448
8/22/1980	22-Aug	0.435
8/23/1980	23-Aug	0.381
8/24/1980	24-Aug	0.332
8/25/1980	25-Aug	0.33
8/26/1980	26-Aug	0.301

8/27/1980	27-Aug	0.296
8/28/1980	28-Aug	0.266
8/29/1980	29-Aug	0.265
8/30/1980	30-Aug	0.28
8/31/1980	31-Aug	0.262
9/1/1980	1-Sep	0.283
9/2/1980	2-Sep	0.273
9/3/1980	3-Sep	0.255
9/4/1980	4-Sep	0.24
9/5/1980	5-Sep	0.231
9/6/1980	6-Sep	0.222
9/7/1980	7-Sep	0.221
9/8/1980	8-Sep	0.207
9/9/1980	9-Sep	0.21
9/10/1980	10-Sep	0.216
9/11/1980	11-Sep	0.201
9/12/1980	12-Sep	0.208
9/13/1980	13-Sep	0.193
9/14/1980	14-Sep	0.194
9/15/1980	15-Sep	0.189
9/16/1980	16-Sep	0.158
9/17/1980	17-Sep	0.143
9/18/1980	18-Sep	0.195
9/19/1980	19-Sep	0.194
9/20/1980	20-Sep	0.188
9/21/1980	21-Sep	0.164
9/22/1980	22-Sep	0.092
9/23/1980	23-Sep	0.075
9/24/1980	24-Sep	0.065
9/25/1980	25-Sep	0.057
9/26/1980	26-Sep	0.049
9/27/1980	27-Sep	0.043
9/28/1980	28-Sep	0.037
9/29/1980	29-Sep	0.033
9/30/1980	30-Sep	0.028
7/28/1981	28-Jul	0.13
7/29/1981	29-Jul	0.215
7/30/1981	30-Jul	0.222
7/31/1981	31-Jul	0.204
8/1/1981	1-Aug	0.156
8/2/1981	2-Aug	0.11
8/3/1981	3-Aug	0.097
8/4/1981	4-Aug	0.093
8/5/1981	5-Aug	0.088

8/6/1981	6-Aug	0.09
8/7/1981	7-Aug	0.297
8/8/1981	8-Aug	0.445
8/9/1981	9-Aug	0.332
8/10/1981	10-Aug	0.237
8/11/1981	11-Aug	0.414
8/12/1981	12-Aug	0.432
8/13/1981	13-Aug	0.388
8/14/1981	14-Aug	0.363
8/15/1981	15-Aug	0.338
8/16/1981	16-Aug	0.3
8/17/1981	17-Aug	0.267
8/18/1981	18-Aug	0.261
8/19/1981	19-Aug	0.278
8/20/1981	20-Aug	0.272
8/21/1981	21-Aug	0.995
8/22/1981	22-Aug	0.814
8/23/1981	23-Aug	0.565
8/24/1981	24-Aug	0.426
8/25/1981	25-Aug	0.3
8/26/1981	26-Aug	0.271
8/27/1981	27-Aug	0.26
8/28/1981	28-Aug	0.48
8/29/1981	29-Aug	0.7
8/30/1981	30-Aug	0.534
8/31/1981	31-Aug	0.217
9/1/1981	1-Sep	0.22
9/2/1981	2-Sep	0.233
9/3/1981	3-Sep	0.135
9/4/1981	4-Sep	0.119
9/5/1981	5-Sep	0.133
9/6/1981	6-Sep	0.142
9/7/1981	7-Sep	0.137
9/8/1981	8-Sep	0.124
9/9/1981	9-Sep	0.118
9/10/1981	10-Sep	0.128
9/11/1981	11-Sep	0.316
9/12/1981	12-Sep	0.545
9/13/1981	13-Sep	0.452
9/14/1981	14-Sep	0.387
9/15/1981	15-Sep	0.205
9/16/1981	16-Sep	0.177
9/17/1981	17-Sep	0.122
9/18/1981	18-Sep	0.089

TULUGAK RIVER DISCHARGE 1975-1983 LATITUDE 67°33'40" N
STATION # 10EU001 LONGITUDE 63°58'54" W

9/19/1981	19-Sep	0.063
9/20/1981	20-Sep	0.048
9/21/1981	21-Sep	0.065
6/1/1982	1-Jun	0
6/2/1982	2-Jun	0
6/3/1982	3-Jun	0
6/4/1982	4-Jun	0
6/5/1982	5-Jun	0
6/6/1982	6-Jun	0
6/7/1982	7-Jun	0
6/8/1982	8-Jun	0
6/9/1982	9-Jun	0
6/10/1982	10-Jun	0
6/11/1982	11-Jun	0
6/12/1982	12-Jun	0
6/13/1982	13-Jun	0.002
6/14/1982	14-Jun	0.45
6/15/1982	15-Jun	0.759
6/16/1982	16-Jun	0.949
6/17/1982	17-Jun	1.3
6/18/1982	18-Jun	1.8
6/19/1982	19-Jun	2.2
6/20/1982	20-Jun	3.2
6/21/1982	21-Jun	4.39
6/22/1982	22-Jun	5.69
6/23/1982	23-Jun	6.6
6/24/1982	24-Jun	5.82
6/25/1982	25-Jun	6.08
6/26/1982	26-Jun	6.18
6/27/1982	27-Jun	5.6
6/28/1982	28-Jun	3.82
6/29/1982	29-Jun	3.51
6/30/1982	30-Jun	1.96
7/1/1982	1-Jul	0.757
7/2/1982	2-Jul	0.726
7/3/1982	3-Jul	0.749
7/4/1982	4-Jul	0.582
7/5/1982	5-Jul	0.44
7/6/1982	6-Jul	0.259
7/7/1982	7-Jul	0.296
7/8/1982	8-Jul	0.267
7/9/1982	9-Jul	0.168
7/10/1982	10-Jul	0.196
7/11/1982	11-Jul	0.197

TULUGAK RIVER DISCHARGE 1975-1983 LATITUDE 67°33'40" N

STATION # 10EU001 LONGITUDE 63°58'54" W

7/12/1982	12-Jul	0.121
7/13/1982	13-Jul	0.093
7/14/1982	14-Jul	0.053
7/15/1982	15-Jul	0.044
7/16/1982	16-Jul	0.036
7/17/1982	17-Jul	0.034
7/18/1982	18-Jul	0.032
7/19/1982	19-Jul	0.031
7/20/1982	20-Jul	0.03
7/21/1982	21-Jul	0.029
7/22/1982	22-Jul	0.027
7/23/1982	23-Jul	0.024
7/24/1982	24-Jul	0.023
7/25/1982	25-Jul	0.023
7/26/1982	26-Jul	0.024
7/27/1982	27-Jul	0.027
7/28/1982	28-Jul	0.042
7/29/1982	29-Jul	0.04
7/30/1982	30-Jul	0.038
7/31/1982	31-Jul	0.034
8/1/1982	1-Aug	0.032
8/2/1982	2-Aug	0.031
8/3/1982	3-Aug	0.031
8/4/1982	4-Aug	0.03
8/5/1982	5-Aug	0.03
8/6/1982	6-Aug	0.032
8/7/1982	7-Aug	0.032
8/8/1982	8-Aug	0.031
8/9/1982	9-Aug	0.032
8/10/1982	10-Aug	0.032
8/11/1982	11-Aug	1.09
8/12/1982	12-Aug	0.684
8/13/1982	13-Aug	0.502
8/14/1982	14-Aug	0.346
8/15/1982	15-Aug	0.226
8/16/1982	16-Aug	0.18
8/17/1982	17-Aug	0.147
8/18/1982	18-Aug	0.156
8/19/1982	19-Aug	0.124
8/20/1982	20-Aug	0.104
8/21/1982	21-Aug	0.106
8/22/1982	22-Aug	0.105
8/23/1982	23-Aug	0.08
8/24/1982	24-Aug	0.065

TULUGAK RIVER DISCHARGE 1975-1983 LATITUDE 67°33'40" N
STATION # 10EU001 LONGITUDE 63°58'54" W

8/25/1982	25-Aug	0.06
8/26/1982	26-Aug	0.064
8/27/1982	27-Aug	0.062
8/28/1982	28-Aug	0.061
8/29/1982	29-Aug	0.055
8/30/1982	30-Aug	0.046
8/31/1982	31-Aug	0.038
9/1/1982	1-Sep	0.034
9/2/1982	2-Sep	0.03
9/3/1982	3-Sep	0.028
9/4/1982	4-Sep	0.025
9/5/1982	5-Sep	0.024
9/6/1982	6-Sep	0.022
9/7/1982	7-Sep	0.021
9/8/1982	8-Sep	0.02
9/9/1982	9-Sep	0.018
9/10/1982	10-Sep	0.016
9/11/1982	11-Sep	0.014
9/12/1982	12-Sep	0.013
9/13/1982	13-Sep	0.013
9/14/1982	14-Sep	0.011
9/15/1982	15-Sep	0.006
9/16/1982	16-Sep	0.005
9/17/1982	17-Sep	0.004
9/18/1982	18-Sep	0.003
9/19/1982	19-Sep	0.003
9/20/1982	20-Sep	0.002
9/21/1982	21-Sep	0.001
9/22/1982	22-Sep	0.001
9/23/1982	23-Sep	0.001
9/24/1982	24-Sep	0
9/25/1982	25-Sep	0
9/26/1982	26-Sep	0
9/27/1982	27-Sep	0
9/28/1982	28-Sep	0
9/29/1982	29-Sep	0
9/30/1982	30-Sep	0
6/1/1983	1-Jun	0
6/2/1983	2-Jun	0
6/3/1983	3-Jun	0
6/4/1983	4-Jun	0
6/5/1983	5-Jun	0
6/6/1983	6-Jun	0
6/7/1983	7-Jun	0

TULUGAK RIVER DISCHARGE 1975-1983 LATITUDE 67°33'40" N
STATION # 10EU001 LONGITUDE 63°58'54" W

6/8/1983	8-Jun	0
6/9/1983	9-Jun	0
6/10/1983	10-Jun	0
6/11/1983	11-Jun	0
6/12/1983	12-Jun	0
6/13/1983	13-Jun	0
6/14/1983	14-Jun	0.001
6/15/1983	15-Jun	0.003
6/16/1983	16-Jun	0.006
6/17/1983	17-Jun	0.023
6/18/1983	18-Jun	0.052
6/19/1983	19-Jun	0.12
6/20/1983	20-Jun	0.3
6/21/1983	21-Jun	0.64
6/22/1983	22-Jun	1.13
6/23/1983	23-Jun	1.6
6/24/1983	24-Jun	2
6/25/1983	25-Jun	2.5
6/26/1983	26-Jun	3.1
6/27/1983	27-Jun	3.38
6/28/1983	28-Jun	3.13
6/29/1983	29-Jun	3.52
6/30/1983	30-Jun	4.85
7/1/1983	1-Jul	4.84
7/2/1983	2-Jul	4.16
7/3/1983	3-Jul	3.48
7/4/1983	4-Jul	3.42
7/5/1983	5-Jul	3.32
7/6/1983	6-Jul	2.71
7/7/1983	7-Jul	2.03
7/8/1983	8-Jul	3.43
7/9/1983	9-Jul	6.65
7/10/1983	10-Jul	6.84
7/11/1983	11-Jul	4.43
7/12/1983	12-Jul	2.79
7/13/1983	13-Jul	2.86
7/14/1983	14-Jul	3.21
7/15/1983	15-Jul	4.4
7/16/1983	16-Jul	5.08
7/17/1983	17-Jul	4.79
7/18/1983	18-Jul	3.18
7/19/1983	19-Jul	2.95
7/20/1983	20-Jul	2.51
7/21/1983	21-Jul	1.07

TULUGAK RIVER DISCHARGE 1975-1983 LATITUDE 67°33'40" N
STATION # 10EU001 LONGITUDE 63°58'54" W

7/22/1983	22-Jul	0.315
7/23/1983	23-Jul	0.475
7/24/1983	24-Jul	2.09
7/25/1983	25-Jul	2.57
7/26/1983	26-Jul	2.9
7/27/1983	27-Jul	1.1
7/28/1983	28-Jul	0.758
7/29/1983	29-Jul	1.09
7/30/1983	30-Jul	0.776
7/31/1983	31-Jul	1.36
8/1/1983	1-Aug	1
8/2/1983	2-Aug	0.668
8/3/1983	3-Aug	0.465
8/4/1983	4-Aug	0.323
8/5/1983	5-Aug	0.465
8/6/1983	6-Aug	0.496
8/7/1983	7-Aug	0.245
8/8/1983	8-Aug	0.322
8/9/1983	9-Aug	0.268
8/10/1983	10-Aug	0.198
8/11/1983	11-Aug	0.387
8/12/1983	12-Aug	0.349
8/13/1983	13-Aug	0.228
8/14/1983	14-Aug	0.287
8/15/1983	15-Aug	0.48
8/16/1983	16-Aug	0.579
8/17/1983	17-Aug	0.757
8/18/1983	18-Aug	0.491
8/19/1983	19-Aug	0.229
8/20/1983	20-Aug	0.182
8/21/1983	21-Aug	0.133
8/22/1983	22-Aug	0.103
8/23/1983	23-Aug	0.082
8/24/1983	24-Aug	0.069
8/25/1983	25-Aug	0.066
8/26/1983	26-Aug	0.064
8/27/1983	27-Aug	0.062
8/28/1983	28-Aug	0.059
8/29/1983	29-Aug	0.055
8/30/1983	30-Aug	0.057
8/31/1983	31-Aug	0.096
9/1/1983	1-Sep	0.159
9/2/1983	2-Sep	0.13
9/3/1983	3-Sep	0.127

TULUGAK RIVER DISCHARGE 1975-1983 LATITUDE 67°33'40" N
STATION # 10EU001 LONGITUDE 63°58'54" W

9/4/1983	4-Sep	0.064
9/5/1983	5-Sep	0.035
9/6/1983	6-Sep	0.034
9/7/1983	7-Sep	0.032
9/8/1983	8-Sep	0.03
9/9/1983	9-Sep	0.03
9/10/1983	10-Sep	0.03
9/11/1983	11-Sep	0.03
9/12/1983	12-Sep	0.029
9/13/1983	13-Sep	0.028
9/14/1983	14-Sep	0.028
9/15/1983	15-Sep	0.029
9/16/1983	16-Sep	0.029
9/17/1983	17-Sep	0.028
9/18/1983	18-Sep	0.027
9/19/1983	19-Sep	0.026
9/20/1983	20-Sep	0.024
9/21/1983	21-Sep	0.023
9/22/1983	22-Sep	0.022
9/23/1983	23-Sep	0.021
9/24/1983	24-Sep	0.021
9/25/1983	25-Sep	0.02
9/26/1983	26-Sep	0.019
9/27/1983	27-Sep	0.018
9/28/1983	28-Sep	0.018
9/29/1983	29-Sep	0.017
9/30/1983	30-Sep	0.016

Appendix D – Water Demands

Qikiqtarjuaq Water Demands Population Estimates

** 120 lpcd

Year	Population	Growth Rate	Annual Use (m3/year)
1994	476		20831.3
1995	482	1.30%	21102.8
1996	488	1.29%	21374.4
1997	494	1.27%	21646.0
1998	500	1.25%	21917.5
1999	507	1.24%	22189.1
2000	513	1.22%	22460.6
2001	519	1.21%	22732.2
2002	540	4.05%	23652.0
2003	528	-2.22%	23126.4
2004	522	-1.14%	22863.6
2005	519	-0.57%	22732.2
2006	473	-8.86%	20717.4
2007	514	8.67%	22513.2
2008	502	-2.33%	21987.6
2009	522	3.98%	22863.6
2010	546	4.60%	23914.8
2011	520	-4.76%	22776.0
2012	566	8.85%	24790.8
2013	581	2.65%	25447.8
2014	526	-9.47%	23038.8
2015	530	0.76%	23214.0
2016	535	0.94%	23433.0
2017	539	0.75%	23608.2
2018	544	0.93%	23827.2
2019	549	0.92%	24046.2
2020	555	1.09%	24309.0
2021	560	0.90%	24,528.00
2022	564	0.71%	24,703.20
2023	568	0.71%	24,878.40
2024	572	0.70%	25,053.60
2025	575	0.52%	25,185.00
2026	578	0.52%	25,316.40
2027	580	0.35%	25,404.00
2028	585	0.86%	25,623.00
2029	586	0.17%	25,666.80
2030	586	0.00%	25,666.80
2031	586	0.00%	25,666.80

Year	Population
1994	476
1995	482
1996	488
1997	494
1998	500
1999	507
2000	513
2001	519
2002	540
2003	528
2004	522
2005	519
2006	473
2007	514
2008	502
2009	522
2010	546
2011	520
2012	566
2013	581
2014	526
2015	530
2016	535
2017	539
2018	544
2019	549
2020	555
2021	560
2022	564
2023	564

Qikiqtarjuaq Water Demands Population Estimates

2032	585	-0.17%	25,623.00	
2033	585	0.00%	25,623.00	
2034	584	-0.17%	25,579.20	Average Growth Rate 2014-2035
2035	583	-0.17%	25,535.40	0.04%
2036	583		25,545.61	
2037	583		25,555.83	
2038	584		25,566.05	
2039	584		25,576.28	
2040	584		25,586.51	
2041	584		25,596.75	
2042	585		25,606.98	
2043	585		25,617.23	
2044	585		25,627.47	
2045	585		25,637.73	
2046	586		25,647.98	
2047	586		25,658.24	
2048	586		25,668.50	
2049	586		25,678.77	
2050	587		25,689.04	
2051	587		25,699.32	
2052	587		25,709.60	
2053	587		25,719.88	
2054	587		25,730.17	
2055	588		25,740.46	
2056	588		25,750.76	
2057	588		25,761.06	
2058	588		25,771.36	
2059	589		25,781.67	
2060	589		25,791.98	
2061	589		25,802.30	
2062	589		25,812.62	
2063	590		25,822.95	
2064	590		25,833.28	

Qikiqtarjuaq Water Demands Population Estimates

Source: Nunavut Water Board Annual Reports

Annual Consumption (L)	Per Capita Consumption (lpcd)	*orange years ommitted
11,991,000.00	69.1	
11,869,000.00	67.5	
12,290,000.00	69.0	
14,321,000.00	79.4	
	0.0	
16,624,000.00	89.9	
16,090,000.00	86.0	
16,765,000.00	88.5	
18,794,000.00	95.4	
20,903,000.00	108.5	
19,957,000.00	104.7	
18,389,000.00	97.1	
20,678,000.00	119.8	
	0.0	
13,966,600.31	76.2	no jan/feb/marc
16,573,913.71	87.0	
17,828,716.40	89.5	
17,761,586.00	93.6	
18,272,985.10	88.5	
18,699,676.00	88.2	
20,946,947.76	109.1	from Scan of consumption report
20,763,385.00	107.3	
21,720,300.00	111.2	
21,325,619.80	108.4	
22,310,161.20	112.4	
22,885,060.93	114.2	from Scan of consumption report
20,940,454.87	103.4	from Scan of consumption report
23,958,956.90	117.2	
24,733,661.00	120.1	
23,797,760.60	115.6	from Scan of consumption report
AVERAGE	97.8	
MAX	120.1	
MIN	67.5	