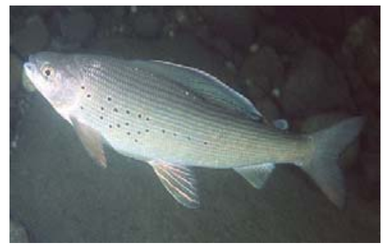
FINAL REPORT

POTABLE WATER SUPPLY STUDY
ARVIAT, NU



Prepared for:

Government of Nunavut
Department of Community Government Services

Prepared by:

IEG Environmental

In association with

KOMEX

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FINAL REPORT

POTABLE WATER SUPPLY STUDY
ARVIAT, NU

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1.0 INTRODUCTION

IEG Environmental in association with Komex International were contracted by the Department of Community & Government Services (CGS) to undertake a potable water supply study for the Hamlet of Arviat. The overall objectives of the project were:

- Assemble and review existing information regarding potable water supply in Arviat, Nunavut;
- Complete a 20-year projected potable water volume study based on expected population growth;
- Determine community potable water goals using western science and engineering and Inuit Qaujimaituqangit;
- Inspect the current potable water source and water reservoirs;

Inspect and sample the four alternative water sources as described in the RFP, i.e. Dionne Lake, Goose Lake, Mikilaaq Lake and the Maguse River;

- Compare identified potential water supply sources based on:
  - Adherence to design objectives;
  - Compliance with Fisheries and Oceans Canada (DFO) regulations;
  - Water truck accessibility;
  - Source water quality and quantity;
  - Capital costs for design procurement and construction (Class D);
  - Operations and Maintenance (O&M) costs (Class D);
  - 20-year life cycle cost (Class D); and
  - Potential treatment requirements
- Identification of possible locations for a second truck fill station at the drinking water reservoir.

1.1 Current Water Infrastructure

Currently the Hamlet of Arviat's raw water source is Wolf Creek. Raw water is pumped seasonally from Wolf Creek to two reservoirs. There is a truckfill station at the reservoirs and while the water delivery trucks are filling chlorine is added for disinfection. Residual chlorine persists throughout the distribution system.

The Department of Community and Government Services (CGS) owns the pumphouse, reservoirs and truckfill station. CGS operates the truckfill station, is responsible for daily water testing and for maintenance of the reservoir, pipeline and pumphouse. CGS contracts the pumping to a third party in Arviat. The pumphouse on Wolf Creek is approximately 7 to 8 km south of the hamlet. The pumphouse inlet line into Wolf Creek is in a pool that is approximately 4 m deep.

The reservoirs, approximately 1.5km from the Hamlet, are both lined with impermeable membranes. Capacity of cell one is 87,000 m^3 and cell two is 56,000 m^3. Total reservoir capacity equals 143,000 m^3. Pumping to the reservoir occurs once a year, usually in August. Pumping takes between 27-30 days. Fluoride is added to the reservoirs just before they are full.During the winter time pumping from the reservoirs alternates monthly.

The Hamlet operates four water delivery trucks and is going to add another truck to the fleet in the near future. While the water delivery trucks are filling, chlorine is added for disinfection. Residual chlorine persists throughout the distribution system. All four trucks run 8 hours a day, three of them do the residential houses from 8am to 5pm and one does the commercial buildings and callouts from 12pm to 8pm. There are currently problems with lineups at the truckfill station.

2.0 SITE VISIT SUMMARY

The purpose of the site visit was to:

- Meet with the SAO and other hamlet and GN staff to discuss the project, if possible;
- Travel to the current water source, Wolf Creek, and to each potential water source, collect samples and observe the surrounding terrain; and
- Investigate the pumphouse, water supply line, water reservoirs, and truckfill station.

All of the above were completed during the site visit August 31- September 3, 2004.

IEG met with the SAO, Richard Van Horne and the Mayor, Peter Kritaqliluk. During the meeting, the mayor expressed concern that the water volumes in Wolf Creek appear to be declining. To illustrate, he suggested a site visit to an important feature on the creek, upstream of the Arviat raw water intake. The location was a narrow spot in the creek that used to wide enough that a bridge was required to cross. Recently the creek had width had changed in that spot so that a bridge was no longer required to cross. The mayor was concerned that the same phenomenon could occur where the intake is located at Wolf Creek, hindering municipal use of the creek for drinking water. Mr. Kritaqliluk had no other observations or concerns with the other sites.

It was determined by the SAO that consulting with the mayor was sufficient to collect Inuit Qaujimaituqangit for this study. No other residents were contacted during the site visit.

Photos of the site visit can be found in Appendix A and a site diagram of the different potential water supply sources and sampling locations can be found in Appendix B.

2.1 Additional Sampling

The main concern of residents is reduced water level in Wolf Creek in the fall. To assess whether water quality is affected by lower flows, water quality was sampled in early September, and again in late September. IEG conducted the water quality sampling in September. A cooler with sampling supplies and sample instructions were left with the SAO during the site visit. Stephen Hartman with CGS was in Arviat on other business and collected the second sample at Wolf Creek on September 28, 2004. All samples were shipped by air to Enviro-Test Laboratories in Winnipeg, MB for analysis.

3.0 WATER STUDY

The results of the water analysis are listed in Table 1 and compared to the *Summary of Guidelines for Canadian Drinking Water Quality (GCDWQ)*. The current source water from Wolf Creek as well as the four future prospective sites all meet or are lower than the guidelines, except for turbidity at Wolf Creek when it was sampled the second time by Steve Hartman later in September.

The bacteriological samples, Fecal Coliforms, Total Coliforms, Heterotrophic Plate Count are included at the bottom of Table 1. They are however not compared to the GCDWQ because the GCDWQ are guidelines for drinking water, the drinking water in Arviat is disinfected prior to being delivered. This is to meet the bacteriological requirements of the GCDWQ and the *Public Health Act*, therefore it is not accurate to compare the source bacteriological data to the GCDWQ. The Environmental Health Officer (EHO) for the Kivalliq region was contacted to determine if there were any water quality issues in Arviat. The EHO responded that the drinking water in Arviat has always met the Public Health Act requirements except for one time at the school but that was a localized occurrence within the water tank at the school it was not a water supply or distribution issue.

The bacteriological samples for Dionne Lake did not reach the lab in the required 24 hour hold time and for Goose Lake E.Coli was analyzed instead of Fecal Coliforms.

The laboratory sample results are appended in Appendix C and the GCDWQ can be found in Appendix D.

3.1 Turbidity

Turbidity from the second water quality sample collected from Wolf Creek (WOLF -2) was 1.2 NTU. The current guideline is 1.0 NTU, with an aesthetic objective of ≤ 5 NTU. Turbidity could likely be higher in the creek when the second sample was collected, due to the greater potential for substrate disruption and because of reduced dilution potential. This may not be of concern because settling in the reservoir before the raw water is disinfected and pumped into the distribution system should settle out enough particles to reduce the turbidity below the guidelines.

The guideline of 1 NTU is currently being reviewed by Health Canada, publishers of the GCDWQ, and it is anticipated that the guideline may be reduced to 0.35 or 0.1 NTU. This reduction would require filtration for all surface drinking water sources across Canada.

The Government of Nunavut in the past has adopted the GCDWQ and used them as design criteria for water treatment projects. Should the GN adopt the new proposed guideline for turbidity across the territory all communities in Nunavut would be affected not just Arviat.

As the proposed guideline is still proposed and has not been adopted, for the purpose of this planning report the current turbidity guideline will be used.

Table 1 Water Quality Analysis Compared to the Guidelines on Canadian Drinking Water Guidelines

ANALYTE	UNITS	GUIDELINE[1]	MIKILAAQ LAKE	WOLF CREEK (SEPT 1)	DIONNE LAKE	WOLF CREEK (SEPT 28)	MAGUSE LAKE	GOOSE LAKE
			MIK-1	WOLF-1	DIONNE-1	WOLF-2	MAG-1	GOOSE-1
pH	pH units	6.5-8.5[2]	7.26	6.85	6.66	6.89	6.92	6.92
Turbidity	NTU	1	0.7	0.25	0.5	1.2	0.4	0.75
Sulphate (SO4)- Soluble	mg/L	<500[2]	15	<9	<9	9	<9	<9
Calcium (Ca)- Extractable	mg/L	N.G	11.6	3.3	3.29	5.37	3.07	5.74
Potassium (K) - Extractable	mg/L	N.G	4.69	0.92	0.87	1.07	0.77	1.52
Magnesium (Mg) - Extractable	mg/L	N.G	16.2	1.65	1.47	2.84	1.04	4.02
Sodium (Na) - Extractable	mg/L	N.G	110	8	7.17	13.6	2.64	22.6
Ion Balance	%	N.G	93.2	Low EC	Low EC	82.7	Low EC	115
TDS (Calculated)	mg/L	<500[2]	403	34	33	72	14	83
Hardness (as CaC03)	mg/L	N.G	96	15	14	25	12	31
Fluoride (F) - Soluble	mg/L	1.5	0.2	<0.1	<0.1	<0.1	<0.1	<0.1
Conductivity	umhos/cm	N.G	843	79	75	134	42.0	205
Chloride (Cl) - Soluble	mg/L	<250[2]	232	15	14	35	<9	41
Alkalinity, Total (As CaC03)	mg/L	N.G	23	9	9	9	10	13
Bicarbonate (HC03)	mg/L	N.G	28	11	11	11	12	16
Carbonate (C03)	mg/L	N.G	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Hydroxide (OH)	mg/L	N.G	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Nitrate + Nitrite- N	mg/L	45	0.03	<0.01	0.13	0.03	<0.01	0.02
Iron (Fe) - Extractable	mg/L	N.G	0.05	0.11	0.08	0.17	0.05	0.09
Manganese (Mn)- Extractable	mg/L	N.G	0.0041	0.0078	0.0067	0.0146	0.0059	0.0045
Silver(Ag) - Total	mg/L	N.G	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Aluminum (Al) - Total	mg/L	N.G	0.13	0.13	0.05	0.07	0.14	0.14
Arsenic (As) - Total	mg/L	0.025	0.0013	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Boron (B) - Total	mg/L	5	0.11	<0.03	<0.03	<0.03	<0.03	0.04
Barium (Ba) - Total	mg/L	1	0.0133	0.0056	0.0064	0.0104	0.0094	0.0074
Beryllium (Be) - Total	mg/L	N.G	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth (Bi) - Total	mg/L	N.G	0.001	<0.0001	<0.0001	0.0007	<0.0001	<0.0001
Calcium (Ca) - Total	mg/L	N.G	16.3	4.3	3.8	9.4	3.7	7.1

ANALYTE	UNITS	GUIDELINE[1]	MIKILAAQ LAKE	WOLF CREEK (SEPT 1)	DIONNE LAKE	WOLF CREEK (SEPT 28)	MAGUSE LAKE	GOOSE LAKE
			MIK-1	WOLF-1	DIONNE-1	WOLF-2	MAG-1	GOOSE-1
Cadmium (Cd) - Total	mg/L	0.005	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cobalt (Co) - Total	mg/L	N.G	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Chromium (Cr) - Total	mg/L	0.05	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Cesium (Cs) - Total	mg/L	N.G	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper (Cu) - Total	mg/L	N.G	0.006	0.003	0.008	<0.001	0.004	0.004
Iron (Fe) - Total	mg/L	<0.3[2]	0.07	0.12	0.13	0.12	<0.05	0.18
Potassium (K) - Total	mg/L	N.G	6.4	1	0.8	1	0.8	1.6
Lithium (Li) - Total	mg/L	N.G	<0.01	<0.01	<0.01	0.02	<0.01	<0.01
Magnesium (Mg) - Total	mg/L	N.G	23.1	2.1	1.63	2.71	1.32	5
Manganese (Mn) - Total	mg/L	<0.05[2]	0.0055	0.0107	0.0082	0.0156	0.007	0.0075
Molybdenum (Mo) - Total	mg/L	N.G	0.0175	0.0106	0.0003	0.0005	<0.0002	0.0003
Mercury (HG) - Total	mg/L	0.001	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Sodium (Na) - Total	mg/L	<200[2]	155	10	7.67	13.3	3.35	27.8
Nickel (Ni) - Total	mg/L	N.G	<0.002	<0.002	<0.002	<0.002	0.002	<0.002
Phosphorus (P) - Total	mg/L	N.G	0.1	0.08	<0.05	<0.05	0.06	0.06
Lead (Pb) - Total	mg/L	0.01	0.0033	<0.0005	0.0008	0.0007	<0.0005	<0.0005
Rubidium (Rb) - Total	mg/L	N.G	0.005	0.0025	0.0022	0.0021	0.0021	0.0035
Antimony (Sb) - Total	mg/L	0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (Se) - Total	mg/L	0.01	0.005	0.002	<0.001	<0.001	0.002	0.002
Tin (Sn) - Total	mg/L	N.G	0.001	0.0027	<0.0005	0.0009	0.0007	0.0006
Strontium (Sr) - Total	mg/L	N.G	0.202	0.029	0.0261	0.0385	0.0209	0.0647
Tellurium (Te) - Total	mg/L	N.G	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium (Ti) - Total	mg/L	N.G	<0.0009	<0.0009	0.001	0.0015	0.0173	0.0035
Thallium (Tl) - Total	mg/L	N.G	0.0006	0.0002	0.0005	0.0003	<0.0001	0.0002
Uranium (U) - Total	mg/L	0.02	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium (V) - Total	mg/L	N.G	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten (W) - Total	mg/L	N.G	0.0015	0.0003	<0.0002	0.0006	<0.0002	<0.0002
Zinc (Zn) - Total	mg/L	N.G	0.02	<0.01	<0.01	0.14	<0.01	<0.01
Zirconium (Zr) - Total	mg/L	N.G	0.0014	0.0005	0.0004	0.001	<0.0004	<0.0004

ANALYTE	UNITS	GUIDELINE[1]	MIKILAAQ LAKE	WOLF CREEK (SEPT 1)	DIONNE LAKE	WOLF CREEK (SEPT 28)	MAGUSE LAKE	GOOSE LAKE
			MIK-1	WOLF-1	DIONNE-1	WOLF-2	MAG-1	GOOSE-1
BACTERIOLOGICAL								
Fecal Coli	CFU/100mL		<10	<10	-	<10	<10	
Total Coliforms	CFU/100mL		<10	<10	-	<10	1580	309
Heterotrophic Plate Count	CFU/mL		775	485	-	90	155	1500
E.Coli	CFU/100mL		-	-	-	-	-	1

1: Guideline for Canadian Drinking Water Quality

2: Aesthetic Objectives

N.G: No Guideline Established

N.L: No limit established

Field analyses were conducted at all sites using a YSI handheld meter and are presented below.

Table 2 Field Water Quality Analysis

PARAMETER	UNITS	WOLF CREEK	MAGUSE LAKE	DIONNE LAKE	MIKILAAQ LAKE	GOOSE LAKE
Temperature	°C	11.26	11.2	11.2	9.87	11.45
Conductivity	µS/cm	60	30	53	617	155
Total Dissolved Solids	mg/L	52	26	47	564	136
Dissolved Oxygen	mg/L	9.74	8.71	8.58	10.42	9.78

3.2 Water Demand Projection

3.2.1 Population Projection

To estimate future water use, the population of Arviat was projected for the next 20-years. The 20-year population projection calculated from population statistics from the GN website, www.stats.gov.nu.ca, is shown in Table 1.

Table 3 Census Population Statistics, Arviat, NU

Census year	Population
1981	1,002
1986	1,189
1991	1,323
1996	1,559
2001	1,899

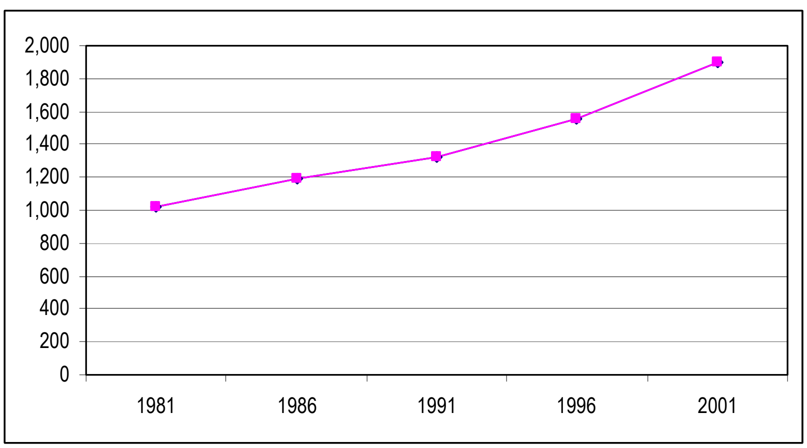


Figure 1 Population Increase, 1981 - 2001

A population growth rate of 2.9% was calculated from the census information.

Past experience has shown that census numbers can under-represent the actual population in communities throughout Nunavut. During the site visit, the SAO mentioned that the Hamlet conducted their own population study in 2000 and determined there were 1,934 residents. The SAO estimates there are approximately 80 births per year. For the best available estimate, IEG will use water data provided by CGS in conjunction with the population growth rate determined by the population increase in the census data to calculate the projected water use rates.

3.2.2 Past Water Use Rates

Water use data was provided by CGS for the 2001-2002 and 2003-2004 fiscal years. From April 1, 2001 to March 31, 2002 the Hamlet of Arviat consumed approximately 57,405,564 L and from April 1, 2003 to March 31, 2004 65,482,349 L.

3.2.3 Projected Water Use Rates

To project future water use for the Hamlet of Arviat, the CGS model was modified. The CGS water use model is as follows:

Projected per capita water use = RWU*(1+(0.00023*Population))

Where:

- The projected per capita water use is the volume of liters used per person per year and includes all commercial and institutional water use
- RWU = Residential water use rate, assumed to be 90 litres per capita per day (lpcd)
- Population is the projected population of the Hamlet for the year

The formula was modified to correspond with the water use rates provided by CGS, the modification was to 65 lpcd for the RWU. This is a relatively low RWU and it was confirmed by the Maintenance Coordinator for the Kivalliq Region, Joe Strickland, that he has observed that Arviat has a lower water use rate per capita than other communities. The following table outlines the per capita and annual projected water use rates for the Hamlet.

Table 4 20-Year Water Use Projection

PLANNING YEAR	CALENDAR YEAR	TOTAL POPULATION[1]	PROJECTED WATER USE (lpcd)	PROJECTED VOLUME (litres/day)	PROJECTED VOLUME (litres/year)	PROJECTED VOLUME (m^3/year)
	2001	1,899	93.4	177,348	64,731,912	64,732
	2002	1,954	94.2	184,100	67,196,353	67,196
	2003	2,011	95.1	191,142	69,766,815	69,767
	2004	2,069	95.9	198,489	72,448,406	72,448
0	2005	2,129	96.8	206,155	75,246,501	75,247
	2006	2,191	97.8	214,156	78,166,758	78,167
	2007	2,254	98.7	222,507	81,215,134	81,215
	2008	2,320	99.7	231,227	84,397,899	84,398
	2009	2,387	100.7	240,333	87,721,657	87,722
5	2010	2,456	101.7	249,845	91,193,361	91,193
	2011	2,527	102.8	259,782	94,820,337	94,820
	2012	2,601	103.9	270,165	98,610,298	98,610
	2013	2,676	105.0	281,017	102,571,372	102,571
	2014	2,754	106.2	292,362	106,712,124	106,712
10	2015	2,834	107.4	304,223	111,041,577	111,042
	2016	2,916	108.6	316,628	115,569,241	115,569
	2017	3,000	109.9	329,603	120,305,140	120,305
	2018	3,087	111.2	343,178	125,259,838	125,260
	2019	3,177	112.5	357,382	130,444,475	130,444
15	2020	3,269	113.9	372,249	135,870,793	135,871
	2021	3,364	115.3	387,811	141,551,176	141,551
	2022	3,461	116.7	404,106	147,498,681	147,499
	2023	3,562	118.2	421,170	153,727,079	153,727
	2024	3,665	119.8	439,044	160,250,895	160,251
20	2025	3,771	121.4	457,768	167,085,452	167,085

[1] Population Increase = 2.9%

[2] Residential Water Use Rate (RWU) = 65 lpcd

The projected water use rates estimated for the Hamlet's water licence submission closely match the IEG water use projection, given that the projection is an estimate. The water licence submission estimates water use rates of 64,871m^3 in 2003 and 78,273m^3 in 2008 compared with the estimates in the above table of 69,767m^3 for 2003 and 84,398m^3 in 2008. For the planning purposes of this study the higher estimates calculated in the table will be used.

3.3 Water Reservoir Capacity

Based on the information provided by CGS and the projected water use prepared by IEG, the 145,000 m^3 of reservoir storage should last the Hamlet until 2021.

3.4 Upgrades

Based on observations during the site visit and on conversations with the Maintenance Coordinator for the Kivalliq region, the SAO and the Mayor, there do not appear to be any requirements for upgrades to the current infrastructure outside those routinely undertaken as part of the Operation and Maintenance program.

3.5 Secondary Truckfill Arm

It was requested by CGS that the potential of a second truckfill be investigated as part of this study because the trucks get backed up at the truckfill station waiting to fill their trucks. The location of the current truckfill arm is not conducive to adding a second arm. The approach to the truckfill station is a half-circle with the arm at the center of the half-circle, so there is not room for two trucks to be lined up even if there was a second arm, please see photos in Appendix A.

Currently a problem does not exist with callouts after hours either due to insufficient time to complete the routes or fill all the tanks on the route. Therefore, modifications to the current schedule may solve the problem of trucks lining up at the truckfill station. If the trucks were to start the day staggered or if routes were changed so not all the trucks fill at the same time, then the waiting time at the truckfill might be alleviated. These options should be explored and implemented to determine effectiveness before planning and design is carried out to expand the current truckfill station and construct another truckfill arm.

4.0 SUSTAINABILITY ASSESSMENT

4.1 General

It is necessary to evaluate each of the sources in order to determine their sustainability. The general features of the area and the individual water sources are evaluated in terms of geology, terrain, and other special features. The quantity that is withdrawn should represent a small portion of the source volume or flow rate. This will ensure that there is no short or long term depletion of the source. Source depletion may have negative environmental impacts. It may also affect the viability of the intake structures and the quality of the extracted water.

4.2 Geological Setting

Arviat and the lakes and creek that have been selected as possible water sources for Arviat are located on the western side of Hudson Bay. Bedrock underlying all of the lakes and Wolf Creek is Precambrian in origin. Wolf Creek, Mikilaaq Lake, Goose Lake and Dionne Lake are all underlain by Precambrian gneiss and schist (Geological Map of Canada, 1250A). Maguse Lake is underlain by Precambrian volcanic rock.

The study area was glaciated by an ice sheet that was standing in the Tyrell Sea; an expanded version of Hudson Bay. This sea covered areas up to 168 m above modern sea level inland and 213 m above sea level near the present coast. Glacial till was deposited in moraines along with sand and gravel deposited by glacio-fluvial melt. The glacial deposits and features were strongly influenced by the ice fronting in and retreating through the deep sea water (Shilts, Kettles, and Arsenault, 1976).

The land rose due to isostatic rebound after the glacier retreated. It rose rapidly at first but the rate of uplift decreased with time. As the land rose out of the sea, shorelines migrated towards the present coast of Hudson Bay. A series of beaches (near shore sediments) formed across the region. These beaches mostly formed where sand and gravel deposited by the glacier was available for "washing" or where uplift was slowest (i.e., where beach locations were left for the longest time). The rate of uplift decreased toward the coast. Therefore, the youngest near shore deposits are best developed.

As the sea retreated, permafrost grew to depths of greater than 3050 m. Peri-glacial patterns developed controlled by the physical properties of the surficial sediments. For example, mud boils are confined to the muddy sediments of glacial or marine origin. Polygonal or orthogonal cracking patterns are found in more stable sandy, gravely, or peaty sediments such as eskers, beaches, or alluvial flats.

4.2.1 Potential Water Sources

Characteristics of the five potential water sources are described in Table 5. The information included in this table was compiled from the Geological Survey of Canada surficial geology map of the Eskimo Point map sheet (GSC Map 8-1980) and from airphotos (not stereoscopic) supplied by the project. A topographic map at 1:250 000 scale (55e) and the figure in Appendix B were also used for the analysis.

Lake size, distance from Arviat, and bedrock and surficial sediments along the lakes and Wolf Creek were described in Table 1. Also a description of material that would be crossed by a water line from each of the sources to Arviat was determined.

Any special features that might affect the water source were also listed, e.g. the turbid lake processes at the west end of Goose Lake, due to surficial geology. An attempt was made to outline both shallow and deeper sections of the lakes (where airphotos were available).

Table 5 Geomorphology Summary

WATER SOURCE	GEOLOGIC SETTING	SPECIAL FEATURES	TERRAIN ALONG ROUTE TO ARVIAT (STRAIGHT LINE	COMMENTS
Wolf Creek (Existing Source)	Bedrock underlying the Quaternary sediments in this area consists of Precambrian igneous and metamorphic rocks (gneiss and schist). The creek is located in a flat area consisting of alluvium with some marine silt and sand that was either washed from slopes by wave action during marine submergence or deposited by melt water streams. The lakes feeding the stream are located in off lap sediments that consist of a thin sheet of sand over clayey marine silt and sand. The creek passes through an area that was once a small glacial lake basin of silt with organic carbon.	The alluvium is covered by .4 to 1 m of peat. Active layer is 15 to 50 cm deep. Ice wedges, thaw ponds, and frost polygons may be present in the alluvial deposits. The sediments in the vicinity of the lakes that feed Wolf Creek have been affected by periglacial processes and gullying.	The most common terrain found between Wolf Creek and Arviat is an area of coastal plain tidal flat sediments. The sediments are poorly sorted stony silt and sand and marine silt. The area was originally a till plain that was affected by marine processes. An esker and marine beach ridges are located immediately south of Arviat. Material from these ridges could be used for construction purposes.	Lakes feeding Wolf Creek may be shallow and will freeze to the bottom. Wolf Creek passes through an area of glacial lake deposits with organic carbon that may affect water quality
Mikilaaq Lake	Bedrock underlying the Quaternary sediments in this area consists of Precambrian igneous and metamorphic rocks (gneiss and schist). Mikilaaq Lake is located in an area of near shore sediments that consists of sand, gravel, cobbles or boulders deposited as beaches, bars, spits, and ice pushed ridges. These deposits appear in the beach ridges north and south of the lake (see airphoto 28-07-92. South of this beach area on the south side of the lake and at the west end of the lake there are coastal plain tidal sediments (silt, sand, clayey silt).	The lake has been infilled to some extent by sediments. These were eroded from the adjacent land areas. Airphoto 28-07-92 shows the areas where sediment deposition has made the lake shallower. Areas underlain by near shore sediments have sparse vegetation and orthogonal frost cracks. Areas underlain by coastal tidal plain sediments have organic cover, shallow thaw lakes and periglacial features.	The most common terrain found between Mikilaaq and Arviat is an area of coastal plain tidal flat sediments. The sediments are poorly sorted stony silt and sand and marine silt. The area was originally a till plain that was affected by marine processes. An esker and marine beach ridges are located immediately south of Arviat. Material from these ridges could be used for construction purposes. Construction material could also be taken from the beach ridge at the south side of Mikilaaq Lake. The existing road to Arviat appears to be made from common borrow material along the road alignment.	Mikilaaq Lake has easy road access to Arviat. The lake has some sections, particularly on the south side that look a bit deeper. It would be prudent to get into the deeper area of the lake for water intake. It is unknown if this lake will freeze to the bottom in winter. This lake appears to be underlain by near shore sediments. Water quality may be better in lake underlain by these sediments.
Goose Lake	Bedrock underlying the Quaternary sediments in this area consists of Precambrian igneous and metamorphic rocks (gneiss and schist).	Areas underlain by coastal tidal plain sediments have organic cover, shallow thaw lakes and periglacial features.	The most common terrain found between Goose Lake and Arviat is an area of coastal plain tidal flat sediments. The sediments are poorly sorted stony silt and sand and marine silt. The area was originally a till plain that was affected by	This lake appears to be underlain by coastal plain tidal flat sediments that are mostly fine grained.

WATER SOURCE	GEOLOGIC SETTING	SPECIAL FEATURES	TERRAIN ALONG ROUTE TO ARVIAT (STRAIGHT LINE	COMMENTS
	The lake is located in an area of coastal plain tidal flat sediments. The sediments are poorly sorted stony silt and sand and marine silt, clayey silt, and pockets of near shore sand and gravel deposits. The area was originally a till plain that was affected by marine processes. A beach ridge of near shore sediments is located south of Goose Lake.	The surficial geology map by GSC Map 8-1980 shows that Goose Lake, particularly the NW end, is a turbid lake that receives a continual load of suspended sediments during ice free periods. Terrain near this lake may exhibit instability or alteration of the active layer because of wave washing or solifluction. Airphotos 25582, # 75 and 37 show the locations in Goose Lake where sediment deposition has made the lake shallower. It is difficult to tell how deep the easternmost part of the lake is from the airphotos. However, the west end is quite infilled.	marine processes. There is an area of near shore beach sediments both south and east of Goose Lake. An esker and marine beach ridges are located immediately south of Arviat. Material from these deposits and from beach ridges to the south and east of Goose Lake could be used for construction materials.	Airphotos and the GSC map 8-1980 indicate that Goose Lake is a turbid lake that is infilling with sediments during ice free periods. It might be difficult to find a deep area in this lake that is close to the shoreline for the water intake (see airphotos 25582 #37 and 75. This lake might freeze to the bottom.
Dionne Lake	Bedrock underlying the Quaternary sediments in this area consists of Precambrian igneous and metamorphic rocks (gneiss and schist). The lake lies within landforms (moraine plain and ridge deposits) that are made of till sediments. These sediments are usually grey sandy, silty, and noncalcareous with <25% clay-sized particles. There are patches of clay- rich red till in the till sediments. At the east end of the lake there are near shore deposits of sand and gravel that form beach ridges. In this area there are also offlap sediments of sand deposited by a migrating shoreline. An esker deposited by melt water crosses the lake.	Till sediments have liquid limits of 8 to 18% and a plasticity index of 0 to 8%. These sediments are susceptible to liquefaction under loading or during periods of increased moisture (heavy rain or spring thaw). Lakes have cobble and boulder paved shorelines. Mudboils and periglacial features occur on till deposits. One shallow part of Dionne Lake was located on its east end (see airphoto A18911 #33).	The terrain between Dionne Lake and Arviat consists of both an area of coastal plain tidal flat sediments near Arviat and an area of near shore and off lap deposits immediately east of Dionne Lake. The coastal plain tidal flat sediments are poorly sorted stony silt and sand and marine silt. The area was originally a till plain that was affected by marine processes. There is an area of near shore beach sediments east of Dionne Lake. An esker and marine beach ridges are located immediately south of Arviat. Material from these deposits and from beach ridges and an esker in Dionne Lake could be used for construction materials.	If is difficult to determine the depth of the lake from the 1:80 000 scale airphotos. One shallow section was determined on the east end. This lake is located in till deposits. The lake is bigger than Goose or Mikilaaq lakes.
Maguse Lake	Bedrock underlying the Quaternary sediments in this area consists of Precambrian volcanic rocks.	Till sediments have liquid limits of 8 to 18% and a plasticity index of 0 to	The terrain between MaguseLake and Arviat consists of coastal plain tidal flat sediments near	If is difficult to determine the depth of the lake because no

WATER SOURCE	GEOLOGIC SETTING	SPECIAL FEATURES	TERRAIN ALONG ROUTE TO ARVIAT (STRAIGHT LINE	COMMENTS
	The lake lies within landforms (moraine plain, ridge, and hummocky deposits) that are made of thicker till sediments. There is also shallow rock around the shoreline of the lake in some locations. Near the proposed water intake location there are some morainal deposits, glaciofluvial outwash, and alluvial deposits. Morainal deposits are made of till sediments that are usually grey sandy, silty, and noncalcareous with <25% clay-sized particles. There are patches of clay- rich red till in the till sediments.	8%. These sediments are susceptible to liquefaction under loading or during periods of increased moisture (heavy rain or spring thaw). Lakes have cobble and boulder paved shorelines. Mudboils and periglacial features occur on till deposits. There were no airphotos available to determine shallow areas within Maguse Lake.	Arviat and areas of morainal, glaciofluvial, alluvial and scattered near shore and off lap deposits immediately east of Maguse Lake. An esker and marine beach ridges are located immediately south of Arviat. Material from these glaciofluvial deposits and from an esker in Maguse Lake could be used for construction materials. It might be possible to follow the esker and/or lakes as a route back to the Maguse River near Hudson Bay. From there a route for the water line could head due south to Arviat.	airphotos were available. This lake is located mostly in shallow bedrock and till deposits. The lake is bigger than Goose, Mikilaaq, or Dionne lakes. This lake may not freeze to the bottom because of its size and possible depth. However, no airphotos were available to assess the lake.

4.3 Flow Modeling

There is no runoff data available for any of the sources being assessed. In order to estimate the runoff volumes and trends we need to model each possible source. The model yields a useful estimate of each sources flow volumes and trends.

Each possible source is associated with a catchment area, which is determined using topographical maps (Energy Mines and Resources Canada, 1994). The annual runoff volumes associated with each catchment is modeled using local precipitation data (Environment Canada, 2004) and the rational method. A run-off coefficients for similar northern terrain was used (Global Runoff Data Center, 2004). The flow profiles for the catchments are simulated using flow trend data from similar catchments in the region (Water Survey of Canada, 2004).

The run-off in these catchments is seasonal. The flow volume that occur after break-up (i.e., June 1) and before freeze-up (i.e., December 1) represent the majority of the annual run-off. There is very little run-off flow during the winter months except for a relatively large lake with a large catchment such as Maguse Lake.

The surface area of the lake sources is estimated using scaled maps (Energy Mines and Resources Canada, 1994). The annual drawdown can be determined using the surface area and the extraction rate. The drawdown is compared to the annual inflow volumes coming from runoff entering the lake. When the water is extracted from a creek, the flow rate of the creek is compared to the extraction rate.

Where the extraction rate has an insignificant drawdown and the inflow or stream flow rate is much greater than the extraction rate, the source is sustainable. The sources are assessed at a maximum extraction rate of 0.05 m^3/s and a maximum annual withdrawal volume of 150,000 m^3. Using this baseline, all of the sources are sustainable.

If we compare the withdrawal rate to the smallest source (i.e., Mikilaaq Lake), it can be seen that the inflow rate is more than ten times greater than the maximum extraction rate. The summary of this analysis is shown below. All of these values are estimates derived from indirect data by the method detailed above.

Table 6 Sustainability Summary Analysis

SOURCE	WOLF CREEK	MAGUSE LAKE	DIONNE LAKE	MIKILAAQ LAKE	GOOSE LAKE
Catchment Area (km^2)	650	12,000	490	38	240
Lake Surface Area (km^2)	n/a	250	40	1	4
Average Flow (m^3/s) -Dec 1 to May 31	0.01	23.6	0.01	0.001	0.003
Average Flow (m^3/s) -Jun 1 to Nov 30	11.6	142.3	8.8	0.7	4.3
Surface Drawdown (mm/yr) - 150,000 m^3 extracted	n/a	0.6	3.8	150	38
Surface Rise due to Inflow (mm/yr)	n/a	9,600	2,400	7,600	12,000

4.4 Regulatory Compliance

If the water sources are fish bearing, as it is suspected they are, special intake screens will be required depending on the types of fish in lake. Should the site selection process move into design the required fish intake screen will have to comply with the DFO *Freshwater Intake End of Pipe Guidelines* prior to preparing the tender documents.

4.5 Cost estimate

4.5.1 General

A screening level cost estimate is a useful tool for evaluating and comparing the economic feasibility of the different sources. At this point, only the basic information of level of service, intake structures, elevations, and route are known. Subsequent investigation and design may result in different characteristics. To establish a common criterion for analysis the following assumptions were made:

- Maximum pumping flow rate of 2,500 m^3/day (460 USgpm),
- Total annual volume of 150,000 m^3,
- Same inlet structure for each source, and;
- Route distance equal to direct map distance plus 10%

Using these assumptions and information compiled from topographic maps, a preliminary hydraulic analysis was done for each source. The hydraulic analysis was performed using EPANET 2.0. The system consists of an intake structure, a pump house located near to the intake, and a pipeline terminating at the Arviat reservoirs. The pipeline slope is assumed to be uniform with no intermediate pumping.

4.5.2 Construction

No major obstructions were identified for the pipeline routes from the various sources.

The pipeline material used is butt-fusion welded high density polyethylene (HDPE). The nominal diameter of the pipeline is 200 mm (8”) with a 110 kPa (160psi) working pressure rating. The construction materials and methods are also likely to change in response to further information and design.

The accuracy of the screening level cost estimates presented can be considered accurate within a confidence of minus 50% to plus 100%. The fixed costs assumed may be variable for each route due to varying field conditions. These costs do not include costs such as transporting materials and technical personnel to Arviat or other items not specifically mentioned. The costs were estimated using a fixed cost for the intake and pump house and an incremental cost (by length) for pipeline materials and installation as shown below.

Table 7 Construction Cost Estimate

ITEM	COST BASIS	COST PER UNIT
Pipeline Materials **-Pipe, fittings, supports, valves, etc.**	Cost per meter	$40.00
Pipeline Installation **-Technician, Labor, Operator, Inspection, and Equipment**	Cost per meter	$20.00
Intake and Pump House **-Supply and Install**	Lump Sum	$300,000

The following table lists the estimated screening level costs for material and installation for each source:

Table 8 Installation Cost Estimate

SOURCE	WOLF CREEK	MAGUSE LAKE	DIONNE LAKE	MIKILAAQ LAKE	GOOSE LAKE
Direct Distance (km)	8	48	25	7	17
Cost ($)	830,000	3,470,000	1,950,000	770,000	1,430,000

4.5.3 Operation & Maintenance

The source chosen will impact the associated operation and maintenance costs. Some maintenance costs are fixed however most of the costs are incremental according increased distance to the source. Some of the incremental operation and maintenance costs associated with longer pipeline lengths are:

- greater pumping energy and associated energy costs,
- longer operator travel time,
- increased monitoring,
- more difficulty draining the pipeline before freeze-up, and;
- higher operating pressure leading to increased equipment maintenance.

The approximate pumping energy requirements for each source were determined by the hydraulic analysis. Energy costs are considerable in the region regardless of the source (electricity, diesel fuel, etc.) The energy costs will represent a significant portion of the operation and maintenance costs. Using sources with higher elevations can decrease the pumping energy required and facilitate pipeline drainage. The estimated energy costs due to pumping are given below. The energy costs have been estimated at $0.50 per kilowatt-hour.

Table 9 Pumping Costs Estimate

SOURCE	WOLF CREEK	MAGUSE LAKE	DIONNE LAKE	MIKILAAQ LAKE	GOOSE LAKE
Pumping Energy (kw)	17	88	42	15	31
Annual Cost ($)	16,000	84,000	41,000	14,000	30,000

4.5.4 20-year Life Cycle Costs

The 20 year life cycle cost allows us to compare the different alternatives. All of the alternatives have similar qualities and assumptions attached to them. The life cycle costs have been calculated based on the capital costs, replacement costs, energy costs, and maintenance costs. The 20 year life cycle costs were calculated using two different discount rates. The calculations assume that community growth will not affect the costs which have been evenly dispersed.

The life expectancy of the pipeline has been estimated to be 25 years while the life expectancy of the intake and pumphouse were estimated to be 15 years. The salvage value of both of these items was assumed to be zero.

The energy costs were assumed to be consistent through the 20 year period. The lifetime maintenance costs were assumed to be twice the capital cost divided evenly over the life expectancy of the equipment.

Table 10 20-year life cycle cost (8% discount rate)

ITEM	WOLF CREEK	MAGUSE LAKE	DIONNE LAKE	MIKILAAQ LAKE	GOOSE LAKE
Pipeline - Capital Cost	480,000	2,880,000	1,500,000	420,000	1,020,000
Intake and Pump House - Capital Cost	350,000	590,000	450,000	350,000	410,000
Pipeline Replacement - Present Worth of Replacement	71,000	421,000	220,000	62,000	149,000
Intake and Pump House – Present Worth of Replacement	111,000	186,000	142,000	111,000	130,000
Energy Costs – Present Worth	174,000	909,000	444,000	152,000	325,000
Maintenance Costs – Present Worth	920,000	3,343,000	1,948,000	866,000	1,472,000
Total	**2,106,000**	**8,329,000**	**4,704,000**	**1,961,000**	**3,506,000**

Table 11 20-year life cycle cost (6% discount rate)

ITEM	WOLF CREEK	MAGUSE LAKE	DIONNE LAKE	MIKILAAQ LAKE	GOOSE LAKE
Pipeline - Capital Cost	480,000	2,880,000	1,500,000	420,000	1,020,000
Intake and Pump House - Capital Cost	350,000	590,000	450,000	350,000	410,000
Pipeline Replacement - Present Worth of Replacement	112,000	672,000	350,000	98,000	238,000
Intake and Pump House – Present Worth of Replacement	147,000	247,000	188,000	147,000	172,000
Energy Costs – Present Worth	200,000	1,048,000	512,000	175,000	375,000
Maintenance Costs – Present Worth	1,060,000	3,854,000	2,245,000	998,000	1,696,000
Total	**2,349,000**	**9,291,000**	**5,245,000**	**2,188,000**	**3,911,000**

4.5.5 Potential Treatment Requirements

Wolf Creek and all of the potential drinking water sources, Maguse Lake, Dionne Lake, Mikilaaq Lake and Goose Lake meet the current drinking water guidelines at the reservoir outlet. As discussed in an earlier section there may be legislated changes in the future regarding turbidity, which would require filtration of surface water sources. This would be consistent with changes in legislation in other provinces in Canada where filtration and disinfection is required or will soon be required. These requirements would be for new or upgraded systems, with a set deadline for existing systems.

While not confirmed during this study, it is likely that the two reservoirs provide some improvement in turbidity over the raw water from Wolf Creek. However, should a filtration system be required in the future, the most effective location in the process would be between the storage reservoir and the delivery trucks. A 1-micron absolute filtration system would be sufficient for turbidity and certain micro-organisms. An ultrafiltration system or a system using multimedia filters with 1-micron cartridge filters would cost in the order of $150,000, housed and skid mounted for installation at the reservoir near the truck fill station.

4.5.6 Discussion

The estimates show the costs for each source increase with distance from the reservoirs in Arviat in terms of construction and operation and maintenance. Other incremental costs that have not been accounted for would only serve to reinforce this conclusion.

The choice of a source that is a greater distance from Arviat would have to be justified in other terms. All of the sources discussed have adequate flow volumes for seasonal withdrawal. The quality varies seasonally and according to the source. To provide an improved and consistent level of service, it may be more cost effective to invest in improved intake facilities and/or water treatment systems.

5.0 CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

- The total reservoir capacity is 143,000 m^3.
- All of the potential new drinking water sources and Wolf Creek meet the Guidelines *for Canadian Drinking Water Quality*, except for the fall sample at Wolf Creek which was higher slightly higher for turbidity than the guidelines.
- The bacteriological results, Fecal Coliforms, Total Coliforms and the Heterophic Plate Count are expected for surface water.
- There is sufficient capacity at all the sources for at least the next 20 years.
- The cost of a seasonal pipeline from the different potential new sources to the current reservoir where proportional to the distance from the source to the reservoir. Therefore Maguse Lake had the highest NPV cost and Mikilaaq Lake the lowest.
- Community concerns were with the capacity of Wolf Creek because it appears to be drying up. Based on the geomorphological study and the flow measurements the water source is sustainable.
- The mayor had concerns that a creek between Dionne Lake and Wolf Creek was changing, part of it was drying up and a bridge was moved further downstream. Mr. Kritaqliluk concern was that a similar phenomen may occur in Wolf Creek.
- The geomorphological study and catchment area calculations determined the current water supply source, Wolf Creek has sufficient capacity to meet the Hamlet's needs for the next 20 years.
- A second truckfill arm may not be required. Changes to scheduling so the trucks are not filling up at the same time should be investigated before design in new infrastructure is undertaken.
- A filtration system could be installed at the reservoir to achieve 1-micron absolute filtration at a capital cost in the order of $150,000.

5.2 Recommendations

- The census population for the Hamlet of Arviat may not be accurate and the population growth rate is higher than most other communities in Nunavut. The population should be monitored and any changes affecting water supply, water treatment & distribution, wastewater collection & treatment and solid waste management should be investigated.
- The water quality at the reservoir meets the *Guidelines for Canadian Drinking Water Quality.* Source water treatment, disinfection, for municipal use is always required. Water quality and palatability at the tap may be of concern to community residents. This falls

outside the jurisdiction of the GN but could be discussed with the Hamlet to determine a resolution, if required.

- The water delivery schedule should be reviewed to have the trucks filling up at different times so they are not at the truckfill station at the same time. There is currently not a problem with call outs so the schedule is efficient in delivering water to the consumers.
- This study is for feasibility purposes. Confirmation of the suitability of the source water supply is required prior to infrastructure construction.

REFERENCES

Arsenault, L., Aylesworth, J.M., Cunningham, C.M., Kettles, I.M., and Shilts, W.W., 1980. Surficial geology of Eskimo Point, District of Keewatin, Geological Survey of Canada, Map 8-1980, scale 1:125 000.

Douglas, R.J.W. 1968. Geological Map of Canada. Geological Survey of Canada, Map 1250A, scale 1:5 000 000.

Environment Canada, 2004, Canadian Climate Normals 1971-2000, Rankin Inlet. http://www.climate.weatheroffice.ec.gc.ca/climate_normals/results_e.html

Energy Mines and Resources Canada, 1994, Arviat, Nunavut, Map 55E, scale 1:250 000

Global Runoff Data Centre, 2004, Estimated Long Term Mean Annual Runoff Coefficient (GRDC runoff/ GPCC precipitation) of GRDC Estimated Hinterland Catchment Areas of Coastal Zones. http://grdc.bafg.de

Shilts, W.W., Kettles, I.M., and Arsenault, L. 1976. Surficial geology, Southeast Keewatin. Geological Survey of Canada, Open File 356.

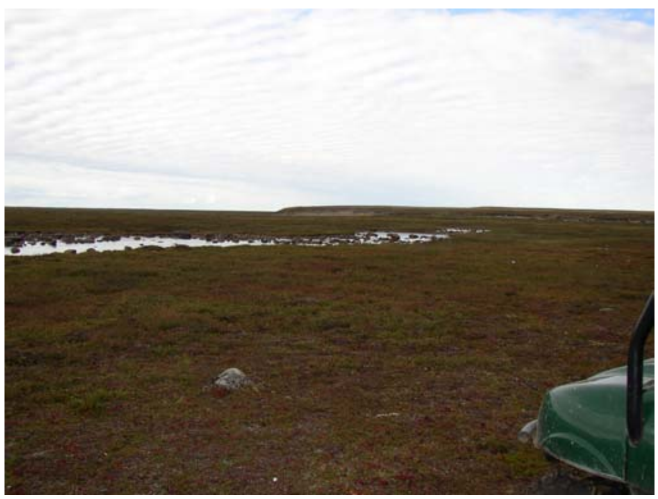
Water Survey of Canada, 2004, Archived Hydrometric Data 1965-2001, Kazan River Above Kazan Falls (06LC001). http://www.wsc.ec.gc.ca/hydat/H2O/

Water Survey of Canada, 2004, Archived Hydrometric Data 1989-1995, Diana River Near Rankin Inlet (06NC001). http://www.wsc.ec.gc.ca/hydat/H2O/

Appendix A-Photos

PHOTO LOG

Date: 09/01/04	Location: Goose Lake
Description: Field sampling equipment looking onto lake	



Date: 09/01/04	Location: Goose Lake
Description: Small creek flowing into Goose Lake	

Date: 09/01/04	Location: Water line pipeline
Description: Pipeline between water supply and reservoir	

Date: 09/01/04	Location: Wolf Creek
Description: Downstream of the natural pond where the intake line is	

Date: 09/01/04	Location: Wolf Creek
Description: Natural pond where the intake line is located	

Date: 09/01/04	Location: Wolf Creek
Description: Pumphouse and natural pond where the intake line is located	

Date: 09/01/04	Location: Wolf Creek
Description: Upstream of the natural pond where the intake line is located	

Date: 09/01/04	Location: Shore of Hudson Bay
Description: Access trail between the pumphouse and Arviat	

Date: 09/01/04	Location: Mikilaaq Lake
Description: Mikilaaq Lake	

Date: 09/02/04	Location: Creek between Dionne Lake & Wolf Creek
Description: Where the bridge used to be looking upstream towards Dionne Lake	

Date: 09/02/04	Location: Creek between Dionne Lake & Wolf Creek
Description: Where the bridge used to be, water depth approximately 6”	

Date: 09/02/04	Location: Creek between Dionne Lake & Wolf Creek
Description: Where the bridge used to be, looking up to the bank	

Date: 09/02/04	Location: Creek between Dionne Lake & Wolf Creek
Description: Where the bridge is now, looking downstream	

Date: 09/02/04	Location: Creek between Dionne Lake & Wolf Creek
Description: Where the bridge is now, looking downstream	

Date: 09/02/04	Location: Dionne Lake
Description: Photo taken from boat, facing the bank ATV in background	

Date: 09/02/04	Location: Dionne Lake
Description: Photo taken from shore looking out onto the lake	

Date: 09/02/04	Location: Trail from Dionne Lake to Arviat
Description: Trail from Dionne Lake to Arviat	

Date: 09/03/04	Location: Maguse Lake
Description: Sample location, cabins in the background	

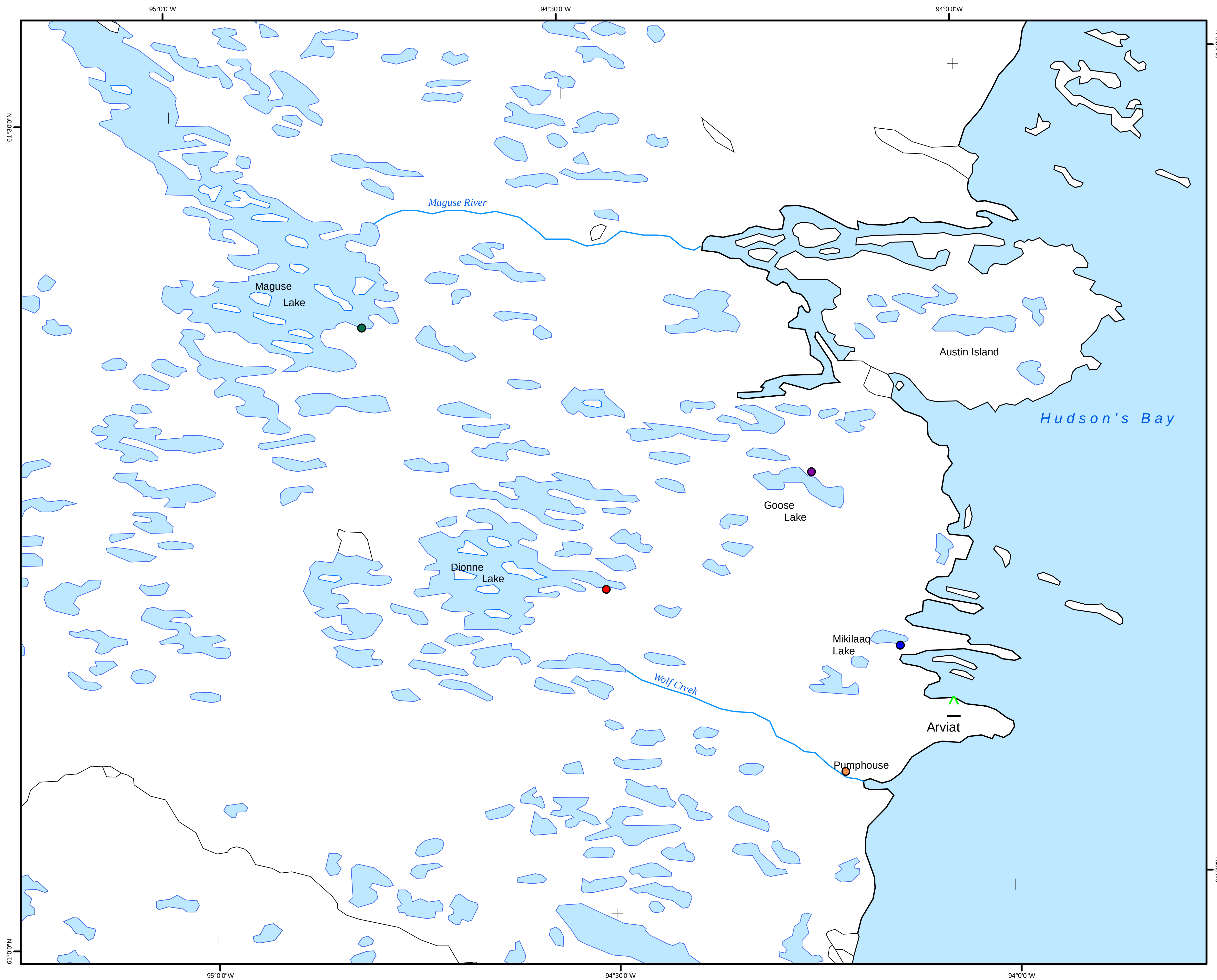
Date: 09/03/04	Location: Maguse Lake
Description: From the shore of lake looking up to where cabins are located	

Date: 09/03/04	Location: Reservoir & truckfill station
Description: Easter berm of reservoir	

Date: 09/03/04	Location: Reservoir & truckfill station
Description: Truckfill station & truck turnaround area	

Date: 09/03/04	Location: Reservoir & truckfill station
Description: Common berm between two reservoir cells	

Appendix B-Figures



Arviat Water Supply
Arviat, Nunavut

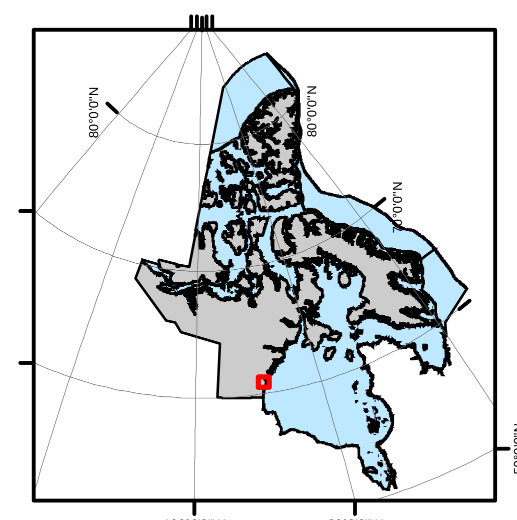
Legend

Field Survey Locations

- Dionne Lake - Sample Location
- Goose Lake - Sample Location
- Maguse Lake - Sample Location
- Mikilaaq Lake - Sample Location
- Pumphouse - Sample Location

2.5 1.25 0 2.5 5 7.5 10 Kilometers

1:250,000



Datum: NAD 83 Zone 15N

Internal Project: 5706-04

Drawn by: RR-B

Date: January, 2005

IEG Environmental