(In reply, please refer to)
Our File: 07-8107-1000

November 13, 2007

Government of Nunavut
Department of Community and Government Services
P.O. Box 200
Cambridge Bay, NU
X0A 0C0

Attention: Sudhir Jha, P.Eng,
Project Officer

RE: Pre-Design Report
Water System Upgrades, Taloyoak

Dear Mr. Jha:

Please find enclosed the pre-design report for the design of the water intake and treatment plant for the Hamlet of Taloyoak. As requested by the Department, various options for the power supply have been studied and presented in this report.

We hope this report meets your requirements at this time.

Yours sincerely,
Dillon Consulting Limited

Gary Strong, P.Eng.
Partner

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Water System Upgrades, Taloyoak

Pre-Design Report

November 13, 2007

Water System Upgrades, Taloyoak - Pre-Design Report

Government of Nunavut, Department of Community and Government Services

07-8107-1000

Gary Strong - Project Manager

Submitted by

Dillon Consulting Limited

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1 INTRODUCTION

1.1 General

The Department of Community and Government Services (CGS), Government of Nunavut, decided that there was a need to improve and upgrade the existing water supply and treatment facilities for the Hamlet due to the increasing population of the community as well as reoccurring problems with the system.

A request for proposals was issued by CGS to complete the engineering services for the development of a combined water intake; treatment plant; and truck fill station. Dillon Consulting Limited (Dillon) was retained by the Department to design the new facility and is completing this work under Contract # CT07-38001.

Presently, the community has an intake structure situated on Water Lake which pumps water to the treatment plant located in an existing building within town. Water Lake is relatively close to the community and the residents have had concerns about the proximity of the water intake to that of the rest of the Hamlet. A number of buildings, in particular the Northern Store, are located relatively close to the lake and the watershed of the lake. This poses concerns with the residents about potential contamination of the water source. Even though there have been no repeated cases of contamination thus far, a close call involving leakage of sewage from the holding tank of the Northern Store in 2005 gave the community uneasiness about potential contamination in the future. The potential for contaminating Water Lake increases as the community grows and begins to develop closer to the shore of the lake and within the watershed area of the new water supply.

1.2 Community Setting

Taloyoak, the northernmost community on the Canadian mainland, is a traditional northern community. It is located 69°32′ north latitude and 93°3′ west longitude, approximately 460 km east of Cambridge Bay and 1224 km northeast of Yellowknife, sitting 26 m above sea level on the Boothia Peninsula on Stanners Harbour.

Climate for Taloyoak consists of reasonable cool summers and extremely cold winters, which is typical climate for the northern arctic. The average mean temperatures for January and July are about -30.6°C and 11.8°C, respectively. Taloyoak receives approximately on average 128.4 cm of rainfall and 141 cm of snowfall that accumulates to a mean precipitation of 223.4 mm per year.

Taloyoak is located within a continuous permafrost zone, which consists of bedrock terrain that is covered with a thin layer of tundra vegetation. Despite poor soil quality, various types of lichen, moss, willow, heather and wildflowers grow in the area. Wildlife in the area consists of ground squirrels, lemmings, weasels, arctic hares, arctic foxes, ringed seals and numerous species of birds and fish.

The Hamlet is accessible all year around by aircraft and by barge during the summer.

1.2.1 Existing Water Treatment Facility

Currently, the Hamlet's water supply is drawn from Water Lake via an intake system located in a small pumphouse that is situated on submerged concrete pad off the shoreline. Water is pumped about 170 m uphill through a pipeline that is elevated and housed in a metal, insulated utilidor to an intermediate junction in the Boothia Inn. The water, then, travels partially buried approximately 120 m downhill to the water treatment plant, a part of the complex attached to the Power Corporation Generating Station. Water is stored in tanks prior to the chlorination treatment. After the water is disinfected, it is again stored in tanks where it remains until service trucks arrive to deliver it to the town residents. **Figure 1** shows a map of Taloyoak illustrates the location of the present water intake pumphouse and treatment plant. The red line represents the water's pathway from the inlet pumphouse to in-town water treatment plant.

Figure 1: Existing Water Supply System

The existing water plant is outdated and requires upgrades to its electrical and mechanical components. There have been a few problems with pipeline of the existing facility in the past. The Government of Nunavut has decided to install a new system and decommission the existing system once the new one is operational.

1.3 Scope of Work

Focus of this project is to develop and design a water supply system for the Hamlet of Taloyoak that will meet the community's 25 year demand by employing appropriate technology that is relatively simple, reliable and cost-effective. The scope of work for the project has been set out in the Request for Proposals, Terms of Reference (TOR) which is included in **Appendix B**.

The project requirements indicated in the TOR for the design components are as follows:

- Intake Pipe System
    - Duel intake and pump arrangement (equipment redundancy as one will be offline, acting as a backup)
    - Backwash and drainage system (no check valves, automatic drainage after each cycle)
- Water Treatment Plant and Truck fill Station which includes the following:
    - Filtration and disinfection
    - Post-treatment storage
    - Building heat and ventilation
    - Prime and backup power requirements
    - Storage room for spare parts and equipment
- Decommissioning of existing facility

In addition to the requirements stated in the TOR, a number of issues concerning the project were discussed during the project initiation teleconference held on July 6th 2007. Those present at the meeting included:

- Sudhir Jha, P.Eng – GN, CGS, Project Officer
- Tom Livingston, P.Eng. – GN, CGS, Regional Municipal Engineer
- Cheryl Selig – GN, CGS, Community Planner
- Stephen King – Hamlet of Taloyoak, SAO
- Gary Strong, P.Eng – Dillon, Project Manager
- Corina Peach, MIT – Dillon, Project Coordinator

From this meeting, the following actions and direction were agreed upon and have been summarized below:

- All parties are in agreement that trucked system is the best option for water delivery within the community. However, Dillon will prepare a report that will summarize and compare the piped and trucked distribution systems.
- Consultation with the local land use planning team as well as the members of the community when selecting the final location for the site.
- Dillon personnel to complete bathymetry survey of the three proposed sites during visit and meeting with council to better determine the best location.

Either Canso or Long Lake is an option for the new source for the water supply and sites will be selected near the lake's shoreline. Following consultation with the client and community, an agreed site will be selected by all parties. For the selected site, topographical and geotechnical studies will be conducted to determine if the proposed site will be the most suitable for the design and construction of the water intake, pumphouse and treatment plant. Members of the community will be consulted during the initial stages of the project.

1.4 Report Setup

The target of this report is to record the preliminary design process while also serving as a decision-making document. Report is setup in sections that describe:

- Design requirements as laid out in the TOR and the background documentation.
- Design criteria, assumptions, and calculations.
- System descriptions.
- Component descriptions.
- Option development and selection.
- Cost estimates.
- Implementation of schedules and strategies.

Where options exist for the design concept, these options are presented in a tabular form. The tables describe the options, list the criteria for design process, and rate the options against the criteria. The report recommends the best option. Cost estimates for all options have been developed using a life cycle cost assessment model. All figures are located in **Appendix A** of this report.

2 BACKGROUND

2.1 Previous Reports

A number of previous studies have been completed in relation to the existing water facility. Following reports and studies are as follows:

- *Taloyoak Water System Site Investigation and Remedial Action Plan*. Dillon Consulting Limited. December, 2004.
- *Taloyoak Water System Upgrade Planning Study*. Dillon Consulting Limited. April 2005.

2.2 Population Projections

Population projections were used to estimate the water consumption for a twenty five year planning horizon. The present population of Taloyoak is around 850 people[1], with more than half of the population under 24 years of age. Like many other small communities in the northern arctic, the Hamlet's population is growing exponentially. However, it is not evident if the current birth rate will continue to rise (as its doing now) and if it will have any correlation on the community's future population. It is unknown if those that are being born in the community today will be a future community member years from now. Due to this uncertainty, the population of Taloyoak was predicted using various methods.

Table 1 shows the actual population growth trend of Taloyoak for the past 20 years. Population data was limited to Census records conducted every five years by Statistics Canada.

[1] Stephen King, Senior Administration Officer (SAO) for the Hamlet of Taloyoak.

Table 1: Historical Growth Trend

Year	Population	% Change
1986	540	-
1991	580	7.4
1996	648	11.7
2001	720	11.1
2006	809	12.4

Source: Statistics Canada.

Population projections were also obtained from Nunavut Bureau of Statistics. **Table 2** shows predictions for the community's population have been estimated to the year 2020. Population values are shown for 5 year intervals with additional data found in **Appendix D**.

Table 2: Population Projections

Year	Population	% Change
2000	804	-
2005	904	12.4
2010	1,016	12.4
2015	1,147	12.9
2020	1,294	12.8

Source: Nunavut Bureau of Statistics.

Different population growths over the lifetime of the water supply and treatment facility have been calculated based on the above collected data. Historical data obtained from Statistics Canada was used to calculate an average growth rate over the past 20 year period. The average growth rate was calculated to be about 2.4% which was then used to predict the following population values for the facility's lifetime.

For design purposes, the largest value predicted for the town's population was selected for the design parameter. In this case, the population predictions estimated by the Nunavut Bureau of Statistics was the highest compared to that obtained from the historical data. Values were only predicted to the year 2020 so population data was extrapolated to the design year using an average 2.4% growth rate that was calculated from the same set of data. The 25-year population projection is illustrated in **Figure 2** below.

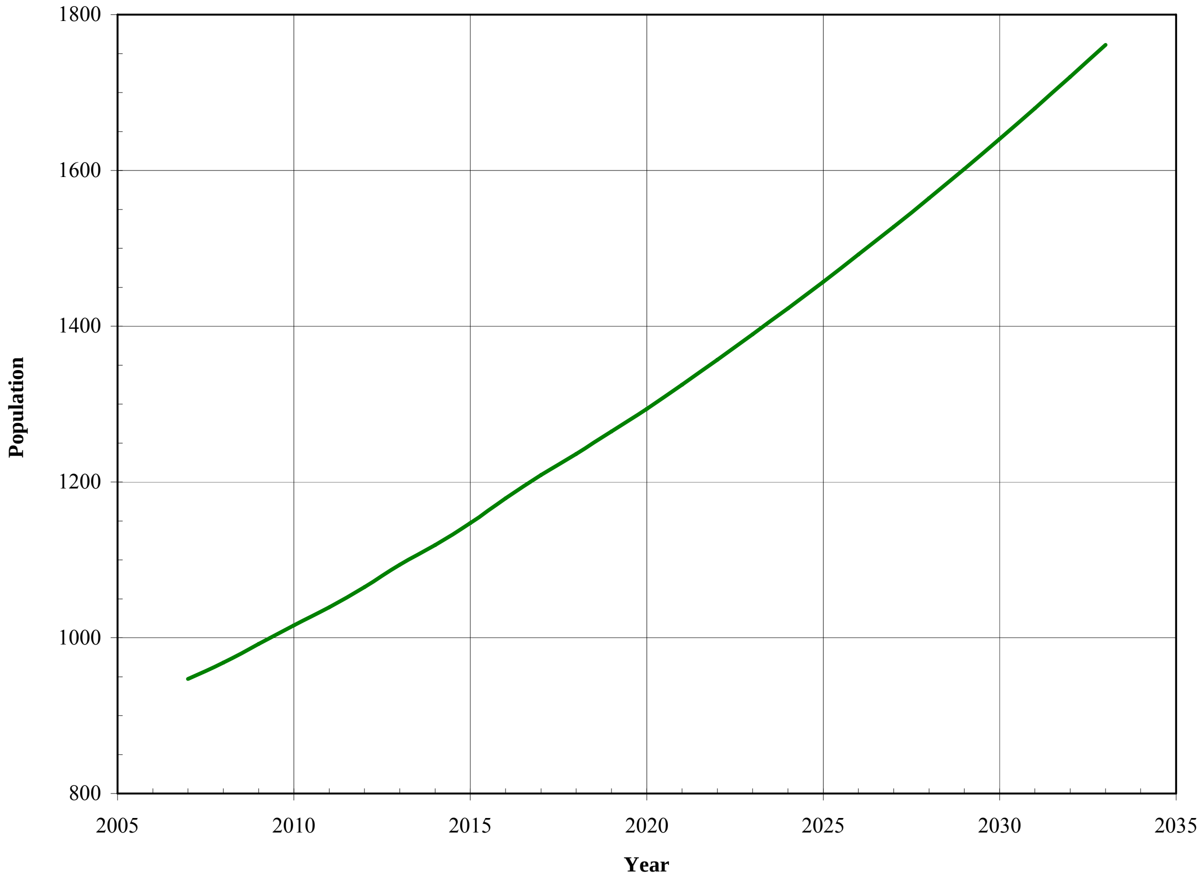


Figure 2: Projected Population Growth, 2007-2033

2.3 Water Demand

2.3.1 Historical Demand

Water consumption data from the period of 2002 to 2006 was obtained from the Hamlet's Senior Administrative Officer (SAO), Stephen King.

Table 3: Water Consumption

Year	Volume (L/yr)
2002-03	32,445,683
2003-04	33,169,759
2004-05	31,040,027
2005-06	31,180,391
2006-07	32,354,121

Currently, the community's daily water demand is using about 89,000 liters, which means that each person is consuming approximately 104 liters of water on average per day.

2.3.2 Projected Future Demand

Table 4, shown below, gives the water demand for the community based on the predicted population values projected by the Nunavut Bureau of Statistics.

Table 4: Average and Peak Water Demand Values

Project Year	Year	Population	Water Demand (Liters per day)		
			Average	Peak w/o TDF	Peak w/ TDF
	2007	947	115,327	172,990	242,186
0	2008	968	118,352	177,527	248,538
1	2009	992	121,833	182,750	255,850
5	2013	1094	136,927	205,391	287,547
10	2018	1236	158,737	238,106	333,348
15	2023	1389	183,344	279,878	385,021
20	2028	1564	212,720	334,348	446,713
25	2033	1761	247,480	400,513	519,709

In 2033, the expected population for Taloyoak is approximately 1761 people. Using the water consumption rate equation advised by MACA and a consumption rate of 100 liters per capita day, average daily water consumption rate per person is about 141 liters per day. This gives a total of 247.5 cubic meters for the community's daily water demand for the design year.

In addition to the daily water demand, water will be required in case of emergency such as fire. Discussion with the Fire Marshal for Nunavut provided the design fire flow rate of 1,000 L/min, which is based on the community's requirements.

2.4 Water Quality Data

2.4.1 Previous Sampling

In 2001, Dillon was retained to perform a study concerning an upgrade of the current water system in Taloyoak. As part of this study, water sampling was performed on Water Lake. A copy of this analysis can be found in **Appendix E**. Comparing the results from this analysis to those obtained from this most recent analysis, the values are quite close.

2.4.2 Recent Sampling

Two sets of water samples were taken by Dillon personnel from Canso Lake during the initial site visit on August 8th 2007. A second water sample was taken on October 8th during the period of the road survey. Due to poor weather conditions at the time of sampling, depth samples could not be taken. Therefore, samples were only taken within the water's surface off the shoreline at the Site 1 location.

The samples were sent to Maxxam Analytics Inc. in Yellowknife, which were further forwarded to their other labs in Edmonton and Calgary for analysis. **Table 5**, below, summaries the laboratory test results for all parameters. Lab analyses of the water sampling are also found in **Appendix E**.

Table 5: Water Sampling Results

Parameter	Units	GCDWQ		S2 T1 (Aug 8th)	S2 B1 (Aug 8th)	Site 2 (Oct 8th)
		MAC	AO			
Physicals						
Alkalinity	-	-	-	-	-	-
Total (as $CaCO_3$)	mg/L	-	-	83	83	97
PP (as $CaCO_3$)	mg/L	-	-	<1	<1	<1
Color, True	PtCo	-	≤15 TCU	5	5	2
Conductivity	uS/cm	-	-	221	221	252
Particle Size	-	-	-	-	-	-
pH	pH	-	6.5-8.5	8.1	8.2	8.1
Total Dissolved Solids	mg/L	-	≤500	110	109	127
Total Suspended Solids	mg/L	-	-	<2	<2	<2
Turbidity	NTU	0.3/1.0/0.1[a]	-	**0.5**	**0.5**	**0.6**
Major Ions (Dissolved)						
Calcium	mg/L	-	-	20.8	20.6	22.1
Chloride	mg/L	-	≤250	14	14	16
Fluoride	mg/L	1.5	-	-	-	-
Hardness (as $CaCO_3$)	mg/L	-	-	90	90	97
Magnesium	mg/L	-	-	9.3	9.3	10.1
Potassium	mg/L	-	-	0.9	0.9	1.2
Sodium	mg/L	-	≤200	9.9	9.9	12.2
Sulphate (as SO_4)	mg/L	-	≤500	5	4	7
Metals (Total)						
Arsenic	mg/L	0.01	-	<0.001	<0.001	<0.001
Aluminum	mg/L	-	0.1/0.2[b]	0.005	0.004	<0.04
Barium	mg/L	1	-	<0.01	<0.01	<0.01
Cadmium	µg/L	5	-	<0.01	<0.01	<0.0002
Chromium	mg/L	0.05	-	<0.001	0.001	<0.01
Copper	mg/L	-	≤1.0	<0.0002	<0.0002	0.0004
Iron	mg/L	-	≤0.3	<0.06	<0.06	<0.06
Lead	mg/L	0.01	-	<0.0002	<0.0002	<0.0002
Manganese	mg/L	-	≤0.05	<0.004	<0.004	<0.004
Mercury	mg/L	0.001	-	-	-	<0.00005
Selenium	mg/L	0.01	-	<0.001	<0.001	<0.001
Uranium	mg/L	0.02	-	0.0003	0.0003	0.0005
Zinc	mg/L	-	≤5.0	<0.0003	<0.0003	<0.0003
Organics						
Total Cyanide	mg/L	0.20	-	< 0.005	< 0.005	< 0.005
Total Trihalomethanes (TTHMs)	mg/L	0.10	-	-	-	-
Tribromomethane (Bromoform)	µg/L	-	-	<0.5	<0.5	<0.4
Trichloromethane (Chloroform)	µg/L	-	-	<0.5	<0.5	<0.4
Bromodichloromethane	µg/L	16	-	<1	<1	<0.4
Chlorodibromomethane	µg/L	-	-	<0.5	<0.5	<0.4
Nutrients						
Total Dissolved Carbon	mg/L	-	-	-	-	3
Total Nitrate + Nitrite	mg/L	10	-	<0.2	<0.2	<0.2
Total Organic Carbon	mg/L	-	-	2.0	1.9	3.2
Total Phosphorous	mg/L	-	-	<0.003	<0.003	<0.1
Microbiological						
E. Coli	mpn/100mL	0 mg/L/100mL	-	**<1**	**<1**	**<1**
Fecal Coliforms	mpn/100mL	-	-	-	-	-
Total Coliforms	mpn/100mL	0 mg/L/100mL	-	**22**	**13**	**<1**
Standard Plate Count	-	-	-	-	-	<1

a. Based on conventional treatment/slow sand or diatomaceous earth filtration/membrane filtration.
b. Operational guidance value, designed to apply only to drinking water treatment plants using aluminum-based coagulants. Based on conventional treatment/all other treatment systems.

Comparing the results from the 2001 analysis to those obtained from this analysis, most values are in the same range. In this analysis, there is good agreement between the two samples for all test parameters.

However, the test results indicated small presences of E. coli and total coli forms. The results shown here could be slightly inaccurate due to the fact that the samples were analyzed after the 24 hour time frame required for the analysis. These parameters – E. coli and coli forms – are time sensitive and they could have fluctuated during the transient period from the site to the lab.

The Federal-Provincial-Territorial Committee on Drinking Water (CDW) has recently developed and updated the standards related to water quality, especially in the area of turbidity. The turbidity parameter has become more stringent in relation to the specific treatment technologies. The new guideline values for the parameters are provided in **Appendix F**. Turbidity is slightly higher than what is required by the new set criteria established by the GCDWQ.

Based on the raw water sampling data, treatment will be required for turbidity and microbiological components such as E. coli and coli forms. Therefore, comparing these results to those requirements for treated water that is described in the Guidelines for Canadian Drinking Water Quality published by Health Canada, treatment will include filtration and disinfection.

It is beneficial for two more sets of samples be taken at a different location on the lake at few different depths to see if there is any fluctuation in theses key parameters. Therefore, it is recommended that additional sampling be performed in the near future to ensure that the above results are indeed true for Canso Lake.

The treatment requirements for the water source are further discussed in **Section 6.0** of this report.

3 DESIGN CRITERIA

The design criteria for this project will be completed in accordance with the parameters set out by the GNWT, Municipal and Community Affairs "*Capital Standards and Criteria, September 1993*”. These are as follows:

Table 6: Design Horizons

Facility	Design Horizon (Years)	Design Economic Life (Years)	Design Expected Life (Years)
Building Envelopment	20	20	40
Pumps	10	20	20
Intakes	20	20	30

Where the following items are defined as follows:

- Design horizon - the period used to establish capacity requirements for a facility.
- Design economic life - the period used in the economic analysis to establish the present value (or equivalent capital cost) of a facility.
- Design expected life - the practical maximum expected life of a facility assuming no premature failure, destruction or obsolescence.

3.1 Design Standards

The following lists below summarize the design criteria that will be used in the development of the water supply system. These are derived from the GNWT "*General Terms of Reference for Water and Sanitation*" (GTR), the "*National Building Code*" (NBC), "*Capital Standards Criteria, September 1993*," MACA and the "*Good Engineering Practice for Northern Water and Sewer Systems, First Edition, April 2004*". Mechanical and building systems design should comply with the "*Good Building Practice for Northern Facilities*" as related to utility buildings.

Table 7: Water Data and Rates

	Value	Reference
Domestic	100 L per capita day	Water/Wastewater Survey[2]
Commercial	0.00023 x Population	MACA
Total Consumption per Capita	100 x (1.0 + 0.00023 x Population)	MACA
Fire Demand	1,000 L/min	Office of the Fire Marshal
Discount Rates	2%, 4% and 6%	MACA

Table 8: Environmental Conditions

Condition	Value
Design Minimum Temperature	-45°C (-43°C)
Degree Days (below 18°C)	12037 (11693)
Design Water Tank Storage Temperature	5.0°C
Design Operation Room Temperature	10.0°C
Design Incoming Water Temperature	0.5°C
Design Generator Room Temperature	10.0°C
Snow Load S_S S_R	1.5 kPa (1.9 kPa) 0.1 kPa (0.1 kPa)
Wind Pressures	0.39 kPa (0.62 kPa)
Seismic Za Zv	2 1

Source: Supplement to the National Building Code of Canada 2005 Third Edition. Cambridge Bay data used, Arctic Bay data is in brackets.

The facility will also to be designed with respect to the current edition of the following documents:

- National Fire Prevention Act
- Electrical Code
- Public Health Act (including reference to the GCDWQ)
- Installation of Oil Burning Equipment (B-139)
- National Fire Code

[2] Kitikmeot Water/Wastewater Survey Reference. Provided by Government of Nunavut, CGS.

3.2 Design Parameters

The main objectives of the project are to provide water services to the community that meet the specifications of the guidelines for drinking water quality.

In the TOR, the following were established as design parameters for the facility. The plant must:

- Be of simple design with respect to operation and maintenance procedures. It must be able to function using local forces where it can easily be operated and maintained with limited equipment, parts and materials that are only available locally.
- Be reliable, efficient and cost-effective.
- Contain self-draining equipment and pipes (after each cycle). In cases where self-draining is not practical, all other major components should have some other means of frost protection incorporated in their design.
- Have all major components capable of recovering from a frozen condition, in an operable state, if there is any possibility of freezing.
- Include provisions for standby power generation at the truck-fill station in accordance with the Office of the Fire Marshals requirement for uninterrupted water supply for fire suppression.
- Fuel storage at the truck-fill station must provide for spill containment (if applicable).

3.3 Cost Analysis

Throughout this document, cost analyses will be performed on the various options proposed for the design. These analyses have been carried out as outlined in the general Terms of Reference as described below:

Cost	Description
Capital Cost	Cost of construction of the facility which include purchase, mobilization and installation of equipment, design and engineering costs as well as contingency.
Operation and Maintenance Costs	Cost of annual operation and maintenance of the facility which may include manpower, energy requirements, fuel, general maintenance (light bulbs, paint) and equipment replacement.
Life Cycle Costs	Cost for total facility over its lifetime, usually calculated over a 25 year period and includes the capital and operation and maintenance costs. The life cycle cost is shown as a present value that is calculated at a discount rate of 2%, 4% and 6%.

4 WATER DISTRIBUTION AND SITE SELECTION

In the startup teleconference meeting on July 6th 2007, the client indicated that their initial thoughts were that the best design option for the Hamlet of Taloyoak would be a trucked delivery system. In order to verify that was indeed the best economical option, a cost comparison was performed for the trucked and piped system for the water systems design. In addition, through discussions, three sites were selected for the options of the new intake and treatment facility location.

4.1 Water Distribution System

4.1.1 Options

Water can either be delivered to the community in one of two ways: by a truck filled delivery system; or a piped transmission line. These two options, explained in more detail below, are not specific to any one site location and have the following components in common - lake intake system, water treatment plant, storage facility, and access road and turn-around area.

Option 1 – Truck fill
Water will be drawn from the lake and treated in the same building at the water intake structure located near the shore of the lake. A truck fill arm will be a part of the building which will be used to distribute water to the community via water delivery trucks.

Option 2 – Pipeline
Similar to the trucked-filled system but the water is transported from the intake building to a treatment plant and distribution pumphouse through a pipeline.

The trucked water delivery system has been servicing the majority of Northern communities. This system has many advantages over a pipeline system. It has a lower capital investment as well as lower operating and maintenance costs. A trucked system also provides employment to the local community as truck drivers and operators will be needed to make the deliveries. The pipeline system is a more expensive system to install and has a number of operational issues to be overcome in the design to be effective in Northern communities. To minimize freezing, constant heating of the pipe is required during the cold season, and this results in high operating costs.

4.1.2 Cost Analysis

The computer program, Excel, assisted with obtaining capital and operating costs associated with the trucked water distribution system. In the case of piped design option, a water intake-piped system was implemented in a similar arctic community of Nunavut so cost data was extracted from this project. **Table 9** gives a summary of the capital and operating costs for the two water delivery options.

Table 9: Cost Comparison of Truck-filled and Pipeline Systems

Description	Distribution Option	
	Truck	Pipeline
Capital Costs		
1) Pipeline/Transmission Main	-	$1,200,000
2) Road Access/Turn Around	$325,000	$325,000
3) Intake Pipe and Pumphouse	$400,000	$400,000
4) Water Treatment Plant	$1,750,000	$1,750,000
5) Heating Station	-	$100,000
6) Trucks (0 Year)	$200,000	-
7) Maintenance Garage	$150,000	-
A. Sub-Total	$2,825,000	$3,775,000
Operation and Maintenance Costs		
1) Pipeline/Transmission Main	-	$40,000
2) Road Access/Turn Around	$5,000	$5,000
3) Intake Pipe and Pumphouse	$50,000	$50,000
4) Water Treatment Plant	$160,000	$160,000
5) Heating Station	$20,000	$20,000
6) Trucks (0 Year)	$25,000	-
7) Maintenance Garage	$10,000	-
B. Sub-Total	$250,000	$275,000
C. Present Value of O&M	**$2,800,000**	**$3,100,000**
Total Present Value (A + C)	**$5,625,000**	**$6,875,000**

The truck fill option for water delivery service is economically more feasible than the piped system on a capital investment as well as comparing operation and maintenance costs.

4.2 Site Locations

Sites for the new water intake and treatment plant were proposed and selected based on environment assessment and community concerns as well as the best possible area for such a construction project. The following items were taken into consideration when selecting the site locations:

- Proximity to Hamlet
- Distance to community
- Available road access
- Topography
- Shallow foreshores
- Shoreline stability

Canso Lake, the northern continuation of Water Lake, and Long Lake, situated 1.5 km east of Water Lake, were the two possible locations for the new water supply proposed in the Request for Proposal. It was stated, however, that Long Lake was not the preferred choice because it is located farther away from the community. To avoid potential contamination from community development, it is proposed to locate the new water intake and treatment plant as far away from the community as practical. Canso Lake was selected as the preferred choice based on the evaluation of distance and cost. **Figure 3**, on the following page, shows the lake area surrounding Taloyoak that may be potential sources for the water supply.

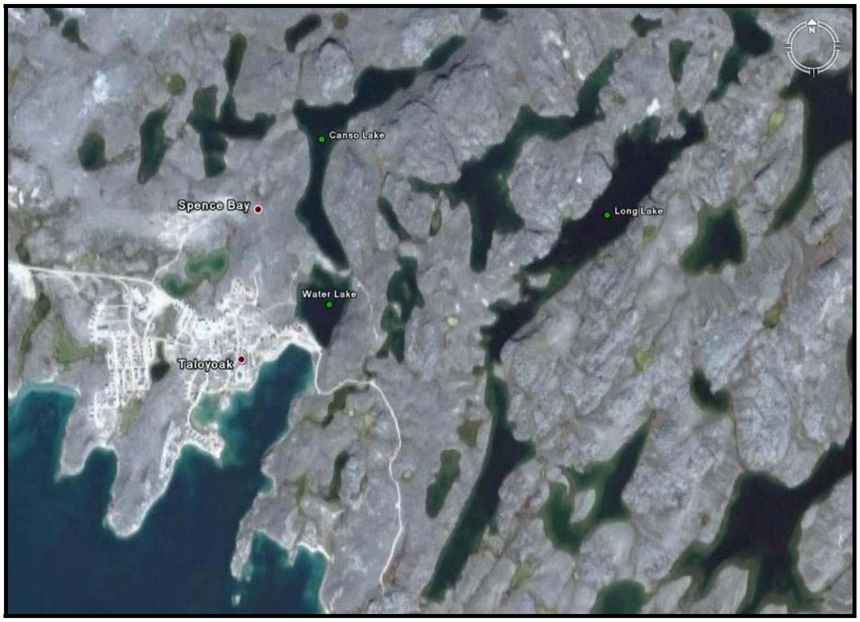


Figure 3: Lake Area

Three sites for the new water intake and treatment system were proposed on Canso Lake and have been highlighted on **Figure 4** below. **A**dditional images of the surrounding lake area as well as the sites are found in **Appendix A**.

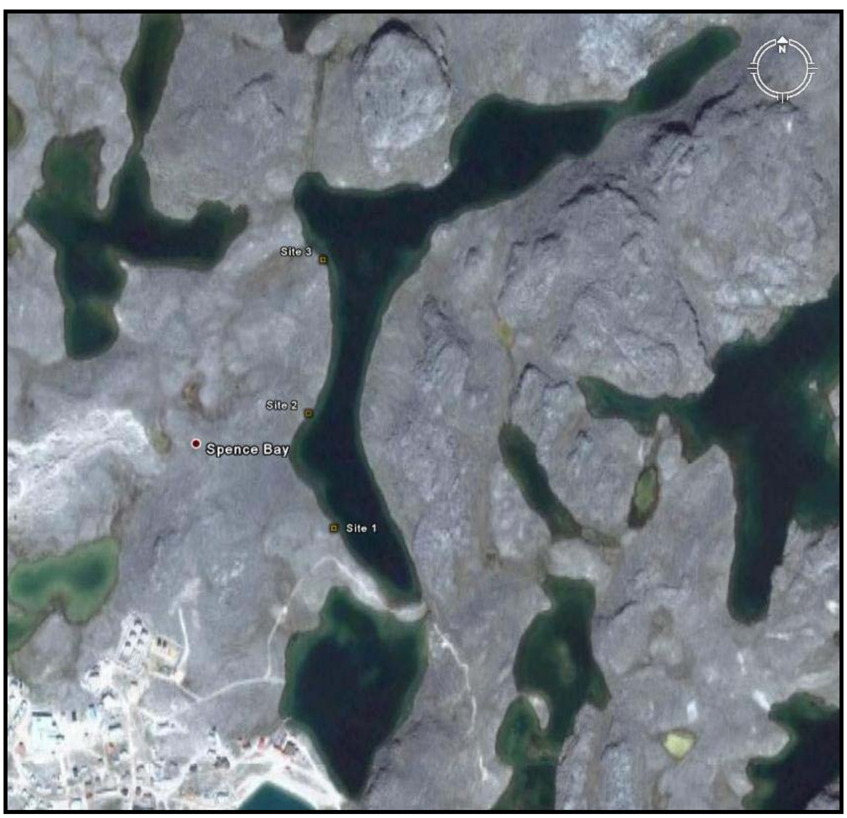


Figure 4: Proposed Sites

Approximate distances from the community as well as site elevations and foreshore lengths associated with each site are listed in **Table 10** shown below.

Table 10: Distances of Proposed Sites

Site	Distance from Center of Community (km)	Elevation above Sea Level (m)	Distance of Foreshore (m)
1	0.87	15.5	14.0
2	1.00	14.9	14.6
3	1.25	15.3	13.8

Source: Google Earth.

The information presented above was the basis of a presentation made to the community.

5 SITE INVESTIGATION

5.1 Preliminary

On August 7th, CGS and Dillon gave a presentation to the Hamlet. The major details concerning the new upgrade of the water intake and treatment plant for the community were presented with the three options for the site location. During the meeting, an assessment of the proposed sites was conducted where the council provided their input as well.

5.1.1 Community Comments

From the comments of the community members, Site 2 was chosen as the best location for the new water intake and treatment plant. Site 1 was less favorable due to the fact that it was still reasonable close to the town. The community was concerned that if Site 1 was selected, there still would be a high chance for contamination in the future as the area surrounding Site 1 seemed to be the only region for the community to develop and grow. As well, this site was in close proximity to a burial area of the community. It was discussed that Site 3 was a reasonable good area to develop as well but it was not the preferred location as the area was used as a pathway during the winter months for the residents to travel to their cabins by snowmobiles.

The community members also suggested that Nipingayulik Lake, located west of Canso Lake, be considered as another potential water supply. This lake was taken into consideration but soon discarded as it was understood that the lake had no form of recharge and was fairly shallow.

5.1.2 Site Survey

A preliminary investigation of all three sites was undertaken to provide a better understanding of constrains and limitations that are associated with each site location. The three sites were evaluated based the following criteria: how easily accessible to the community; distance from the community; terrain of the area; and potential length of intake pipe.

The orange dots indicate the potential locations for the proposed sites that were selected in the preliminary work prior to the community visit. During the visit, GPS coordinates for both the site and depth requirements were taken at each site. These coordinates are displayed in **Figure 5** and listed in table format (**Table 11**) below. The red dots represent the actual site location while the white dots indicate the required water depth.

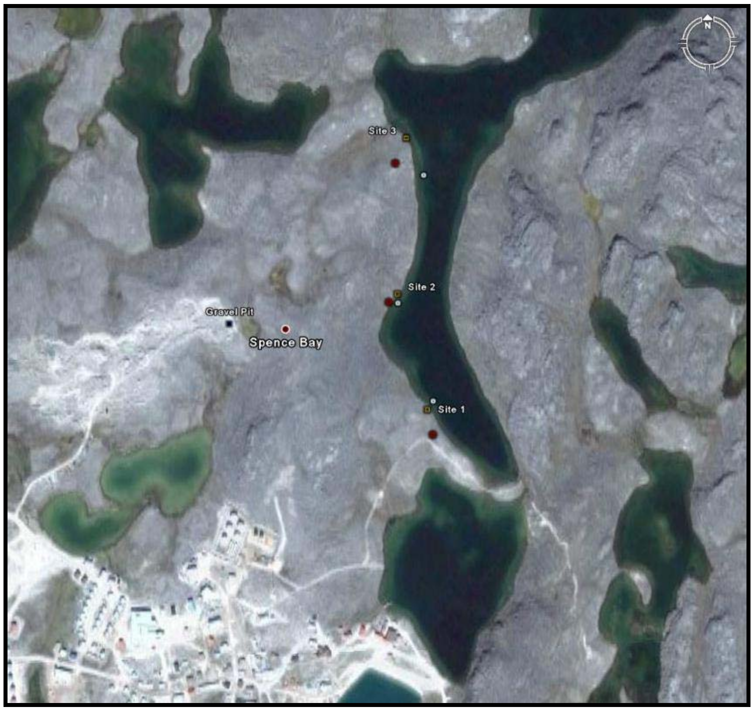


Figure 5: Site Locations

Table 11: Site GPS Coordinates

Site	Site Location		Required Water Depth	
	North Latitude	West Longitude	North Latitude	West Longitude
1	69°32'30.60"	93°30'58.99"	69°32'32.77"	93°30'58.67"
2	69°32'39.30"	93°31'06.22"	69°32'39.20"	93°31'04.55"
3	69°32'48.28"	93°310'4.04"	69°32'47.42"	93°30'58.84"
Gravel Pit	69°32'38.27"	93°31'36.10"	-	-

Site 1 is the most the easiest accessibility as there is an already a rough roadway mapped out that passes by the site location. Sites 2 and 3 do have existing access as there is boulder field to the south of Site 2.

In the following sections, the lengths of the access roadway and intake pipe were estimated based on the GPS coordinates and bathymetric measurements obtained from the site on August 7th and 8th 2007.

5.1.2.1 Access Road

Using the recorded GPS coordinates at each site, distances were measured from the point at which the newly constructed road would connect with the existing road system. **Figure 6** illustrates the possible alignment for the access roads to the sites.

Figure 6: Access Road Alignments to Sites

Distances measured from the preliminary site survey are listed in **Table 12** below. R1 and R2, represented by the blue and orange lines, respectively shown in **Figure 6** above, correspond to the two possible alignments (and lengths) to each location that link the site and Hamlet using established routes. There is only one possible option for Site 1 as this location has somewhat of an established road already constructed.

Table 12: Preliminary Distances of Access Roads

Site	Length of Access Road (m)	
	R1	R2
1	550	-
2	360	350
3	500	600

Site 1 is accessible from the existing road near the fuel tank farm whereas for Sites 2 and 3, the access road will connect into the roadway that provides access to the gravel pit. Connecting to the access way to the gravel pit will decrease the amount of construction necessary to provide a roadway out to these sites.

5.1.2.2 Intake Alignment

Similarly, GPS coordinates were also recorded at each site when a desired depth of 6 m was reached. This is denoted by the white points shown in **Figure 6**. Actual distances from the shoreline to the required depth position were measured using the ruler function in Google Earth and are summarized in **Table 13** below. The following lengths were measured from the GPS coordinates obtained during the site visit.

Table 13: Preliminary Lengths of Intake Pipe

Site	Length of Intake (m)
1	45
2	40
3	50

Actual lengths of the intake pipes at each site take into account the distance of the foreshore as well as the necessary meters of land, 30 m minimum, off the shoreline that is required for the construction of the pumphouse station. These values might change as exact placement of the truck turn around and building pad are not known.

5.1.3 Cost Analysis

Taking into account the different lengths for the access road and intake pipe for each site, the capital as well as the operation and maintenance costs associated with each site option. A cost comparison between all sites was performed based on above data. **Table 14**, located on the following page, presents the cost summary of the truck-filled distribution system at the different site locations.

Table 14: Cost of Truck-filled Distribution System at Different Sites

Description	Option		
	1	2	3
Capital Costs			
1) Power Line	$238,500	$362,000	$425,700
2) Road Access/Turn Around	$438,500	$287,000	$478,000
3) Intake Pipe	$112,500	$100,000	$125,000
4) Intake Pumphouse	$300,000	$300,000	$300,000
5) Water Treatment Plant	$1,750,000	$1,750,000	$1,750,000
6) Trucks (0 Year)	$200,000	$200,000	$200,000
7) Maintenance Garage	$150,000	$150,000	$150,000
A. Sub-Total	$3,189,500	$3,149,000	$3,428,700
Operation and Maintenance Costs			
1) Power Line	$4,500	$6,600	$7,750
2) Road Access/Turn Around	$3,850	$2,550	$4,200
3) Intake Pipe	$1,800	$1,600	$2,000
4) Intake Pumphouse	$45,000	$45,000	$45,000
5) Water Treatment Plant	$160,000	$160,000	$160,000
6) Trucks (0 Year)	$25,000	$25,000	$25,000
7) Maintenance Garage	$10,000	$10,000	$10,000
B. Sub-Total	$250,150	$250,750	$253,950
C. Present Value of O&M	**$2,702,000**	**$2,710,000**	**$2,745,000**
Total Present Value (A + C)	**$5,891,500**	**$5,859,000**	**$6,173,700**

Site 2 is both the most economical option as well as the preferred option identified by the community. Therefore, it is recommended that Site 2 be the selected location for the new water intake and treatment facility.

5.2 Pre-Design

After all parties agreed that on Site 2 was the best location for the new water treatment facility. On September 12th, the CGS issued a letter of authorization for a crew to proceed with the survey of the road alignment.

Between October 4th and 8th 2007, Dillon completed a site survey of the proposed intake and water treatment plant to the agreed site. Assistance was obtained from the Hamlet Office with the use of a vehicle during the survey. Details of the work completed on site during this time are described below:

- The survey work used a survey control monument (Geodetic control) location adjacent to the Northern Store. A new control point was established at a location near the gravel pit, halfway down the access road, between the road entrance and site location. Data from the survey control monument was used to adjust the coordinates for the new control point.
- Survey work was completed using a Global Positioning System (GPS) instrument.
- The existing access road was first outlined. Cuts were taken along each side of the road approximately every 6 m (20 ft).
- Major areas such as the scrap yard, fuel tower and gravel pit were also mapped out to show their relation to (and distance from) the access road.
- Depth measurements were collected for the gravel pit by taking cross sections of the pit.

- Shots were taken on both sides of the gravel pit to determine which side would be better suit the road construction. Topography of the area between the gravel pit and site location consists of patches of mossy areas and boulder fields. Small water basins surrounding the area between the gravel pit and the site location were outlined. As well, shots were taken to establish the grade boundaries between the mossy areas and boulder field.
- Cross-sectional shots were conducted parallel and perpendicular to the lake shoreline. These cuts helped to determine the smallest slope (of the hill) to the lake.

It is recommended that the new section of the road, giving access to the site location, to be built and connected off the right side of the gravel pit. This side is more easily accessible to the site and has less mossy and low areas. Also, it is recommended that the turn around pad and building skid be placed prior to the grade boundary (separating the mossy area and boulder field). Based on these recommendations, the total length of the access road is approximately 850 meters and be designed to minimize on the amount of fill and cuts required for construction. Access road will be built to a width of 6.0 m with a 2:1 slope on each side. A maximum grade of 8% rock or gravel and minimum fill of 1.0 m will be used.

Results of the survey work are shown in **Figure 7** on the following page. Data from this survey was used to determine the best alignment of the access road to Site 2.

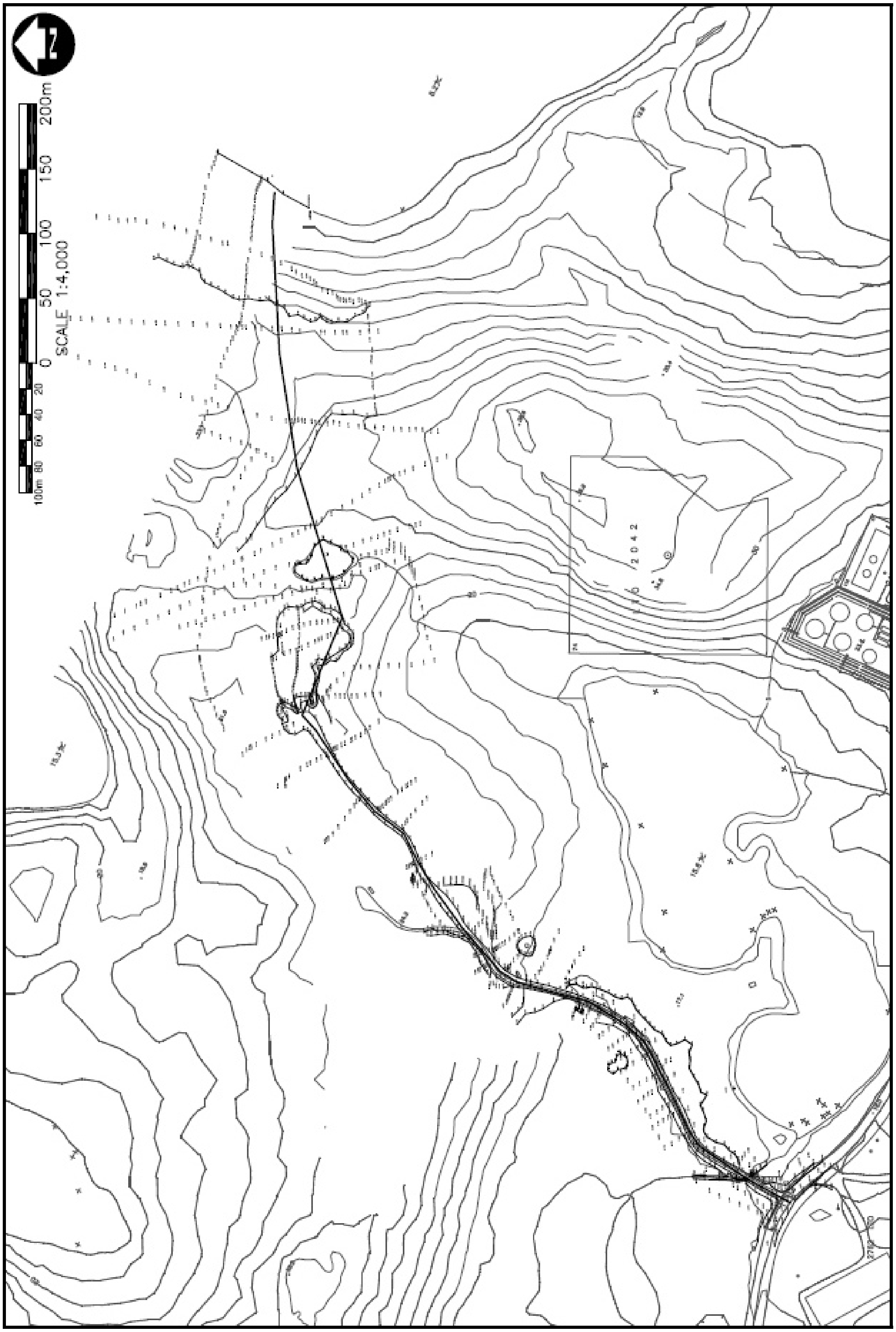


Figure 7: Survey Results of Access Road

6 WATER TREATMENT SYSTEM SELECTION

6.1 Design Criteria

The criterion for the water treatment process is to provide water meeting the quality goals of the project. This goal was stated in the project terms or reference as follows:

"***The facility must produce potable water meeting the requirements of the Guidelines for Canadian Drinking Water Quality (Health Canada).***"

For this design, the following treatment parameters that must meet water quality guidelines are as follows:

- Turbidity
- Disinfection

6.2 Water Quality

The water analysis data described in **Section 2.4** was used to provide information on the water quality for Canso Lake. As previously discussed above, a summary report of the water quality analysis is provided **Appendix E**.

A review of the above analysis shows that all health-related parameters with the exception of turbidity and microbiological parameters meet the Guidelines for Canadian Drinking Water Quality. None of the parameters exceeded the aesthetic objectives (AO) of the GCDWQ.

6.3 Fire Flow Requirements

After consultation with the Fire Marshal for Nunavut, it was recommended that the flow rate required for fire is 1,000 L/min.

6.4 Design Capacity

The proposed water treatment plant has a design capacity of 1,000 liters per minute (L/min) at the truck fill arm.

6.5 Treatment Options

6.5.1 Filtration

Various options were proposed for the design of process water treatment system. These include the following filtration technologies:

- Rapid Sand
- Slow Sand
- Membrane
- Cartridge

The degree of treatment depends on the quality of the water from Canso Lake. Water samples were taken during the initial visit to the community. Test results from the lab analysis for the different parameters are presented in **Appendix E** of this report. Based on these results, all filtration techniques would theoretically work. However, one technology may be a better choice over another based on other factors such as system simplicity, maintenance, and cost. **Table 15**, shown below, lists the advantages and disadvantages of the four filtration systems.

Table 15: Advantages and Disadvantages of Filtration Technologies

	Filtration Technology			
	Rapid Sand	**Slow Sand**	**Membrane**	**Cartridge**
ADVANTAGES	- Higher throughout capacity than slow sand - Low capital cost - Requires smaller land area - Good removal of color and organics	- Little or no mechanical power, chemicals or replacement parts - Low operating and maintenance costs - Minimal operation; lower level of operator training - Periodic maintenance - Appropriate technology for poor and/or isolated areas - Makes use of locally available materials	- Not sensitive to water quality; can treat broad range of raw water - Removal of bacteria, particulate matter and natural organic compounds - Small footprint - Small size; low space requirements - Automatic operation	- Simple operation and technology (minimal operator skill and attention demands) - Low capital cost - Low maintenance requirements (only filter replacement) - Small footprint - Low space requirements - No addition chemicals required (besides chlorine)
DISADVANTAGES	-Not an adequate treatment alone; some form of pre-treatment required, making use of flocculation chemicals - Large sludge generation - Higher operating & maintenance costs than slow sand; requires mechanical pumping for backwashing - Ineffective treatment for taste and odor unless activated carbon is included - Sensitive to rapid changes in water quality	- Replacement of top layer of sand - Requires a large land area due to size of filtration cells - Operation best for high quality (low turbidity) water	- Replacement of membranes due to fouling, which is expensive - More complex operation due to more complex mechanical and electrical equipment - Not recommended for small remote communities (based on manufacturers) - High capital cost	- Requires high quality (low turbidity) water - Replacement of cartridge filters, which is expensive - Fouling of and microbial growth on filters; disinfectant required for removal - Poor removal of Cryptosporidium - Source of future replacement elements is uncertain

Cartridge filtration appears to be the best technology for the water treatment plant and is recommended for this project.

6.5.2 Disinfection

The two chemicals that are most commonly used for water disinfection in the small facilities are sodium hypochlorite and calcium hypochlorite. Generally, they both can come in the form of solid pucks or liquid solution.

The existing facility in Taloyoak currently uses calcium hypochlorite in the chlorination process. It is recommended that this chemical be retained as the disinfection compound.

7 SITE DEVELOPMENT

7.1 Intake Line Requirements

Intake line will be installed as discussed in **Section 5.1.2.2** and **Section 5.2**. The line will have a submerged section that is approximately 90 m. The top of the intake screen is to be set at elevation 3.2 m above sea level. The intake will be installed within an insulated casing pipe. Standard detail for these intakes and intake casing is as follows:

- Intake pump is housed within a steel skid that allows for pump extraction.
- Skid has a steel cable attached. The cables leads the length of the off take pipe. The cable is used to extract the pump for maintenance and repairs.
- The off take pipe from the pump will be 100 mm HDPE DR 11 pipe. The pipe is sized to handle the proposed upgraded flow of 1,000 L/min. The DR 11 pipe is selected over the DR 17 due to the length of the off take pipe, and the need to "push" the pump into the casing using the off take pipe. The stiffer pipe will provide better performance in the pump placement effort.
- The casing pipe will be HDPE DR32 300 mm diameter. The pipe size is selected to meet the needs of the 1,000 L/min pump.
- Casing pipe will have 62 mm of ridge foam insulation and the outer jacket will be 2-counter wound layers of heat tape.
- Two heat traces will be installed in the casing pipe, next to the 100 mm pipe in a copper tube.
- All heat trace will be installed with controllers.

7.2 Turn Access and Building Pad

The truck turning access pad and building pad will become the overall foundation for the building.

- Installation of a 150 mm thick leveling course using clean bedding sand.
- A 75 mm thick layer of rigid Styrofoam insulation on the bedding sand.
- 150 mm layer of clean bedding sand over the insulation.
- 300 mm layer of granular material.

The truck turn around pad requires a radius of 15 m in order for the standard water trucks to be is to be used in the future. The owner may select to use a smaller pad suitable for the use of a pull behind trailer, recognizing that there will need to be an upgrade to the turn around pad in the future.

The side slopes of the building pad and turn around pad are to be 3:1 (H:V). Building pad will be 1.5 m larger than the width of the building on all sides.

8 PROCESS FLOW SCHEMATIC

8.1 Treatment System Requirements

The treatment system components are designed to meet the needs of the community throughout the 25-year facility life. The sections that follow describe each of these components in more detail.

8.2 Fire Flow Requirements

A fire flow of 1,000 L/min was specified by the Fire Marshal for the design of the plant. The required flow to meet the demand of the population for the design horizon is also around 1,000 L/min. Design head of the intake pump was calculated using the following approximations for the fire flow rate:

Static Head (from top of intake screen to discharge of truck fill)	7.5 m
Length of Intake Pipe, 100 mm HDPE - Exterior	80 m
Length of Pipe, 100 mm HDPE - Interior	10 m
Roughness Factor for HDPE Pipe	140
Total Resistance Coefficient for Entrance, Exit and Fittings	1.5
Number of Bends	5
Total Resistance Coefficient for Bend	2.2
Pump Efficiency	65%

This results in a total dynamic head loss of approximately 16.19 m (53.13 ft) which gives a pump with a power requirement of approximately 4.0 kW. Detailed pump hydraulic calculations as well as pump specifications meeting the above requirements are shown in **Appendix G** of this report.

8.3 Water Storage

There is a need to store water within the facility for several reasons. The water storage requirements for the facility are described below.

- Facility Domestic Use - There is a need for water to be used in the facility for testing, laboratory/optimization work, and general cleaning. A volume of 25 L of treated water is recommended for domestic use. Filter wash down will occur approximately every month. The water used in the wash down is included in the 500 L. Therefore, a total volume for post treatment water storage of 1,500 L is carried forward.
- Wastewater Storage - There will also need to have a wastewater tank in the facility. The waste water tank size needs to be sufficient to provide a minimum of one (1) week's worth of wastewater. Peak flow will occur during the weeks where the filters are washed down in addition to the other normal operating procedures. For this case, a volume of 250 L is recommended.

8.4 Treatment Facility Truck Fill Control

The treatment facility system will have a pre-treatment buffering tank. The truck fill system will operate as follows:

- Cycle is activated by the truck fill operator accessing the control panel through a lock on the panel and pressing the "start" button on the truck fill arm.
- Raw Water Pump 1 (RWP) will start.
- Flow Switch FS 2 will be activated by flow to the truck fill arm and will energize CMP1 to inject disinfection fluid to the Truck fill arm.
- A flow sensor will record the flow volume by the plant totalyzer.
- The cycle will be stopped by the expiration of the timer or the truck fill operator by pressing the "stop" button.
- RWP 2 will be de-energized.

Note that RWP 1 pump is a duplex and only one of each set will be operational in any one cycle.

8.5 Conveyance Piping

The process piping used to draw water from the lake to the treatment plant will consist of the following items:

- An intake screen, submersible pump on 100 mm HDPE DR11 piping, contained within a 300 mm HDPE DR32 casing. The casing will be insulated with 62 mm of polyurethane foam and will be heat traced.
- PVC 100 mm and 50 mm Schedule 80 piping with Victaulic or flanged system connections will be used in the facility.
- Chlorine injection piping will be clear nylon tubing.

8.6 Monitoring and Controls

The building will have a monitoring and control system that will contain two levels of alarms: major and minor. Major alarms are setup to activate an exterior alarm light whereas minor alarms will trigger the start of an interior alarm light. The system alarms have been established as follows:

Major	Minor
Intake pump failure Low building temperature Power-off, Stand-by generator failure Very low fuel level	Treatment facility pump failure High building temperature Power-off, Stand-by power on Process plant failure Low fuel level

9 WATER TREATMENT PLANT BUILDING COMPONENTS

9.1 Building Foundation

Based on the recommendations from the geotechnical report, the building's foundation will be developed and constructed in the following way:

- Installation of a 150 mm thick leveling course using clean bedding sand.
- A 75 mm thick layer of rigid Styrofoam insulation on the bedding sand.
- 150 mm layer of clean bedding sand over the insulation.
- 300 mm layer of granular material.

The building will have a steel skid foundation. Skid mounting system will be suitable to carry the load of the building while mobilizing it to the community as well as through the installation process. The skid will be developed to have four lifting pints, thereby allowing it to be loaded and unloaded from a truck without the use of a crane.

9.2 Building Envelop

9.2.1 Construction

Building envelop can either be constructed from wood frame on-site or by pre-engineered, pre-fabricated material off-site.

9.2.1.1 Wood Frame

The wood frame building will be constructed in accordance to the standard used by the Government of Nunavut for the construction of truck-fill stations. This standard states that the items of the building will be built in the following way and using the following materials:

- Wall constructed of 38 mm × 150 mm (nominal 2×6) studs with 150 mm (nominal R-20) fiberglass batt insulation.
- Walls with vapor barrier on the inside and air barrier on the outside of the wall studs.
- Walls with plywood sheathing on the outside face and 50 mm of rigid foam insulation.
- Interior of the walls sheathed with plywood and clad with metal siding. (The interior plywood is for convenient equipment installation.)
- Roofing provided by a pre-manufactured truss, or rafter system.

9.2.1.2 Pre-Engineered

Pre-manufactured building will be constructed to provide the equivalent insulation value as the wood frame building. Several companies produce these structures (Bally, Brytex, Butler) and each have a slightly different building design but all typically have an insulation value of RSI 7.0 (nominal R-50).

Based on the construction sequence, IE building the facility in a southern location and mobilizing the completed building, the use of a pre-engineered building is recommended. These building are typically more durable when being relocated after construction. Building elements will include:

- Wall section will be 125 mm thick (R7.0) foam insulation.
- Exterior surface will be metal cladding.
- Interior surface will be 12 mm plywood covered with metal cladding.
- Metal cladding will be 26 gauge.
- Roof will be flat or low slope.
- Floor will be checker plate over pressure treated plywood, over TGI joists filled with Styrofoam insulation with 12 mm OSB under the insulation.
- A one-man door will be provided.
- The building will not have any windows.

9.2.2 Compartments

The building will be designed so that each specific plant operation is housed in a different area. Different areas of the building shall include the following: intake lines, water treatment plant, storage units, and stand-by power generator. Furthermore, the plant will have a laboratory area that contains a sink and counter space for conducting water quality testing as well as cupboards for the storage of the laboratory equipment.

9.3 Power Requirements

9.3.1 Prime Power

A summary of the major power requirements for the water intake and treatment facility are outlined in **Table 16** below.

Table 16: Major Power Requirements

Component	Power (kW)
Intake Pumps	4.0
Hot Water Tank	3.5
Furnace/Building Heat	1.5
Lighting	2.0
Heat Trace	2.5
Chemical Feed Pumps	0.5

Total power requirements are estimated to be about 25 kW. From the total power demand, energy use per day was calculated using the actual power consumption of each device and the number of hours of operation per day. The use of emergency equipment was not considered in this development.

There is currently no source of power to the proposed site for the plant due to the fact it is located approximately 1 km from the center of the community and there is no developed that has taken place in the area. The two possible options for power supply are as follows:

- Transmission line that connects to the community's power source with the Nunavut Power Corporation.
- On-site diesel generator with its own fuel supply.

9.3.2 Stand-by Power

It is important to provide stand-by power to the plant for many reasons. This additional power will help to prevent the following:

- Interruption in water flow in the event of an emergency (such as a fire); and
- Shortage or no supply of heat for freeze protection due to power outages.

Stand-by power for the plant will be supplied by a 30 kW back-up diesel generator. A fuel tank will be located on site which will be equipped with its own spill containment storage unit.

9.3.3 Alternative Energy Options

The CGS expressed interest in researching alternative energy options to minimize the power consumption rates and lifetime costs for the facility. Alternative energies such as solar power have been implemented in other facilities throughout the north in communities such as Colville Lake, NT. Information from this facility suggests that the addition of such technologies have proven to contribute to decreasing costs associated with power generation.

A number of alternatives energy sources were studied to help minimize the operating costs related to the facility's power requirements. Possible alternative energies for power include battery, solar, and wind. Similar alternative energies have been implemented in other facilities throughout Nunavut and have been found to work well in the arctic climate. These options will be incorporated with the prime power source options to provide a better system.

Several of the goals and objectives that were set out in the project's TOR were also applicable to the development of the prime power supply analysis. The prime power supply should be:

- Simple to operate and maintain by local forces as available equipment, parts and materials are limited
- Reliable, efficient and cost-effective to operate and maintain.
- Highly capable of recovering from frozen condition to operational state as is the case for all major components (if there is any possibility of freezing).

These criteria will be the assessment criteria for selection of the best applicable alternative. The main results have been written in the Alternative Energy report attached in **Appendix H** of this report.

9.3.3.1 Battery Bank

A battery bank will be implemented as the main power source but will be charged by the diesel generator. The diesel generator will also act as backup during power outages and peak power demand.

Not typically an option used in the northern climates, the battery bank adds both advantages and disadvantages to the system. Retention time allowance in the event of system failure increases with the addition of a battery bank. Operational problems arise with the use of batteries in extreme low temperatures. Batteries require monthly checking of their electrolyte levels and cannot be frozen. For instance, if there is a heat loss or plant failure and the batteries are in discharged condition, than they can be damaged and/or rupture. They are also not completely recoverable from a frozen condition to operational state. Due to the fact that the batteries have a life expectancy of 7 years and contain strong chemicals, there are concerns with proper disposal of hazardous waste in remote communities.

Capital investment for a battery bank is reasonable. It becomes costly, however, when the bank has to be replaced every seventh year. Operating and maintenance costs are also higher than the other options.

9.3.3.2 Solar Energy

Photovoltaic (PV) cells, which are semiconductor devices usually made of silicon, convert energy from the sun into electricity using an inverter and stored in batteries. Electricity produced is based on the amount of hours of sunlight that the modules are exposed to during the day.

This technology is one of the cleanest and safest methods of power generation. Cells are environmental friendly as they contain no chemicals and emit no pollutants. As well, there is little maintenance required as there are no moving parts within the system. Energy obtained is also free and renewable.

Systems such as this have been quite expensive to install in the past. However, costs associated with PV panels have substantial decrease making it now a somewhat affordable option. The increase in the capital investment compensates for the higher operating and maintenance costs over the lifetime of the facility.

9.3.3.3 Wind Energy

A wind turbine or generator produces mechanical energy which is converted into electricity through the use of an inverter. The inverter converts the power from AC to DC and stores it in batteries if not used immediately. Amount of electricity generated from the turbine depends on the velocity and constancy of the wind. High winds can decrease the efficiency of the power generated.

Like solar energy, wind power is a free, renewable green energy source. There is no or very little pollution generated. Turbine requires maintenance on a regular basis to ensure that it is operating efficiently, especially during the winter, as the cold weather causes reliability issues when in operation. Low temperatures create problems with the mechanics of the turbine and ice can accumulate on blades. Lightening strikes to wind turbines are common due to their height which causes damage to the control circuits. The addition of a wind turbine adds to the complexity of the system in the area of controls and monitoring but provides more power sources while reducing the overall power demands on the other supply.

Capital costs for a wind generator are similar to that of solar panels as there are a number of controls to be installed. Operating and maintenance costs are higher due to fact that continually monitoring and maintenance of the turbine is required to provide optimal operation and service.

9.3.3.4 Various Options

Combinations of the power options described above were examined to distinguish which system would be the best for the facility. A list of the various power options are listed and described in **Table 17** below.

Table 17: Power Generation Options

Option	Prime Source	Description
A	Transmission Line	Power supplied by Nunavut Power Corporation (NPC) through the use of a power transmission line to site.
B	Diesel Generator	Onsite diesel generator with its own fuel storage tank, complete with spill containment. Control system to switch from prime to standby power is also included.
C	Battery Bank charged by Generator	Battery bank added into the stand-alone power generation provided by a diesel generator. Batteries will provide the majority of the power requirements for the WTP and the generator will operate during times of peak demand such as when the process plant is in operation. Batteries will be monitored so that when their stored amp-hours (or voltage) drop below a certain set point, the generator will start to charge the batteries.
D	Option C with PV Modules	Photovoltaic (PV) modules are implemented into the battery bank-diesel generator system. The PV panels will provide power directly to the inverter/charger unit, which will control the power supply to the batteries. Most of the power demands will be provided by the PV panels but during high power requirements (total demand exceeds that which can be generated by the PV modules) the installed process controller will switch from solar power to the power line.
E	Option C with Wind Generator	Wind generator is integrated with the battery bank-diesel generator system. Inverters are required to convert the mechanical power created by the turbine to electrical power. Majority of the power demands will be provided using power generated by the wind turbine. During times of high power requirements, the power line will offset for the additional power not being supplied by the wind generator.
F	Option C with PV Modules & Wind Generator	PV modules and wind generator are incorporated into the battery bank-diesel generator system as described in Option C. Inverter is required to convert the power generated by the solar panels and wind turbine to electrical power. Most power requirements will be provided by the PV panels and e wind turbine but during times of high power demands, the power line will offset for the additional power needs.
G	Option A with PV Modules	Installation of PV modules will be added to power transmission line. Battery bank and an inverter are required to operate the PV system as the panels will provide power directly to the inverter and charger unit which further controls the power supply to the batteries and prime power. High power operations will be run using the transmission line while low power operation will run from power generated by PV panel and stored in the battery bank.
H	Option A with Wind Generator	Wind turbine the use of a wind generator as another power source along with the power transmission line. Like Option G, the addition of batteries and inverters are required to convert the mechanical energy from the wind generator into power. During low power operations, power supply will come from the wind generator whereas high power operations will be provided by the transmission line.
I	Option A with PV Modules & Wind Generator	Both PV modules and a wind generator will be implemented into the power supply proposed in Option A. Energy obtained from these sources will be converted into electricity by an inverter and stored in batteries. Majority of the power is provided by PV cells and wind generator with the exception of high demands in which case the transmission line will begin to supply the remaining power.

With the exception of the power transmission line, equipment for all of the options will be housed separately, either in another room located in the water treatment building or in second building on site.

9.3.4 Comparison of Options

Estimated costs shown in this section were extracted from a previous study for alternative energy sources for the water treatment facility in Colville Lake, NT that was performed in 2005. A factor of 1.3 was added to these estimates to incorporate the cost increase for the community of Taloyoak, NU. As well, an average inflation rate of 2% was used to adjust the time value of money over the lifetime of the facility.

Costs shown in **Table 18** below were calculated at a discount rate of 4%. For those options that have incorporated another power source such as solar and wind generation, a 30% usage was used. Additional calculations and conclusions are discussed in the AE report shown in **Appendix H.**

Table 18: Cost Analysis of Alternative Energy

Option	Capital Cost	Life Cycle Cost
A	$120,000	$493,950
B	$93,000	$1,494,550
C	$160,200	$1,059,950
D	$197,200	$871,250
E	$187,200	$878,750
F	$225,200	$726,800
G	$230,200	$588,550
H	$220,200	$615,500
I	$255,200	$532,150

Comparing all options based on an economical and operational viewpoint, it is recommended that Option I be implemented as the prime power supply for the new water treatment facility.

It is beneficial to provide a power source that will not only assist with reducing costs for today's power requirements but with those anticipated in the future. Even though this option has the highest capital investment, it has the second lowest life cycle cost. The addition of the PV modules and wind generator increases the capital cost but reduces the electricity demands and costs that are obtained from the transmission line. Majority of the time, the plant can operate using the power generated from the alternative energy sources. Option I is also one of the most reliable power supplies as there are three power sources that can be called upon during peak power demands.

9.4 Heating and Ventilation

9.4.1 Building Heating Systems

Three different heating systems - boiler, furnace and combination of overheat unit heater - were evaluated for the water treatment plant.

9.4.1.1 Boiler System

This system is comprised of a hot water boiler, which feeds the overhead unit heaters. A Heat Recovery Ventilator (HRV) exhausts stale air from the building and brings fresh air into the building. As it does this, the heat from the stale air is transferred to the cold air brought into the building.

9.4.1.2 Furnace System

This system uses a furnace combined with a HRV to supply both warmed and fresh air to all rooms in the building.

9.4.1.3 Overheat Unit Heaters System

This system is comprised of unit heaters, mounted on the walls or ceiling, which supply the rooms with warm air. A HRV will also be incorporated to supply fresh air to the building. For the oil fired system, as the smallest oil unit heater is the size of the one used to heat the entire building, a separate electric unit heater is necessary to keep the generator room just above freezing (5°C).

9.4.2 Cost Analysis of Heating Systems

Costs associated with each heating system are shown in **Table 19** below. These costs were extracted from a previous report outlining costs for a heating system in the WTP for Colville Lake, NT. Again, a location factor of 1.3 and inflation rate of 2% were used incorporate the cost increase for Taloyoak and time value of money.

Table 19: Cost Estimate of Heating Systems

System	Fuel Type	Capital Cost	Annual O&M Cost	Life Cycle Cost		
				2%	4%	6%
Boiler	Oil-fired	$32,000	$17,000	$464,300	$374,700	$310,450
	Electric	$18,000	$68,000	$1,785,350	$1,419,150	$1,156,600
Furnace	Oil-fired	$24,000	$15,000	$392,350	$316,050	$261,350
	Electric	$7,000	$66,000	$1,721,700	$1,336,350	$1,111,575
Unit Heaters	Oil-fired	$21,000	$18,500	$493,600	$395,575	$325,300
	Electric	$11,000	$69,000	$1,800,300	$1,429,500	$1,163,700

The capital investments for the electricity powered heating systems are substantially lower than that of the oil-fired systems. However, their operating and maintenance costs are quite high due to the high electricity which increases the overall life cycle costs. Due to this comparison, the electrical heating systems are not as feasible as the oil-fired systems.

When comparing all options for each fuel type, the furnace is the most economical choice. Therefore, it is recommended that a furnace be installed as the building heating system. The furnace has a lower electricity requirement compared to the other systems. It uses a low horsepower fan but also permits the

HRV fan to stop when the furnace is operating. These two factors help to minimize electricity needs and costs.

9.5 Freeze Protection

To ensure that the intake casing and pipe and the truck fill arm do not get damaged during the winter, a heating system such as electric heat traces and/or insulation will be installed for freeze protection.

9.5.1 Intake Casing and Pipe

Intake casing and pipe will both be protected from freezing by installing an electric heat trace cable within the casing and pipe structure. Positioned adjacent to the outside of the intake pipe, the cable will be 15 W/m self-limiting, so that it will not damage the HDPE pipe. Four lengths of cable will be installed, two on the intake casing and two on the raw water pipeline. Under normal operation, only one of the raw water pipeline heat trace cables will run while the second will act as a back-up in case of the failure of the first cable. The heat trace for intake casing will only be used in case of freeze up or a means to assist in the thawing of the intake. Cables will be removable and have automatic controls.

9.5.2 Truck fill Arm

The truck fill arm must also be equipped with heat trace cable to help protect it from as well as recover it from freezing. A key to successfully avoiding freezing of the treatment facility pipe is to ensure that it drains quickly and completely after use. The truck fill pipe will be installed with a 4% or greater slope back into the building. The pipe will be stainless steel and insulated with the provision for heat trace cable conduit. Freezing of the pipe is unlikely, due to the draining system, however, the provision to allow for easy installation of a heat trace and switch is recommended. A switch will be located near the wall penetration of the building at the truck ill arm.

9.6 Monitoring and Controls

The treatment facility control has been established using past practices of the Government of Nunavut for similar facilities in other small communities. The treatment facility control system will have the following components:

- Treatment facility control with one customer key lock. This will have a flow accumulator to record cumulative flows. The control will be on the treatment facility arm, with a start and stop switch, and a timer.
- Flow rate indicator.
- Flow sensor installed in the treatment facility pipe to control the flow accumulator.
- Flow switch to interlock with the pump and chlorine pump to avoid damage to the equipment or excessive chlorine injection into an empty line.
- All measurements for the metering are to be in SI units (L).

- The accumulators, flow indicator, and miscellaneous control devices will be located in a main control panel inside the IPH.
- Online turbidity monitoring.

9.7 Laboratory and Testing Requirements

The laboratory equipment as listed in the following table will be provided for the operator's use.

Table 20: Laboratory Equipment

Item	Quantity	Description	Catalog No.
1	1	Hach DR890 portable colorimeter complete with Procedures Manual	48470-00
2	1	Hach DR890 hard-sided case	49425-00
3	1	Hach 2100P portable turbidity meter complete with Instrument and Procedure Manual	46500-00
4	1	2100P Battery Eliminator 120V North American plug	46079-00
5	6	Silicon Oil, 15 mL SCDB	1269-36
6	6	Sample cell oiling cloth	47076-00
7	2	Sample cells, 6-pack, 1 in. round glass, 10 mL with cap	24347-06
8	2	Sample cells, 6-pack, 1 in. round glass, 10 mL with cap	24276-06
9	2	Sample cells, 6-pack, 1 in. round glass, 10 mL and 20 mL with cap	24019-06
10	2	Rack holder, 6 sample cells	-
11	1	Beakers, polypropylene, 100 mL, 12-pack	1080-72
12	1	Beakers, polypropylene, 250 mL, 6-pack	1080-76
13	1	Beakers, polypropylene, 1000 mL, 3-pack	1080-83
14	2	Graduated cylinder, polypropylene, 100 mL	1081-42
15	2	Graduated cylinder, polypropylene, 500 mL	1081-49
16	2	Graduated cylinder, polypropylene, 1000 mL	1081-53
17	2	Wash bottle, polypropylene, 500 mL	620-11
18	2	Thermometer with nylon case, -5 to 45°C	26763-00
19	20	Sample bottles, Dynalon HDPE	D00022
20	1	Hach Ferro Ver iron reagents (100)	21057-69
21	1	Hach LR manganese reagents (100)	22433-00
22	5	Hach Total chlorine reagents (100)	21055-69
23	15	Hach Free chlorine reagents (100)	21056-69
24	1	Hach color standard kit	26353-00
25	20	Brush, Test tube	6900
26	10	Syringe, Luer-Lock Tip, plastic, disposable, 1 mL with 0.1 mL divisions	12263-00
27	1	General laboratory cleaner (phosphate free), 4 L bottle	-
28	1	Logbook with reproducible log sheets	-

9.8 System Spares

The following table lists the spare components, replacement parts, and ancillary components that will be included in the construction of the water intake and treatment plant design.

Table 21: Spare Equipment Parts

Spare Component	Parts
Intake and Process Pumps	One (1) pump complete with power cable. One (1) spare pump of each type installed.
Disinfection Feed System and Chemical Pump	One (1) rebuild kit for chemical pumps. Two (2) chemical feed pumps. Two (2) chlorine mixing pumps. Two (2) chlorine flow switches. Nylon tubing.
Eyewash	One (1) spare container of solution.
Lighting, Exterior and Interior	Six (6) spare indicating lamps of each type installed. One (1) case of all fluorescent lamps of each type and size installed.
Distribution Panel	Two (2) breakers of each size and type.
Terminal Blocks	One (1) set of blocks for each size and type installed. End caps, end plates, cross connectors and tear-off markers are to be included.
Fuses	Twelve (12) spares of each type installed, unless otherwise noted.
Valves	Two (2) rebuild kits for each type and size installed including gaskets. One (1) spare of each valve installed.
Motor Starters	Two (2) of each type of pilot light and overhead heaters. One (1) of each type of coil and contact.
Control Devices	Two (2) push buttons, 6 pilot lights and 2 lens for each type. One (1) spare flow display/totalizer. One (1) spare flow sensor.
Alarm Panel	One (1) alarm annunciator.
Mini-Breaker (or six (6) of each fuses)	Two (2) of each relay and timer. One (1) of each relay and timer base.
Fan Belts	One (1) of each type installed.
Fuel Filters	Twelve (12) month supply.
Oil and Oil Filters	Twelve (12) month supply of oil (± 24 L) and oil filters.
Thermostats	One (1) spare of each type installed.
Heat Trace	One (1) spare controller. One (1) spare thermometer.
Fire Extinguisher	One (1) per room.
Miscellaneous	Chlorination chemical as well as testing chemicals. Timers.

9.9 Miscellaneous Equipment

A list of miscellaneous equipment for the facility is provided below.

- Fire Extinguisher: Class XBC, UL listed, 9 kg capacity, external nitrogen cartridge Foray powder with wall mounting brackets. Mount on wall near exterior door.
- Goggles & Respirator
- Gloves: Twelve (12) Fisher 11-394-30, large, extra long, heavyweight rubber gloves, 19 mm by 380 mm length.
- Apron: One (1) Fisher 01-357 double coated abrasion resistant, rubberized cloth apron.
- Push Broom.
- Mop.
- Mop Bucket and Wringer.

- Dust Pan.
- Garbage Can: One (1) 100 L, galvanized, with cover.
- Floor Cleaner.
- Lighting: Two (2) fluorescent tubes and One (1) low temperature ballasts.
- Storage Cabinet: Combination shelving/wardrobe unit; Two (2) doors; Four (4) half shelves; Pre-finished in grey.
- Laboratory equipment for completing bench tests. One (1) year supply of reagents.
- Eye wash station and first aid kit.

10 CONSTRUCTION STRATEGY

The intention of the Department of CGS, Government of Nunavut, is to complete the project in the 2008-09 fiscal years.

Tender of the intake and water treatment facility is to be completed in March 2008 with the award of the contract likely to occur in April or May 2008. Work for the water intake will be done on site whereas construction of the water treatment plant will be completed off site over 2008.

Work will commence with the supply and installation of the intake casing pipe shortly following the award of the contract. At the same time, the building envelope and skid will be constructed off site and mobilized to Taloyoak on the barge during the spring/summer of 2008. Remaining work of the water treatment facility will be completed once placed on site during the fall and winter. Depending on the timeline, commissioning will likely occur in April 2009. A schedule outlining the construction strategy for the project is shown in **Table 22**.

Table 22: Project Schedule

Task	Date
Tender Submission	Mar 2008
Contract Award	Apr 2008
Intake Works	
Material Order	May 2008
Mobilization	Aug 2008
Installation	Aug - Sept 2008
Facility Works	
Off-Site Construction	May - Jul 2008
Mobilization	Aug 2008
On-Site Installation	Sept - Dec 2008

11 APPROVALS

Several agencies need to be made aware of the intended works for the project in order for it to go to final completion. Authorization is not required from all agencies for the design and construction of the project but they all can be actively involved in the process of obtaining licenses and authorizations that is required of the project owner. **Table 23** summarizes the approval agencies that need to be involved in the approval process.

Table 23: Approval Agencies

Agency	Regulations
Council of the Hamlet	Site Acceptance
Nunavut Environment Impact Review Board (NIRB)	Review Only
Nunavut Water Board (NWB)	Water License
Nunavut Planning Commission	Review Only
Government of Nunavut (GN) Environment Protection	Hazardous Material Fuel Storage
Indian and Northern Affairs Canada (INAC)	Inland Waters Act Marine Waters Act Monitoring of Water License
Department of Health	Health Act General Sanitation Act
Department of Fisheries and Oceans (DFO)	Fisheries Act, Section 35 related to Fish Habitat
Environment Canada	Fisheries Act, Section 36 related to Discharge of Deleterious Substances
Office of the Fire Marshal	Fire Code, NFPA, B139

Each of the above agencies needs to be contacted to verify that their specific concerns related to this project are being met. The Hamlet council will be an active member involved in the decision process for the site location.

Agencies of particular importance are the Nunavut Water Board and Department of Fisheries and Oceans. It is imperative that approval has been accepted from these two organizations as the project work cannot proceed without their authorization.

Due to the fact that water is being drawn from a natural water body, a Water License has to be issued by the Nunavut Water Board to the community in order to withdraw water (over 50,000 L) from the lake. A license is also required for the discharge of wastewater. The license is obtained through a formalized licensing process and application form to be completed and submitted to the Water Board for review and approval.

The Department of Fisheries and Oceans will have to give authorization for the installation of the intake casing and screen as this construction is considered violation of the section 35 of the Fisheries Act since there will be destruction of fish and/or fish habitat. An application form which includes the plans and details of the project has to be submitted for review, comments and approval to DFO. Approval will be obtained in the form of a letter of authorization once the organization has accepted the work associated with the project.

12 SUMMARY OF RECOMMENDATIONS

A summary of the design recommendations for the new water intake and treatment facility are provided in the form of a table shown below.

Table 24: Summary of Design Recommendations

Design Element	Recommendation
Fire Flow Requirement	1,000 L/min
Process Flow Rate	1,000 L/min
Treatment Process Selection	Cartridge Filtration
Post Treatment Storage	1,500 L
Disinfection	Calcium hypochlorite
Intake Length	90 m
Building Foundation	Skid steel
Building Envelop	Pre-engineered sandwich wall construction with metal exterior finish and plywood and metal interior finish. RSI 7.0
Conveyance Piping	Intake Casing: HDPE DR 32 Intake Pump Off-take Piping: HDPE DR 11 Internal Piping: PVC Schedule 80 Truck fill Arm: Galvanized Steel
Freeze Protection - Intake Casing and Raw Water Pump Pipe	2 Self limiting Heat Trace Cable
Prime Power Source including Alternative Energy System	Power Transmission Line with PV modules and Wind Generator
Building Heat	Oil-fired Furnace
Stand-by Power	30 kW Diesel Generator

The Class 'C' cost estimate for the project based on the above project summary is shown in **Table 25** on the following page. The estimates presented here are based on both supplied information from manufacturers as well as recent tender prices that have been received for similar projects. Prices that were extracted from other projects have been adjusted for this site using an inflation rate of 2% and a factor of 1.3 for the location of the facility.

Table 25: Class 'C' Cost Estimate for Recommended Options

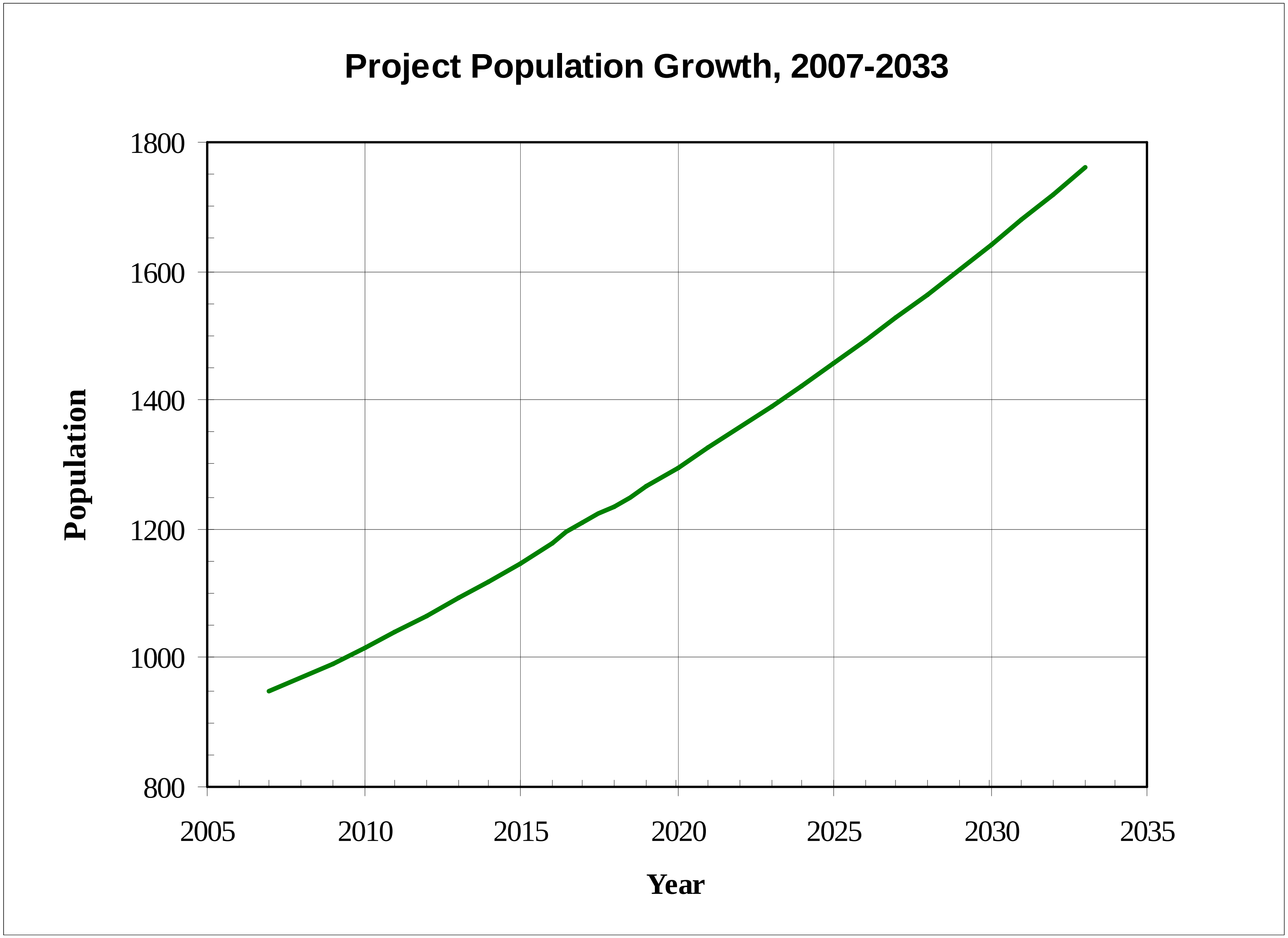
Item	Total Cost 2007		
	Without PV and Wind Generator	**With PV Only**	**With PV and Wind Generator**
Access Road	$410,000	$410,000	$410,000
Truck Pad and Turn Around	$80,000	$80,000	$80,000
Foundation Skid	$35,000	$45,000	$55,000
Building Envelop	$170,000	$220,000	$240,000
Intake Pipe	$540,000	$540,000	$540,000
Process Water	$180,000	$180,000	$180,000
Electrical	$155,000	$275,000	$325,000
HVAC and Plumbing	$135,000	$142,500	$145,000
Office/Laboratory/Sink/Spares	$75,000	$75,000	$75,000
SUB-TOTAL	**$1,780,000**	**$1,967,500**	**$2,050,000**
Engineering, 10%	$178,000	$196,750	$205,000
Contingency, 15%	$267,000	$295,125	$307,500
Power Transmission Line	$120,000	$120,000	$120,000
TOTAL	**$2,345,000**	**$2,579,375**	**$2,682,500**

Cost estimates shown in the table above are the total costs for the water treatment facility if Option A or Option G (as were discussed in **Section 9.3.3** above) were to be used as the prime power source. Note that the above estimates will either stay the same or increase depending on the design details of the new power system, costs would be adjusted to reflect the additional components pertaining to that power option design in each specific section.

APPENDIX A

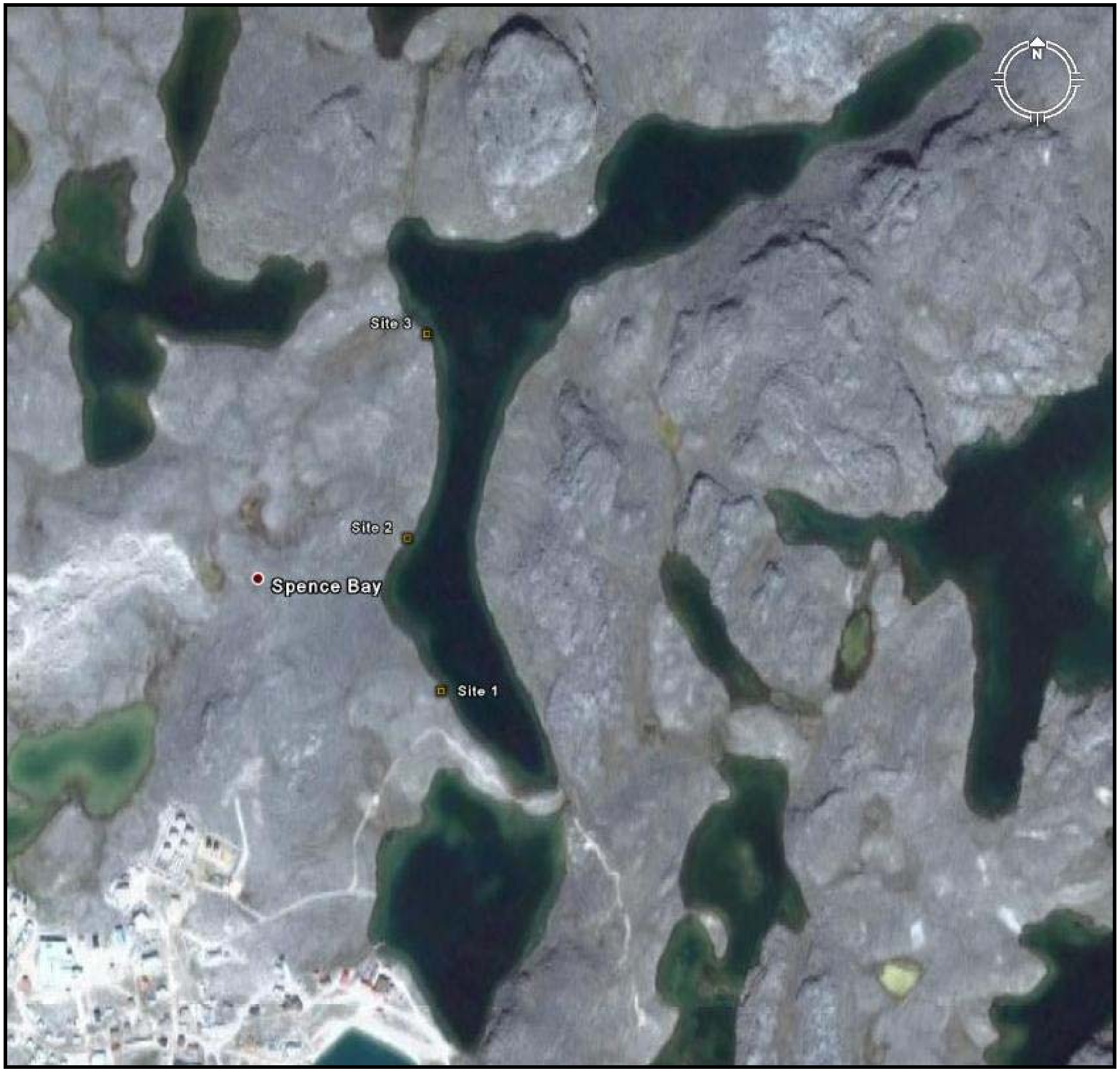
Figures

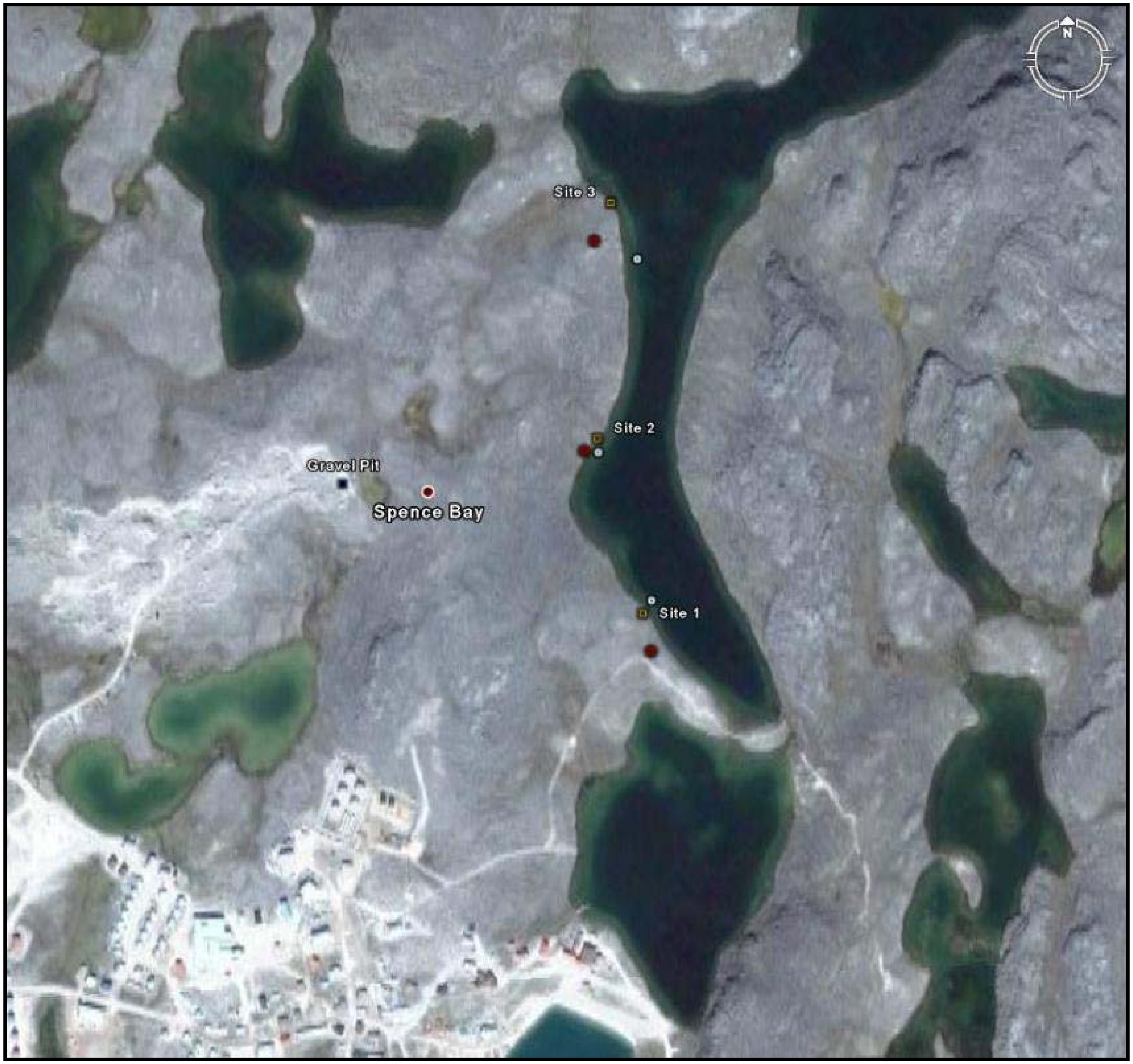

N
Existing IPH
Boothia Inn
Existing WTP
Taloyoak



Project Population Growth, 2007-2033
Population
1800
1600
1400
1200
1000
800
2005
2010
2015
2020
2025
2030
2035
Year

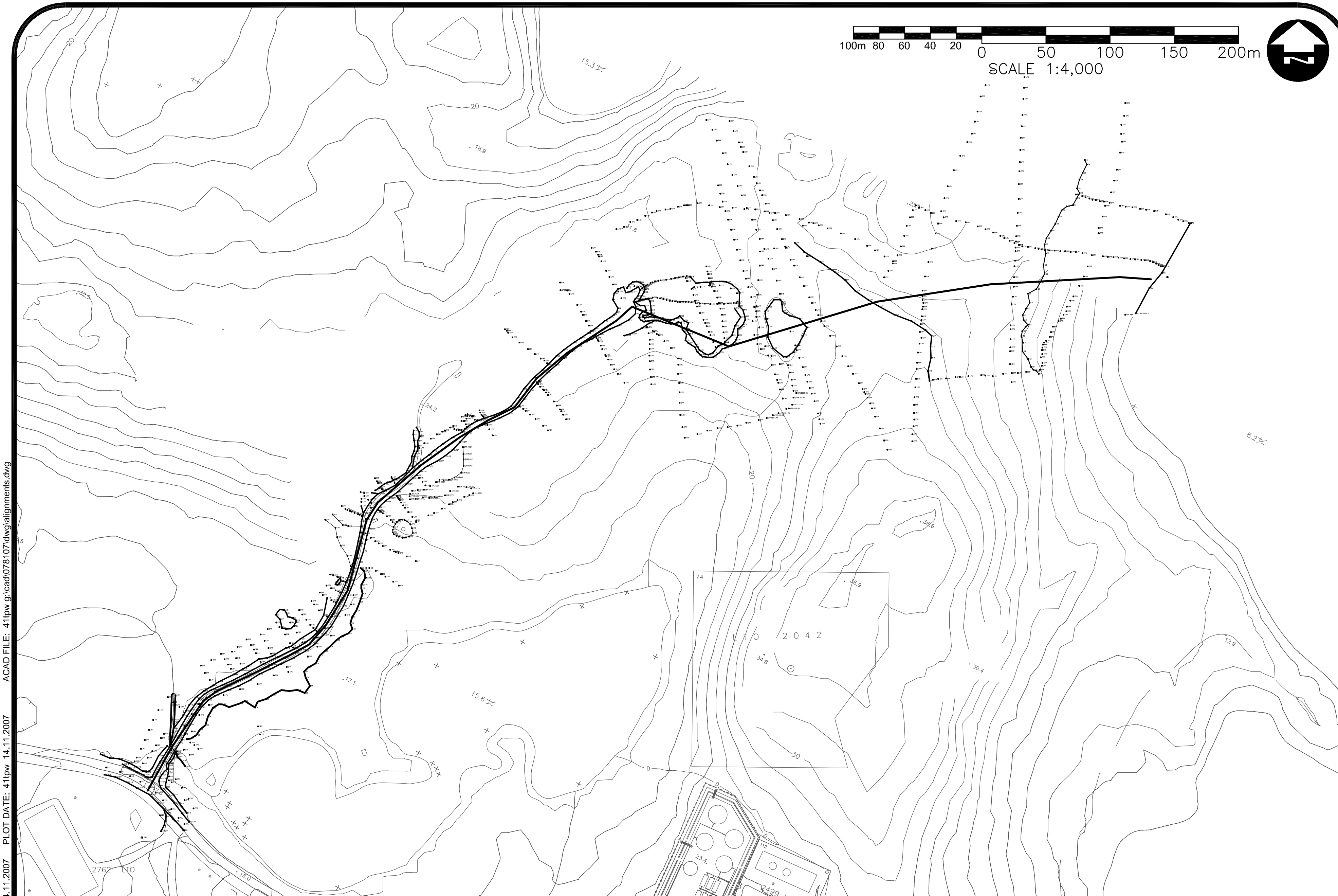
N
Canso Lake
Spence Bay
Long Lake
Water Lake
Taloyoak


N
Site 3
Site 2
Spence Bay
Site 1



Site 3
Site 2
Gravel Pit
Spence Bay
Site 1
N

N
Site 3
Site 2
Gravel Pit
Spence Bay
Site 1



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DILLON CONSULTING

PROJECT
Water System Design
Taloyoak, Nunavut

TITLE
Survey Results

PROJECT NUMBER 07-8107-1000

DATE Nov 2007

FIGURE NUMBER Figure 7

APPENDIX B

Terms of Reference

Request for Proposals

The Government of Nunavut (GN), Department of **Community and Government Services** is requesting Proposals from qualified consultants experienced in the design of potable water systems in the Arctic. This is a request for the provisions of consulting and design services as outlined below.

Table of Contents

Note: a CD accompanies this RFP contains all of the above and:

- NWT *Good Engineering Practices*
- Appendices to Dillon Report, including all available water quality analyses and *Guidelines for Canadian Drinking Water Quality (Turbidity)*
- Map of Taloyoak, pdf format

1. Standard Instructions to Proponents

1. Proposals must be received before *3.00 pm* local time on ***June 6, 2007*** at:

> Regional Director, Brent Boddy, Kitikmeot Region
> Government of Nunavut
> Community And Government Services
>
> Delivered to 2nd floor, Enokhok Building
> P.O. Bag 200, Cambridge Bay, NU, X0B 0C0
>
> In care of: Sudhir Jha, Project Officer
> Community and Government Services
> Telephone: ***(867)*** 983-4008 Fax: ***(867) 983-4124***

Proposals received after the exact time and date noted above will be rejected.

The original and **3** copies are to be submitted, quoting **"Taloyoak Water System Design: CGS Project No 04-4403 ."** on the outside of the envelope or package.

After the closing time, only the identity and addresses of the proponents will be posted.

2. The GN will not be responsible for any proposal that
   - does not indicate the Request for Proposal reference, closing date and proposer's name;
   - is delivered to any address other than that provided above.

3. Electronically-submitted proposals will be accepted under the following conditions:
   - the proposal is received before the submission at the e-mail address provided (note that the GN server transmits attachments 2 MB or less instantly, but all attachments greater than 2 MB are transmitted over night)
   - the GN will not accept liability for any claim, demand, or other actions for any reason should the e-mail transmission be returned, not received in its entirety (or at all), received after stated closing time and date, sent to a different address other than that stated herein, attachments contain corrupted information or viruses and are filtered out by the GN server, attachments are submitted in a format other than Adobe .pdf, or for any other reasons
   - the proposer shall submit an original proposal and **3 (three)** copies of the proposal to the address stated herein immediately following sending the e–mail transmission
   - the GN cannot guarantee the complete confidentiality of information contained in the proposal received by facsimile

4. Facsimile transmitted proposals will be accepted under the following conditions:

   - the proposal is received before the submission deadline at the facsimile number stated;
   - the GN will not accept liability for any claim, demand or other actions for any reason should a facsimile transmission be interrupted, not received in its entirety, received after stated closing time and date, received by any other facsimile unit other than that stated herein, or for any other reasons;
   - the GN cannot guarantee the complete confidentiality of information contained in the proposal received by facsimile;
   - it is understood that the GN is not allowed to comment on the completeness of the submission, or offer any other opinion other than to state, upon inquiry by the proposer, that a submission has been received
   - the proposer shall submit an original proposal and **3 (threes)** copies to the address stated herein immediately following the transmission of the facsimile.

5. All questions or enquiries concerning this Request for Proposals must be in writing and be submitted to the address provided above no later than five (**5**) calendar days prior to the proposal deadline. Verbal responses to any enquiry cannot be relied upon and are not binding on either party. The GN contact for this project is:

Sudhir Jha, M.Eng, Project Officer
Community and Government Services
Cambridge Bay, NU, X0B 0C0

Phone no: (867)983-4008
Fax no: (867)983-4123
E- mail: sjha@gov.nu.ca

6. This is not a Request for Tenders or otherwise an offer. The GN is not bound to accept either the proposal which provides for the lowest cost or price to the GN, or any proposal of those submitted.

7. If a contract is to be awarded as a result of this request for proposals, it will be awarded to the proposer who is responsible and whose proposal provides the best potential value to the GN. Responsible means the capability in all respects to perform fully the contract requirements and the integrity and reliability to assure performance of the contract obligations.

8. Notice in writing to a proposer and the subsequent execution of a written agreement shall constitute the making of a contract. No proposer will acquire any legal or equitable rights or privileges whatever until the contract is signed.

9. The contract will be in the form of the standard "GN Architectural/Engineering Services Agreement" and it will contain the relevant provisions of this Request for Proposals, the accepted proposal as well as such other terms as may be mutually agreed upon, whether arising from the accepted proposal or as a result of any negotiations prior or subsequent thereto. The GN reserves the right to negotiate modifications with any proposer who has submitted a proposal.

10. In the event of any inconsistency between this Request for Proposal, and the ensuing contract, the contract shall govern.

11. The GN has the right to cancel this Request for Proposals at any time and to reissue it for any reason whatsoever, without incurring any liability and no proposer will have any claim against the GN as a consequence.

12. Any amendments made by the GN to the Request for Proposals will be issued in writing and sent to all who have received the documents.

12. The GN is not liable for any costs of preparation or presentation of proposals.

13. An evaluation committee will review each proposal. The GN reserves the exclusive right to determine the qualitative aspects of all proposals relative to the evaluation criteria.

14. Proposers may not amend their proposal after the closing date and time but may withdraw their proposal at any time prior to acceptance.

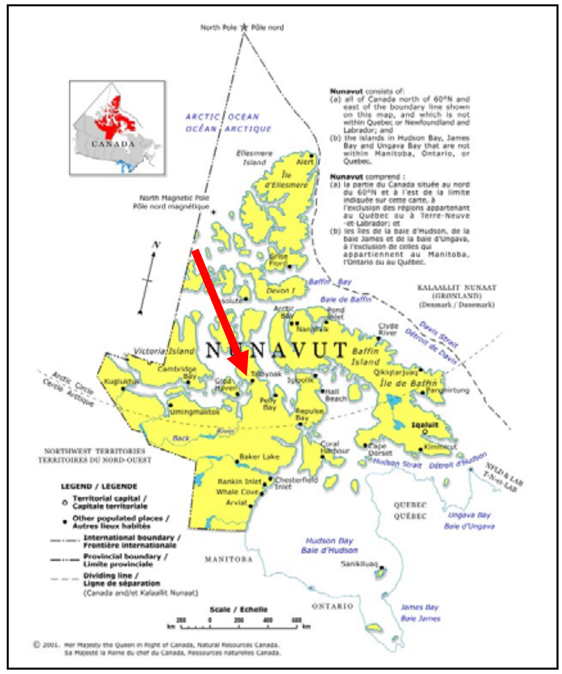
15. Proposals will be evaluated as soon as practicable after the closing time. No detail of any proposal will be made public except the names of all parties submitting proposals.

16. Provisions of the Government of Nunavut Nunavummi Nangminiqaqtunik Ikajuuti (NNI) Policy will be applied in the evaluation of all proposals.

17. The proposal and accompanying documentation submitted by the proposers are the property of the GN and will not be returned.

2. Terms of Reference

The consultant will work in collaboration with the Regional Municipal Planning Engineer and the Project Officer, who will together provide a range of design, engineering, and site management services for the Hamlet of Taloyoak. In addition, the consultant will work closely with hamlet staff (in particular with the water treatment plant foreman and the SAO) and hamlet council, keeping them informed and part of the design team through strategic presentations, consultations, and communications.



The proposal must demonstrate that the design work will utilize appropriate technology and must be shown to provide simple, cost-effective solutions.

Much of the background design information for this RFP will be found in the report by Dillon Consulting. This report, along with the notes given herein, will be the basis for engineering design. It is important to note that since the Dillon report was received, some changes have occurred in the GN's approach. These changes are outlined in the paragraphs below.

2.1 INTRODUCTION

Taloyoak, formerly known as Spence Bay until July 1992, is located at 69° 32' North Latitude, and 93° 31' West Longitude. It rests at 26 m above sea level on thee Boothia Peninsula at the foot of a series of rocky hills on the shores of a small body of water known as Stanners Harbour. Taloyoak is the northernmost community on the Canadian mainland. The word Taloyoak means "large caribou blind" in Inuktitut, one of the two languages spoken in the community. As of the 2006 census, the population was 809, a 12% increase from five years before.The distance from Taloyoak to Cambridge Bay is 460 km to the West, and to Yellowknife is 1224 km to the Southwest.

"Bedrock terrain, weathered bedrock hills, outcrops, boulder fields, lakes, streams and small valleys are all common. Taloyoak is within the zone of continuous permafrost and is covered with a thin layer of tundra vegetation. Lichens, mosses, willows and wildflowers grow despite poor soil quality. Poorly-drained depressions support some grasses. The wildlife consists of ground squirrels, lemmings, weasels, arctic hares, arctic foxes, ringed seals, and numerous bird and fish species.

"Taloyoak's climate is typical of far northern regions and thus receives an average of 6.5 cm of rainfall and 103 cm of snowfall per year, accumulating to a mean annual precipitation of 18.1 cm. July mean high and low temperatures are 11.5° C and 3.2° C and January mean high and low temperatures are -29.7° C and -39.3° C, respectively. Winds are generally from the east and southeast.

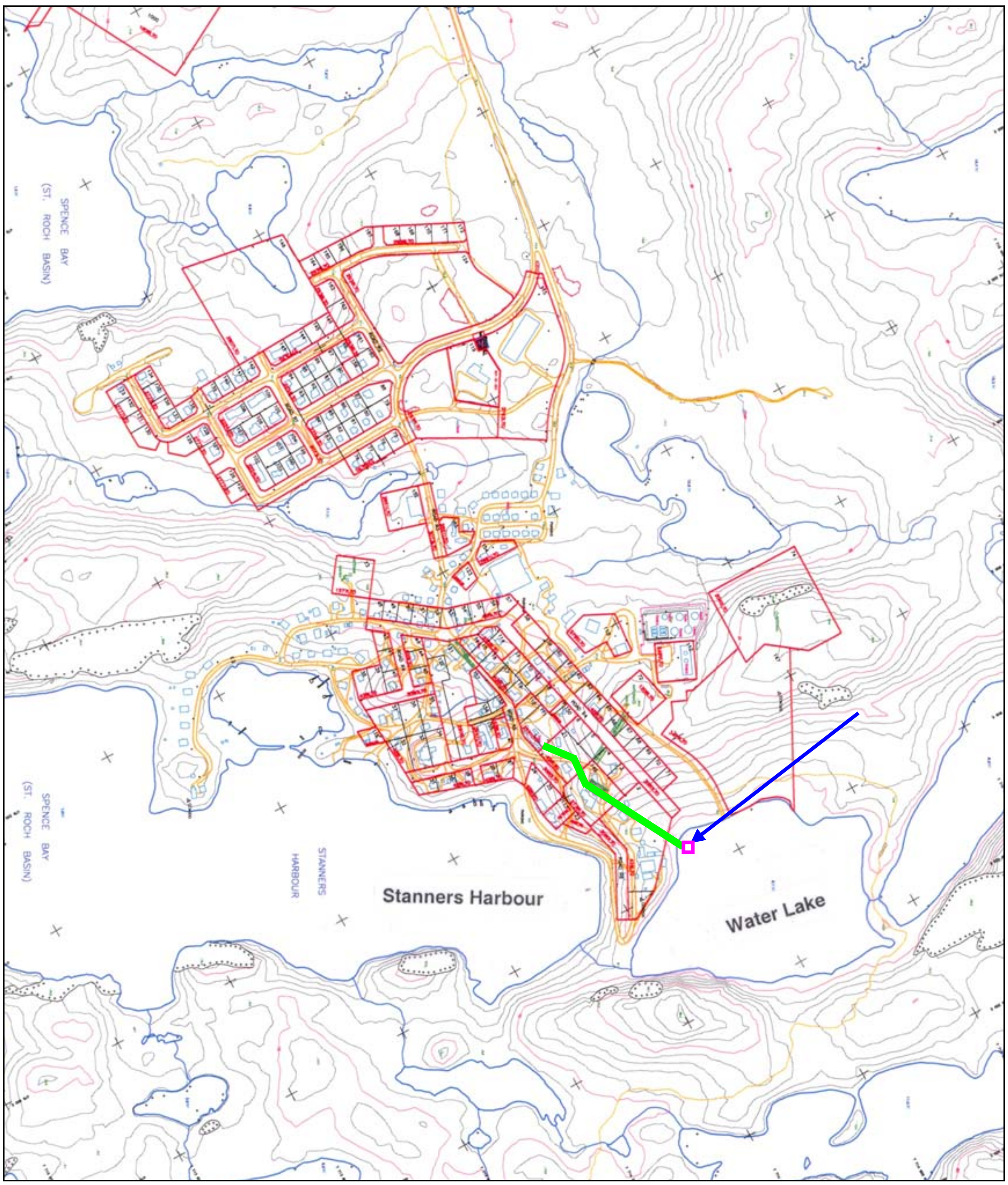
"Accessibility is limited to aircraft year long and barge in the summer."[1] See map on page 13

1 *Phase III Environmental Assessment – Bulk Fuel Storage Facility: Taloyoak,* Feb, 2001, Dillon Consulting p. 2

2.2 BACKGROUND and DISCUSSION

2.2.1 Description of the system as it exists now

The community draws its water via an intake pump extending from a small pumphouse located on a submerged concrete pad that extends out into Water Lake (see the map below). The water is pumped uphill to a junction in what was the old health centre (now the Boothia Inn) through a pipe that is housed in a metal elevated and insulated utilidor. From there it travels, partially submerged, downhill to tanks at the water treatment plant which is located in town, and is part of a complex attached to the power corporation's generating station. The map below shows the water line (light green), and the blue arrow points to the intake pumphouse in the lake.



As can be seen, the hamlet is extremely close to Water Lake. Although so far this has not seemed to cause any health problems, it is a continuing concern. There are a number of buildings located near the shores of the Lake. The Northern Store is one of them. In the winter of 2005 the sewage tank located underneath the store leaked a great deal of sewage. Luckily, the sewage remained frozen long enough for hamlet crews to remove it to the sewage lagoon. In addition, since the store is located somewhat downstream from the intake pipe, any plume of pollution is likely to flow towards the harbour. As the community continues to grow, the chances of polluting Water Lake will only increase.

2.2.2 Preliminary approach by the GN:

Although we expect that the following approaches will be modified through discussions with the successful consultant using the introduction of new data or innovative technological advancements, the GN's present approach has, and will remain to have, one key philosophy: to use appropriate engineering and relatively simple technologies – technologies that are capable of being operated easily (without the need for a great deal of training or certification[2]) and that do not require either expensive or hard-to-acquire components or replacement parts. Durability is also essential, as is being able to function in the harsh environment of the arctic.

Funding: This project has been identified as being eligible for Federal Gas Tax funding. For more information see the website: http://www.infrastructure.gc.ca/communities-collectivites/agreements-ententes/gas-essence_tax/gt_can_nu_e.shtml

2.3 SCOPE OF WORK:

2.3.1 Location of New Water Source

For the reasons explained in Section 2.2.1, it has become necessary to locate a new water source for the community. This has not been indicated in the Dillon Report because the GN did not, at the time, feel this was a necessary condition. At present there are two possibilities for a new water source (though others may be identified). The first is the northern continuation of Water Lake, connected to the present reservoir by a small stream. This can be clearly seen on the map above, the lake to the immediate right (North) of Water Lake. If this lake is chosen, it may be desirable to locate the new facilities as far from any habitations or infrastructure as possible – at the northern-most end of the lake. The second possibility is Long Lake, a body of water that is to the east of the community. This is much further away, and is not the preferred choice. Whatever body of water is chosen, in designing the new system, precautions must be taken to minimize the effects of potential pollutants reaching the reservoir. The sampling program as discussed in the Dillon Report is a necessary first step in determining the suitability of the water quality. The 2006 Summary Table of the Guidelines for Canadian Drinking Water Quality is included as an Appendix of this RFP.

2 Although for the foreseeable future there is no certification program for water treatment plant operators in Nunavut, it is imperative that hamlet personnel receive the appropriate training for the kind of facility they are hired to operate. If it is necessary to design a WTP that in other jurisdictions is a Class 2 plant, then an appropriate training program must be designed to upgrade the WTP operators so they are able to successfully and properly operate the plant. The consultant will, as part of this proposal, provide the necessary training.

2.3.1.1 Topographical, Geotechnical, and Bathymetric Investigations: Once the new source has been identified, a location study for the new intake pumphouse, truck turnaround, and water treatment plant will be undertaken. A road from the hamlet to the new location will need to be surveyed and designed. These requirements involve a certain amount of geotechnical investigation. As well, once the location study for the new facilities has been completed, a bathymetric study of the lake bed profile should be undertaken so that the correct location of the intakes can be chosen. It is probably better to perform this bathymetry in the summer months with a weighted line from a boat (and not from the ice surface, as the Dillon report states on p. 17). Note that at present the GN has no information on the depth of this northern extension of Water Lake.

2.3.2 New Intake, Intake Pump House (IPH), and Water Treatment Plant (WTP)

The design of these new facilities will involve meeting the community's potable and fire water needs for at least the next 25 years (to 2032). It will be necessary to take into consideration the expected increase in activity due to mining, exploration, and tourism. In addition, it is required to work with CGS Planning Department to ensure that the hamlet will not encroach on areas near the new water source in the future. This may involve further topographical surveys to ascertain overland flow patterns which may lead to pollution in the future, as well as runoff diversion strategies.

The GNWT MACA standard for water demand is based on an 8-hour water plant operation, 5 days per week. The equation is:

$EV_{design\ year} = PDD_{design\ year}$ – Avg system production in an 8-hr day

Where:

$EV_{design\ year}$= Equalization Volume in the design year horizon

$PDD_{design\ year} = PDF \times TDF \times ADD_{design\ year}$

$PDD_{design\ yhear}$=Peak Day Demand in the design year

PDF = Peak Day Factor = 1.5

TDF = Truck Delivery Factor = 7/5 based on water delivery 5 days per week

$ADD_{design\ year}$= Average Daily Demand in the design year

The Dillon report recommends that in-town water storage facilities be built only if the water source is more than 3.5 km from the community, or if the loading rate is less than 1000 L/min.[3] There may also be some merit in using one of the old existing in-town tanks for fire water requirements, modifying the system to allow trucks to pump water into the tanks when required. The successful consultant will determine through consultations with the Nunavut Fire Marshall's office, and by good engineering practice how much water must be held in reserve at the 10 and 25 year design horizons.

At this stage, a piped system from source to town is not being considered. Systems like this in the past have proven costly to design, build, and operate, and have been fraught with break-down and freeze-up problems. In addition, a trucked system adds employment dollars directly to community residents because operators of water trucks and road maintenance crews are required. If any piped system were to be considered, it should be both above-ground and internally accessible.

Thus, the simplest water system, involving the least maintenance and monitoring, consists of a water treatment plant with fill arm located at the water source. This will involve a new access

3 p. 3

road with turn-around area for hamlet water trucks, pumper fire trucks (unless fire water storage is located in town) and fuel delivery vehicles.

The accompanying report by Dillon Consulting includes many system characteristics in Section 4 (pp. 15-30). Note that the report has had comments added to it at various places by GN staff. The bulleted list below is in addition to this report.

- Walls, floor, and ceiling of the WTP must be built to high modern standards of energy efficiency that are the norm for arctic conditions. Such features as super-insulation, air-tightness, and natural light are essential. Heating the building is required, of course, but its size will be minimal if the building is sufficiently energy-efficient.

- Redundancy in intake pumps (i.e.: two intakes and two pumps), each automatically draining back to the lake at the end of their pumping cycle (no check valves).

- Backwash system capable of providing high flow for periodic removal of sediments from the line.

- The type of chlorine disinfection system (Calcium Hypochlorite vs Sodium Hypochlorite) found in the Dillon Report will be discussed.

- Digital Data Control (DDC) system that will sense, monitor, trend, and operate control points as may be required. This system must be Siemens-compatible and have remote monitoring and control capability through a standard IBM- compatible computer. Provision for a second CPU will be made in case the primary CPU is sent out for repairs.

- Controllers for electrical heat trace cables, and alarms should the heat trace fail. Capability of remote monitoring is desirable.

- Phone (or effective mobile radio).

- Fill arm, pump, and chlorinator pump. Exterior light sufficient for truck filling. This must be caged to protect from accidental damage.

- Adequate power supply and back-up generator with its own dedicated fuel supply (tanks with double walls and spill containment (redundant sytem) and proper isolation from the main part of the building).

- Sufficient room to store a spare pump, as well as chlorine, cleaning supplies, and other essential spares.

2.3.3 Other Requirements

O&M Manuals: The successful engineering company will work with the Regional Engineer, the Project Officer, and the hamlet WTP staff to create new O&M manual for the system. These manuals will, in addition to containing up-to-date technical literature produced by component manufacturers, contain the following:

- Complete schematic drawings and any other systems that are deemed useful to understanding how the system works. These drawings will be completely labelled with numbers/letters correlating to tags on the actual component..
- A plain-language introduction to the operations of each of these systems.
- A series of tables showing vital system checks – checks that are necessary to keep all aspects of the water system from failure. Included in this will be information on the correct temperatures and pressures at various points in the system, along with specific procedures to take in case of emergencies.
- A series of Maintenance Schedule tables organized by: daily maintenance, weekly maintenance, monthly, semi-annually, annually, and other times as needed. These, too, will have reference to the label letter/numbers as needed. These tables will be able to be photocopied and will contain columns for maintainers' initials and dates of maintenance, plus a place for comments.
- A series of Component Testing Schedule tables, whereby each component that is subject to wear-and-tear can be isolated and tested on a regular basis. For example, a relief valve should be tested for proper operation periodically or there is a great risk it will fail to open when it is required.
- Corresponding to the Maintenance Schedule tables and Component Testing Schedule tables will be specific methodologies on how to maintain and test each component.
- The schematic drawings will be reproduced in large format and will be mounted behind plexiglass in the WTP, and any other place that is appropriate.
- Label with either brass or durable plastic each component (pump, valve, etc). The label numbers/letters will correspond to those on the schematic drawings.

On-going training for WTP operators: The successful consultant will advise the GN on training options. This may include on-site presence for periods of one or two weeks per month for the first six months to one year of operation of the new system.

Requests for Tenders: The successful engineering company will perform all necessary designs, drawings, and specifications to enable one or more requests for construction tenders (RFT) to be issued for the issues discussed above. Furthermore, the successful firm will write the RFT(s), to be reviewed by the CGS team and subsequently delivered to hamlet staff for further possible input. Included in each RFT will be a **detailed, clearly written description (plain language) of the work required**, as well as detailed drawings and the usual contract sections.

Water License: The Hamlet does not have an up-to-date water license. See Section 2.5.4 below.

Assured water supply: In addition, it must be made absolutely clear that at no time will it be allowed to jeopardize the continued supply of adequate and safe drinking water (as well as fire water reserves) to the community. The engineering design must reflect this basic requirement, as must the RFT, construction specification, and drawings.

Decommissioning and Removal of the existing water system is also required (or those components that are no longer required).

Important Note: No consideration will be allowed for increasing the contract price after contract award due to any failure by the consultant to completely familiarize himself/herself with any requirements of this request for proposals. Should there be any questions prior to RFP closing, they may be addressed to either the Project Officer or to the Regional Engineer.

2.4 Project Identification:

Name: Taloyoak Water System Upgrades
Project Number 04-4403
Location: Taloyoak, Nunavut
Client: Department of Community and Government Services (CGS)

2.4.1 Project Personnel:

The primary contacts for this project are:

Sudhir Jha, M.Eng, Project Officer
Community and Government Services
Cambridge Bay, Nunavut, X0B 0C0
Phone: 867-983-4008
Fax: 867-983-4123
e-mail: sjha@gov.nu.ca

- **Thomas G. Livingston**, P.Eng
  Regional Municipal Planning Engineer
  Community and Government Services
  Cambridge Bay, Nunavut, X0B 0C0eP
  Phone: 867-983-4156
  Fax: 867-983-4123
  e-mail: tlivingston@gov.nu.ca

2.5 : Project Schedule and Deliverables

2.5.1 The Architectural and Engineering Services shall be delivered as described in Section E of the Standard GN Architectural / Engineering Services Agreement and modified as follows. The consultant shall provide the GN with:

- three electronic copies (CD) of all drawings (AutoCAD 2005) and specifications (MS Word format), with complete read/write access. (The GN will provide those topographical AutoCAD community maps in the possession of the Regional Engineer. However, if better maps are required, the consultant will be required to provide updated contour maps.)
- all submissions also in Adobe .pdf format for review by CGS Technical Services Division
- “as-built” electronic drawings (AutoCAD 2005) from marked up white prints produced by the construction contractor.
- commissioning services as follows:
  1. Mechanical
  2. Electrical
  3. Instrumentation and Digital Control

- site survey as required for considerations of layout and design, including soil mechanics lab analyses, geo-technical investigation as required for structural and civil works, and topographical and bathymetric surveys, if required.
- documents labeled "**Issued for Tender, Not for Construction**", at the tender stage.
- after Tender Close, and prior to contract award, modified tender documents incorporating all addenda, labeling the documents "**Issued for Construction**".
- all details shown on project documents cross-referenced to note detail number, originating location and location shown.
- all tender documents for construction, completed and available for tender on the 21st of January, 2008
- Environmental Assessment studies or reports, as required
- brief report regarding options explored, along with Class D estimates for each
- all engineering services necessary to determine viable solutions to the issues discussed in the Terms of Reference and Scope of Work above. All relevant calculations, spreadsheets (in MS Excel format), and equations supporting these proposed solutions and designs will also be provided to the GN so that the CGS Project team is fully informed.
- clear information about which authorities having jurisdiction should be approached for permits or approval for any of the work entailed. These will consist of, but not be limited to, the hamlet council, Nunavut Environment Impact Review Board (NIRB), Nunavut Water Board (NWB), Nunavut Planning Commission, GN Environmental Protection, Canadian Department of Fisheries and Oceans (DFO), and Indian and Northern Affairs Canada. Furthermore, the consultant will be responsible for all regulatory submissions and compliance to accepted standards and practices, including new standards that are expected to be applied.

In addition, the consultant will be responsible for making presentations to hamlet councils, mayors, and staff regarding the various options being considered, on an as-needed basis.

2.5.2 Existing Water Quality Analyses:

All proposers are being given copies of all water quality analyses available. They are located in the Appendix of the Dillon Report on the CD accompanying this RFP

2.5.3 Local employment and training potential:

The consultant and contractor(s) will be encouraged to use local labour as much as possible. Where training opportunities for Nunavummiut exist, these too will be pursued. NNI minimum standards will be referenced.

2.5.4 Water License through the Nunavut Water Board

The successful consultant will be responsible for applying for the water license. To aid this process, CGS will obtain a letter from the hamlet of Taloyoak giving permission for CGS to act on the Hamlet's behalf in matters pertaining to the NWB. All correspondence to the NWB will subsequently originate with CGS. The successful consultant will be responsible for doing all that is required to apply for a new water license, and will devote whatever time is necessary to carry the application through to a successful conclusion. Although this may include several iterations and a series of long questions to be answered for the NWB, the consultant will provide sufficient budget for this process. The NWB will require one submission with any back-up documentation and studies that may be necessary. This submission must contain no inconsistencies, gaps, or contradictions. It must also be written in such a way as to make it clear to any member of the public who reads it during the review process that the applied science behind the designs is both comprehensible and comprehensive. This implies that the consultant will provide a full engineering rationale for each issue, including citing relevant engineering precedents, models, equations, or studies by acknowledged experts.

2.5.5 Site Visits,:

The successful consultant will provide sufficient time and budget to carry out all necessary site investigations, including airfare, room and board, geotechnical, river bathymetric cross-sectional analyses, salinity data collection, ice and wind studies, reading of available studies and will provide other on-site analyses as needed, equipment rental, and ancillary expenses including. The consultant will also be aware of the following needs.

- On-going discussions with RMPE and hamlet mayor, Council, SAO, and hamlet staff
- Rental of necessary equipment
- Sample jars to for analyses via air freight
- Bathymetric, topographical, geotechnical, and water quality studies deemed necessary

2.5.6 Project Delivery:

It is expected that this project will be delivered through the standard tendering procedure. The Project Officer of Community Government and Services will be responsible for managing the project through the stages of the investigation. CGS Technical Services in Iqaluit may provide assistance. The Project Officer will be the lead contact within the GN, and it is to him that the consultant reports. The RMPE is responsible for providing over-all program information and direction, and taking part in design and subsequent review of all design submissions. The RMPE must approve any modifications to the program contained within this Request for Proposal prior to implementation of these changes.

2.5.7 Past Relevant Experience and Methodology:

Provide a short list of projects in which the Consultant and Sub-Consultant have performed similar work. The outline of experience should indicate how schedules were met and how final costs compared with estimates. References for substantiation are to be provided. The successful proposer must provide information showing all areas of required expertise are present on the engineering team.

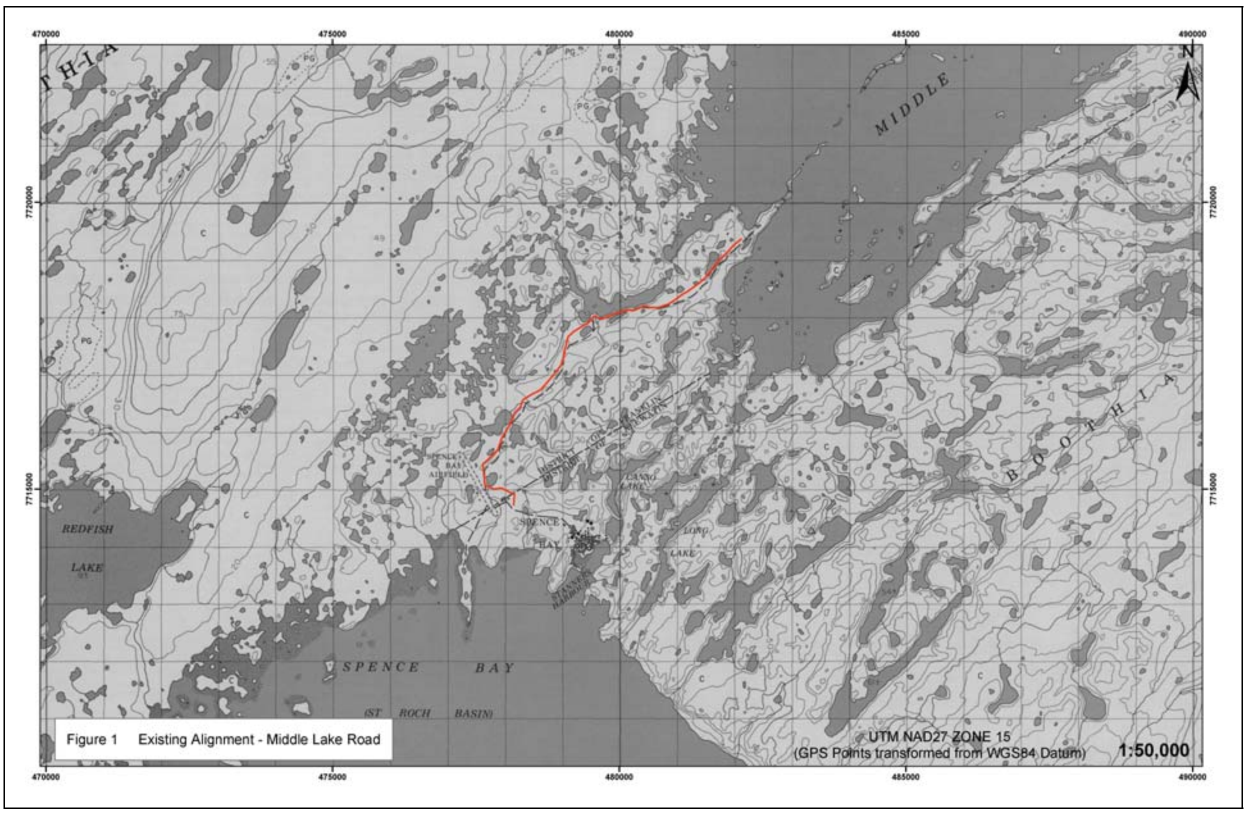
In addition, all proposers will provide a clear outline of their ideas and methodologies proposed to provide solutions for each of the issues discussed in the Terms of Reference and Scope of Work above.

2.5.8 Target Schedule:

Note: Periodic review meetings will be held, with the Consultant and GN representatives present. Location of meeting will be dependent on the phase, and will be either in Cambridge bay, on site, the consultant's offices, or via teleconference.

June 6, 2007	RFP close
June 13, 2007	Consultant Contract award
June 15, 2007	Start-up teleconference

July 3, 2007	Preliminary Report outlining design directions, providing recommendations and proposed design parameters.
July 10, 2007	The GN will review and amend the Preliminary Report as required, will make recommendations for change, and will authorize the Consultant to proceed to Design Development Phase
July, 2007	Site visits, investigations, water analyses, bathymetric survey, other surveys, etc.
August, September, 2007	Further on-site investigations as needed, consultations with Hamlet staff, CGS team
September 24, 2007	Development of design, including a class “C” estimate (consultant)
October 1, 2007	GN review of design development complete
November 12, 2007	50% construction tender specifications and drawings including submission of a class “A” estimate.
December 10, 2007	90% construction tender specifications and drawings
January 21, 2008	Tender documents ready to be sent to contractors
April 2, 2008	Construction tender award
Summer, 2008/09	On-site project services as required
Fall, Winter, Spring, 08/09	On-going training of staff at WTP
August, 2010	Warranty inspections



Taloyoak Area Map

3. Proposal Evaluation

3.1 Selection Methods
When an alternative is proposed regarding any specific requirement, it will be evaluated to ensure that the desired results will be achieved.

Proposers should be aware that certain mandatory requirements may have been set out in the Terms of Reference. Proposals that fail to provide these requirements will be deemed not responsive and will not be evaluated.

3.2 Rating

- The evaluation team will utilize specific criteria to rate each proposal. Ratings will be confidential and no details will be released to any of the other proposers.
- Each proposal will be evaluated using the standard "Architecture/Engineering Consultant Proposal Rating Schedule included as part of this proposal request." See Appendix "C"

3.3 Proposal Content
The following information should be provided in the proposal. This information will be utilised in evaluating each proposal submitted.

3.3.1 Project Team (Proposed Personnel)

- The proposer is to describe the capability of the resources proposed to meet the requirements described in the terms of reference.
- The proposal shall include brief resumes for the proposed sub consultants and project team members with a description indicating how, and in what ways the proposed resource satisfies the needs identified in the Request for Proposal.
- The proposer must demonstrate that the assembled team comprises, at the least, a qualified (experienced in Arctic water systems) hydraulics engineer, a soil mechanics engineer, a water quality expert, a structural engineer, an experienced water treatment engineer, a civil engineer qualified in Arctic water delivery systems, and an expert in river flow and river channel modelling.

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3.3.2 Methodology
Describe how the proposer intends to achieve the project's objectives. Demonstrate understanding of the work involved, design collaboration with the RMPE and PO, as well as with hamlet administration and Council, community input, budget schedule and other significant factors to be considered. It is expected that the methodology and schedule will demonstrate how the proponent will proceed and how much time each stage is expected to take.

3.3.4 Past Relevant Company Experience
Provide a list of projects in which the Consultant and Sub consultants have performed similar work.

3.3.5 Schedule
Indicate how closely the proponent's schedule meets the project requirements in a logical manner delivering a quality service.

3.3.6 Fees and Expenses

Prices bid must be stated in actual dollars and cents expressed in Canadian funds. The proposal must include cost information as follows (broken down according to each facility):

- A lump sum fee for preliminary design, design development, construction documents, bidding
- A lump sum for each of the following Construction Phase requirements (include an estimate for disbursements):
  1. 30 days resident engineer services
  2. 60 days discipline engineers / technicians / 3rd party inspectors for commissioning of project.
  3. 10 site inspection trips, from the consultants designated home office, for structural, mechanical, electrical, geotechnical, survey, instrumentation and civil sections.
  4. A minimum of 6 months training time for new water treatment systems, on the basis of one week on site per month, and on-call for the remainder of the month to answer operator questions

     Note: The number of days and trips listed above are an estimate based on our experience with similar projects and are meant to provide a consistent measure across all proposals. The actual numbers may differ and will be amended based on the Consultants published rates and per diems.

- The Consultant is to provide cost details, daily rate schedule and per diem rates for project team members for in and out of office services.
- Prices must be stated in actual dollars and cents expressed in Canadian funds.
- The Government of Nunavut will pay the Goods and Services Tax (GST); however, do not include GST in your proposed pricing.
- The proposal must include a total contract amount and a total estimated disbursement cost.
- An estimate of disbursements of non–field expenses such as telephones, facsimile, courier, copy, photographic, postage, computer and tender document printing costs. Assume 25 sets of tender documents for each tender.
- A lump sum for each of the Construction phase requirements (include an estimate for disbursements) as outlined above
- Cost details, daily rate schedule and per diem rates for project team members for in and out of office services.
- An estimated total contract amount
- Do not include GST in your proposed pricing. The Government of Nunavut will pay the Goods and Services Tax (GST).

Note: The number of days and trips listed above are an estimate based on our experience with similar projects and are meant to provide a consistent measure across all proposals. The actual numbers may be different and will be amended based on information as it becomes known.

3.3.7 Local and Nunavut Content

Identify the place of residence of each member of the team, his or her home office location and provide an estimate of the percentage of work that will be performed in Nunavut and the communities. Provide an estimate of the percentage of the total work for the project that will be completed by Nunavut businesses and businesses local in the subject community for the project.

3.3.8 Inuit Content

In compliance with Article 24 of the Nunavut Land Claim Agreement, the Government of Nunavut will provide consideration for the use of Inuit goods and services and labour. Proponents should describe fully the proposed Inuit content. This Inuit content will be the percentage of work for this project to be completed by Inuit firms listed on the registry of Inuit firms maintained by Nunavut Tunngavik (NTI), and the amount of Inuit employment created related to this project.

ACRONYMS and TERMS used in this RFP

C/BA	Cost-Benefit Analysis
CGS	Community and Government Services
CPU	Central Processing Unit (of a computer)
DDC	Digital Data Control
DFO	Department of Fisheries and Oceans (Federal)
DIAND	Department of Indian and Northern Development (part of INAC)
GTI	Gas Tax Initiative
INAC	Indian and Northern Affairs Canada
IPH	Intake Pump House
lpcd	Litres per capita per day
NIRB	Nunavut Impact Review Board
NWB	Nunavut Water Board
ntu	nephelometric turbidity unit
PO	Project Officer
RFP	Request for Proposals
RFT	Request for Tenders
RMPE	Regional Municipal Planning Engineer
RWU	Residential Water Use
SAO	Senior Administrative Officer of the hamlet
WPT	Water Treatment Plant

Appendix A: ARCHITECTURAL/ENGINEERINGCONSULTANT PROPOSAL RATING SCHEDULE

Item	Rating Criteria		Unit Points Awarded (A)	Assigned Weight (B)	Total Points (A) x (B) = (C)
1	Project Team – personnel Assigned/made available to project			20	
2	Methodology or approach proposed by the consultant			20	
3	Past Relevant Company Experience			10	
4	Project Schedule			10	
5	Project Budget Fees and Expenses			10	
6	Past Performance References/ Appraisals			10	
7	Location of Company and Team Relative to Project Site			5	
8	Inuit Content	Inuit Labour		10	
		Inuit Firms		5	
				SUB-TOTAL WEIGHTED SCORE (C):	

LOCAL/NUNAVUT BONUS POINTS

Nunavut
Businesses (C) __________ x (D) _________ x 7 % = _____________
Labour (C) __________ x (E) _________ x 7 % = _____________

Add the results of the above calculations for the **TOTAL NUNAVUT BONUS PONTS:**

Local
Businesses (C) _________ x (F)___________ x 1. 5 % = ___________
Labour (C) _________ x (G) __________ x 1. 5 % = ___________

Add the results of the above calculations for the **TOTAL LOCAL BONUS POINTS:**

PROPOSER ________ **TOTAL:**

Comments: ____.

Committee Member:____. **Date:**________________________.

LEGEND:	RATING POINTS:
A – Evaluation Points Awarded B – Weighting Factor C – Sub-Total Weighted Score (A times B) D - % of Work to be done be Registered Nunavut Businesses including Local E - % of Work to be done by Nunavut Residents including Local Residents F - % of Work to be done by Nunavut Businesses or Inuit Firms Local to the subject community G - % of Work to be done by Local Residents of the Subject Community Note: for Definitions of terms used in the Legend refer to the NNI Policy Definitions section.	Poor 1 - 3 points Fair 4 - 6 points Good 7 - 8 points Excellent 9 - 10 points

APPENDIX C

Minutes of Project Initiation Meeting

Date: July 6, 2007
Location: Teleconference (Cambridge Bay/Yellowknife)
Present: Sudhir Jha, M.Eng. P.Eng – CGS– Cambridge Bay
Tom Livingston, P. Eng. – CGS Cambridge Bay
Gary Strong, P. Eng – Dillon Consulting Ltd.
Distribution: All in attendance – Via E- mail
Dillon Project Team – Via E- mail

		Action By:
	Old Business	
	None	
	New Business	
1	The GN requested Dillon consulting to provide certificates of their insurance for general liability and professional liability to GN	Dillon
2	The Project representatives are; GN CGS – Sudhir Jha– Main project contact. GN CGS – Tom Livingston, Regional Municipal Engineer GN CGS – Cheryl Selig, Community Planner Dillon – Gary Strong	None
3	CGS will accompany the consultant for all site trips and investigations. Dillon is to provide adequate notification prior to any site visit. The first Site visit will also be attended by Tom Livingston. Tom will also be present during other site visits on an as-needed basis. The intake pump house location and road may require a formal land lease. Coordination with GCS Planning (Cheryl Selig) and Taloyoak Lands Officer as required	Dillon
4	The current GN budget contains funding for the full design. Funding for the construction is not yet entirely in place, depending on cost estimates. The project is eligible for Gas Tax funding.	INFO
5	The GN is in agreement with the approach as suggested in Dillon's proposal, including a thorough life cycle cost analysis of a trucked system vs other options.	INFO
6	GN requested to Dillon to provide revised schedule for this project	Dillon
7	Monthly reporting to be completed by e-mail	Dillon
8	Dillon is directed to communicate only to the SAO when communication with the community is required. GN will be keeping the SAO constantly informed of project status and concerns.	Dillon, GN
9	The TOR set out the criteria for the project. However, should Dillon feel that	Dillon

		Action By:
	alternatives to the options presented in the TOR would meet the project requirements, then Dillon is to make the client group aware of these options. Options are to be presented with pros and cons, and Dillon recommendations.	
10	As part of the tender documents, Dillon is to verify that all shop drawings and co-ordination drawings are reviewed and approved prior to the commencement of construction.	Dillon
11	Site survey, geotechnical investigation, and bathymetric work to be completed after the design brief has been approved by the community. The GN agrees that, due to the nature of the project, no further geotechnical investigation may be required for either IPH pad or road work	Dillon
12	Permit requirements- - Dionne Filiatrault, P. Eng. of the NWB - DFO is a concern. Dillon to provide advice on this regulator. - INAC as well will be kept informed by the GN	Dillon, GN
13	NWB process: This is under review. However, it is now understood that, in order to facilitate the up-dating of the existing water license (potable water portion), the following approaches are to be adopted: 1). Community consultations (open to all residents) are to be held each time the GN/Dillon team make presentations to SAO, Mayor and Council. To that end, posters (in Inuktitut and English) will be placed on community bulletin boards explaining the salient features of the project and identifying the GN representative (Sudhir Jha) as the contact person should there be any questions or concerns. This approach will parallel the same approach as the NWB public hearings, and will speed the license process. 2). NWB and INAC will be kept apprised by the GN of significant aspects of the project throughout the life of the design process. 3). Dillon will prepare the portion of the water license having to do with the water system and will work through the GN with the SAO to facilitate a new license. This may also involve further work for the sewage lagoon portion of the license.	INFO
14	Consultant invoices are to be issued directly through Project officer	INFO
15	A Class C estimate is required in late September, 2007 to allow for the appropriate budget adjustments in the GN capital planning process.	Dillon
16	Other Business	

These minutes were recorded by Gary Strong of Dillon Consulting Limited. Any errors or omissions should be reported to Dillon Consulting Limited immediately.

Water System Upgrades, Taloyoak
Government of Nunavut
Community and Government Services

DILLON CONSULTING

Minutes of Meeting

Project Team Meeting No. _1_

FILE NO.:	07-8107
DATE:	July 26, 2007
TIME:	11:00 am MDT
LOCATION:	Tele-conference
PRESENT:	Sudhir Jha, MIT, Project Officer, C&GS Tom Livingston, P. Eng Regional Engineer, C&GS Cheryl Selig, Community planner Steven King, Senior Administrative Officer Kevin Taylor, Hamlet of Taloyoak Corina Peach, MIT, Dillon Consulting Limited Gary Strong, P. Eng – Project Manager, Dillon Consulting Limited

Item	Discussion	Action By	Date Required
1	The proposed date of the community meeting is August 7, 2007. At this time, GS has another commitment, which maybe able to be moved.	All	August 6th.
2	The subject lake is called Canso Lake, not Lange Lake.	All	
3	The proposed sites should take into account the expansion of the community. If the selected site is too close to the community, then the community may eventually develop too close to the intake.	Info	
4	Site 3 maybe a difficult site due to the amount of rocky ground towards that site. The community will likely prefer site 2. Steven had pictures of the sites for reference. Sudhir to forward the pictures to Dillon	CGS	
5	The community will arrange a truck to get to the sites and a boat rental.	Steven King	August 7
6	Cheryl to check the land tenure of the proposed site and provide some direction of the land transfer process.	Cheryl Selig	August 6th.

Item	Discussion	Action By	Date Required
7	The question was raised about known constraints to any of the sites. There were none noted at the meeting, but this is an issue that will be raised with the council.	All	August 7th
8	The community currently uses a private contractor to deliver the water.	Info	
9	The requirement for fire protection water is to be addressed as part of the site selection process. If one or all of the options require in town fire protection water, then this needs to be known as part of the selection process.	Dillon	

These minutes were recorded by G Strong, P. Eng. Any errors or omissions should be reported to Dillon Consulting Limited within 10 days, at which time these minutes will be deemed correct.

Distribution:	Those present.

R:\PROJECTS\DRAFT\078107 Taloyoak Water\Task 1000\Minutes\Minutes Meeting #1.doc

APPENDIX D

Population Projections

Table 1: Population Growth Trend

Source: Statistics Canada

Year	Population	Growth Rate
1981	431	-
1985	452	4.9%
1986	540	19.5%
1988	540	0.0%
1991	580	7.4%
1996	648	11.7%
2001	720	11.1%
2006	809	12.4%
Average over 5 Years		9.6%
Average per Year		1.9%

Table 2: Population Projections

Source: Nunavut Bureau of Statistics

Year	Population	Growth Rate
2000	804	-
2005	904	12.4%
2010	1016	12.4%
2015	1147	12.9%
2020	1294	12.8%
Average over 5 Years		12.6%
Average per Year		2.5%

Table 3: Population Growth

Source: Nunavut Bureau of Statistics, March 2000

Assumptions

Domestic Water Demand (W/WW Survey) 100 Lcpd

Peak Day Factor, PDF 1.5

Truck Delivery Factor, TDF 1.4

Year	Population Growth	Percent Growth Rate (%)
2000	804	-
2001	825	2.6%
2002	847	2.7%
2003	866	2.2%
2004	886	2.3%
2005	904	2.0%
2006	925	2.3%
2007	947	2.4%
2008	968	2.2%
2009	992	2.5%
2010	1016	2.4%
2011	1039	2.3%
2012	1065	2.5%
2013	1094	2.7%
2014	1119	2.3%
2015	1147	2.5%
2016	1179	2.8%
2017	1209	2.5%
2018	1236	2.2%
2019	1265	2.3%
2020	1294	2.3%
Average		2.4%

Table 4: Water Consumption Rates and Demands

Population Growth Rate 2.4%

Year	Population based on Growth Rate	Water Consumption Rate (Litres per capita per day)			Water Day Demand (L per day)		
		Average	Peak w/o TDF	Peak w/ TDF	Average	Peak w/o TDF	Peak w/ TDF
2000	804	118.5	177.7	248.8	95,268	142,901	200,062
2001	825	119.0	178.5	249.8	98,154	147,232	206,124
2002	847	119.5	179.2	250.9	101,200	151,801	212,521
2003	866	119.9	179.9	251.8	103,849	155,773	218,083
2004	886	120.4	180.6	252.8	106,655	159,982	223,975
2005	904	120.8	181.2	253.7	109,196	163,794	229,312
2006	925	121.3	181.9	254.7	112,179	168,269	235,577
2007	947	121.8	182.7	255.7	115,327	172,990	242,186
2008	968	122.3	183.4	256.8	118,352	177,527	248,538
2009	992	122.8	184.2	257.9	121,833	182,750	255,850
2010	1016	123.4	185.1	259.1	125,342	188,013	263,218
2011	1039	123.9	185.8	260.2	128,729	193,093	270,331
2012	1065	124.5	186.7	261.4	132,587	198,881	278,433
2013	1094	125.2	187.7	262.8	136,927	205,391	287,547
2014	1119	125.7	188.6	264.0	140,700	211,050	295,469
2015	1147	126.4	189.6	265.4	144,959	217,439	304,414
2016	1179	127.1	190.7	266.9	149,871	224,806	314,729
2017	1209	127.8	191.7	268.4	154,519	231,778	324,489
2018	1236	128.4	192.6	269.7	158,737	238,106	333,348
2019	1265	129.1	193.6	271.1	163,305	244,958	342,941
2020	1294	129.8	194.6	272.5	167,912	251,868	352,615
2021	1325	130.5	195.7	274.0	172,888	259,333	363,066
2022	1357	131.2	196.8	275.5	178,030	267,045	373,863
2023	1389	132.0	197.9	277.1	183,344	275,015	385,021
2024	1423	132.7	199.1	278.7	188,835	283,252	396,553
2025	1457	133.5	200.3	280.4	194,511	291,767	408,474
2026	1492	134.3	201.5	282.1	200,379	300,569	420,797
2027	1528	135.1	202.7	283.8	206,446	309,670	433,538
2028	1564	136.0	204.0	285.6	212,720	319,081	446,713
2029	1602	136.8	205.3	287.4	219,209	328,813	460,339
2030	1640	137.7	206.6	289.2	225,920	338,881	474,433
2031	1680	138.6	207.9	291.1	232,863	349,295	489,013
2032	1720	139.6	209.3	293.1	240,047	360,070	504,099
2033	1761	140.5	210.8	295.1	247,480	371,221	519,709

APPENDIX E

Water Quality Data

Maxxam Analytics Inc

Your P.O. #: 07 8107
Your Project #: TALOYOAK WTP
Site:TALOYOAK
Your C.O.C. #: 116738

Attention: CORINA PEACH
DILLON CONSULTING LTD.
BOX 1409 SUITE 303, 4920-47ST
YELLOWKNIFE, NT
CANADA X1A ZP1

Report Date: 2007/08/17

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: A736574
Received: 2007/08/10, 10:24

Sample Matrix: Water
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Alkalinity - Water	2	2007/08/13	2007/08/13	EENVSOP-00054 V.1	SM 2320
Cadmium - low level CCME Aquatic	2	2007/08/15	2007/08/15	EENVSOP-00123 v2	EPA 6020A
Chloride (IC)	2	N/A	2007/08/14	EENVSOP-00055 v3	SM 4110B
Str. Acid Diss. Cyanide water	2	N/A	2007/08/10	EENVSOP-00062 V.1	EPA SW-846 9012A
True Colour	2	2007/08/16	2007/08/16	EENVSOP-00065 V.1	SM 2120B
Total Coliforms and E.Coli (1)	2	2007/08/10	2007/08/10	EDM SOP-0013	MPN
Conductance - water	2	N/A	2007/08/13	EENVSOP-00054 V.1	SM 2510B
Hardness	2	N/A	2007/08/14		
Elements by ICP - Dissolved	2	N/A	2007/08/13	EENVSOP-00034	EPA 6010C
Elements by ICP - Total	2	N/A	2007/08/15	EENVSOP-00034	EPA 6010C
Elements by ICPMS - Total	2	N/A	2007/08/15	EENVSOP-00123	EPA 6020A
Ion Balance	2	N/A	2007/08/15		
Nitrite (NO2) BY IC-EC	2	N/A	2007/08/14	EENVSOP-00055 v3	SM 4110B
Nitrate + Nitrite-N (calculated)	2	2007/08/13	2007/08/15		
Nitrate (NO3) BY IC-EC	2	N/A	2007/08/14	EENVSOP-00055 v3	SM 4110 B
pH Water	2	N/A	2007/08/13	EENVSOP-00054 v1	SM 4500H
Sulphate (SO4)	2	N/A	2007/08/14	EENVSOP-00055 v3	SM 4110B
Total Dissolved Solids (Calculated)	2	N/A	2007/08/15	CAL SOP-00086, EDM SOP-00037	Calculation
Trihalomethanes in Water by P&T GC/MS	2	N/A	2007/08/16	EENVSOP-00003v4	EPA 8260C
Carbon (Total Organic)	2	N/A	2007/08/16	EENVSOP-00060 v2	SM 5310C
Total Phosphate (2)	2	N/A	2007/08/15	CAL SOP-00078	SM - 4500-P B & 4500
Total Suspended Solids	2	N/A	2007/08/16	EENVSOP-00073 v2	SM 2540 D
Turbidity	2	N/A	2007/08/16	EENVSOP-00066 v2	SM 2130B

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) This test was performed by Maxxam Edmonton Industrial
(2) This test was performed by Maxxam Calgary

../2

Your P.O. #: 07 8107
Your Project #: TALOYOAK WTP
Site:TALOYOAK
Your C.O.C. #: 116738

Attention: CORINA PEACH
DILLON CONSULTING LTD.
BOX 1409 SUITE 303, 4920-47ST
YELLOWKNIFE, NT
CANADA X1A ZP1

Report Date: 2007/08/17

CERTIFICATE OF ANALYSIS

-2-

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

JEREMY WAKARUK, B.Sc., Senior Project Manager
Email: jwakaruk@maxxamanalytics.com
Phone# (780) 577-7105

==

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. SCC and CAEAL have approved this reporting process and electronic report format.

Total cover pages: 2

Maxxam Analytics Inc
Maxxam Job #: A736574
Report Date: 2007/08/17

DILLON CONSULTING LTD.
Client Project #: TALOYOAK WTP
Site Reference: TALOYOAK
Your P.O. #: 07 8107
Sampler Initials: GS

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		G42476	G42508		
Sampling Date		2007/08/08	2007/08/08		
COC Number		116738	116738		
	Units	**S2 T1**	**S2 B1**	**RDL**	**QC Batch**
CONVENTIONALS					
Nitrate (N)	mg/L	<0.2	<0.2	0.2	1788566
Nitrite (N)	mg/L	<0.06	<0.06	0.06	1788565
Total Phosphate (P)	mg/L	<0.003	<0.003	0.003	1792005
Calculated Parameters					
Hardness (CaCO3)	mg/L	90	90	0.5	1784945
Ion Balance	N/A	1.04	1.04	0.01	1785603
Total Dissolved Solids	mg/L	110	109	10	1784946
Misc. Inorganics					
Strong Acid Dissoc. Cyanide (CN)	mg/L	<0.005	<0.005	0.005	1782991
Alkalinity (Total as CaCO3)	mg/L	83	83	1	1786814
Total Organic Carbon (C)	mg/L	2.0	1.9	0.5	1793523
Alkalinity (PP as CaCO3)	mg/L	<1	<1	1	1786814
Bicarbonate (HCO3)	mg/L	102	101	1	1786814
Carbonate (CO3)	mg/L	<1	<1	1	1786814
Hydroxide (OH)	mg/L	<1	<1	1	1786814
Low Level Elements					
Total Cadmium (Cd)	ug/L	<0.01	<0.01	0.01	1794935
Anions					
Dissolved Sulphate (SO4)	mg/L	5	4	1	1788564
Dissolved Chloride (Cl)	mg/L	14	14	1	1788537
Microbiological Param.					
E.Coli DST	mpn/100mL	<1	<1	1	1795469
Total Coliforms DST	mpn/100mL	22	13	1	1795469
Nutrients					
Nitrate plus Nitrite (N)	mg/L	<0.2	<0.2	0.2	1785605
Physical Properties					
True Colour	PtCo units	5	5	2	1792131
Conductivity	uS/cm	221	221	1	1786828
pH	pH Units	8.1	8.2	0.1	1786827
Physical Properties					
Total Suspended Solids	mg/L	<2	<2	2	1792168
Turbidity	NTU	0.5	0.5	0.1	1792172

RDL = Reportable Detection Limit

Maxxam Analytics Inc

Maxxam Job #: A736574
Report Date: 2007/08/17

DILLON CONSULTING LTD.
Client Project #: TALOYOAK WTP
Site Reference: TALOYOAK
Your P.O. #: 07 8107
Sampler Initials: GS

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		G42476	G42508		
Sampling Date		2007/08/08	2007/08/08		
COC Number		116738	116738		
	Units	**S2 T1**	**S2 B1**	**RDL**	**QC Batch**
Elements					
Total Aluminum (Al)	mg/L	0.005	0.004	0.001	1791533
Total Antimony (Sb)	mg/L	<0.0002	<0.0002	0.0002	1791533
Total Arsenic (As)	mg/L	<0.001	<0.001	0.001	1791533
Total Barium (Ba)	mg/L	<0.01	<0.01	0.01	1791478
Total Beryllium (Be)	mg/L	<0.001	<0.001	0.001	1791533
Total Boron (B)	mg/L	<0.02	<0.02	0.02	1791478
Dissolved Calcium (Ca)	mg/L	20.8	20.6	0.3	1785980
Total Calcium (Ca)	mg/L	18.3	18.0	0.3	1791478
Total Chromium (Cr)	mg/L	<0.001	0.001	0.001	1791533
Total Cobalt (Co)	mg/L	<0.0003	<0.0003	0.0003	1791533
Total Copper (Cu)	mg/L	<0.0002	<0.0002	0.0002	1791533
Dissolved Iron (Fe)	mg/L	<0.06	<0.06	0.06	1785980
Total Iron (Fe)	mg/L	<0.06	<0.06	0.06	1791478
Total Lead (Pb)	mg/L	<0.0002	<0.0002	0.0002	1791533
Total Lithium (Li)	mg/L	<0.02	<0.02	0.02	1791478
Dissolved Magnesium (Mg)	mg/L	9.3	9.3	0.2	1785980
Total Magnesium (Mg)	mg/L	8.8	8.6	0.2	1791478
Dissolved Manganese (Mn)	mg/L	<0.004	<0.004	0.004	1785980
Total Manganese (Mn)	mg/L	<0.004	<0.004	0.004	1791478
Total Molybdenum (Mo)	mg/L	0.0004	0.0004	0.0002	1791533
Total Nickel (Ni)	mg/L	<0.0005	<0.0005	0.0005	1791533
Total Phosphorus (P)	mg/L	<0.1	<0.1	0.1	1791478
Dissolved Potassium (K)	mg/L	0.9	0.9	0.3	1785980
Total Potassium (K)	mg/L	0.9	0.9	0.3	1791478
Total Selenium (Se)	mg/L	<0.001	<0.001	0.001	1791533
Total Silicon (Si)	mg/L	0.6	0.6	0.1	1791478
Total Silver (Ag)	mg/L	<0.0001	<0.0001	0.0001	1791533
Dissolved Sodium (Na)	mg/L	9.9	9.9	0.5	1785980
Total Sodium (Na)	mg/L	10.0	9.8	0.5	1791478
Total Strontium (Sr)	mg/L	0.04	0.04	0.02	1791478
Total Sulphur (S)	mg/L	1.2	1.1	0.2	1791478
Total Thallium (Tl)	mg/L	<0.0002	<0.0002	0.0002	1791533

RDL = Reportable Detection Limit

Maxxam Job #: A736574
Report Date: 2007/08/17

DILLON CONSULTING LTD.
Client Project #: TALOYOAK WTP
Site Reference: TALOYOAK
Your P.O. #: 07 8107
Sampler Initials: GS

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		G42476	G42508		
Sampling Date		2007/08/08	2007/08/08		
COC Number		116738	116738		
	Units	**S2 T1**	**S2 B1**	**RDL**	**QC Batch**
Total Tin (Sn)	mg/L	<0.001	<0.001	0.001	1791533
Total Titanium (Ti)	mg/L	<0.001	<0.001	0.001	1791533
Total Uranium (U)	mg/L	0.0003	0.0003	0.0001	1791533
Total Vanadium (V)	mg/L	<0.001	<0.001	0.001	1791533
Total Zinc (Zn)	mg/L	<0.003	<0.003	0.003	1791533

RDL = Reportable Detection Limit

Maxxam Job #: A736574
Report Date: 2007/08/17

DILLON CONSULTING LTD.
Client Project #: TALOYOAK WTP
Site Reference: TALOYOAK
Your P.O. #: 07 8107
Sampler Initials: GS

VOLATILE ORGANICS BY GC-MS (WATER)

Maxxam ID		G42476	G42508		
Sampling Date		2007/08/08	2007/08/08		
COC Number		116738	116738		
	Units	**S2 T1**	**S2 B1**	**RDL**	**QC Batch**
Volatiles					
Bromodichloromethane	ug/L	<0.5	<0.5	0.5	1792383
Bromoform	ug/L	<0.5	<0.5	0.5	1792383
Chlorodibromomethane	ug/L	<1	<1	1	1792383
Chloroform	ug/L	<0.5	<0.5	0.5	1792383
Surrogate Recovery (%)					
4-BROMOFLUOROBENZENE (sur.)	%	94	93		1792383
D4-1,2-DICHLOROETHANE (sur.)	%	101	97		1792383
D8-TOLUENE (sur.)	%	98	98		1792383

RDL = Reportable Detection Limit

General Comments

Results relate only to the items tested.

Maxxam Analytics Inc

DILLON CONSULTING LTD.
Attention: CORINA PEACH
Client Project #: TALOYOAK WTP
P.O. #: 07 8107
Site Reference: TALOYOAK

Quality Assurance Report

Maxxam Job Number: EA736574

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
1782991 YY	MATRIX SPIKE	Strong Acid Dissoc. Cyanide (CN)	2007/08/10		54 (1)	%	80 - 120
	SPIKE	Strong Acid Dissoc. Cyanide (CN)	2007/08/10		91	%	85 - 115
	BLANK	Strong Acid Dissoc. Cyanide (CN)	2007/08/10	<0.005		mg/L	
	RPD	Strong Acid Dissoc. Cyanide (CN)	2007/08/10	NC		%	25
1785980 DZ1	Calibration Check	Dissolved Calcium (Ca)	2007/08/13		97	%	90 - 110
		Dissolved Iron (Fe)	2007/08/13		96	%	90 - 110
		Dissolved Magnesium (Mg)	2007/08/13		99	%	90 - 110
		Dissolved Manganese (Mn)	2007/08/13		104	%	90 - 110
		Dissolved Potassium (K)	2007/08/13		95	%	90 - 110
		Dissolved Sodium (Na)	2007/08/13		101	%	90 - 110
	MATRIX SPIKE [G42476-01]	Dissolved Manganese (Mn)	2007/08/13		104	%	80 - 120
	BLANK	Dissolved Calcium (Ca)	2007/08/13	<0.3		mg/L	
		Dissolved Iron (Fe)	2007/08/13	<0.06		mg/L	
		Dissolved Magnesium (Mg)	2007/08/13	<0.2		mg/L	
		Dissolved Manganese (Mn)	2007/08/13	<0.004		mg/L	
		Dissolved Potassium (K)	2007/08/13	<0.3		mg/L	
		Dissolved Sodium (Na)	2007/08/13	<0.5		mg/L	
	RPD [G42476-01]	Dissolved Calcium (Ca)	2007/08/13	0.8		%	20
		Dissolved Iron (Fe)	2007/08/13	NC		%	20
		Dissolved Magnesium (Mg)	2007/08/13	0.3		%	20
		Dissolved Manganese (Mn)	2007/08/13	NC		%	20
		Dissolved Potassium (K)	2007/08/13	NC		%	20
		Dissolved Sodium (Na)	2007/08/13	0.9		%	20
1786814 MR3	Calibration Check	Alkalinity (Total as CaCO3)	2007/08/13		96	%	80 - 120
	BLANK	Alkalinity (Total as CaCO3)	2007/08/13	<1		mg/L	
		Alkalinity (PP as CaCO3)	2007/08/13	<1		mg/L	
		Bicarbonate (HCO3)	2007/08/13	<1		mg/L	
		Carbonate (CO3)	2007/08/13	<1		mg/L	
		Hydroxide (OH)	2007/08/13	<1		mg/L	
	RPD	Alkalinity (Total as CaCO3)	2007/08/13	0.2		%	25
		Alkalinity (PP as CaCO3)	2007/08/13	5.0		%	25
		Bicarbonate (HCO3)	2007/08/13	0.8		%	25
		Carbonate (CO3)	2007/08/13	5.0		%	25
		Hydroxide (OH)	2007/08/13	NC		%	25
1786827 MR3	Calibration Check	pH	2007/08/13		101	%	97 - 103
	RPD	pH	2007/08/13	0.03		%	25
1786828 MR3	Calibration Check	Conductivity	2007/08/13		99	%	80 - 120
	BLANK	Conductivity	2007/08/13	<1		uS/cm	
	RPD	Conductivity	2007/08/13	0.6		%	25
1788537 SY1	Calibration Check	Dissolved Chloride (Cl)	2007/08/14		98	%	80 - 120
	MATRIX SPIKE	Dissolved Chloride (Cl)	2007/08/14		94	%	80 - 120
	BLANK	Dissolved Chloride (Cl)	2007/08/14	<1		mg/L	
	RPD	Dissolved Chloride (Cl)	2007/08/14	NC		%	25
1788564 SY1	Calibration Check	Dissolved Sulphate (SO4)	2007/08/14		98	%	80 - 120
	MATRIX SPIKE	Dissolved Sulphate (SO4)	2007/08/14		92	%	80 - 120
	BLANK	Dissolved Sulphate (SO4)	2007/08/14	<1		mg/L	
	RPD	Dissolved Sulphate (SO4)	2007/08/14	0.05		%	25
1788565 SY1	Calibration Check	Nitrite (N)	2007/08/14		91	%	80 - 120
	MATRIX SPIKE	Nitrite (N)	2007/08/14		99	%	80 - 120
	BLANK	Nitrite (N)	2007/08/14	<0.06		mg/L	
	RPD	Nitrite (N)	2007/08/14	NC		%	25
1788566 SY1	Calibration Check	Nitrate (N)	2007/08/14		100	%	80 - 120
	MATRIX SPIKE	Nitrate (N)	2007/08/14		103	%	80 - 120
	BLANK	Nitrate (N)	2007/08/14	<0.2		mg/L	

DILLON CONSULTING LTD.
Attention: CORINA PEACH
Client Project #: TALOYOAK WTP
P.O. #: 07 8107
Site Reference: TALOYOAK

Quality Assurance Report (Continued)

Maxxam Job Number: EA736574

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
1788566	SY1	RPD	Nitrate (N)	2007/08/14	NC		%	25
1791478	AS7	Calibration Check	Total Barium (Ba)	2007/08/15		99	%	80 - 120
			Total Boron (B)	2007/08/15		98	%	80 - 120
			Total Calcium (Ca)	2007/08/15		90	%	80 - 120
			Total Iron (Fe)	2007/08/15		92	%	80 - 120
			Total Lithium (Li)	2007/08/15		100	%	80 - 120
			Total Magnesium (Mg)	2007/08/15		97	%	80 - 120
			Total Manganese (Mn)	2007/08/15		101	%	80 - 120
			Total Phosphorus (P)	2007/08/15		99	%	80 - 120
			Total Potassium (K)	2007/08/15		99	%	80 - 120
			Total Sodium (Na)	2007/08/15		102	%	80 - 120
			Total Strontium (Sr)	2007/08/15		97	%	80 - 120
		MATRIX SPIKE	Total Barium (Ba)	2007/08/15		96	%	80 - 120
			Total Boron (B)	2007/08/15		92	%	80 - 120
			Total Lithium (Li)	2007/08/15		93	%	80 - 120
			Total Manganese (Mn)	2007/08/15		107	%	80 - 120
			Total Strontium (Sr)	2007/08/15		95	%	80 - 120
		BLANK	Total Barium (Ba)	2007/08/15	<0.01		mg/L	
			Total Boron (B)	2007/08/15	<0.02		mg/L	
			Total Calcium (Ca)	2007/08/15	<0.3		mg/L	
			Total Iron (Fe)	2007/08/15	<0.06		mg/L	
			Total Lithium (Li)	2007/08/15	<0.02		mg/L	
			Total Magnesium (Mg)	2007/08/15	<0.2		mg/L	
			Total Manganese (Mn)	2007/08/15	<0.004		mg/L	
			Total Phosphorus (P)	2007/08/15	<0.1		mg/L	
			Total Potassium (K)	2007/08/15	<0.3		mg/L	
			Total Silicon (Si)	2007/08/15	<0.1		mg/L	
			Total Sodium (Na)	2007/08/15	<0.5		mg/L	
			Total Strontium (Sr)	2007/08/15	<0.02		mg/L	
			Total Sulphur (S)	2007/08/15	<0.2		mg/L	
		RPD	Total Barium (Ba)	2007/08/15	NC		%	20
			Total Boron (B)	2007/08/15	NC		%	20
			Total Calcium (Ca)	2007/08/15	2.7		%	20
			Total Iron (Fe)	2007/08/15	1.6		%	20
			Total Lithium (Li)	2007/08/15	NC		%	20
			Total Magnesium (Mg)	2007/08/15	2.3		%	20
			Total Manganese (Mn)	2007/08/15	2.9		%	20
			Total Phosphorus (P)	2007/08/15	NC		%	20
			Total Potassium (K)	2007/08/15	NC		%	20
			Total Silicon (Si)	2007/08/15	1.7		%	20
			Total Sodium (Na)	2007/08/15	NC		%	20
			Total Strontium (Sr)	2007/08/15	NC		%	20
			Total Sulphur (S)	2007/08/15	5.5		%	20
1791533	LL2	Calibration Check	Total Aluminum (Al)	2007/08/15		106	%	80 - 120
			Total Antimony (Sb)	2007/08/15		105	%	80 - 120
			Total Arsenic (As)	2007/08/15		102	%	80 - 120
			Total Beryllium (Be)	2007/08/15		93	%	80 - 120
			Total Chromium (Cr)	2007/08/15		101	%	81 - 120
			Total Cobalt (Co)	2007/08/15		99	%	80 - 120
			Total Copper (Cu)	2007/08/15		104	%	81 - 120
			Total Lead (Pb)	2007/08/15		100	%	80 - 120
			Total Molybdenum (Mo)	2007/08/15		101	%	80 - 120
			Total Nickel (Ni)	2007/08/15		105	%	80 - 120
			Total Selenium (Se)	2007/08/15		108	%	80 - 120
			Total Silver (Ag)	2007/08/15		104	%	80 - 120

DILLON CONSULTING LTD.
Attention: CORINA PEACH
Client Project #: TALOYOAK WTP
P.O. #: 07 8107
Site Reference: TALOYOAK

Quality Assurance Report (Continued)

Maxxam Job Number: EA736574

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
1791533 LL2	Calibration Check	Total Thallium (Tl)	2007/08/15		103	%	80 - 120
		Total Tin (Sn)	2007/08/15		115	%	80 - 120
		Total Titanium (Ti)	2007/08/15		107	%	80 - 120
		Total Uranium (U)	2007/08/15		107	%	80 - 120
		Total Vanadium (V)	2007/08/15		111	%	80 - 120
		Total Zinc (Zn)	2007/08/15		105	%	80 - 120
	MATRIX SPIKE	Total Antimony (Sb)	2007/08/15		99	%	80 - 120
		Total Arsenic (As)	2007/08/15		105	%	80 - 120
		Total Cobalt (Co)	2007/08/15		100	%	80 - 120
		Total Copper (Cu)	2007/08/15		107	%	80 - 120
		Total Lead (Pb)	2007/08/15		108	%	80 - 120
		Total Molybdenum (Mo)	2007/08/15		110	%	80 - 120
		Total Nickel (Ni)	2007/08/15		105	%	80 - 120
		Total Selenium (Se)	2007/08/15		107	%	80 - 120
		Total Thallium (Tl)	2007/08/15		114	%	80 - 120
		Total Titanium (Ti)	2007/08/15		115	%	80 - 120
	BLANK	Total Aluminum (Al)	2007/08/15	<0.001		mg/L	
		Total Antimony (Sb)	2007/08/15	<0.0002		mg/L	
		Total Arsenic (As)	2007/08/15	<0.001		mg/L	
		Total Beryllium (Be)	2007/08/15	<0.001		mg/L	
		Total Chromium (Cr)	2007/08/15	<0.001		mg/L	
		Total Cobalt (Co)	2007/08/15	<0.0003		mg/L	
		Total Copper (Cu)	2007/08/15	<0.0002		mg/L	
		Total Lead (Pb)	2007/08/15	<0.0002		mg/L	
		Total Molybdenum (Mo)	2007/08/15	0.0002, RDL=0.0002		mg/L	
		Total Nickel (Ni)	2007/08/15	<0.0005		mg/L	
		Total Selenium (Se)	2007/08/15	<0.001		mg/L	
		Total Silver (Ag)	2007/08/15	<0.0001		mg/L	
		Total Thallium (Tl)	2007/08/15	<0.0002		mg/L	
		Total Tin (Sn)	2007/08/15	<0.001		mg/L	
		Total Titanium (Ti)	2007/08/15	<0.001		mg/L	
		Total Uranium (U)	2007/08/15	<0.0001		mg/L	
		Total Vanadium (V)	2007/08/15	<0.001		mg/L	
		Total Zinc (Zn)	2007/08/15	<0.003		mg/L	
	RPD	Total Copper (Cu)	2007/08/15	1.9		%	20
1792005 VR1	Calibration Check	Total Phosphate (P)	2007/08/15		98	%	87 - 113
	QC STANDARD	Total Phosphate (P)	2007/08/15		98	%	75 - 125
	BLANK	Total Phosphate (P)	2007/08/15	0.003, RDL=0.003		mg/L	
	RPD	Total Phosphate (P)	2007/08/15	0.7		%	20
1792131 AL2	Calibration Check	True Colour	2007/08/16		99	%	80 - 120
	BLANK	True Colour	2007/08/16	2, RDL=2		PtCo units	
	RPD [G42476-01]	True Colour	2007/08/16	NC		%	25
1792168 RW3	MATRIX SPIKE	Total Suspended Solids	2007/08/16		99	%	80 - 120
	SPIKE	Total Suspended Solids	2007/08/16		98	%	80 - 120
	BLANK	Total Suspended Solids	2007/08/16	<2		mg/L	
		Total Suspended Solids	2007/08/16	<2		mg/L	
	RPD	Total Suspended Solids	2007/08/16	NC		%	25
		Total Suspended Solids	2007/08/16	NC		%	25
1792172 RW3	Calibration Check	Turbidity	2007/08/16		100	%	80 - 120
	BLANK	Turbidity	2007/08/16	<0.1		NTU	
	RPD	Turbidity	2007/08/16	NC		%	20
1792383 PC1	MATRIX SPIKE [G42508-02]	4-BROMOFLUOROBENZENE (sur.)	2007/08/16		94	%	70 - 130
		D4-1,2-DICHLOROETHANE (sur.)	2007/08/16		100	%	70 - 130
		D8-TOLUENE (sur.)	2007/08/16		91	%	70 - 130

Maxxam Analytics Inc

DILLON CONSULTING LTD.
Attention: CORINA PEACH
Client Project #: TALOYOAK WTP
P.O. #: 07 8107
Site Reference: TALOYOAK

Quality Assurance Report (Continued)

Maxxam Job Number: EA736574

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
1792383 PC1	MATRIX SPIKE						
	[G42508-02]	Bromodichloromethane	2007/08/16		91	%	70 - 130
		Bromoform	2007/08/16		83	%	70 - 130
		Chlorodibromomethane	2007/08/16		79	%	70 - 130
		Chloroform	2007/08/16		105	%	70 - 130
	SPIKE	4-BROMOFLUOROBENZENE (sur.)	2007/08/16		92	%	70 - 130
		D4-1,2-DICHLOROETHANE (sur.)	2007/08/16		96	%	70 - 130
		D8-TOLUENE (sur.)	2007/08/16		91	%	70 - 130
		Bromodichloromethane	2007/08/16		91	%	70 - 130
		Bromoform	2007/08/16		87	%	70 - 130
		Chlorodibromomethane	2007/08/16		81	%	70 - 130
		Chloroform	2007/08/16		104	%	70 - 130
	BLANK	4-BROMOFLUOROBENZENE (sur.)	2007/08/16		92	%	70 - 130
		D4-1,2-DICHLOROETHANE (sur.)	2007/08/16		95	%	70 - 130
		D8-TOLUENE (sur.)	2007/08/16		97	%	70 - 130
		Bromodichloromethane	2007/08/16	<0.5		ug/L	
		Bromoform	2007/08/16	<0.5		ug/L	
		Chlorodibromomethane	2007/08/16	<1		ug/L	
		Chloroform	2007/08/16	<0.5		ug/L	
	RPD [G42476-02]	Bromodichloromethane	2007/08/16	NC		%	N/A
		Bromoform	2007/08/16	NC		%	N/A
		Chlorodibromomethane	2007/08/16	NC		%	N/A
		Chloroform	2007/08/16	NC		%	N/A
1793523 YY	MATRIX SPIKE						
	[G42476-03]	Total Organic Carbon (C)	2007/08/16		92	%	80 - 120
	SPIKE	Total Organic Carbon (C)	2007/08/16		88	%	80 - 120
	BLANK	Total Organic Carbon (C)	2007/08/16	<0.5		mg/L	
	RPD [G42476-03]	Total Organic Carbon (C)	2007/08/16	NC		%	20
1794935 LL2	Calibration Check	Total Cadmium (Cd)	2007/08/15		107	%	85 - 115
	MATRIX SPIKE						
	[G42476-02]	Total Cadmium (Cd)	2007/08/15		114	%	80 - 120
	BLANK	Total Cadmium (Cd)	2007/08/15	<0.01		ug/L	
	RPD [G42476-02]	Total Cadmium (Cd)	2007/08/15	NC		%	20
1795469 EE	BLANK	E.Coli DST	2007/08/10	<1		mpn/100mL	
		Total Coliforms DST	2007/08/10	<1		mpn/100mL	

N/A = Not Applicable
NC = Non-calculable
RPD = Relative Percent Difference
(1) Please note that the recovery of some compounds are outside control limits however the overall quality control for this analysis meets our acceptability criteria.

Maxxam Analytics Inc

Your P.O. #: 07-8107
Your Project #: 07-8107 TALOYOAK WTP
Site:TALOYOAK
Your C.O.C. #: 31033

Attention: CORINA PEACH
DILLON CONSULTING LTD.
BOX 1409
SUITE 303, 4920 - 47th STREET
YELLOWKNIFE, NT
CANADA X1A ZP1

Report Date: 2007/10/22

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: A748869
Received: 2007/10/11, 9:25

Sample Matrix: Water
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Alkalinity - Water	1	2007/10/15	2007/10/15	EENVSOP-00054 V.1	SM 2320
Chloride (IC)	1	N/A	2007/10/15	EENVSOP-00055 v3	SM 4110B
Str. Acid Diss. Cyanide water	1	N/A	2007/10/12	EENVSOP-00062 V.1	EPA SW-846 9012A
True Colour	1	2007/10/19	2007/10/19	EENVSOP-00065 V.1	SM 2120B
Total Coliforms and E.Coli (1)	1	2007/10/11	2007/10/11	EDM SOP-0013	MPN
Carbon (DOC)	1	N/A	2007/10/17	EENVSOP-00060 v2	MMCW 119
Conductance - water	1	N/A	2007/10/15	EENVSOP-00054 V.1	SM 2510B
Hardness	1	N/A	2007/10/17		
Mercury (Dissolved)	1	2007/10/15	2007/10/16	EENVSOP-00031 v2	EPA 245.1
Mercury (Total)	1	2007/10/15	2007/10/15	EENVSOP-00031 v2	EPA 245.1
Elements by ICP - Dissolved	1	N/A	2007/10/16	EENVSOP-00034	EPA 6010C
Elements by ICP - Total	1	N/A	2007/10/17	EENVSOP-00034	EPA 6010C
Elements by ICPMS - Dissolved	1	N/A	2007/10/19	EENVSOP-00123	EPA 6020A
Elements by ICPMS - Total	1	N/A	2007/10/19	EENVSOP-00123	EPA 6020A
Ion Balance	1	N/A	2007/10/17		
Ammonia-N	1	2007/10/12	2007/10/12	EENVSOP-00058 v1	EPA 350.1
Nitrite (NO2) BY IC-EC	1	N/A	2007/10/15	EENVSOP-00055 v3	SM 4110B
Nitrate + Nitrite-N (calculated)	1	2007/10/11	2007/10/17		
Nitrate (NO3) BY IC-EC	1	N/A	2007/10/15	EENVSOP-00055 v3	SM 4110 B
pH Water	1	N/A	2007/10/15	EENVSOP-00054 v1	SM 4500H
Sulphate (SO4)	1	N/A	2007/10/15	EENVSOP-00055 v3	SM 4110B
Heterotrophic Plate Count (1)	1	N/A	2007/10/11	EDM SOP-0016	Pour Plate
Total Dissolved Solids (Calculated)	1	N/A	2007/10/17	CAL SOP-00086, EDM SOP-00037	Calculation
Trihalomethanes (2)	1	2007/10/11	2007/10/15	CAL SOP-00104	EPA 8260 B
Carbon (Total Organic)	1	N/A	2007/10/17	EENVSOP-00060 v2	SM 5310C
Total Suspended Solids	1	N/A	2007/10/19	EENVSOP-00073 v2	SM 2540 D
Turbidity	1	N/A	2007/10/19	EENVSOP-00066 v2	SM 2130B

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) This test was performed by Maxxam Edmonton Industrial
(2) This test was performed by Maxxam Calgary

../2

Your P.O. #: 07-8107
Your Project #: 07-8107 TALOYOAK WTP
Site:TALOYOAK
Your C.O.C. #: 31033

Attention: CORINA PEACH
DILLON CONSULTING LTD.
BOX 1409
SUITE 303, 4920 - 47th STREET
YELLOWKNIFE, NT
CANADA X1A ZP1

Report Date: 2007/10/22

CERTIFICATE OF ANALYSIS

-2-

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

JEREMY WAKARUK, B.Sc. Biology, Senior Project Manager
Email: jwakaruk@maxxamanalytics.com
Phone# (780) 577-7105

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Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. SCC and CAEAL have approved this reporting process and electronic report format.

Total cover pages: 2

Maxxam Job #: A748869
Report Date: 2007/10/22

DILLON CONSULTING LTD.
Client Project #: 07-8107 TALOYOAK WTP
Site Reference: TALOYOAK
Your P.O. #: 07-8107
Sampler Initials: CP

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID			H36828		
Sampling Date			2007/10/10 11:00		
COC Number			31033		
	Units	**Criteria**	**SITE 2**	**RDL**	**QC Batch**
CONVENTIONALS					
Nitrate (N)	mg/L	**10**	<0.2	0.2	1904882
Nitrite (N)	mg/L	**1**	<0.06	0.06	1904881
Calculated Parameters					
Hardness (CaCO3)	mg/L	**-**	97	0.5	1896061
Ion Balance	N/A	**-**	0.98	0.01	1896062
Total Dissolved Solids	mg/L	**500**	127	10	1896068
Misc. Inorganics					
Strong Acid Dissoc. Cyanide (CN)	mg/L	**.2**	<0.005	0.005	1900886
Dissolved Organic Carbon (C)	mg/L	**-**	3	1	1909168
Alkalinity (Total as CaCO3)	mg/L	**-**	97	1	1904325
Total Organic Carbon (C)	mg/L	**-**	3.2	0.5	1909223
Alkalinity (PP as CaCO3)	mg/L	**-**	<1	1	1904325
Bicarbonate (HCO3)	mg/L	**-**	119	1	1904325
Carbonate (CO3)	mg/L	**-**	<1	1	1904325
Hydroxide (OH)	mg/L	**-**	<1	1	1904325
Anions					
Dissolved Sulphate (SO4)	mg/L	**500**	7	1	1904880
Dissolved Chloride (Cl)	mg/L	**250**	16	1	1904878
Microbiological Param.					
E.Coli DST	mpn/100mL	**0**	<1	1	1904378
Heterotrophic Plate Count	CFU/mL	**-**	<1	1	1904468
Total Coliforms DST	mpn/100mL	**10**	<1	1	1904378
Nutrients					
Ammonia (N)	mg/L	**-**	0.02	0.01	1899862
Nitrate plus Nitrite (N)	mg/L	**10**	<0.2	0.2	1896066
Physical Properties					
True Colour	PtCo units	**15**	2	2	1912431
Conductivity	uS/cm	**-**	252	1	1904350
pH	pH Units	**6.5:8.5**	8.1	0.1	1904349
Physical Properties					
Total Suspended Solids	mg/L	**-**	<2	2	1912464
Turbidity	NTU	**1**	0.6	0.1	1912465

RDL = Reportable Detection Limit

Maxxam Job #: A748869
Report Date: 2007/10/22

DILLON CONSULTING LTD.
Client Project #: 07-8107 TALOYOAK WTP
Site Reference: TALOYOAK
Your P.O. #: 07-8107
Sampler Initials: CP

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID			H36828		
Sampling Date			2007/10/10 11:00		
COC Number			31033		
	Units	**Criteria**	**SITE 2**	**RDL**	**QC Batch**
Elements					
Dissolved Aluminum (Al)	mg/L	**.1**	<0.04	0.04	1905149
Total Aluminum (Al)	mg/L	**.1**	<0.04	0.04	1908101
Dissolved Antimony (Sb)	mg/L	**.006**	<0.0002	0.0002	1914092
Total Antimony (Sb)	mg/L	**.006**	<0.0002	0.0002	1912968
Dissolved Arsenic (As)	mg/L	**.025**	<0.001	0.001	1914092
Total Arsenic (As)	mg/L	**.025**	<0.001	0.001	1912968
Dissolved Barium (Ba)	mg/L	**1**	<0.01	0.01	1905149
Total Barium (Ba)	mg/L	**1**	<0.01	0.01	1908101
Dissolved Beryllium (Be)	mg/L	**-**	<0.001	0.001	1914092
Total Beryllium (Be)	mg/L	**-**	<0.001	0.001	1912968
Dissolved Boron (B)	mg/L	**5**	<0.02	0.02	1905149
Total Boron (B)	mg/L	**5**	<0.02	0.02	1908101
Dissolved Cadmium (Cd)	mg/L	**.005**	<0.0002	0.0002	1914092
Total Cadmium (Cd)	mg/L	**.005**	<0.0002	0.0002	1912968
Dissolved Calcium (Ca)	mg/L	**-**	22.1	0.3	1905149
Total Calcium (Ca)	mg/L	**-**	22.1	0.3	1908101
Dissolved Chromium (Cr)	mg/L	**.05**	<0.01	0.01	1905149
Total Chromium (Cr)	mg/L	**.05**	<0.01	0.01	1908101
Dissolved Cobalt (Co)	mg/L	**-**	<0.0003	0.0003	1914092
Total Cobalt (Co)	mg/L	**-**	<0.0003	0.0003	1912968
Dissolved Copper (Cu)	mg/L	**1**	0.0005	0.0002	1914092
Total Copper (Cu)	mg/L	**1**	0.0004	0.0002	1912968
Dissolved Iron (Fe)	mg/L	**0.3**	<0.06	0.06	1905149
Total Iron (Fe)	mg/L	**0.3**	<0.06	0.06	1908101
Dissolved Lead (Pb)	mg/L	**.01**	<0.0002	0.0002	1914092
Total Lead (Pb)	mg/L	**.01**	<0.0002	0.0002	1912968
Dissolved Lithium (Li)	mg/L	**-**	<0.02	0.02	1905149
Total Lithium (Li)	mg/L	**-**	<0.02	0.02	1908101
Dissolved Magnesium (Mg)	mg/L	**-**	10.1	0.2	1905149
Total Magnesium (Mg)	mg/L	**-**	10.0	0.2	1908101
Dissolved Manganese (Mn)	mg/L	**0.05**	<0.004	0.004	1905149
Total Manganese (Mn)	mg/L	**0.05**	<0.004	0.004	1908101

RDL = Reportable Detection Limit

Maxxam Analytics Inc
Maxxam Job #: A748869
Report Date: 2007/10/22

DILLON CONSULTING LTD.
Client Project #: 07-8107 TALOYOAK WTP
Site Reference: TALOYOAK
Your P.O. #: 07-8107
Sampler Initials: CP

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID			H36828		
Sampling Date			2007/10/10 11:00		
COC Number			31033		
	Units	**Criteria**	**SITE 2**	**RDL**	**QC Batch**
Dissolved Molybdenum (Mo)	mg/L	**-**	0.0007	0.0002	1914092
Total Molybdenum (Mo)	mg/L	**-**	0.0007	0.0002	1912968
Dissolved Nickel (Ni)	mg/L	**-**	0.0005	0.0005	1914092
Total Nickel (Ni)	mg/L	**-**	0.0008	0.0005	1912968
Dissolved Phosphorus (P)	mg/L	**-**	<0.1	0.1	1905149
Total Phosphorus (P)	mg/L	**-**	<0.1	0.1	1908101
Dissolved Potassium (K)	mg/L	**-**	1.2	0.3	1905149
Total Potassium (K)	mg/L	**-**	0.9	0.3	1908101
Dissolved Selenium (Se)	mg/L	**.01**	<0.001	0.001	1914092
Total Selenium (Se)	mg/L	**.01**	<0.001	0.001	1912968
Dissolved Silicon (Si)	mg/L	**-**	0.5	0.1	1905149
Total Silicon (Si)	mg/L	**-**	0.5	0.1	1908101
Dissolved Silver (Ag)	mg/L	**-**	<0.0001	0.0001	1914092
Total Silver (Ag)	mg/L	**-**	<0.0001	0.0001	1912968
Dissolved Sodium (Na)	mg/L	**200**	12.2	0.5	1905149
Total Sodium (Na)	mg/L	**200**	11.5	0.5	1908101
Dissolved Strontium (Sr)	mg/L	**-**	0.03	0.02	1905149
Total Strontium (Sr)	mg/L	**-**	0.04	0.02	1908101
Dissolved Sulphur (S)	mg/L	**-**	3.4	0.2	1905149
Total Sulphur (S)	mg/L	**-**	1.9	0.2	1908101
Dissolved Thallium (Tl)	mg/L	**-**	<0.0002	0.0002	1914092
Total Thallium (Tl)	mg/L	**-**	<0.0002	0.0002	1912968
Dissolved Tin (Sn)	mg/L	**-**	<0.001	0.001	1914092
Total Tin (Sn)	mg/L	**-**	<0.001	0.001	1912968
Dissolved Titanium (Ti)	mg/L	**-**	<0.001	0.001	1914092
Total Titanium (Ti)	mg/L	**-**	<0.001	0.001	1912968
Dissolved Uranium (U)	mg/L	**.02**	0.0004	0.0001	1914092
Total Uranium (U)	mg/L	**.02**	0.0005	0.0001	1912968
Dissolved Vanadium (V)	mg/L	**-**	0.004	0.001	1914092
Total Vanadium (V)	mg/L	**-**	0.003	0.001	1912968
Dissolved Zinc (Zn)	mg/L	**5**	<0.003	0.003	1914092
Total Zinc (Zn)	mg/L	**5**	<0.003	0.003	1912968
Low Level Elements					
Dissolved Mercury (Hg)	ug/L	**1**	<0.05	0.05	1903704

RDL = Reportable Detection Limit

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID			H36828		
Sampling Date			2007/10/10 11:00		
COC Number			31033		
	Units	**Criteria**	**SITE 2**	**RDL**	**QC Batch**
Total Mercury (Hg)	ug/L	**1**	<0.05	0.05	1903699

RDL = Reportable Detection Limit

Maxxam Analytics Inc
Maxxam Job #: A748869
Report Date: 2007/10/22

DILLON CONSULTING LTD.
Client Project #: 07-8107 TALOYOAK WTP
Site Reference: TALOYOAK
Your P.O. #: 07-8107
Sampler Initials: CP

VOLATILE ORGANICS BY GC-MS (WATER)

Maxxam ID			H36828		
Sampling Date			2007/10/10 11:00		
COC Number			31033		
	Units	**Criteria**	**SITE 2**	**RDL**	**QC Batch**
Volatiles					
Bromodichloromethane	mg/L	**-**	<0.00040	0.00040	1895981
Bromoform	mg/L	**-**	<0.00040	0.00040	1895981
Chlorodibromomethane	mg/L	**-**	<0.00040	0.00040	1895981
Chloroform	mg/L	**.1**	<0.00040	0.00040	1895981
Surrogate Recovery (%)					
4-BROMOFLUOROBENZENE (sur.)	%	-	103		1895981
D4-1,2-DICHLOROETHANE (sur.)	%	-	105		1895981
D8-TOLUENE (sur.)	%	-	101		1895981

RDL = Reportable Detection Limit

General Comments

CRITERIA: Canadian Drinking Water Quality Guidelines (April 1996)

Results relate only to the items tested.

Maxxam Analytics Inc

DILLON CONSULTING LTD.
Attention: CORINA PEACH
Client Project #: 07-8107 TALOYOAK WTP
P.O. #: 07-8107
Site Reference: TALOYOAK

Quality Assurance Report

Maxxam Job Number: EA748869

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
1895981 WW1	Calibration Check	4-BROMOFLUOROBENZENE (sur.)	2007/10/15		103	%	86 - 115
		D4-1,2-DICHLOROETHANE (sur.)	2007/10/15		100	%	76 - 114
		D8-TOLUENE (sur.)	2007/10/15		103	%	88 - 110
		Bromodichloromethane	2007/10/15		109	%	85 - 115
		Bromoform	2007/10/15		96	%	85 - 115
		Chlorodibromomethane	2007/10/15		103	%	85 - 115
		Chloroform	2007/10/15		112	%	85 - 115
	BLANK	4-BROMOFLUOROBENZENE (sur.)	2007/10/15		106	%	86 - 115
		D4-1,2-DICHLOROETHANE (sur.)	2007/10/15		105	%	76 - 114
		D8-TOLUENE (sur.)	2007/10/15		101	%	88 - 110
		Bromodichloromethane	2007/10/15	<0.00040		mg/L	
		Bromoform	2007/10/15	<0.00040		mg/L	
		Chlorodibromomethane	2007/10/15	<0.00040		mg/L	
		Chloroform	2007/10/15	<0.00040		mg/L	
	RPD	Bromodichloromethane	2007/10/15	1.1		%	40
		Bromoform	2007/10/15	2.4		%	40
		Chlorodibromomethane	2007/10/15	3.5		%	40
		Chloroform	2007/10/15	2.5		%	40
1899862 JK2	MATRIX SPIKE	Ammonia (N)	2007/10/12		91	%	80 - 120
	SPIKE	Ammonia (N)	2007/10/12		100	%	80 - 120
	BLANK	Ammonia (N)	2007/10/12	<0.05		mg/L	
	RPD	Ammonia (N)	2007/10/12	NC		%	25
1900886 YY	MATRIX SPIKE	Strong Acid Dissoc. Cyanide (CN)	2007/10/12		106	%	80 - 120
	SPIKE	Strong Acid Dissoc. Cyanide (CN)	2007/10/12		102	%	85 - 115
	BLANK	Strong Acid Dissoc. Cyanide (CN)	2007/10/12	<0.005		mg/L	
	RPD	Strong Acid Dissoc. Cyanide (CN)	2007/10/12	NC		%	25
1903699 RB3	Calibration Check	Total Mercury (Hg)	2007/10/15		95	%	85 - 115
	MATRIX SPIKE	Total Mercury (Hg)	2007/10/15		87	%	85 - 115
	BLANK	Total Mercury (Hg)	2007/10/15	<0.05		ug/L	
	RPD	Total Mercury (Hg)	2007/10/15	NC		%	25
1903704 RB3	Calibration Check	Dissolved Mercury (Hg)	2007/10/16		98	%	85 - 115
	MATRIX SPIKE	Dissolved Mercury (Hg)	2007/10/16		86	%	85 - 115
	BLANK	Dissolved Mercury (Hg)	2007/10/16	<0.05		ug/L	
	RPD	Dissolved Mercury (Hg)	2007/10/16	NC		%	25
1904325 WZ	Calibration Check	Alkalinity (Total as CaCO3)	2007/10/15		100	%	80 - 120
	BLANK	Alkalinity (Total as CaCO3)	2007/10/15	<1		mg/L	
		Alkalinity (PP as CaCO3)	2007/10/15	<1		mg/L	
		Bicarbonate (HCO3)	2007/10/15	<1		mg/L	
		Carbonate (CO3)	2007/10/15	<1		mg/L	
		Hydroxide (OH)	2007/10/15	<1		mg/L	
	RPD	Alkalinity (Total as CaCO3)	2007/10/15	2.2		%	25
		Alkalinity (PP as CaCO3)	2007/10/15	NC		%	25
		Bicarbonate (HCO3)	2007/10/15	2.2		%	25
		Carbonate (CO3)	2007/10/15	NC		%	25
		Hydroxide (OH)	2007/10/15	NC		%	25
1904349 WZ	Calibration Check	pH	2007/10/15		100	%	97 - 103
	RPD	pH	2007/10/15	0.5		%	5
1904350 WZ	Calibration Check	Conductivity	2007/10/15		99	%	80 - 120
	BLANK	Conductivity	2007/10/15	<1		uS/cm	
	RPD	Conductivity	2007/10/15	0.4		%	25
1904378 EE	BLANK	E.Coli DST	2007/10/11	<1		mpn/100mL	
		Total Coliforms DST	2007/10/11	<1		mpn/100mL	
1904468 EE	BLANK	Heterotrophic Plate Count	2007/10/11	<1		CFU/mL	
1904878 JQ	Calibration Check	Dissolved Chloride (Cl)	2007/10/15		99	%	80 - 120
	MATRIX SPIKE	Dissolved Chloride (Cl)	2007/10/15		90	%	80 - 120

DILLON CONSULTING LTD.
Attention: CORINA PEACH
Client Project #: 07-8107 TALOYOAK WTP
P.O. #: 07-8107
Site Reference: TALOYOAK

Quality Assurance Report (Continued)

Maxxam Job Number: EA748869

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
1904878 JQ	BLANK	Dissolved Chloride (Cl)	2007/10/15	<1		mg/L	
	RPD	Dissolved Chloride (Cl)	2007/10/15	0.4		%	25
1904880 JQ	Calibration Check	Dissolved Sulphate (SO4)	2007/10/15		100	%	80 - 120
	MATRIX SPIKE	Dissolved Sulphate (SO4)	2007/10/15		102	%	80 - 120
	BLANK	Dissolved Sulphate (SO4)	2007/10/15	<1		mg/L	
	RPD	Dissolved Sulphate (SO4)	2007/10/15	0.2		%	25
1904881 JQ	Calibration Check	Nitrite (N)	2007/10/15		110	%	80 - 120
	MATRIX SPIKE	Nitrite (N)	2007/10/15		103	%	80 - 120
	BLANK	Nitrite (N)	2007/10/15	<0.06		mg/L	
	RPD	Nitrite (N)	2007/10/15	NC		%	25
1904882 JQ	Calibration Check	Nitrate (N)	2007/10/15		95	%	80 - 120
	MATRIX SPIKE	Nitrate (N)	2007/10/15		114	%	80 - 120
	BLANK	Nitrate (N)	2007/10/15	<0.2		mg/L	
	RPD	Nitrate (N)	2007/10/15	0.05		%	25
1905149 DZ1	Calibration Check	Dissolved Aluminum (Al)	2007/10/16		103	%	80 - 120
		Dissolved Barium (Ba)	2007/10/16		86	%	80 - 120
		Dissolved Boron (B)	2007/10/16		100	%	80 - 120
		Dissolved Calcium (Ca)	2007/10/16		101	%	80 - 120
		Dissolved Chromium (Cr)	2007/10/16		89	%	80 - 120
		Dissolved Iron (Fe)	2007/10/16		90	%	80 - 120
		Dissolved Lithium (Li)	2007/10/16		99	%	80 - 120
		Dissolved Magnesium (Mg)	2007/10/16		102	%	80 - 120
		Dissolved Manganese (Mn)	2007/10/16		100	%	80 - 120
		Dissolved Phosphorus (P)	2007/10/16		107	%	80 - 120
		Dissolved Potassium (K)	2007/10/16		101	%	80 - 120
		Dissolved Silicon (Si)	2007/10/16		102	%	80 - 120
		Dissolved Sodium (Na)	2007/10/16		101	%	80 - 120
		Dissolved Strontium (Sr)	2007/10/16		97	%	80 - 120
	MATRIX SPIKE	Dissolved Barium (Ba)	2007/10/16		91	%	80 - 120
		Dissolved Boron (B)	2007/10/16		106	%	80 - 120
		Dissolved Chromium (Cr)	2007/10/16		95	%	80 - 120
		Dissolved Lithium (Li)	2007/10/16		101	%	80 - 120
		Dissolved Manganese (Mn)	2007/10/16		103	%	80 - 120
		Dissolved Strontium (Sr)	2007/10/16		100	%	80 - 120
	SPIKE	Dissolved Sulphur (S)	2007/10/16		96	%	80 - 120
	BLANK	Dissolved Aluminum (Al)	2007/10/16	<0.04		mg/L	
		Dissolved Barium (Ba)	2007/10/16	<0.01		mg/L	
		Dissolved Boron (B)	2007/10/16	<0.02		mg/L	
		Dissolved Calcium (Ca)	2007/10/16	<0.3		mg/L	
		Dissolved Chromium (Cr)	2007/10/16	<0.01		mg/L	
		Dissolved Iron (Fe)	2007/10/16	<0.06		mg/L	
		Dissolved Lithium (Li)	2007/10/16	<0.02		mg/L	
		Dissolved Magnesium (Mg)	2007/10/16	<0.2		mg/L	
		Dissolved Manganese (Mn)	2007/10/16	<0.004		mg/L	
		Dissolved Phosphorus (P)	2007/10/16	<0.1		mg/L	
		Dissolved Potassium (K)	2007/10/16	<0.3		mg/L	
		Dissolved Silicon (Si)	2007/10/16	<0.1		mg/L	
		Dissolved Sodium (Na)	2007/10/16	<0.5		mg/L	
		Dissolved Strontium (Sr)	2007/10/16	<0.02		mg/L	
		Dissolved Sulphur (S)	2007/10/16	<0.2		mg/L	
	RPD	Dissolved Barium (Ba)	2007/10/16	2.4		%	20
		Dissolved Boron (B)	2007/10/16	NC		%	20
		Dissolved Calcium (Ca)	2007/10/16	0.02		%	20
		Dissolved Iron (Fe)	2007/10/16	NC		%	20
		Dissolved Lithium (Li)	2007/10/16	NC		%	20

Maxxam Analytics Inc

DILLON CONSULTING LTD.
Attention: CORINA PEACH
Client Project #: 07-8107 TALOYOAK WTP
P.O. #: 07-8107
Site Reference: TALOYOAK

Quality Assurance Report (Continued)

Maxxam Job Number: EA748869

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
1905149 DZ1	RPD	Dissolved Magnesium (Mg)	2007/10/16	0.5		%	20
		Dissolved Manganese (Mn)	2007/10/16	0.4		%	20
		Dissolved Phosphorus (P)	2007/10/16	NC		%	20
		Dissolved Potassium (K)	2007/10/16	1.3		%	20
		Dissolved Silicon (Si)	2007/10/16	0.8		%	20
		Dissolved Sodium (Na)	2007/10/16	3.3		%	20
		Dissolved Strontium (Sr)	2007/10/16	0.9		%	20
		Dissolved Sulphur (S)	2007/10/16	NC		%	20
1908101 AS7	Calibration Check	Total Aluminum (Al)	2007/10/17		101	%	80 - 120
		Total Boron (B)	2007/10/17		100	%	80 - 120
		Total Calcium (Ca)	2007/10/17		105	%	80 - 120
		Total Chromium (Cr)	2007/10/17		90	%	80 - 120
		Total Iron (Fe)	2007/10/17		88	%	80 - 120
		Total Lithium (Li)	2007/10/17		96	%	80 - 120
		Total Magnesium (Mg)	2007/10/17		105	%	80 - 120
		Total Manganese (Mn)	2007/10/17		101	%	80 - 120
		Total Phosphorus (P)	2007/10/17		108	%	80 - 120
		Total Potassium (K)	2007/10/17		101	%	80 - 120
		Total Silicon (Si)	2007/10/17		103	%	80 - 120
		Total Sodium (Na)	2007/10/17		101	%	80 - 120
		Total Strontium (Sr)	2007/10/17		95	%	80 - 120
	MATRIX SPIKE	Total Barium (Ba)	2007/10/17		98	%	80 - 120
		Total Boron (B)	2007/10/17		98	%	80 - 120
		Total Chromium (Cr)	2007/10/17		91	%	80 - 120
		Total Lithium (Li)	2007/10/17		91	%	80 - 120
		Total Manganese (Mn)	2007/10/17		115	%	80 - 120
		Total Strontium (Sr)	2007/10/17		102	%	80 - 120
	SPIKE	Total Sulphur (S)	2007/10/17		96	%	80 - 120
	BLANK	Total Aluminum (Al)	2007/10/17	<0.04		mg/L	
		Total Barium (Ba)	2007/10/17	<0.01		mg/L	
		Total Boron (B)	2007/10/17	<0.02		mg/L	
		Total Calcium (Ca)	2007/10/17	<0.3		mg/L	
		Total Chromium (Cr)	2007/10/17	<0.01		mg/L	
		Total Iron (Fe)	2007/10/17	<0.06		mg/L	
		Total Lithium (Li)	2007/10/17	<0.02		mg/L	
		Total Magnesium (Mg)	2007/10/17	<0.2		mg/L	
		Total Manganese (Mn)	2007/10/17	<0.004		mg/L	
		Total Phosphorus (P)	2007/10/17	<0.1		mg/L	
		Total Potassium (K)	2007/10/17	<0.3		mg/L	
		Total Silicon (Si)	2007/10/17	<0.1		mg/L	
		Total Sodium (Na)	2007/10/17	<0.5		mg/L	
		Total Strontium (Sr)	2007/10/17	<0.02		mg/L	
		Total Sulphur (S)	2007/10/17	<0.2		mg/L	
	RPD	Total Barium (Ba)	2007/10/17	NC		%	20
		Total Boron (B)	2007/10/17	NC		%	20
		Total Calcium (Ca)	2007/10/17	5.9		%	20
		Total Iron (Fe)	2007/10/17	6.0		%	20
		Total Lithium (Li)	2007/10/17	NC		%	20
		Total Magnesium (Mg)	2007/10/17	5.7		%	20
		Total Manganese (Mn)	2007/10/17	5.7		%	20
		Total Phosphorus (P)	2007/10/17	NC		%	20
		Total Potassium (K)	2007/10/17	6.6		%	20
		Total Silicon (Si)	2007/10/17	5.9		%	20
		Total Sodium (Na)	2007/10/17	5.7		%	20
		Total Strontium (Sr)	2007/10/17	5.9		%	20

Maxxam Analytics Inc

DILLON CONSULTING LTD.
Attention: CORINA PEACH
Client Project #: 07-8107 TALOYOAK WTP
P.O. #: 07-8107
Site Reference: TALOYOAK

Quality Assurance Report (Continued)

Maxxam Job Number: EA748869

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
1908101 AS7	RPD	Total Sulphur (S)	2007/10/17	6.3		%	20
1909168 YY	MATRIX SPIKE	Dissolved Organic Carbon (C)	2007/10/17		94	%	80 - 120
	SPIKE	Dissolved Organic Carbon (C)	2007/10/17		98	%	80 - 120
	BLANK	Dissolved Organic Carbon (C)	2007/10/17	<1		mg/L	
	RPD	Dissolved Organic Carbon (C)	2007/10/17	8.5		%	20
1909223 YY	MATRIX SPIKE	Total Organic Carbon (C)	2007/10/17		83	%	80 - 120
	SPIKE	Total Organic Carbon (C)	2007/10/17		101	%	80 - 120
	BLANK	Total Organic Carbon (C)	2007/10/17	<0.5		mg/L	
	RPD	Total Organic Carbon (C)	2007/10/17	7.6		%	20
1912431 AL2	Calibration Check	True Colour	2007/10/19		98	%	80 - 120
	BLANK	True Colour	2007/10/19	<2		PtCo units	
	RPD [H36828-02]	True Colour	2007/10/19	NC		%	25
1912464 RW3	MATRIX SPIKE	Total Suspended Solids	2007/10/19		95	%	80 - 120
	SPIKE	Total Suspended Solids	2007/10/19		99	%	80 - 120
	BLANK	Total Suspended Solids	2007/10/19	<2		mg/L	
		Total Suspended Solids	2007/10/19	<2		mg/L	
	RPD	Total Suspended Solids	2007/10/19	NC		%	25
1912465 RW3	Calibration Check	Turbidity	2007/10/19		93	%	80 - 120
	BLANK	Turbidity	2007/10/19	<0.1		NTU	
	RPD [H36828-02]	Turbidity	2007/10/19	3.2		%	20
1912968 LL2	Calibration Check	Total Aluminum (Al)	2007/10/19		91	%	80 - 120
		Total Antimony (Sb)	2007/10/19		93	%	80 - 120
		Total Arsenic (As)	2007/10/19		101	%	80 - 120
		Total Beryllium (Be)	2007/10/19		87	%	80 - 120
		Total Cadmium (Cd)	2007/10/19		81	%	80 - 120
		Total Chromium (Cr)	2007/10/19		91	%	81 - 120
		Total Cobalt (Co)	2007/10/19		102	%	80 - 120
		Total Copper (Cu)	2007/10/19		90	%	81 - 120
		Total Lead (Pb)	2007/10/19		95	%	80 - 120
		Total Molybdenum (Mo)	2007/10/19		91	%	80 - 120
		Total Nickel (Ni)	2007/10/19		97	%	80 - 120
		Total Selenium (Se)	2007/10/19		96	%	80 - 120
		Total Silver (Ag)	2007/10/19		95	%	80 - 120
		Total Thallium (Tl)	2007/10/19		101	%	80 - 120
		Total Tin (Sn)	2007/10/19		88	%	80 - 120
		Total Titanium (Ti)	2007/10/19		89	%	80 - 120
		Total Uranium (U)	2007/10/19		104	%	80 - 120
		Total Vanadium (V)	2007/10/19		113	%	80 - 120
		Total Zinc (Zn)	2007/10/19		94	%	80 - 120
	MATRIX SPIKE	Total Antimony (Sb)	2007/10/19		101	%	80 - 120
		Total Arsenic (As)	2007/10/19		104	%	80 - 120
		Total Cadmium (Cd)	2007/10/19		85	%	80 - 120
		Total Cobalt (Co)	2007/10/19		97	%	80 - 120
		Total Copper (Cu)	2007/10/19		94	%	80 - 120
		Total Lead (Pb)	2007/10/19		95	%	80 - 120
		Total Molybdenum (Mo)	2007/10/19		103	%	80 - 120
		Total Nickel (Ni)	2007/10/19		90	%	80 - 120
		Total Selenium (Se)	2007/10/19		96	%	80 - 120
		Total Thallium (Tl)	2007/10/19		113	%	80 - 120
		Total Titanium (Ti)	2007/10/19		113	%	80 - 120
	BLANK	Total Aluminum (Al)	2007/10/19	<0.001		mg/L	
		Total Antimony (Sb)	2007/10/19	<0.0002		mg/L	
		Total Arsenic (As)	2007/10/19	<0.001		mg/L	
		Total Beryllium (Be)	2007/10/19	<0.001		mg/L	
		Total Cadmium (Cd)	2007/10/19	<0.0002		mg/L	

DILLON CONSULTING LTD.
Attention: CORINA PEACH
Client Project #: 07-8107 TALOYOAK WTP
P.O. #: 07-8107
Site Reference: TALOYOAK

Quality Assurance Report (Continued)

Maxxam Job Number: EA748869

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
1912968 LL2	BLANK	Total Chromium (Cr)	2007/10/19	<0.001		mg/L	
		Total Cobalt (Co)	2007/10/19	<0.0003		mg/L	
		Total Copper (Cu)	2007/10/19	0.0002, RDL=0.0002		mg/L	
		Total Lead (Pb)	2007/10/19	<0.0002		mg/L	
		Total Molybdenum (Mo)	2007/10/19	<0.0002		mg/L	
		Total Nickel (Ni)	2007/10/19	<0.0005		mg/L	
		Total Selenium (Se)	2007/10/19	<0.001		mg/L	
		Total Silver (Ag)	2007/10/19	<0.0001		mg/L	
		Total Thallium (Tl)	2007/10/19	<0.0002		mg/L	
		Total Tin (Sn)	2007/10/19	<0.001		mg/L	
		Total Titanium (Ti)	2007/10/19	<0.001		mg/L	
		Total Uranium (U)	2007/10/19	<0.0001		mg/L	
		Total Vanadium (V)	2007/10/19	<0.001		mg/L	
		Total Zinc (Zn)	2007/10/19	<0.003		mg/L	
	RPD	Total Aluminum (Al)	2007/10/19	1.3		%	20
		Total Antimony (Sb)	2007/10/19	NC		%	20
		Total Arsenic (As)	2007/10/19	NC		%	20
		Total Beryllium (Be)	2007/10/19	NC		%	20
		Total Cadmium (Cd)	2007/10/19	NC		%	20
		Total Chromium (Cr)	2007/10/19	NC		%	20
		Total Cobalt (Co)	2007/10/19	NC		%	20
		Total Copper (Cu)	2007/10/19	5.7		%	20
		Total Lead (Pb)	2007/10/19	NC		%	20
		Total Molybdenum (Mo)	2007/10/19	4.1		%	20
		Total Nickel (Ni)	2007/10/19	4.1		%	20
		Total Selenium (Se)	2007/10/19	NC		%	20
		Total Silver (Ag)	2007/10/19	NC		%	20
		Total Thallium (Tl)	2007/10/19	NC		%	20
		Total Tin (Sn)	2007/10/19	NC		%	20
		Total Titanium (Ti)	2007/10/19	1.6		%	20
		Total Uranium (U)	2007/10/19	2.5		%	20
		Total Vanadium (V)	2007/10/19	6.4		%	20
		Total Zinc (Zn)	2007/10/19	NC		%	20
1914092 LL2	Calibration Check	Dissolved Aluminum (Al)	2007/10/19		100	%	80 - 120
		Dissolved Antimony (Sb)	2007/10/19		94	%	80 - 120
		Dissolved Arsenic (As)	2007/10/19		96	%	80 - 120
		Dissolved Beryllium (Be)	2007/10/19		98	%	80 - 120
		Dissolved Cadmium (Cd)	2007/10/19		101	%	80 - 120
		Dissolved Chromium (Cr)	2007/10/19		93	%	81 - 120
		Dissolved Cobalt (Co)	2007/10/19		92	%	80 - 120
		Dissolved Copper (Cu)	2007/10/19		95	%	81 - 120
		Dissolved Lead (Pb)	2007/10/19		95	%	80 - 120
		Dissolved Molybdenum (Mo)	2007/10/19		101	%	80 - 120
		Dissolved Nickel (Ni)	2007/10/19		95	%	80 - 120
		Dissolved Selenium (Se)	2007/10/19		96	%	80 - 120
		Dissolved Silver (Ag)	2007/10/19		102	%	80 - 120
		Dissolved Thallium (Tl)	2007/10/19		100	%	80 - 120
		Dissolved Tin (Sn)	2007/10/19		106	%	80 - 120
		Dissolved Titanium (Ti)	2007/10/19		100	%	80 - 120
		Dissolved Uranium (U)	2007/10/19		94	%	80 - 120
		Dissolved Vanadium (V)	2007/10/19		101	%	80 - 120
		Dissolved Zinc (Zn)	2007/10/19		95	%	80 - 120
	MATRIX SPIKE [H36828-02]	Dissolved Antimony (Sb)	2007/10/19		88	%	80 - 120
		Dissolved Arsenic (As)	2007/10/19		99	%	80 - 120

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Quality Assurance Report (Continued)

Maxxam Job Number: EA748869

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
1914092 LL2	MATRIX SPIKE						
	[H36828-02]	Dissolved Cadmium (Cd)	2007/10/19		98	%	80 - 120
		Dissolved Cobalt (Co)	2007/10/19		99	%	80 - 120
		Dissolved Copper (Cu)	2007/10/19		96	%	80 - 120
		Dissolved Lead (Pb)	2007/10/19		96	%	80 - 120
		Dissolved Molybdenum (Mo)	2007/10/19		102	%	80 - 120
		Dissolved Nickel (Ni)	2007/10/19		97	%	80 - 120
		Dissolved Selenium (Se)	2007/10/19		95	%	80 - 120
		Dissolved Thallium (Tl)	2007/10/19		98	%	80 - 120
		Dissolved Titanium (Ti)	2007/10/19		102	%	80 - 120
	BLANK	Dissolved Aluminum (Al)	2007/10/19	0.002, RDL=0.001		mg/L	
		Dissolved Antimony (Sb)	2007/10/19	<0.0002		mg/L	
		Dissolved Arsenic (As)	2007/10/19	<0.001		mg/L	
		Dissolved Beryllium (Be)	2007/10/19	<0.001		mg/L	
		Dissolved Cadmium (Cd)	2007/10/19	<0.0002		mg/L	
		Dissolved Chromium (Cr)	2007/10/19	<0.001		mg/L	
		Dissolved Cobalt (Co)	2007/10/19	<0.0003		mg/L	
		Dissolved Copper (Cu)	2007/10/19	<0.0002		mg/L	
		Dissolved Lead (Pb)	2007/10/19	<0.0002		mg/L	
		Dissolved Molybdenum (Mo)	2007/10/19	<0.0002		mg/L	
		Dissolved Nickel (Ni)	2007/10/19	<0.0005		mg/L	
		Dissolved Selenium (Se)	2007/10/19	<0.001		mg/L	
		Dissolved Silver (Ag)	2007/10/19	<0.0001		mg/L	
		Dissolved Thallium (Tl)	2007/10/19	<0.0002		mg/L	
		Dissolved Tin (Sn)	2007/10/19	<0.001		mg/L	
		Dissolved Titanium (Ti)	2007/10/19	<0.001		mg/L	
		Dissolved Uranium (U)	2007/10/19	<0.0001		mg/L	
		Dissolved Vanadium (V)	2007/10/19	<0.001		mg/L	
		Dissolved Zinc (Zn)	2007/10/19	<0.003		mg/L	
	RPD [H36828-02]	Dissolved Aluminum (Al)	2007/10/19	NC		%	20
		Dissolved Antimony (Sb)	2007/10/19	NC		%	20
		Dissolved Arsenic (As)	2007/10/19	NC		%	20
		Dissolved Beryllium (Be)	2007/10/19	NC		%	20
		Dissolved Cadmium (Cd)	2007/10/19	NC		%	20
		Dissolved Chromium (Cr)	2007/10/19	9.6		%	20
		Dissolved Cobalt (Co)	2007/10/19	NC		%	20
		Dissolved Copper (Cu)	2007/10/19	NC		%	20
		Dissolved Lead (Pb)	2007/10/19	NC		%	20
		Dissolved Molybdenum (Mo)	2007/10/19	NC		%	20
		Dissolved Nickel (Ni)	2007/10/19	NC		%	20
		Dissolved Selenium (Se)	2007/10/19	NC		%	20
		Dissolved Silver (Ag)	2007/10/19	NC		%	20
		Dissolved Thallium (Tl)	2007/10/19	NC		%	20
		Dissolved Tin (Sn)	2007/10/19	NC		%	20
		Dissolved Titanium (Ti)	2007/10/19	NC		%	20
		Dissolved Uranium (U)	2007/10/19	NC		%	20
		Dissolved Vanadium (V)	2007/10/19	NC		%	20
		Dissolved Zinc (Zn)	2007/10/19	NC		%	20

NC = Non-calculable
RPD = Relative Percent Difference

APPENDIX F

Guidelines for Canadian Drinking Water Quality

Guidelines for Canadian Drinking Water Quality

Summary Table

Prepared by the
Federal-Provincial-Territorial Committee on Drinking Water
of the
Federal-Provincial-Territorial Committee
on Health and the Environment

March 2007

The *Guidelines for Canadian Drinking Water Quality* are published by Health Canada on behalf of the Federal-Provincial-Territorial Committee on Drinking Water (CDW). This summary table is updated regularly and published on Health Canada's website (www.healthcanada.gc.ca/waterquality). It supersedes all previous versions, as well as the published booklet of the *Sixth Edition of the Guidelines for Canadian Drinking Water Quality*.

These guidelines are based on current, published scientific research related to health effects, aesthetic effects, and operational considerations. Health-based guidelines are established on the basis of comprehensive review of the known health effects associated with each contaminant, on exposure levels and on the availability of treatment and analytical technologies. Aesthetic effects (e.g., taste, odour) are taken into account when these play a role in determining whether consumers will consider the water drinkable. Operational considerations are factored in when the presence of a substance may interfere with or impair a treatment process or technology (e.g., turbidity interfering with chlorination or UV disinfection) or adversely affect drinking water infrastructure (e.g., corrosion of pipes).

In general, the highest priority guidelines are those dealing with microbiological contaminants, such as bacteria, protozoa and viruses. Any measure taken to reduce concentrations of chemical contaminants should not compromise the effectiveness of disinfection.

Inquiries can be directed to: water_eau@hc-sc.gc.ca

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Membership of the Federal-Provincial-Territorial Committee on Drinking Water

Jurisdictional representatives

Alberta	Department of Environment	Mr. Karu Chinniah
British Columbia	Ministry of Health Services	Mr. Barry Boettger
Manitoba	Department of Water Conservation	Mr. Don Rocan
New Brunswick	Department of Health and Wellness	Mr. Gary O'Toole
Newfoundland and Labrador	Department of Environment and Conservation	Mr. Martin Goebel
Northwest Territories	Stanton Territorial Health Authority	Mr. Duane Fleming
Nova Scotia	Department of Environment and Labour	Ms. Judy MacDonald
Nunavut Territory	Department of Health and Social Services	Mr. Peter Workman
Ontario	Ministry of the Environment	Dr. Satish Deshpande
Prince Edward Island	Department of Environment, Energy and Forestry	Mr. George Somers
Québec	Ministère du Développement durable, de l'Environnement et des Parcs	Ms. Caroline Robert
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Yukon Territory	Department of Health and Social Services	Ms. Patricia Brooks
Canada	Department of Health	Dr. John Cooper

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Federal-Provincial-Territorial Committee on Health and the Environment (CHE)	Dr. Michael Routledge
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Canadian Advisory Council on Plumbing	Mr. William Fallow

Committee secretary

Health Canada (Water, Air and Climate Change Bureau, Safe Environments Programme, Healthy Environments and Consumer Safety Branch)	Mr. David Green

New, revised, reaffirmed and upcoming guidelines

Guidelines for several chemical, physical and microbiological parameters are new or have been revised since the publication of the *Sixth Edition of the Guidelines for Canadian Drinking Water Quality* in 1996. These new and revised guidelines are presented in Table 1.

Table 1. New and revised guidelines

Parameter	Guideline (mg/L)	Previous guideline (mg/L)	CHE approval
Microbiological parameters[a]			
Bacteriological		0 coliforms/100 mL	
E.coli	0 per 100 mL		2006
Total coliforms	0 per 100 mL		2006
Heterotrophic plate count	No numerical guideline required		2006
Emerging pathogens	No numerical guideline required		2006
Protozoa	No numerical guideline required	None	2004
Enteric viruses	No numerical guideline required	None	2004
Turbidity	0.3/1.0/0.1 NTU[b]	1.0 NTU	2004
Chemical and physical parameters			
Aluminum	0.1/0.2[c]	None	1999
Antimony	0.006	None	1997
Arsenic	0.010	0.025	2006
Bromate	0.01	None	1999
Bromodichloromethane (BDCM)	0.016	None	2006
Cyanobacterial toxins—microcystin-LR	0.0015	None	2002
Fluoride	1.5	1.5	1996
Formaldehyde	No numerical guideline required	None	1998
Methyl *tertiary*-butyl ether (MTBE)	0.015	None	2006
Trichloroethylene (TCE)	0.005	0.05	2005
Trihalomethanes—Total (THMs)	0.100	0.100	2006
Uranium	0.02	0.1	2000

[a]Refer to section on Guidelines for microbiological parameters.
[b]Based on conventional treatment/slow sand or diatomaceous earth filtration/membrane filtration.
[c]This is an operational guidance value, designed to apply only to drinking water treatment plants using aluminum-based coagulants. The operational guidance values of 0.1 mg/L applies to conventional treatment plants, and 0.2 mg/L applies to other types of treatment systems.

The Federal-Provincial-Territorial Committee on Drinking Water has established a science-based process to systematically review older guidelines to assess the need to update them. Table 2 provides the list of parameters whose guidelines remain appropriate and have been reaffirmed as a result of this review. Health Canada and the FPT Committee on Drinking Water will continue to monitor research on these parameters and recommend any revision(s) to the guidelines that is deemed necessary.

Table 2. Reaffirmed guidelines (2005)

Asbestos	Cyanazine	Iron	Taste
Azinphos-methyl	Diazinon	Magnesium	Temperature
Bendiocarb	Dicamba	Malathion	Terbufos
Benzo(a)pyrene	2,4-Dichlorophenol	Methoxychlor	2,3,4,6-Tetrachlorophenol
Bromoxynil	Diclofop-methyl	Metribuzin	Toluene
Cadmium	Dimethoate	Odour	2,4,6-Trichlorophenol
Calcium	Diquat	Paraquat	Trifluralin
Carbaryl	Diuron	Pentachlorophenol	Xylenes
Carbofuran	Ethylbenzene	Phorate	Zinc
Chloride	Gasoline	Picloram	
Colour	Glyphosate	Silver	

Table 3 outlines the guidelines which are being or have been developed and are awaiting approval through the Federal-Provincial-Territorial process. All current public consultation documents are available on Health Canada's web site (www.healthcanada.gc.ca/waterquality).

Table 3. Upcoming guidelines (not yet approved)

Parameter	Current status
Benzene	In preparation
Carbon tetrachloride	In preparation
Chloral hydrate	Consultation concluded[a]
Chlorine	In preparation
Chlorite Chlorate Chlorine dioxide	Consultation concluded[a]
Corrosion control	In preparation
Haloacetic Acids—Total (HAAs)	Consultation concluded[a]
2-Methyl-4-chlorophenoxyacetic acid (MCPA)	Consultation concluded[a]
Potassium	Consultation ending May 31, 2007
Radiological characteristics	Consultation concluded[a]

[a]Final guideline technical document in preparation

Guidelines for microbiological parameters

Currently available detection methods do not allow for the routine analysis of all microorganisms that could be present in inadequately treated drinking water. Instead, microbiological quality is determined by testing drinking water for *Escherichia coli*, a bacterium that is always present in the intestines of humans and other animals and whose presence in drinking water would indicate faecal contamination of the water.

Bacteriological guidelines

Escherichia coli

The maximum acceptable concentration (MAC) of *Escherichia coli* in public, semi-public, and private drinking water systems is none detectable per 100 mL.

Testing for *E. coli* should be carried out in all drinking water systems. The number, frequency, and location of samples for *E. coli* testing will vary according to the type and size of the system and jurisdictional requirements.

Total coliforms

The MAC of total coliforms in water leaving a treatment plant in a public system and throughout semi-public and private supply systems is none detectable per 100 mL.

For distribution systems in public supplies where fewer than 10 samples are collected in a given sampling period, no sample should contain total coliform bacteria. In distribution systems where greater than 10 samples are collected in a given sampling period, no consecutive samples from the same site or not more than 10% of samples should show the presence of total coliform bacteria.

Testing for total coliforms should be carried out in all drinking water systems. The number, frequency, and location of samples for total coliform testing will vary according to the type and size of the system and jurisdictional requirements.

Heterotrophic plate count

No MAC is specified for heterotrophic plate count (HPC) bacteria in water supplied by public, semi-public, or private drinking water systems. Instead, increases in HPC concentrations above baseline levels are considered undesirable.

Emerging pathogens

No MAC for current or emerging bacterial waterborne pathogens has been established. Current bacterial waterborne pathogens include those that have been previously linked to gastrointestinal illness in human populations. Emerging bacterial waterborne pathogens include, but are not limited to, *Legionella*, *Mycobacterium avium* complex, *Aeromonas hydrophila*, and *Helicobacter pylori*.

Protozoa

Although *Giardia* and *Cryptosporidium* can be responsible for severe and, in some cases, fatal gastrointestinal illness, it is not possible to establish MACs for these protozoa in drinking water at this time. Routine methods available for the detection of cysts and oocysts suffer from low recovery rates and do not provide any information on their viability or human infectivity. Nevertheless, until better monitoring data and information on the viability and infectivity of cysts and oocysts present in drinking water are available, measures should be implemented to reduce the risk of illness as much as possible. If the presence of viable, human-infectious cysts or oocysts is known or suspected in source waters, or if *Giardia* or *Cryptosporidium* has been responsible for past waterborne outbreaks in a community, a treatment and distribution regime and a watershed or wellhead protection plan (where feasible) or other measures known to reduce the risk of illness should be implemented. Treatment technologies in place should achieve at least a 3-log reduction in and/or inactivation of cysts and oocysts, unless source water quality requires a greater log reduction and/or inactivation.

Viruses

Although enteric viruses can be responsible for severe and, in some cases, fatal illnesses, it is not possible to establish MACs for enteric viruses in drinking water at this time. Treatment technologies and watershed or wellhead protection measures known to reduce the risk of waterborne outbreaks should be implemented and maintained if source water is subject to faecal contamination or if enteric viruses have been responsible for past waterborne outbreaks. Where treatment is required, treatment technologies should achieve at least a 4-log reduction and/or inactivation of viruses.

Boil water advisories

General guidance on the issuing and rescinding of boil water advisories is provided. In the event of an advisory, a rolling boil for 1 minute is considered adequate.

Turbidity

Waterworks systems that use a surface water source or a groundwater source under the direct influence of surface water should filter the source water to meet the following health-based turbidity limits, as defined for specific treatment technologies. Where possible, filtration systems should be designed and operated to reduce turbidity levels as low as possible, with a treated water turbidity target of less than 0.1 NTU at all times. Where this is not achievable, the treated water turbidity levels from individual filters:

1. For **chemically assisted filtration**, shall be less than or equal to **0.3 NTU** in at least 95% of the measurements made, or at least 95% of the time each calendar month, and shall not exceed 1.0 NTU at any time.
2. For **slow sand or diatomaceous earth filtration**, shall be less than or equal to **1.0 NTU** in at least 95% of the measurements made, or at least 95% of the time each calendar month, and shall not exceed 3.0 NTU at any time.
3. For **membrane filtration**, shall be less than or equal to **0.1 NTU** in at least 99% of the measurements made, or at least 99% of the time each calendar month, and shall not exceed 0.3 NTU at any time. If membrane filtration is the sole treatment technology employed, some form of virus inactivation* should follow the filtration process.

*Some form of virus inactivation is required for all technologies. The difference is that chemically assisted, slow sand and diatomaceous earth filters are credited with log virus reductions and membrane filters receive no credit.

Guidelines for chemical and physical parameters

Table 4 provides the complete list of all current numerical Guidelines for chemical and physical parameters. Guidelines are either health-based and listed as Maximum Acceptable Concentrations (MAC), based on aesthetic considerations and listed as aesthetic objectives (AO) or established based on operational considerations and listed as Operational Guidance Values (OG). Parameters for which the health-based guideline was developed as an interim maximum acceptable concentration (IMAC) are identified with an asterisk (*) in the table below. The use of these 'interim' MACs was discontinued by the Federal-Provincial-Territorial Committee on Drinking Water in 2003. For more information on specific guidelines, please refer to the guideline technical document for the parameter of concern.

Table 4. Health-based and aesthetic guidelines

Parameter	MAC (mg/L)	AO [or OG] (mg/L)	Year of approval (or reaffirmation)
Aldicarb	0.009		1994
Aldrin + dieldrin	0.0007		1994
Aluminum[a]		[0.1/0.2]	1998
*Antimony[b]	0.006		1997
Arsenic	0.010		2006
*Atrazine + metabolites	0.005		1993
Azinphos-methyl	0.02		1989 (2005)
Barium	1		1990
Bendiocarb	0.04		1990 (2005)
Benzene	0.005		1986
Benzo[a]pyrene	0.00001		1988 (2005)
*Boron	5		1990
*Bromate	0.01		1998
Bromodichloromethane (BDCM)	0.016		2006
*Bromoxynil	0.005		1989 (2005)
Cadmium	0.005		1986 (2005)
Carbaryl	0.09		1991 (2005)
Carbofuran	0.09		1991 (2005)
Carbon tetrachloride	0.005		1986
Chloramines—total	3		1995
Chloride		≤250	1979 (2005)
Chlorpyrifos	0.09		1986
Chromium	0.05		1986
Colour[d]		≤15 TCU	1979 (2005)
Copper[b]		≤1.0	1992

Parameter	MAC (mg/L)	AO [or OG] (mg/L)	Year of approval (or reaffirmation)
*Cyanazine	0.01		1986 (2005)
Cyanide	0.2		1991
Cyanobacterial toxins–Microcystin-LR[c]	0.0015		2002
Diazinon	0.02		1986 (2005)
Dicamba	0.12		1987 (2005)
1,2-Dichlorobenzene[e]	0.2	≤0.003	1987
1,4-Dichlorobenzene[e]	0.005	≤0.001	1987
*1,2-Dichloroethane	0.005		1987
1,1-Dichloroethylene	0.014		1994
Dichloromethane	0.05		1987
2,4-Dichlorophenol,	0.9	≤0.0003	1987 (2005)
*2,4-Dichlorophenoxyacetic acid (2,4 -D)	0.1		1991
Diclofop-methyl	0.009		1987 (2005)
*Dimethoate	0.02		1986 (2005)
Dinoseb	0.01		1991
Diquat	0.07		1986 (2005)
Diuron	0.15		1987 (2005)
Ethylbenzene		≤0.0024	1986 (2005)
Fluoride	1.5		1996
*Glyphosate	0.28		1987 (2005)
Iron		≤0.3	1978 (2005)
Lead[b]	0.01		1992
Malathion	0.19		1986 (2005)
Manganese		≤0.05	1987
Mercury	0.001		1986
Methoxychlor	0.9		1986 (2005)
Methyl tertiary-butyl ether (MTBE)		0.015	2006
*Metolachlor	0.05		1986
Metribuzin	0.08		1986 (2005)
Monochlorobenzene	0.08	≤0.03	1987
Nitrate[f]	45		1987
Nitrilotriacetic acid (NTA)	0.4		1990
Odour		Inoffensive	1979 (2005)
*Paraquat (as dichloride)[g]	0.01		1986 (2005)

Parameter	MAC (mg/L)	AO [or OG] (mg/L)	Year of approval (or reaffirmation)
Parathion	0.05		1986
Pentachlorophenol	0.06	≤0.030	1987 (2005)
pH[h]		6.5–8.5	1995
Phorate	0.002		1986 (2005)
*Picloram	0.19		1988 (2005)
Selenium	0.01		1992
*Simazine	0.01		1986
Sodium[i]		≤200	1992
Sulphate[j]		≤500	1994
Sulphide (as H_2S)		≤0.05	1992
Taste		Inoffensive	1979 (2005)
Temperature		≤15°C	1979 (2005)
*Terbufos	0.001		1987 (2005)
Tetrachloroethylene	0.03		1995
2,3,4,6-Tetrachlorophenol	0.1	≤0.001	1987 (2005)
Toluene		≤0.024	1986 (2005)
Total dissolved solids (TDS)		≤500	1991
Trichloroethylene	0.005		2005
2,4,6-Trichlorophenol	0.005	≤0.002	1987 (2005)
*Trifluralin	0.045		1989 (2005)
Trihalomethanes-total (THMs)[k]	0.100		2006
Turbidity[l]			2004
*Uranium	0.02		1999
Vinyl chloride	0.002		1992
Xylenes—total		≤0.3	1986 (2005)
Zinc[b]		≤5.0	1979 (2005)

[a]This is an operational guidance value, designed to apply only to drinking water treatment plants using aluminum-based coagulants. The operational guidance values of 0.1 mg/L applies to conventional treatment plants, and 0.2 mg/L applies to other types of treatment systems.
[b]Faucets should be thoroughly flushed before water is taken for consumption or analysis.
[c]The guideline is considered protective of human health against exposure to other microcystins (total microcystins) that may also be present.
[d]TCU = true colour unit.
[e]In cases where total dichlorobenzenes are measured and concentrations exceed the most stringent value (0.005 mg/L), the concentrations of the individual isomers should be established.
[f]Equivalent to 10 mg/L as nitrate–nitrogen. Where nitrate and nitrite are determined separately, levels of nitrite should not exceed 3.2 mg/L.

[g]Equivalent to 0.007 mg/L for paraquat ion.
[h]No units.
[i]It is recommended that sodium be included in routine monitoring programmes, as levels may be of interest to authorities who wish to prescribe sodium-restricted diets for their patients.
[j]There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.
[k]Expressed as a running annual average. The guideline is based on the risk associated with chloroform, the trihalomethane most often present and in greatest concentration in drinking water.
[l]Refer to section on Guidelines for microbiological parameters for information related to various treatment processes.

Parameters without guidelines

Some chemical and physical parameters for which a Guideline Technical Document is available have been identified as not requiring a numerical guideline, because currently available data indicate that it poses no health risk or aesthetic problem at the levels generally found in drinking water in Canada.

Table 5. Parameters without numerical guidelines

Ammonia	Asbestos
Calcium	Formaldehyde
Gasoline	Hardness[a]
Magnesium	Radon
Silver	

[a]Public acceptance of hardness varies considerably. Generally, hardness levels between 80 and 100 mg/L (as $CaCO_3$) are considered acceptable; levels greater than 200 mg/L are considered poor but can be tolerated; those in excess of 500 mg/L are normally considered unacceptable. Where water is softened by sodium ion exchange, it is recommended that a separate, unsoftened supply be retained for culinary and drinking purposes.

Archived parameters

The Federal-Provincial-Territorial Committee on Drinking Water has established a science-based process to systematically review older guidelines and archive older guidelines which are no longer required. Guidelines are archived for parameters which are no longer found in Canadian drinking water supplies at levels that could pose a risk to human health, including pesticides which are no longer registered for use in Canada, and for mixtures of contaminants that are addressed individually. Table 6 provides the list of parameters whose guidelines have been archived as a result of this review.

Table 6. Parameters that have been archived[a]

Chlordane (total isomers)[b]	Polychlorinated biphenyls (PCBs)
Dichlorodiphenyltrichloroethane (DDT) + metabolites[b]	Polycyclic aromatic hydrocarbons (PAH)[c]
Endrin[b]	Resin acids
Heptachlor + heptachlor epoxide[b]	Tannin
Lignin[b]	Temephos[d]
Lindane[b]	Total organic carbon (TOC)
Methyl-parathion[b]	Toxaphene[b]
Mirex	Triallate[d]
Pesticides (total)	2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)[d]
Phenols (total)	2,4,5-Trichlorophenoxypropionic acid (2,4,5-TP)[b]
Phthalic acid esters (PAE)	

[a]Published in the 1978 version of the *Supporting Documentation* for these parameters (available upon request).
[b]In 1978 ‘Pesticides’ Supporting Documentation.
[c]Other than benzo[a]pyrene.
[d]No documentation available.

Guidelines for radiological parameters

In setting dose guidelines for radionuclides in drinking water, it is recognized that water consumption contributes only a portion of the total radiation dose and that some radionuclides present are natural in origin and therefore cannot be excluded. Consequently, maximum acceptable concentrations for radionuclides in drinking water have been derived based on a committed effective dose of 0.1 mSv** from one year's consumption of drinking water. This dose represents less than 5% of the average annual dose attributable to natural background radiation.

To facilitate the monitoring of radionuclides in drinking water, the reference level of dose is expressed as an activity concentration, which can be derived for each radionuclide from published radiological data. The National Radiological Protection Board has calculated dose conversion factors (DCFs) for radionuclides based on metabolic and dosimetric models for adults and children. Each DCF provides an estimate of the 50-year committed effective dose resulting from a single intake of 1 Bq*** of a given radionuclide.

The MACs of radionuclides in public water supplies are derived from adult DCFs, assuming a daily water intake of 2 L, or 730 L/year, and a maximum committed effective dose of 0.1 mSv, or 10% of the International Commission on Radiological Protection limit on public exposure:

$$\text{MAC (Bq/L)} = \frac{1 \times 10^{-4}\ \text{(Sv/year)}}{730\ \text{(L/year)} \times \text{DCF (Sv/Bq)}}$$

When two or more radionuclides are found in drinking water, the following relationship should be satisfied:

$$\frac{C_1}{MAC_1} + \frac{C_2}{MAC_2} + \ldots \frac{C_i}{MAC_i} \leq 1$$

where C_i and MAC_i are the observed and maximum acceptable concentrations, respectively, for each contributing radionuclide.

MACs for radionuclides that should be monitored in water samples are listed in Table 7. If a sample is analysed by gamma-spectroscopy, additional screening for radionuclides that may be present under certain conditions can be performed. MACs for these radionuclides are given in Table 8. MACs for a number of additional radionuclides, both natural and artificial, can be found in the sixth edition of the guidelines booklet.

Water samples may be initially screened for radioactivity using techniques for gross alpha and gross beta activity determinations. Compliance with the guidelines may be inferred if the measurements for gross alpha and gross beta activity are less than 0.1 Bq/L and 1 Bq/L, respectively, as these are lower than the strictest MACs. Sampling and analyses should be carried out often enough to accurately characterize the annual exposure. If the source of the activity is known, or expected, to be changing rapidly with time, then the sampling frequency should reflect this factor. If there is no reason to suppose that the source varies with time, then the sampling may be done annually. If measured concentrations

** Sievert (Sv) is the unit of radiation dose. It replaces the old unit, rem (1 rem = 0.01 Sv).
*** Becquerel (Bq) is the unit of activity of a radioactive substance, or the rate at which transformations occur in the substance. One becquerel is equal to one transformation per second and is approximately equal to 27 picocuries (pCi).

are consistent and well below the reference levels, this would be an argument for reducing the sampling frequency. On the other hand, the sampling frequency should be maintained, or even increased, if concentrations are approaching the reference levels. In such a case, the specific radionuclides should be identified and individual activity concentrations measured.

Table 7. Primary list of radionuclides

Radionuclide		Half-life t½	DCF (Sv/Bq)	MAC (Bq/L)
Natural radionuclides				
Lead-210	^{210}Pb	22.3 years	1.3×10^{-6}	0.1
Radium-224	^{224}Ra	3.66 days	8.0×10^{-8}	2
Radium-226	^{226}Ra	1600 years	2.2×10^{-7}	0.6
Radium-228	^{228}Ra	5.76 years	2.7×10^{-7}	0.5
Thorium-228	^{228}Th	1.91 years	6.7×10^{-8}	2
Thorium-230	^{230}Th	7.54×10^{4} years	3.5×10^{-7}	0.4
Thorium-232	^{232}Th	1.40×10^{10} years	1.8×10^{-6}	0.1
Thorium-234	^{234}Th	24.1 days	5.7×10^{-9}	20
Uranium-234[a]	^{234}U	2.45×10^{5} years	3.9×10^{-8}	4
Uranium-235[a]	^{235}U	7.04×10^{8} years	3.8×10^{-8}	4
Uranium-238[a]	^{238}U	4.47×10^{9} years	3.6×10^{-8}	4
Artificial radionuclides				
Cesium-134	^{134}Cs	2.07 years	1.9×10^{-8}	7
Cesium-137	^{137}Cs	30.2 years	1.3×10^{-8}	10
Iodine-125	^{125}I	59.9 days	1.5×10^{-8}	10
Iodine-131	^{131}I	8.04 days	2.2×10^{-8}	6
Molybdenum-99	^{99}Mo	65.9 hours	1.9×10^{-9}	70
Strontium-90	^{90}Sr	29 years	2.8×10^{-8}	5
Tritium[b]	^{3}H	12.3 years	1.8×10^{-11}	7000

[a] The activity concentration of natural uranium corresponding to the chemical guideline of 0.02 mg/L (see separate guideline technical document on uranium) is about 0.5 Bq/L.

[b] Tritium is also produced naturally in the atmosphere in significant quantities.

Table 8. Secondary list of radionuclides

Radionuclide		Half-life t½	DCF (Sv/Bq)	MAC (Bq/L)
Natural radionuclides				
Beryllium-7	^{7}Be	53.3 days	3.3×10^{-11}	4000
Bismuth-210	^{210}Bi	5.01 days	2.1×10^{-9}	70
Polonium-210	^{210}Po	138.4 days	6.2×10^{-7}	0. 2
Artificial radionuclides				
Americium-241	^{241}Am	432 years	5.7×10^{-7}	0. 2
Antimony-122	^{122}Sb	2.71 days	2.8×10^{-9}	50
Antimony-124	^{124}Sb	60.2 days	3.6×10^{-9}	40
Antimony-125	^{125}Sb	2.76 years	9.8×10^{-10}	100
Barium-140	^{140}Ba	12.8 days	3.7×10^{-9}	40
Bromine-82	^{82}Br	35.3 hours	4.8×10^{-10}	300
Calcium-45	^{45}Ca	165 days	8.9×10^{-10}	200
Calcium-47	^{47}Ca	4.54 days	2.2×10^{-9}	60
Carbon-14[a]	^{14}C	5730 years	5.6×10^{-10}	200
Cerium-141	^{141}Ce	32.5 days	1.2×10^{-9}	100
Cerium-144	^{144}Ce	284.4 days	8.8×10^{-9}	20
Cesium-131	^{131}Cs	9.69 days	6.6×10^{-11}	2000
Cesium-136	^{136}Cs	13.1 days	3.0×10^{-9}	50
Chromium-51	^{51}Cr	27.7 days	5.3×10^{-11}	3000
Cobalt-57	^{57}Co	271.8 days	3.5×10^{-9}	40
Cobalt-58	^{58}Co	70.9 days	6.8×10^{-9}	20
Cobalt-60	^{60}Co	5.27 years	9.2×10^{-8}	2
Gallium-67	^{67}Ga	78.3 hours	2.6×10^{-10}	500
Gold-198	^{198}Au	2.69 days	1.6×10^{-9}	90
Indium-111	^{111}In	2.81 days	3.9×10^{-10}	400
Iodine-129	^{129}I	1.60×10^{7} years	1.1×10^{-7}	1
Iron-55	^{55}Fe	2.68 years	4.0×10^{-10}	300
Iron-59	^{59}Fe	44.5 days	3.1×10^{-9}	40
Manganese-54	^{54}Mn	312.2 days	7.3×10^{-10}	200
Mercury-197	^{197}Hg	64.1 hours	3.3×10^{-10}	400
Mercury-203	^{203}Hg	46.6 days	1.8×10^{-9}	80
Neptunium-239	^{239}Np	2.35 days	1.2×10^{-9}	100
Niobium-95	^{95}Nb	35.0 days	7.7×10^{-10}	200
Phosphorus-32	^{32}P	14.3 days	2.6×10^{-9}	50
Plutonium-238	^{238}Pu	87.7 years	5.1×10^{-7}	0.3

Radionuclide		**Half-life t½**	**DCF (Sv/Bq)**	**MAC (Bq/L)**
Plutonium-239	^{239}Pu	2.41×10^4 years	5.6×10^{-7}	0.2
Plutonium-240	^{240}Pu	6560 years	5.6×10^{-7}	0.2
Plutonium-241	^{241}Pu	14.4 years	1.1×10^{-8}	10
Rhodium-105	^{105}Rh	35.4 hours	5.4×10^{-10}	300
Rubidium-81	^{81}Rb	4.58 hours	5.3×10^{-11}	3000
Rubidium-86	^{86}Rb	18.6 days	2.5×10^{-9}	50
Ruthenium-103	^{103}Ru	39.2 days	1.1×10^{-9}	100
Ruthenium-106	^{106}Ru	372.6 days	1.1×10^{-8}	10
Selenium-75	^{75}Se	119.8 days	2.1×10^{-9}	70
Silver-108m	^{108m}Ag	127 years	2.1×10^{-9}	70
Silver-110m	^{-10m}Ag	249.8 days	3.0×10^{-9}	50
Silver-111	^{111}Ag	7.47 days	2.0×10^{-9}	70
Sodium-22	^{22}Na	2.61 years	3.0×10^{-9}	50
Strontium-85	^{85}Sr	64.8 days	5.3×10^{-10}	300
Strontium-89	^{89}Sr	50.5 days	3.8×10^{-9}	40
Sulphur-35	^{35}S	87.2 days	3.0×10^{-10}	500
Technetium-99	^{99}Tc	2.13×10^5 years	6.7×10^{-10}	200
Technetium-99m	^{99m}Tc	6.01 hours	2.1×10^{-11}	7000
Tellurium-129m	^{129m}Te	33.4 days	3.9×10^{-9}	40
Tellurium-131m	^{131m}Te	32.4 hours	3.4×10^{-9}	40
Tellurium-132	^{132}Te	78.2 hours	3.5×10^{-9}	40
Thallium-201	^{201}Tl	3.04 days	7.4×10^{-11}	2000
Ytterbium-169	^{169}Yb	32.0 days	1.1×10^{-9}	100
Yttrium-90	^{90}Y	64 hours	4.2×10^{-9}	30
Yttrium-91	^{91}Y	58.5 days	4.0×10^{-9}	30
Zinc-65	^{65}Zn	243.8 days	3.8×10^{-9}	40
Zirconium-95	^{95}Zr	64.0 days	1.3×10^{-9}	100

[a] ^{14}C is also produced naturally in the atmosphere in significant quantities.

APPENDIX G

Intake Pump Calculations

Intake Pump Power Calculation

CONVERSIONS FACTORS

1 US gpm	=	6.309E-05	m^3/s
1 m	=	39.37	inch
1 m	=	3.2808	ft
1 ft	=	0.3048	m
1 HP (elect)	=	746	W

INPUT VARIABLES

Flow Rate req'd at Truckfill, Q (US gpm)	251.7
Fire Flow Rate, Q (m^3/s)	0.0167
Length of Intake Pipe, L_p (m)	90
Nominal Pipe Diameter, D_p (inch)	4
Outside Pipe Diameter, D_{po} (m)	0.1143
Wall Thickness, w_t (m)	0.0104
Inside Pipe Diameter, D_{pi} (m)	0.0935
Roughness Factor of Pipe, C	140
Total Resistance Coefficient for Entrance & Exit	1.5
Static Lift (m)	7.5
Pump Efficiency (%)	65
Accelertaion due to Gravity, g (m/s^2)	9.81
Specific Gravity of Water, SG	1
Number of Bends in Pipe	5
Resistance Coefficient for Bend	2.2

OUTPUT VARIABLES

Cross-Sectional Area of Pipe, A_p (m^2)	6.87E-03
Velocity in Pipe, *v* (m/s)	2.43
Fricton Loss due to Pipe, $h_{L,pipe}$ (ft/100ft pipe)	5.50
Fricton Loss due to Pipe, $h_{L,pipe}$ (m)	4.95
Fricton Loss due to Entrance, Exit & Fittings, $h_{L,fittings}$ (m)	3.75
Total Dynamic Head, TDH (m)	16.19
Total Dynamic Head, TDH (ft)	53.13
Brake Horsepower, BHP (HP)	5.19
Power, P (kW)	3.88

APPENDIX H

Alternative Energy Report

Water System Upgrades, Taloyoak

Alternative Energy Report

November 8, 2007

Department of Community and Government Services, Government of Nunavut

07-8107-1000

Gary Strong - Project Manager

Submitted by

Dillon Consulting Limited

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(In reply, please refer to)
Our File: 07-8107-1000

November 8, 2007

Government of Nunavut
Department of Community and Government Services
P.O. Box 200
Cambridge Bay, NU
X0A 0C0

Attention: Sudhir Jha, P. Eng.
Senior Project Officer

RE: Alternative Power Generation Report
Water System Upgrades, Taloyoak

Dear Mr. Jha:

Enclosed please find our report on the assessment of the alternative power generation options for the new Taloyoak Water Treatment Plant. This report responds to the Department's request to investigate the use of various options of prime power that will be provided to the plant.

We trust that this meets your requirements at this time.

Yours sincerely,

DILLON CONSULTING LIMITED

Gary Strong, P. Eng.
Project Manager

GS/cm
Encl.

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TABLES

APPENDICES

1 INTRODUCTION

In June 2007, Dillon Consulting Limited (Dillon) was retained by the Department of Community and Government Services (CGS) to develop and design the water intake and treatment facility for the Hamlet of Taloyoak.

The CGS expressed interest in researching options for alternative energies to minimize the power consumption rates and lifetime costs for the facility. Alternative energies such as solar power have been implemented in other facilities throughout the north in communities such as Colville Lake, NT. Information from this facility suggests that the addition of such technologies have proven to assist with reducing the costs associated with power generation.

The purpose of this report is to investigate the various options that are available for the prime and standby power sources for the water treatment plant in Taloyoak.

A number of goals and objectives that were set out in the project's Terms of Reference (TOR). Several of these are applicable to the development of the prime power supply analysis. The goals of the project are to produce potable water meeting the requirements of the GCDWQ and in accordance to the Nunavut Public Health Act. In meeting this goal, the following items are identified in the TOR and considered applicable to this assessment:

- The facility must be simple to operate and maintain by local forces with limited locally available equipment, parts and materials.
- It is extremely important that the facility is reliability as well as efficient and cost-effective.
- All major components of the system must be capable of recovering from a frozen condition, in an operable state, if there is any possibility of freezing.

These criteria will be the assessment criteria for selection of the best applicable alternative.

2 POWER REQUIREMENTS

A summary of the power requirements for the water intake and treatment plant are outlined in **Table 1** below.

Table 1: Power Requirements for Water Treatment Plant

Description	Power
Total Power (kW)	25
Energy Use, Daily (kWh)	73
Energy Use, Annual (kWh)	26,645
Electrical Costs @ $0.6808 per kWh	$18,140

Energy use per day was calculated using the actual power consumption of each device and the number of hours of operation per day. The use of emergency equipment was not considered in the development of the annual power costs.

Table 2: Cost Description

Cost	Description
Capital Cost	Cost of construction of the facility which include purchase, mobilization and installation of equipment, design and engineering costs as well as contingency.
Operation and Maintenance Costs	Cost of annual operation and maintenance of the facility which may include manpower, energy requirements, fuel, general maintenance (light bulbs, paint) and equipment replacement.
Life Cycle Costs	Cost for total facility over its lifetime, usually calculated over a 25 year period and includes the capital and operation and maintenance costs. The life cycle cost is shown as a present value that is calculated at a discount rate of 2%, 4% and 6%.

The following is a list of the design criteria to be used in the development of the water supply system. These are derived from the GNWT "*General Terms of Reference for Water and Sanitation*" (GTR), the "*National Building Code*" (NBC), "*Capital Standards Criteria, September 1993*," MACA and the "*Good Engineering Practice for Northern Water and Sewer Systems, First Edition, April 2004*". Mechanical and building systems design should comply with the "*Good Building Practice for Northern Facilities*" as related to utility buildings.

The facility is also to be designed to the current edition of:

- National Fire Prevention Act
- Electrical Code
- Public Health Act (including reference to the GCDWQ)
- Installation of Oil Burning Equipment (B-139)
- National Fire Code

Estimated costs shown in this report were extracted from a previous study for alternative energy sources for the water treatment facility in Colville Lake, NT that was performed in 2005. A factor of 1.3 was added to these estimates to incorporate the cost increase for the community of Taloyoak, NU. As well, an average inflation rate of 2% was used to adjust the time value of money over the lifetime of the facility.

3 OPTIONS

There are various power supply options available for the water treatment facility in Taloyoak. Descriptions of these options are provided in **Table 3** shown on the following page.

Table 3: Power Generation Options

Option	Main Power Source	Building Location
A	Power Transmission Line	None
B	Diesel Generator	Separate room or building
C	Battery Bank with Generator	Separate room or building
D	Option C with PV Cells	Separate room or building
E	Option C with Wind Generator	Separate room or building
F	Option C with PV Cells and Wind Generator	Separate room or building
G	Option A with PV Cells	Separate room or building
H	Option A with Wind Generator	Separate room or building
I	Option A with PV Cells and Wind Generator	Separate room or building

The standby generator was not included in the cost analysis as all options would require an additional generator as a backup power source. A separate room or building from the water intake and treatment plant may be built to house the power sources.

3.1 Option A: Power Transmission Line

Option A is the original design concept proposed for this project. Similar to the most Water Treatment Plants in the Northern arctic, this option consists of using power provided by the Nunavut Power Corporation (NPC) station in Taloyoak as the main source of energy to the building and water treatment processes.

3.1.1 Capital Costs

In order to connect to the existing power grid with the NPC, a power transmission line, approximately 850 m in length, will have to be installed as the water intake and treatment facility is located outside of the community. Total estimated cost for the installation of the power line is estimated to be approximately $120,000.

3.1.2 Operating and Maintenance Costs

The electricity rate for commercial or industrial clients in Taloyoak is about $0.6808 per kWh. Using the estimated power requirements shown above in **Table 1**, the annual costs for NPC power are approximately $18,140. The 25 year life cycle costs at varying discount rates are shown in **Table 4**.

Table 4: Life Cycle Costs at Varying Discount Rates for Option A

Discount Rate	Life Cycle Cost
2%	$591,650
4%	$493,950
6%	$315,900

3.1.3 Criteria Assessment

Option A is the most common method of power supply for a plant with the majority of the facilities throughout the NWT and Nunavut being supplied in this manner. Facilities that utilize a transmission line as the prime power and a diesel generator as backup have proven to be a highly reliable power sources. However, problems, described below, can arise with this system.

- High winds, which are more prevalent in barren land communities than in the more southern communities, create problems with the power transmission line.
- Electronic systems in the plant have problems due to a dirty power supply. Over and under voltage issues have occurred in many locations which have resulted in premature failure of pumps, controllers and electronics.
- Failure of stand-by power supply units occur due to inexperienced operators, poor maintenance procedures. Lack of monthly testing and verification procedures are also common problems. Often the prime power is sufficiently stable that the diesel powered plant is not called on for several years, unless exercised monthly by the operator. Long periods of time without operation are not recommended for the standby units.

Table 5: Criteria Assessment of Option A

Criteria Description	Discussion	Score
Simple to Operate and Maintain with Local Operators	All options require some sort of diesel power generator on site. The use of line power provides the simplest approach for the plant operator.	10
Reliability of Facility	Line power is reliable; however an issue with dirty power is a potential concern.	8
Recovery From Frozen Condition in operable State	Fully recoverable from frozen condition into operable state. Battery (for the starter) may become damaged if discharged from frozen state or low temperatures.	9

3.2 Option B: Diesel Generator

Option B consists of an onsite diesel generator system with the following components:

- Building structure for WTP, which does not contain a room for the standby generator.
- Separate power building that would house both the prime and standby power systems.
- Two 20 kW diesel generators.
- One switch gear that will transfer power from the prime power generator to the stand-by power generator.
- Ventilation and fresh air supply for room cooling and engine combustion.
- Monitoring and control system for the room ventilation.
- Fuel storage tank, complete with spill containment.

3.2.1 Capital Costs

A capital cost for the proposed system was obtained from a quotation from Adco Power, which is used for budget purposes only. The cost for the proposed system is $160,000 FOB Edmonton with an additional $13,000 required for shipping.

The system would eliminate the requirement for a stand-by generator system within the WTP. This will result in a cost savings to the WTP, both in capital cost and operational costs. The capital cost saving is estimated to be $80,000. Therefore, the total net capital cost for this option is approximately $93,000.

3.2.2 Operating and Maintenance Costs

For this option, the costs for the operation and maintenance include only those for one full time generator. The basis of the operations cost estimate is as follows:

- Fuel consumption is estimated at $1.70 per liter, for a total value of $41,000. A detailed fuel consumption calculation is completed and shown in the appendix.
- Maintenance cost, which includes oil, filters and monthly maintenance, is estimated to be $22,100 per year.
- The generator will require a major overhaul on a 3 year cycle, and full replacement on a 9 year cycle. The cost of the overhaul is estimated to be 50% of the replacement cost which is quoted at $26,000.

Table 6: Breakdown of O&M Costs for Option B

Component	Cost	Lifespan	Cost in Current dollars
Fuel Consumption	$1.70 per L	Annual	$41,000
Filters/Oil/Other Consumables	$22,100	Annual	$22,100
Major Over Haul	$13,000	3 yrs	$13,000
Engine Replacement	$26,000	9 yrs	$26,000

Table 7: Life Cycle Costs at Varying Discount Rates for Option B

Discount Rate	Life Cycle Cost
2%	$1,863,600
4%	$1,494,550
6%	$1,229,850

3.2.3 Criteria Assessment

Option B is an approach used most common for prime power supply in the north, but less so in the NWT. The water treatment plants in Kugaaruk, Pond Inlet and Repulse Bay are all powered fulltime by onsite generators. Typical problem areas with this system are:

- Dirty power supply creates problems with electronics in the plant. Over and under voltage issues have occurred, resulting in premature failure of pumps, controllers and electronics. An on-site power supply is similar to prime power obtained from the utilities power plant, and this is an inherent issue with power generated by diesel and gas powered generators.
- Inexperienced operators and poor maintenance procedures are common reasons why power supply units tend to fail. Lack of monthly testing and verification procedures are also common problems.
- Like in the case of Option A, the prime power is often sufficiently stable that the diesel-powered plant is not called on for several years, unless it exercised monthly by the operator. Long periods of time without operation are not recommended for the standby units.

Table 8 : Criteria Assessment of Option B

Criteria Description	Discussion	Score
Simple to Operate and Maintain with Local Operators	All options require some sort of diesel power generator on site. The use of on site power generation adds to the complexity of the overall system when compared to line power.	7
Reliability of Facility	Onsite power generation is less reliable than line power. Even though it has been proven to be reliable elsewhere in the north, dirty power is still a potential concern.	7
Recovery From Frozen Condition in operable State	Fully recoverable from frozen condition into operable state. Battery (for starter) maybe damaged is discharged when frozen to low temperatures.	9

3.3 Option C: Battery Bank with Diesel Generator

Option C consists of the integration of a battery bank into the stand-alone power generation provided by the diesel generator. This option allows the generator to provide power at a more efficient operating point. The power supply strategy would be as follows:

- This additional will provide sufficient battery back up to operate the building heat, monitoring and controls, and domestic plumbing and lighting.
- When the process plant is running, the generator will operate. This will typically be 4 hours per day, 5 days per week.
- The batteries will be monitored so that when the batteries' stored amp-hours (or voltage) drops below a certain set point, the generator will start to charge the batteries.

3.3.1 Capital Costs

Capital costs for Option C include those stated in Option B for the power diesel powered generator as the system is identical to the previous system. Quotes from Adco Power and Niagara Wind Power Inc. provided estimates for the proposed system - diesel generator, battery bank and inverters. Total capital investment would be $220,200 FOB Edmonton. The proposed setup of the system would dismiss the requirement for a standby generator; therefore, savings to the both capital and operational costs would be similar as in Option B, with capital costs estimated to be about $80,000. Total net capital cost for this option is calculated to be about $160,200, which includes an additional $20,000 required for shipment of the equipment.

3.3.2 Operating and Maintenance Costs

The operation cost of this option uses only the cost of the one full time generator. The basis of the cost estimate is as follows:

- Fuel consumption which was estimated to be 35% of the actual fuel used by the generator. At a cost of $1.70 per liter, total fuel costs were estimated to be $14,400 per year. A detailed fuel consumption calculation is shown in the appendix.
- Maintenance cost, which includes oil, filters and monthly maintenance, is estimated to be $22,100 per year.
- The generator will require a major overhaul on a 5 year cycle, and full replacement on a 15 year cycle. Cost for the overhaul is estimated to be 50% of the replacement cost which is quoted at $26,000.
- Battery replacement will be required every 7 years.

Table 9: Breakdown of O&M Costs of Option C

Component	Cost	Lifespan	Cost in Current Dollars
Fuel Consumption	$1.70 per L	Annual	$14,400
Filters/Oil/Other Consumables	$22,100	Annual	$22,100
Major Over Haul	$13,000	5 yrs	$13,000
Engine Replacement	$26,000	15 yrs	$26,000
Battery Replacement	$42,000	7 yrs	$42,000

Table 10: Life Cycle Costs at Varying Discount Rates of Option C

Discount Rate	Life Cycle Cost
2%	$1,300,200
4%	$1,059,950
6%	$887,200

3.3.3 Criteria Assessment

Option C is an approach that is not used anywhere in the north. The use of battery back up is exercised by the GNWT at the remote research station at Daring Lake, run by ENR. Air quality monitoring stations run by ENR also use a PV, battery wind system. Both of these systems have been successful in the arctic regions. Some issues to consider for this approach have been discussed below.

- Dirty power supply causes problems with electronics in the plant. Issues of over- and under-voltage have occurred in many locations, resulting in premature failure of pumps, controllers and electronics. Onsite power supply is similar to prime power provided by the utilities power plant, and this is an inherent issue with power generated by diesel and gas powered generators.

- Power supply units often fail due to inexperienced operators, poor maintenance procedures. Lack of monthly testing and verification procedures are common problems as well.
- Similar to Option A and B, often the prime power is sufficiently stable that the back up power plant is not called on for several years, unless exercised monthly by the operator. Long periods of time without operation are not recommended for the standby units.
- The use of batteries and inverters would be new to the community. Operators may find the system's uniqueness a challenge. Having said that, batteries and inverters have limited service requirements. Batteries require monthly checking for electrolyte levels while inverters/chargers have non serviceable parts.
- Due to the fact that the batteries have a life expectancy of 7 years, the community will need to deal with the disposal of the batteries.
- Batteries cannot be frozen. If the there is a heat loss/plant failure, and the batteries are in a discharged condition, they can be damaged and/or rupture.

Table 11: Criteria Assessment of Option C

Criteria Description	Discussion	Score
Simple to Operate and Maintain with Local Operators	All options require some sort of diesel power generator on site. The use of on-site power generation adds to the complexity of the overall system when compared to line power. The use of batteries and inverters increases the complexity of the system.	6
Reliability of Facility	On-site power generation has proven else where to be a reliable, however, issues with dirty power is a potential concern. On-site power generation is less reliable than line power. The addition of batteries increasing the reaction time allowance in the event of system failure. The battery system will provide power for heat and controls.	8
Recovery From Frozen Condition in Operable State	Not fully recoverable from frozen condition into operable state. The batteries may become damaged if discharged from a frozen or low temperature state.	7

3.4 Option D: Option C with PV Modules

Option D is identical to Option C in all aspects with the exception of the PV addition. The PV panels would provide power directly to the inverter/charger unit, which will control the power supply to the batteries.

In theory, the PV battery-inverter system can provide power to the plant for full operation, provided sufficient controls are provided to modulate the power consumption. During the part of the year that there is sufficient sunlight, the inverter can deliver power to operate both process pumps simultaneously, provided all other major power components (hot water heater, heat trace) are not drawing power. This can be achieved through the use of a process controller.

It was difficult to determine power output available from the PV panels without a site specific study to determine the amount of solar charge that will be received from PV. Every year, Taloyoak has about 24 hours of daylight during the time period of May 17th to July 27th and complete darkness from November 25th to January 16th. From this data, it was estimated that Taloyoak has approximately 2400 hours of sunlight each year. However, using this data and a few approximations, an estimate of the cost savings provided by this system could be calculated. Varying cost estimates were developed based on a percentage of annual power supply from the PV units.

3.4.1 Capital Costs

The capital cost of the proposed system was obtained through a quotation from Adco Power and Niagara Wind Power Inc., which are used for budget purposes only. Compared to Option C, the capital cost would be increased by $25,000 for the supply of the PV cells as well as an additional $12,000 for their transport and installation. Total capital investment is approximately $197,200.

3.4.2 Operating and Maintenance Costs

Operating and maintenance costs for this option apply only those associated with the use of one full time generator. The basis of the operations cost estimate is as follows:

- Fuel consumption which was estimated to be 35% of the actual fuel used by the generator. At a cost of $1.70 per liter, total fuel costs were estimated to be $14,400 per year. A detailed fuel consumption calculation is shown in the appendix.
- Maintenance costs include those associated with the replacement of oil and filters as well as general monthly maintenance. These costs are estimated to be $22,100 per year.
- Generator will require a major overhaul on a 5 year cycle and full replacement on a 15 year cycle. Cost of the overhaul is estimated to be 50% of the replacement cost for the generator, which is quoted as $26,000.
- Battery replacement will be required every 7 years.

Table 12: Breakdown of O&M Costs of Option D

Component	Cost	Lifespan	Cost in Current Dollars
Fuel Consumption	$1.70 per L	Annual	$14,400*
Filters/Oil/Other Consumables	$22,100	Annual	$22,100
Major Over Haul	$13,000	5 yrs	$13,000
Engine Replacement	$26,000	15 yrs	$26,000
Battery Replacement	$42,000	7 yrs	$42,000

*Under full demand scenario.

Fuel consumption will decrease as the use of the PV system increases. This is seen in Table 13 below; as the percentage usage of the PV utilities increases, the O&M costs and further the life cycle costs decrease.

Table 13: Life Cycle Costs at Varying PV Utilities at 4% Discount Rate

% Usage	Life Cycle Cost
10	$1,021,700
20	$946,475
30	$871,250
40	$796,000
50	$725,750

3.4.3 Criteria Assessment

The use of PV and batteries is not a common approach used elsewhere in the north for prime power supply to a WTP. Some issues to consider in this approach are as follows:

- As is the case in Option B and C, often the prime power is sufficiently stable that the back up power plant is not called on for several years, unless exercised monthly by the operator. Long periods of time without operation are not recommended for standby units.
- Use of batteries and inverters would be new to the community, and the operators may find the system uniqueness a challenge. Having said that, batteries and inverters have limited service requirements. Batteries require monthly checking for electrolyte levels. Inverters/chargers have not serviceable parts.
- Batteries have a typical life expectancy of 7 years which means that the community will need to deal with the disposal of waste batteries.
- The batteries cannot be frozen. If there is a heat loss and/or plant failure, and the batteries are in a discharged condition, they can become damaged and/or rupture.

Table 14: Criteria Assessment of Option D

Criteria Description	Discussion	Score
Simple to Operate and Maintain with Local Operators	The use of on site power generation adds to the complexity of the overall system when compared to line power. Also, the use of batteries and inverters increases the complexity of the system.	8
Reliability of Facility	On-site power generation has proven else where to be a reliable, however, issues with dirty power is a potential concern. On-site power generation is less reliable than line power. The addition of batteries increasing the reaction time allowance in the event of system failure. The battery system will provide power for heat and controls.	8
Recovery From Frozen Condition in Operable State	Not fully recoverable from frozen condition into operable state. Batteries may become damaged if discharged from a frozen state or low temperatures.	7

3.5 Option E: Option C with Wind Generator

Option E is similar to Option C but a wind generator will be integrated into the system to create additional power.

Wind studies have not been researched in Taloyoak but wind data obtained from Environment Canada shows that the community has sufficient resources to benefit from the use of a wind generator. The average annual wind speed is approximately 5.9 m/s; however, data from Environment Canada indicates that speeds can become as high as 80 km per hour (22.2 m/s). Similarly, it is difficult to estimate the exact amount of usable wind power that will occur for the area over the course of a year. A wind study performed near Kugluktuk also illustrates that there is potential to obtain a considerate amount of power from wind generation.

3.5.1 Capital Costs

Capital costs for this option include those of the Option C along with the cost for the purchase and installation of the wind generator, estimated at $15,000. Shipment and installation would cost an additional approximately $32,000, which give a total investment of $187,200.

Wind turbines are becoming more prominent throughout Canada. Canadian Tire, for instance, has incorporated green energy items such as solar panels and wind generators. Presently, a 400 W rating wind generator can be purchased for a cost of about $800 at Canadian Tire.

3.5.2 Operating and Maintenance Costs

Operating and maintenance costs would include general maintenance of the turbine as well as those associated for the generator and battery bank. Depending on environmental and working conditions, a wind turbine has an approximate life span of 10 years.

Table 15: Breakdown of O&M Costs of Option E

Component	Cost	Lifespan	Cost in Current Dollars
Fuel Consumption	$1.70 per liter	Annual	$14,400*
Filters/Oil/Other Consumables	$22,100	Annual	$22,100
Turbine Maintenance	$1,000	Annual	$1,000
Major Over Haul	$13,000	5 yrs	$13,000
Engine Replacement	$26,000	15 yrs	$26,000
Battery Replacement	$42,000	7 yrs	$42,000
Turbine Replacement	$15,000	10 yrs	$15,000

*Under full demand scenario requirements.

Table 16: Life Cycle Costs at Varying Wind Turbine Utilities at 4% Discount Rate

% Usage	Life Cycle Cost
10	$1,033,350
20	$956,050
30	$878,750
40	$801,450
50	$724,150

3.5.3 Criteria Assessment

There have been a few facilities throughout the NWT and Nunavut that have incorporated wind generation into the power supplies. Wind turbines are more common in Nunavut than in the NWT. Cambridge Bay, Rankin Inlet, and Kugluktuk all have larger scale wind turbines in place to assist with power supply. Even though wind turbines help to reduce overall fuel costs, there are still a few drawbacks to this system. These concerns are described below.

- Cold weather causes reliability issues for operation. Low temperatures create problems with the mechanics of the turbine. Ice accumulation on rotor blades is also a concern.
- High winds can decrease the efficiency of the power generated by the turbine.
- Lightening strikes to wind turbines are common due to their height which causes damage to the control circuits.
- Addition of a wind turbine adds to the complexity of the system in the area of controls and monitoring.
- Turbines require regular monitoring and maintenance to ensure that they are working at optimum conditions. Therefore, it is beneficial to coordinate training for local operations and personnel to understand the system as there will not be a need for manpower from the south. This will reduce the amount of downtime and maintenance costs of the system.

Table 17: Criteria Assessment of Option E

Criteria Description	Discussion	Score
Simple to Operate and Maintain with Local Operators	The use of on site power generation adds to the complexity of the overall system when compared to line power. Also, the use of batteries and inverters increases the complexity of the system. Although simple operation, wind turbine requires a high volume of monitoring and maintenance, especially during the winter.	8
Reliability of Facility	On-site power generation has proven else where to be a reliable, however, issues with dirty power is a potential concern. On-site power generation is less reliable than line power. The addition of batteries increasing the reaction time allowance in the event of system failure as it will provide power for heat and controls. High winds can decrease the efficiency of the power supplied by turbine. If winds are too strong, then the amount of power that can be converted will decrease.	7
Recovery From Frozen Condition in Operable State	Not completely recoverable from a frozen state. Batteries may become damaged if discharged from a frozen state or low temperatures. Ice accumulation on blades creates problems with efficiency of the system.	7

3.6 Option F: Option C with PV Modules and Wind Generator

Option F incorporates the use of PV cells and a wind generator to the battery bank-generator system discussed in Option C. The plant will generally operate using power generated from the PV panels and wind generator and stored in the battery bank. However, during peak power times as well as power outages, additional power will be supplied by the diesel generator.

3.6.1 Capital Costs

Capital investment for this option has a total cost of $225,200 which takes into account the purchase and installation of all components of the diesel generator, battery bank, inverters, PV panels and wind generator.

3.6.2 Operating and Maintenance Costs

Operating and maintenance costs for this option are listed below which include those for the operation and maintenance of the include those stated in Option E.

Table 18: Breakdown of O&M Costs of Option F

Component	Cost	Lifespan	Cost in Current Dollars
Fuel Consumption	$1.70 per liter	Annual	$14,400*
Filters/Oil/Other Consumables	$22,100	Annual	$22,100
Turbine Maintenance	$1,000	Annual	$1,000
Major Over Haul	$13,000	5 yrs	$13,000
Engine Replacement	$26,000	15 yrs	$26,000
Battery Replacement	$42,000	7 yrs	$42,000
Turbine Replacement	$15,000	10 yrs	$15,000

*Under full demand scenario.

Table 19: Life Cycle Costs at Varying Utilities at 4% Discount Rate

% Usage	Life Cycle Cost
10	$1,021,000
20	$873,900
30	$726,800
40	$579,675
45	$506,125

3.6.3 Criteria Assessment

Presently, there is no system such as this established in NWT or Nunavut for power generation. Although the PV and wind generator systems are compatible, issues that were discussed in Options D and E apply to this option as well.

Table 20: Criteria Assessment of Option F

Criteria Description	Discussion	Score
Simple to Operate and Maintain with Local Operators	The use of on site power generation adds to the complexity of the overall system when compared to line power. Also, the use of batteries and inverters increases the complexity of the system. Although simple operation, wind turbine requires a high volume of monitoring and maintenance, especially during the winter.	8
Reliability of Facility	On-site power generation has proven else where to be a reliable, however, issues with dirty power is a potential concern. On-site power generation is less reliable than line power. The addition of batteries increases the reaction time allowance in the event of system failure as it will provide power for heat and controls. High winds can decrease the efficiency of the power supplied by turbine. If winds are too strong, then the amount of power that can be converted will decrease.	9
Recovery From Frozen Condition in Operable State	Not completely recoverable from a frozen state. Batteries may become damaged if discharged from a frozen state or low temperatures. Ice accumulation on blades creates problems with efficiency of the system.	7

3.7 Option G: Option A with PV Modules

This option is similar to Option A but would included the addition of photovoltaic cells as another power source. Installation of a battery bank and an inverter is required to operate the PV panels. The panels would provide power directly to the inverter/charger unit which controls the power supply to the batteries and to prime power. During high power operations, the plant will run using power from the NPC transmission line while lower power needs will run from the battery bank.

3.7.1 Capital Costs

Capital costs for Option G will include those costs associated with Option A as well as an increase of $25,000 for the purchase of the PV cell panels and $12,000 for their shipment and installation. An additional cost of $60,200 will be required for the inverter and battery bank with shipment costs $13,000. Total capital cost for this option is approximately $230,200.

3.7.2 Operating and Maintenance Costs

Costs for the operation and maintenance consist of electricity costs as well as battery replacement every 7 years.

Table 21: Breakdown of Operational Costs for Option G

Component	Cost	Lifespan	Cost in Current dollars
Electricity Demand Charges	$0.6808 per kWh	Annual	$10,437*
Battery Replacement	$42,000	7 yrs	$42,000

*Under full demand scenario.

Table 22: Life Cycle Costs at Varying PV Utilities at 4% Discount Rate

% Usage	Life Cycle Cost
10	$663,350
20	$625,950
30	$588,550
40	$551,200
50	$513,800

3.7.3 Criteria Assessment

Presently, the WTP in Colville Lake, NT is making use of PV panels and batteries with a transmission line as the prime power source. Option G has advantages but there are also issues that were previously discussed in Option D that are the same for this option.

Table 23: Criteria Assessment of Option G

Criteria Description	Discussion	Score
Simple to Operate and Maintain with Local Operators	All options require some sort of diesel power generator on site. The use of prime power as line power is the simplest approach. However, the use of batteries and inverters increases the complexity of the system.	9
Reliability of Facility	The addition of battery system increases the reaction time allowance in the event of system failure as it will provide power for heat and controls.	9
Recovery From Frozen Condition in Operable State	Completely recoverable from frozen condition into operable state. The batteries may become damaged if discharged from frozen state or low temperatures.	8

3.8 Option H: Option A with Wind Generator

Option H incorporates the use of a wind generator as another power source along with the power transmission line. Like Option G, the addition of batteries and inverters are required to convert the mechanical energy from the wind generator into power.

3.8.1 Capital Costs

Costs associated with the capital investment of the transmission line with the addition of the purchase and installation costs for the wind turbine and its other components. Total capital cost, including shipment and installation, is calculated to be $220,200.

3.8.2 Operating and Maintenance Costs

Operating and maintenance costs include the cost of electricity of the power line as well as those associated with the wind generator. These costs are broken down and shown in the tables below.

Table 24: Breakdown of O&M Costs of Option H

Component	Cost	Lifespan	Cost in Current Dollars
Electricity Demand Charges	$0.6808 per kWh	Annual	$10,437*
Turbine Maintenance	$1,000	Annual	$1,000
Battery Replacement	$42,000	7 yrs	$42,000
Turbine Replacement	$15,000	10 yrs	$15,000

*Under full demand scenario.

Table 25: Life Cycle Costs at Varying Wind Turbine Utilities at 4% Discount Rate

% Usage	Life Cycle Cost
10	$694,450
20	$655,000
30	$615,500
40	$576,050
50	$536,600

3.8.3 Criteria Assessment

Option H has similar issues as proposed in Option E concerning the operation of a wind generator in an arctic climate.

Table 26: Criteria Assessment of Option H

Criteria Description	Discussion	Score
Simple to Operate and Maintain with Local Operators	All options require some sort of diesel power generator on site. The use of prime power as line power is the simplest approach. However, the use of batteries and inverters increases the complexity of the system.	9
Reliability of Facility	The addition of battery system increases the reaction time allowance in the event of system failure as it will provide power for heat and controls. High winds can decrease the efficiency of the power supplied by turbine. If winds are too strong, then the amount of power that can be converted will decrease.	8
Recovery From Frozen Condition in Operable State	Fully recoverable from frozen condition into operable state. Batteries may become damaged if discharged from frozen state or low temperatures. Ice accumulation on rotor blades creates efficiency problems with the wind generator.	7

3.9 Option I: Option A with PV Modules and Wind Generator

For this option, both PV cells and a wind generator will be implemented into the power supply proposed in Option A. Again, battery bank and inverters are required to store the power generated by the PV cells and wind generator. The majority of the power requirements will be supplied by the power generated from the PV panels and wind generator but in those cases where power demands are greater than what can be produced by these two sources, the power line will provide the remaining power demands.

3.9.1 Capital Costs

Total capital cost will be approximately $255,200 which includes additional charged for the purchase and installation of the PV panels ($25,000), the wind generator ($15,000) and the battery bank/inverter system ($60,200). Shipment costs were estimated to be about $35,000.

3.9.2 Operating and Maintenance Costs

Costs for the operation and maintenance of the system are electricity charges, battery and turbine replacements that were stated previously in Option H.

Table 27: Breakdown of O&M Costs of Option I

Component	Cost	Lifespan	Cost in Current Dollars
Electricity Demand Charges	$0.6808 per kWh	Annual	$10,437*
Turbine Maintenance	$1,000	Annual	$1,000
Battery Replacement	$42,000	7 yrs	$42,000
Turbine Replacement	$15,000	10 yrs	$15,000

*Under full demand scenario.

Table 28: Life Cycle Costs at Varying Utilities at 4% Discount Rate

% Usage	Life Cycle Cost
10	$689,950
20	$611,050
30	$532,150
40	$453,250
45	$412,800

3.9.3 Criteria Assessment

As with Options G and H, the same issues and concerns are seen for Option I. However, this option is more reliable as there are additional power sources to call upon during times of high power needs.

Table 29: Criteria Assessment of Option I

Criteria Description	Discussion	Score
Simple to Operate and Maintain with Local Operators	All options require some sort of diesel power generator on site. The use of prime power as line power is the simplest approach. However, the use of batteries and inverters increases the complexity of the system.	9
Reliability of Facility	The addition of batteries increasing the reaction time allowance in the event of system failure. The battery system will provide power for heat and controls.	9
Recovery From Frozen Condition to Operable State	Fully recoverable from frozen condition into operable state. Batteries may become damaged if discharged from frozen state or low temperatures. Ice accumulation on rotor blades creates efficiency problems with the wind generator.	9

4 COMPARISON OF POWER GENERATION OPTIONS

Table 30, shown below, summarizes the capital and life cycle costs for each option.

Table 30: Cost Comparison of Options at 4% Discount Rate and 30% Usage

Option	Capital Cost	Life Cycle Cost
A	$120,000	$493,950
B	$93,000	$1,494,550
C	$160,200	$1,059,950
D	$197,200	$871,250
E	$187,200	$878,750
F	$225,200	$726,800
G	$230,200	$588,550
H	$220,200	$615,500
I	$255,200	$532,150

Comparing all factors of the analysis, Option A appears to be the best option. It is highly reliable source of power that has the lowest capital investment of all options proposed. Operating and maintenance costs are also fairly low compared to the other alternatives.

In the case of Option B, the use of onsite power generation is not a viable option. Capital costs are on par with the other options but the main difference is that is has extremely high operating and maintenance costs. As well, this option is also more complex to operate. Due to the fact there are no tangible benefits for implementing this option, it was not considered further in the analysis.

Option C, the use of a generator and batteries, has some benefits to the project. While more expensive to install, the life cycle costs are fairly similar. However, the use of on-site power generation is more complex than that of line power.

The addition of PV and wind generator to Option C as described in Options D and E provide benefits to the project as the operating and maintenance costs over the lifetime of the facility decrease. Implementing both alternative energy systems to Option C, as is discussed in Option F, improves the reliability of the power supply system but adds additional operation and maintenance costs. However, this increase in the O&M costs as well as a higher capital cost does not affect the life cycle costs as they are reduced even though capital investment is higher.

Similar to discussion of Options D and E, the same can also be said for Options G, H and I. Reliability of the systems discussed in Options G and H increase as there is another power source to provide additional power. This is even more so when both PV cells and a wind generator are implemented into the system. For example, even though Option I has a slightly higher life cycle cost compared to Option A, the addition of the PV cells and wind generator creates a more reliable power source as there is additional sources to rely on when there is an undersupply of power. Even though the capital investment of Option I is approximately 72% higher compared to Option A, its operation and maintenance costs are decreased by

30% which further results in only a 7% increase for the lifecycle costs. This correlation will improve as the usage of both systems increases.

It is still early in the development phase that the any of the above options for the main power supply can be implemented into plant design. However, it is beneficial to provide a power source that will not only assist with reducing costs for today's power requirements but with those that are anticipated in the future. It is recommended that Option I be implemented as the prime power supply for the new water treatment facility.

5 REFERENCES

[1] Dillon Consulting Limited. "*Colville Lake Water Intake and Treatment Facility - Alternative Power Generation Brief.*" Produced for Public Works and Service, Government of Northwest Territories. October 2005.

[2] Nunavut Power Corporation. http://www.nunavutpower.com

[3] Natural Resources Canada. http://cetc-varennes.nrcan.gc.ca/fichier/41712/retscreen_table6_e.xls

[4] Canadian Wind Energy Association. http://www.smallwindenergy.ca/en/SmallWind.html

[5] The Canadian Solar Industries Association. http://cansia.ca/

APPENDIX A

Cost Estimate Data

Alternative Energy Options

Option	Power Source		Building Location
	Main	Backup	
A	Power Transmission Line	Diesel Generator	None
B	Diesel Generator	Diesel Generator	Separate room and/or building from WTP
C	Battery Bank, charged by Generator	Diesel Generator	Separate room and/or building from WTP
D	Battery Bank, charged by Generator with PV Cells	Diesel Generator	Separate room and/or building from WTP
E	Battery Bank, charged by Generator with Wind Generator	Diesel Generator	Separate room and/or building from WTP
F	Battery Bank, charged by Generator with PV Cells and Wind Generator	Diesel Generator	Separate room and/or building from WTP
G	Power Transmission Line with PV Cells	Diesel Generator	Separate room and/or building from WTP
H	Power Transmission Line with Wind Generator	Diesel Generator	Separate room and/or building from WTP
I	Power Transmission Line with PV Cells and Wind Generator	Diesel Generator	Separate room and/or building from WTP

Criteria Assessment of AE Options

Option	Criteria Description						Total Score
	Simple to Operate and Maintain with Local Operators		Reliablilty of Facility		Recovery from Frozen Condition in Operational State		
	Discussion	Score	Discussion	Score	Discussion	Score	
A	Provides the simplest approach for plant operator. Requires some sort of diesel power generator on site.	10	Line power is reliable; however there is an issue with dirty power being a potential concern.	8	Fully recoverable from frozen condition into operational state. Battery (for starter) may become damaged if discharged from frozen state or low temperatures.	9	27
B	Onsite power generation adds to the complexity of the overall system compared to power supplied by transmission line. Also requires some sort of diesel power generator on site.	7	Less reliable than power line. Even though proven to be effective elsewhere, dirty power is still a potential concern for onsite generation.	7	Fully recoverable from frozen condition into operational state. Battery (for starter) may become damaged if discharged from frozen state or low temperatures.	9	23
C	Onsite power generation as well as the installation of battery bank and inverters add to the complexity of the overall system compared to power supplied by transmission line. Also requires some sort of diesel power generator on site.	6	Less reliable than power line. Even though proven to be effective elsewhere, dirty power is still a potential concern for onsite generation. Addition of battery bank will increase retention time allowance in the event of system failure.	8	Not fully revocerable from frozen condition to operational state. Batteries may become damaged if discharged from frozen or low temperature state.	7	21
D	Onsite power generation as well as the installation of battery bank and inverters add to the complexity of the overall system compared to power supplied by transmission line. Also requires some sort of diesel power generator on site.	8	Less reliable than power line. Even though proven to be effective elsewhere, dirty power is still a potential concern for onsite generation. Addition of battery bank charged by PV cells will increase retention time allowance in the event of system failure.	8	Not fully revocerable from frozen condition to operational state. Batteries may become damaged if discharged from frozen or low temperature state.	7	23
E	Onsite power generation as well as the installation of battery bank and inverters add to the complexity of the overall system compared to power supplied by transmission line. Also requires some sort of diesel power generator on site. Although simple to operate, turbine requires substantial amount of monitoring and maintenance, especially during winter.	8	Less reliable than power line. Even though proven to be effective elsewhere, dirty power is still a potential concern for onsite generation. Addition of battery bank charged by wind turbine will increase retention time allowance in the event of system failure. High winds decrease the efficiency of the power supplied by the turbine.	7	Not fully revocerable from frozen condition to operational state. Batteries may become damaged if discharged from frozen or low temperature state. Ice accumulation on blades creates problems with system's efficiency.	7	22
F	Onsite power generation as well as the installation of battery bank and inverters add to the complexity of the overall system compared to power supplied by transmission line. Also requires some sort of diesel power generator on site. Although simple to operate, turbine requires substantial amount of monitoring and maintenance, especially during winter.	8	Less reliable than power line. Even though proven to be effective elsewhere, dirty power is still a potential concern for onsite generation. Addition of battery bank charged by PV panel and wind turbine will increase retention time allowance in the event of system failure. High winds decrease the efficiency of the power supplied by the turbine.	9	Not fully revocerable from frozen condition to operational state. Batteries may become damaged if discharged from frozen or low temperature state. Ice accumulation on blades creates problems with system's efficiency.	7	24
G	Provides the simplest approach for plant operator. Requires some sort of diesel power generator on site. Batter bank and inverters increases the complexity of the system.	9	Line power is reliable; however there is an issue with dirty power being a potential concern. Battery bank chraged by PV cells will increase the retention time allowance in the event of system failure.	9	Fully recoverable from frozen condition into operational state. Battery (for starter) may become damaged if discharged from frozen state or low temperatures.	8	26
H	Provides the simplest approach for plant operator. Requires some sort of diesel power generator on site. Batter bank and inverters increases the complexity of the system.	9	Line power is reliable; however there is an issue with dirty power being a potential concern. Battery bank chraged by wind turbine will increase the retention time allowance in the event of system failure. However, high winds can decrease the efficiency of the system.	8	Fully recoverable from frozen condition into operational state. Battery (for starter) may become damaged if discharged from frozen state or low temperatures. Ice accumulation on blades creates problems with system's efficiency.	7	24
I	Provides the simplest approach for plant operator. Requires some sort of diesel power generator on site. Batter bank and inverters increases the complexity of the system.	9	Line power is reliable; however there is an issue with dirty power being a potential concern. Battery bank chraged by PV cells and wind turbine will increase the retention time allowance in the event of system failure. However, high winds can decrease the efficiency of the system.	9	Fully recoverable from frozen condition into operational state. Battery (for starter) may become damaged if discharged from frozen state or low temperatures. Ice accumulation on blades creates problems with system's efficiency.	9	27

Power Consumption Calculations

Electicity Cost 0.6808 $/kWhr

Type	Power (kW)	Hours per Day		Daily Load (kWh)		Annnual Usage (kWh)		Annual Costs	
		Average	Peak	Average	Peak	Average	Peak	Average	Peak
Interior Lighting	1.0	4	8	4	8	1460	2920	$994	$1,988
Exterior Lighting	1.0	12	24	12	24	4380	8760	$2,982	$5,964
Engine Block Heater	0.5	0	2	0	1	0	365	$0	$248
Fuel Transfer Pump	0.5	4	8	2	4	730	1460	$497	$994
Motor Dampers	0.5	0.1	0.1	0.05	0.05	18	18	$12	$12
Furnance	1.5	4	8	6	12	2190	4380	$1,491	$2,982
Hot Water Tank	3.5	0.5	1	1.75	3.5	639	1278	$435	$870
Chlorine Feed Pump	0.5	0.2	0.5	0.1	0.25	37	91	$25	$62
Battery Charger	0.5	0.5	2	0.25	1	91	365	$62	$248
Chlorine Mixer	0.5	0.2	0.2	0.1	0.1	37	37	$25	$25
HRV Unit	0.5	3	6	1.5	3	548	1095	$373	$745
Heat Trace	2.5	12	24	30	60	10950	21900	$7,455	$14,910
Intake Pump	4.0	2	4	8	16	2920	5840	$1,988	$3,976
Truck Fill Pumps	3.5	2	4	7	14	2555	5110	$1,739	$3,479
Total	**21**	**45**	**92**	**73**	**147**	**26,554**	**53,619**	**$18,078**	**$36,503**

Fuel Costs for Operating a 20 kW Generator

Conversions

1 US gal	=	3.785	L
Size of Generator		20	kW
Specific Heat Energy of Diesel		38.6	MJ/L
		138,700	BTU/US gal
Energy Density of Diesel		9.7	kWh/L
Cost of Diesel Fuel		$1.70	$/L

Load	Fuel Consumption		Energy Produced (kW)	Energy Consumed (kW)	Efficiency
	gal/hr	L/hr			
0.25	0.60	2.27	5	22.03	23%
0.50	0.90	3.41	10	33.04	30%
0.75	1.30	4.92	15	47.73	31%
1.00	1.60	6.06	20	58.74	34%

Hour	Load	Fuel Consumption	
		gal/hr	L/hr
1	0.25	0.60	2.27
2	0.25	0.60	2.27
3	0.25	0.60	2.27
4	0.25	0.60	2.27
5	0.25	0.60	2.27
6	0.25	0.60	2.27
7	0.25	0.60	2.27
8	0.25	0.60	2.27
9	1	1.60	6.06
10	1	1.60	6.06
11	1	1.60	6.06
12	0.25	0.60	2.27
13	0.25	0.60	2.27
14	0.25	0.60	2.27
15	0.25	0.60	2.27
16	0.25	0.60	2.27
17	0.25	0.60	2.27
18	0.25	0.60	2.27
19	0.25	0.60	2.27
20	0.25	0.60	2.27
21	0.25	0.60	2.27
22	0.25	0.60	2.27
23	0.25	0.60	2.27
24	0.25	0.60	2.27
		17.4	66

Fuel Consumption	66	L/day
Annual Cost of Diesel	$40,866	$/yr

Fuel Costs for Operating Battery Bank with Generator

Assumptions

% of Generator Use for Charging of Batteries	0.35	%

Fuel Consumption	23	L/day
Annual Cost of Diesel	$14,303	$/yr

Source: Approximate Fuel Consumption Chart. Diesel Service and Supply. http://www.dieselserviceandsupply.com/

Assumptions

Electricity, Nunavut Power Corporation	0.6808	$/kWhr
Diesel Fuel	1.70	$/L
Power Requirements	25	kW
	73	kWhr/day
	26,645	kWhr/yr
Inflation Rate	0.02	

Option A - Power Transmission Line

CAPITAL COSTS

Item	Cost
Power Line (including installation and shipment of equipment)	$120,000
Total	$120,000

O&M COSTS

Item	Cost
Electricity Costs	$18,140
Total	$18,140

DISCOUNTED CASH FLOW

Planning Year	Year	Future Costs			Discounted Cash Flow		
		Annual O&M	Replacements	Total O&M	2%	4%	6%
0	2008	$18,140	$0	$18,140	$18,140	$18,140	$18,140
1	2009	$18,503	$0	$18,503	$18,140	$17,791	$17,455
2	2010	$18,873	$0	$18,873	$18,140	$17,449	$16,797
3	2011	$19,250	$0	$19,250	$18,140	$17,113	$16,163
4	2012	$19,635	$0	$19,635	$18,140	$16,784	$15,553
5	2013	$20,028	$0	$20,028	$18,140	$16,462	$14,966
6	2014	$20,428	$0	$20,428	$18,140	$16,145	$14,401
7	2015	$20,837	$0	$20,837	$18,140	$15,834	$13,858
8	2016	$21,254	$0	$21,254	$18,140	$15,530	$13,335
9	2017	$21,679	$0	$21,679	$18,140	$15,231	$12,832
10	2018	$22,112	$0	$22,112	$18,140	$14,938	$12,347
11	2019	$22,555	$0	$22,555	$18,140	$14,651	$11,882
12	2020	$23,006	$0	$23,006	$18,140	$14,369	$11,433
13	2021	$23,466	$0	$23,466	$18,140	$14,093	$11,002
14	2022	$23,935	$0	$23,935	$18,140	$13,822	$10,587
15	2023	$24,414	$0	$24,414	$18,140	$13,556	$10,187
16	2024	$24,902	$0	$24,902	$18,140	$13,295	$9,803
17	2025	$25,400	$0	$25,400	$18,140	$13,040	$9,433
18	2026	$25,908	$0	$25,908	$18,140	$12,789	$9,077
19	2027	$26,426	$0	$26,426	$18,140	$12,543	$8,734
20	2028	$26,955	$0	$26,955	$18,140	$12,302	$8,405
21	2029	$27,494	$0	$27,494	$18,140	$12,065	$8,088
22	2030	$28,044	$0	$28,044	$18,140	$11,833	$7,782
23	2031	$28,605	$0	$28,605	$18,140	$11,606	$7,489
24	2032	$29,177	$0	$29,177	$18,140	$11,383	$7,206
25	2033	$29,760	$0	$29,760	$18,140	$11,164	$6,934
		$610,787	$0	$610,787	**$471,638**	**$373,930**	**$303,887**

Option B - Diesel Generator

CAPITAL COSTS

Item	Cost
Generator, Diesel	$160,000
Shipment	$13,000
Second Generator	$80,000
Total	$93,000

O&M COSTS

Item	Cost
Fuel Consumption	$41,000
Filters/Oil/Other Consumables	$22,100
Total	$63,100

REPLACEMENTS

Item	Cost	Year
Major Over Haul of Generator	$13,000	3rd, 6th, 12th, 15th, 21st, 24th
Engine Replacement	$26,000	9th, 18th
Total	$39,000	

DISCOUNTED CASH FLOW

Planning Year	Year	Future Costs			Discounted Cash Flow		
		Annual O&M	Replacements	Total O&M	2%	4%	6%
0	2008	$63,100	$0	$63,100	$63,100	$63,100	$63,100
1	2009	$64,362	$0	$64,362	$63,100	$61,887	$60,719
2	2010	$65,649	$0	$65,649	$63,100	$60,696	$58,428
3	2011	$66,962	$13,796	$80,758	$76,100	$71,794	$67,806
4	2012	$68,301	$0	$68,301	$63,100	$58,384	$54,101
5	2013	$69,667	$0	$69,667	$63,100	$57,262	$52,060
6	2014	$71,061	$14,640	$85,701	$76,100	$67,731	$60,416
7	2015	$72,482	$0	$72,482	$63,100	$55,080	$48,205
8	2016	$73,932	$0	$73,932	$63,100	$54,021	$46,386
9	2017	$75,410	$31,072	$106,483	$89,100	$74,813	$63,027
10	2018	$76,919	$0	$76,919	$63,100	$51,963	$42,951
11	2019	$78,457	$0	$78,457	$63,100	$50,964	$41,330
12	2020	$80,026	$16,487	$96,513	$76,100	$60,282	$47,964
13	2021	$81,627	$0	$81,627	$63,100	$49,023	$38,270
14	2022	$83,259	$0	$83,259	$63,100	$48,080	$36,826
15	2023	$84,924	$17,496	$102,421	$76,100	$56,871	$42,737
16	2024	$86,623	$0	$86,623	$63,100	$46,249	$34,099
17	2025	$88,355	$0	$88,355	$63,100	$45,359	$32,812
18	2026	$90,122	$37,134	$127,257	$89,100	$62,818	$44,584
19	2027	$91,925	$0	$91,925	$63,100	$43,631	$30,382
20	2028	$93,763	$0	$93,763	$63,100	$42,792	$29,236
21	2029	$95,639	$19,704	$115,342	$76,100	$50,616	$33,929
22	2030	$97,551	$0	$97,551	$63,100	$41,162	$27,071
23	2031	$99,502	$0	$99,502	$63,100	$40,371	$26,049
24	2032	$101,492	$20,910	$122,402	$76,100	$47,752	$30,231
25	2033	$103,522	$0	$103,522	$63,100	$38,833	$24,121
		$2,124,634	$171,239	$2,295,874	**$1,770,600**	**$1,401,534**	**$1,136,836**

Option C - Battery Bank charged by Generator

CAPITAL COSTS

Item	Cost
Diesel Generator	$160,000
Battery Bank	$42,000
Inverters	$18,200
Shipment	$20,000
Second Generator	$80,000
Total	$160,200

O&M COSTS

Item	Cost
Fuel Consumption	$14,400
Filters/Oil/Other Consumables	$22,100
Total	$36,500

REPLACEMENTS

Item	Cost	Year
Major Over Haul of Generator	$13,000	5th, 10th, 20th
Engine Replacement	$26,000	15th
Battery Replacement	$42,000	7th, 14th, 21st
Total	$81,000	

DISCOUNTED CASH FLOW

Planning Year	Year	Future Costs			Discounted Cash Flow		
		Annual O&M	Replacements	Total O&M	2%	4%	6%
0	2008	$36,500	$0	$36,500	$36,500	$36,500	$36,500
1	2009	$37,230	$0	$37,230	$36,500	$35,798	$35,123
2	2010	$37,975	$0	$37,975	$36,500	$35,110	$33,797
3	2011	$38,734	$0	$38,734	$36,500	$34,434	$32,522
4	2012	$39,509	$0	$39,509	$36,500	$33,772	$31,295
5	2013	$40,299	$14,353	$54,652	$49,500	$44,920	$40,839
6	2014	$41,105	$0	$41,105	$36,500	$32,486	$28,977
7	2015	$41,927	$48,245	$90,172	$78,500	$68,523	$59,969
8	2016	$42,766	$0	$42,766	$36,500	$31,248	$26,832
9	2017	$43,621	$0	$43,621	$36,500	$30,647	$25,819
10	2018	$44,493	$15,847	$60,340	$49,500	$40,764	$33,694
11	2019	$45,383	$0	$45,383	$36,500	$29,480	$23,907
12	2020	$46,291	$0	$46,291	$36,500	$28,913	$23,005
13	2021	$47,217	$0	$47,217	$36,500	$28,357	$22,137
14	2022	$48,161	$55,418	$103,579	$78,500	$59,814	$45,813
15	2023	$49,124	$34,993	$84,117	$62,500	$46,707	$35,099
16	2024	$50,107	$0	$50,107	$36,500	$26,752	$19,724
17	2025	$51,109	$0	$51,109	$36,500	$26,238	$18,980
18	2026	$52,131	$0	$52,131	$36,500	$25,733	$18,264
19	2027	$53,174	$0	$53,174	$36,500	$25,238	$17,575
20	2028	$54,237	$19,317	$73,554	$49,500	$33,569	$22,935
21	2029	$55,322	$63,658	$118,980	$78,500	$52,212	$34,999
22	2030	$56,428	$0	$56,428	$36,500	$23,810	$15,659
23	2031	$57,557	$0	$57,557	$36,500	$23,352	$15,068
24	2032	$58,708	$0	$58,708	$36,500	$22,903	$14,500
25	2033	$59,882	$0	$59,882	$36,500	$22,463	$13,952
		$1,228,988	$251,831	$1,480,819	**$1,140,000**	**$899,747**	**$726,984**

Option D - Battery Bank charged by Generator with PV Cells

CAPITAL COSTS

Item	Cost
Diesel Generator	$160,000
Battery Bank	$42,000
Inverters	$18,200
PV Cells	$25,000
Shipment	$32,000
Second Generator	$80,000
Total	$197,200

O&M COSTS

Item	Cost
Fuel Consumption	$14,400
Filters/Oil/Other Consumables	$22,100
Total	$36,500

REPLACEMENTS

Item	Cost	Year
Major Over Haul of Generator	$13,000	5th, 10th, 20th
Engine Replacement	$26,000	15th
Battery Replacement	$42,000	7th, 14th, 21st
Total	$81,000	

DISCOUNTED CASH FLOW

% Usage 0.9

Planning Year	Year	Future Costs			Discounted Cash Flow		
		Annual O&M	Replacements	Total O&M	2%	4%	6%
0	2008	$32,850	$0	$32,850	$32,850	$32,850	$32,850
1	2009	$33,507	$0	$33,507	$32,850	$32,218	$31,610
2	2010	$34,177	$0	$34,177	$32,850	$31,599	$30,418
3	2011	$34,861	$0	$34,861	$32,850	$30,991	$29,270
4	2012	$35,558	$0	$35,558	$32,850	$30,395	$28,165
5	2013	$36,269	$14,353	$50,622	$45,850	$41,608	$37,828
6	2014	$36,994	$0	$36,994	$32,850	$29,237	$26,080
7	2015	$37,734	$48,245	$85,979	$74,850	$65,337	$57,181
8	2016	$38,489	$0	$38,489	$32,850	$28,124	$24,148
9	2017	$39,259	$0	$39,259	$32,850	$27,583	$23,237
10	2018	$40,044	$15,847	$55,891	$45,850	$37,758	$31,209
11	2019	$40,845	$0	$40,845	$32,850	$26,532	$21,517
12	2020	$41,662	$0	$41,662	$32,850	$26,022	$20,705
13	2021	$42,495	$0	$42,495	$32,850	$25,521	$19,923
14	2022	$43,345	$55,418	$98,763	$74,850	$57,033	$43,683
15	2023	$44,212	$34,993	$79,204	$58,850	$43,979	$33,049
16	2024	$45,096	$0	$45,096	$32,850	$24,077	$17,752
17	2025	$45,998	$0	$45,998	$32,850	$23,614	$17,082
18	2026	$46,918	$0	$46,918	$32,850	$23,160	$16,437
19	2027	$47,856	$0	$47,856	$32,850	$22,715	$15,817
20	2028	$48,813	$19,317	$68,131	$45,850	$31,094	$21,243
21	2029	$49,790	$63,658	$113,448	$74,850	$49,785	$33,371
22	2030	$50,785	$0	$50,785	$32,850	$21,429	$14,093
23	2031	$51,801	$0	$51,801	$32,850	$21,017	$13,561
24	2032	$52,837	$0	$52,837	$32,850	$20,613	$13,050
25	2033	$53,894	$0	$53,894	$32,850	$20,217	$12,557
		$1,106,089	$251,831	$1,357,920	**$1,045,100**	**$824,507**	**$665,837**

% Usage of PV Cells	Future Costs			Discounted Cash Flow		
	Annual O&M	Replacements	Total O&M	2%	4%	6%
10	$1,106,089	$251,831	$1,357,920	$1,045,100	$824,507	$665,837
20	$983,190	$251,831	$1,235,021	$950,200	$749,267	$604,691
30	$860,292	$251,831	$1,112,123	$855,300	$674,027	$543,545
40	$737,393	$251,831	$989,224	$760,400	$598,788	$482,399
50	$614,494	$251,831	$866,325	$665,500	$523,548	$421,252

Option E - Battery Bank charged by Generator with Wind Generator

CAPITAL COSTS

Item	Cost
Diesel Generator	$160,000
Battery Bank	$42,000
Inverters	$18,200
Wind Generator	$15,000
Shipment	$32,000
Second Generator	$80,000
Total	$187,200

O&M COSTS

Item	Cost
Fuel Consumption	$14,400
Filters/Oil/Other Consumables	$22,100
Turbine Maintenance	$1,000
Total	$37,500

REPLACEMENTS

Item	Cost	Year
Major Over Haul of Generator	$13,000	5th, 10th, 20th
Engine Replacement	$26,000	15th
Battery Replacement	$42,000	7th, 14th, 21st
Turbine Replacement	$15,000	10th, 20st
Total	$96,000	

DISCOUNTED CASH FLOW

% Usage 1.0

Planning Year	Year	Future Costs			Discounted Cash Flow		
		Annual O&M	Replacements	Total O&M	2%	4%	6%
0	2008	$37,500	$0	$37,500	$37,500	$37,500	$37,500
1	2009	$38,250	$0	$38,250	$37,500	$36,779	$36,085
2	2010	$39,015	$0	$39,015	$37,500	$36,072	$34,723
3	2011	$39,795	$0	$39,795	$37,500	$35,378	$33,413
4	2012	$40,591	$0	$40,591	$37,500	$34,698	$32,152
5	2013	$41,403	$14,353	$55,756	$50,500	$45,827	$41,664
6	2014	$42,231	$0	$42,231	$37,500	$33,376	$29,771
7	2015	$43,076	$48,245	$91,321	$79,500	$69,396	$60,733
8	2016	$43,937	$0	$43,937	$37,500	$32,105	$27,567
9	2017	$44,816	$0	$44,816	$37,500	$31,487	$26,527
10	2018	$45,712	$34,132	$79,844	$65,500	$53,940	$44,585
11	2019	$46,627	$0	$46,627	$37,500	$30,288	$24,562
12	2020	$47,559	$0	$47,559	$37,500	$29,705	$23,635
13	2021	$48,510	$0	$48,510	$37,500	$29,134	$22,743
14	2022	$49,480	$55,418	$104,899	$79,500	$60,576	$46,397
15	2023	$50,470	$0	$50,470	$37,500	$28,024	$21,059
16	2024	$51,479	$0	$51,479	$37,500	$27,485	$20,265
17	2025	$52,509	$0	$52,509	$37,500	$26,957	$19,500
18	2026	$53,559	$0	$53,559	$37,500	$26,438	$18,764
19	2027	$54,630	$0	$54,630	$37,500	$25,930	$18,056
20	2028	$55,723	$41,607	$97,330	$65,500	$44,420	$30,348
21	2029	$56,837	$63,658	$120,495	$79,500	$52,877	$35,444
22	2030	$57,974	$0	$57,974	$37,500	$24,463	$16,088
23	2031	$59,134	$0	$59,134	$37,500	$23,992	$15,481
24	2032	$60,316	$0	$60,316	$37,500	$23,531	$14,897
25	2033	$61,523	$0	$61,523	$37,500	$23,078	$14,335
		$1,262,659	$257,412	$1,520,071	**$1,170,000**	**$923,455**	**$746,295**

% Usage of Wind Generator	Future Costs			Discounted Cash Flow		
	Annual O&M	Replacements	Total O&M	2%	4%	6%
10	$1,136,393	$257,412	$1,393,805	$1,072,500	$846,154	$683,473
20	$1,010,127	$257,412	$1,267,539	$975,000	$768,853	$620,652
30	$883,861	$257,412	$1,141,273	$877,500	$691,552	$557,830
40	$757,595	$257,412	$1,015,007	$780,000	$614,251	$495,009
50	$631,329	$257,412	$888,741	$682,500	$536,950	$432,187

Option F - Battery Bank charged by Generator with PV Cells and Wind Generator

CAPITAL COSTS

Item	Cost
Diesel Generator	$160,000
Battery Bank	$42,000
Inverters	$18,200
PV Cells	$25,000
Wind Generator	$15,000
Shipment	$45,000
Second Generator	$80,000
Total	$225,200

O&M COSTS

Item	Cost
Fuel Consumption	$14,400
Filters/Oil/Other Consumables	$22,100
Turbine Maintenance	$1,000
Total	$37,500

REPLACEMENTS

Item	Cost	Year
Major Over Haul of Generator	$13,000	5th, 10th, 20th
Engine Replacement	$26,000	15th
Battery Replacement	$42,000	7th, 14th, 21st
Turbine Replacement	$15,000	10th, 20st
Total	$96,000	

DISCOUNTED CASH FLOW

% Usage 1.0

Planning Year	Year	Future Costs			Discounted Cash Flow		
		Annual O&M	Replacements	Total O&M	2%	4%	6%
0	2008	$37,500	$0	$37,500	$37,500	$37,500	$37,500
1	2009	$38,250	$0	$38,250	$37,500	$36,779	$36,085
2	2010	$39,015	$0	$39,015	$37,500	$36,072	$34,723
3	2011	$39,795	$0	$39,795	$37,500	$35,378	$33,413
4	2012	$40,591	$0	$40,591	$37,500	$34,698	$32,152
5	2013	$41,403	$14,353	$55,756	$50,500	$45,827	$41,664
6	2014	$42,231	$0	$42,231	$37,500	$33,376	$29,771
7	2015	$43,076	$48,245	$91,321	$79,500	$69,396	$60,733
8	2016	$43,937	$0	$43,937	$37,500	$32,105	$27,567
9	2017	$44,816	$0	$44,816	$37,500	$31,487	$26,527
10	2018	$45,712	$34,132	$79,844	$65,500	$53,940	$44,585
11	2019	$46,627	$0	$46,627	$37,500	$30,288	$24,562
12	2020	$47,559	$0	$47,559	$37,500	$29,705	$23,635
13	2021	$48,510	$0	$48,510	$37,500	$29,134	$22,743
14	2022	$49,480	$55,418	$104,899	$79,500	$60,576	$46,397
15	2023	$50,470	$34,993	$85,463	$63,500	$47,454	$35,661
16	2024	$51,479	$0	$51,479	$37,500	$27,485	$20,265
17	2025	$52,509	$0	$52,509	$37,500	$26,957	$19,500
18	2026	$53,559	$0	$53,559	$37,500	$26,438	$18,764
19	2027	$54,630	$0	$54,630	$37,500	$25,930	$18,056
20	2028	$55,723	$41,607	$97,330	$65,500	$44,420	$30,348
21	2029	$56,837	$63,658	$120,495	$79,500	$52,877	$35,444
22	2030	$57,974	$0	$57,974	$37,500	$24,463	$16,088
23	2031	$59,134	$0	$59,134	$37,500	$23,992	$15,481
24	2032	$60,316	$0	$60,316	$37,500	$23,531	$14,897
25	2033	$61,523	$0	$61,523	$37,500	$23,078	$14,335
		$1,262,659	$292,405	$1,555,064	**$1,196,000**	**$942,886**	**$760,896**

% Usage of Each	Future Costs			Discounted Cash Flow		
	Annual O&M	Replacements	Total O&M	2%	4%	6%
5	$1,140,143	$292,405	$1,432,548	$1,102,250	$869,334	$701,825
10	$1,017,627	$292,405	$1,310,032	$1,008,500	$795,783	$642,753
15	$895,111	$292,405	$1,187,516	$914,750	$722,232	$583,682
20	$772,595	$292,405	$1,065,000	$821,000	$648,681	$524,610
25	$650,079	$292,405	$942,484	$727,250	$575,130	$465,539
30	$527,564	$292,405	$819,969	$633,500	$501,579	$406,467
35	$405,048	$292,405	$697,453	$539,750	$428,028	$347,396
40	$282,532	$292,405	$574,937	$446,000	$354,476	$288,324
45	$160,016	$292,405	$452,421	$352,250	$280,925	$229,253

Option G - Transmission Line with PV Cells

CAPITAL COSTS

Item	Cost
Transmission Line	$120,000
Battery Bank	$42,000
Inverters	$18,200
PV Cells	$25,000
Shipment	$25,000
Total	$230,200

O&M COSTS

Item	Cost
Electricity	$18,140
Total	$18,140

REPLACEMENTS

Item	Cost	Year
Battery Replacement	$42,000	7th, 14th, 21st
Total	$42,000	

DISCOUNTED CASH FLOW

% Usage 1.0

Planning Year	Year	Future Costs			Discounted Cash Flow		
		Annual O&M	Replacements	Total O&M	2%	4%	6%
0	2008	$18,140	$0	$18,140	$18,140	$18,140	$18,140
1	2009	$18,503	$0	$18,503	$18,140	$17,791	$17,455
2	2010	$18,873	$0	$18,873	$18,140	$17,449	$16,797
3	2011	$19,250	$0	$19,250	$18,140	$17,113	$16,163
4	2012	$19,635	$0	$19,635	$18,140	$16,784	$15,553
5	2013	$20,028	$0	$20,028	$18,140	$16,462	$14,966
6	2014	$20,428	$0	$20,428	$18,140	$16,145	$14,401
7	2015	$20,837	$48,245	$69,082	$60,140	$52,497	$45,943
8	2016	$21,254	$0	$21,254	$18,140	$15,530	$13,335
9	2017	$21,679	$0	$21,679	$18,140	$15,231	$12,832
10	2018	$22,112	$0	$22,112	$18,140	$14,938	$12,347
11	2019	$22,555	$0	$22,555	$18,140	$14,651	$11,882
12	2020	$23,006	$0	$23,006	$18,140	$14,369	$11,433
13	2021	$23,466	$0	$23,466	$18,140	$14,093	$11,002
14	2022	$23,935	$55,418	$79,353	$60,140	$45,825	$35,098
15	2023	$24,414	$0	$24,414	$18,140	$13,556	$10,187
16	2024	$24,902	$0	$24,902	$18,140	$13,295	$9,803
17	2025	$25,400	$0	$25,400	$18,140	$13,040	$9,433
18	2026	$25,908	$0	$25,908	$18,140	$12,789	$9,077
19	2027	$26,426	$0	$26,426	$18,140	$12,543	$8,734
20	2028	$26,955	$0	$26,955	$18,140	$12,302	$8,405
21	2029	$27,494	$63,658	$91,152	$60,140	$40,001	$26,813
22	2030	$28,044	$0	$28,044	$18,140	$11,833	$7,782
23	2031	$28,605	$0	$28,605	$18,140	$11,606	$7,489
24	2032	$29,177	$0	$29,177	$18,140	$11,383	$7,206
25	2033	$29,760	$0	$29,760	$18,140	$11,164	$6,934
		$610,787	$167,321	$778,108	**$597,638**	**$470,530**	**$379,209**

% Usage of PV Cells	Future Costs			Discounted Cash Flow		
	Annual O&M	Replacements	Total O&M	2%	4%	6%
10	$549,709	$167,321	$717,030	$550,474	$433,137	$348,821
20	$488,630	$167,321	$655,951	$503,310	$395,744	$318,432
30	$427,551	$167,321	$594,872	$456,146	$358,351	$288,043
40	$366,472	$167,321	$533,793	$408,983	$320,958	$257,655
50	$305,394	$167,321	$472,715	$361,819	$283,565	$227,266
60	$244,315	$167,321	$411,636	$314,655	$246,172	$196,877

Option H - Transmission Line with Wind Generator

CAPITAL COSTS

Item	Cost
Transmission Line	$120,000
Battery Bank	$42,000
Inverters	$18,200
Wind Generator	$15,000
Shipment	$25,000
Total	$220,200

O&M COSTS

Item	Cost
Electricity	$18,140
Wind Trubine	$1,000
Total	$19,140

REPLACEMENTS

Item	Cost	Year
Battery Replacement	$42,000	7th, 14th, 21st
Turbine Replacement	$15,000	10th, 20th
Total	$57,000	

DISCOUNTED CASH FLOW

% Usage 1.0

Planning Year	Year	Future Costs			Discounted Cash Flow		
		Annual O&M	Replacements	Total O&M	2%	4%	6%
0	2008	$19,140	$0	$19,140	$19,140	$19,140	$19,140
1	2009	$19,523	$0	$19,523	$19,140	$18,772	$18,418
2	2010	$19,913	$0	$19,913	$19,140	$18,411	$17,723
3	2011	$20,311	$0	$20,311	$19,140	$18,057	$17,054
4	2012	$20,718	$0	$20,718	$19,140	$17,710	$16,410
5	2013	$21,132	$0	$21,132	$19,140	$17,369	$15,791
6	2014	$21,555	$0	$21,555	$19,140	$17,035	$15,195
7	2015	$21,986	$48,245	$70,231	$61,140	$53,369	$46,707
8	2016	$22,425	$0	$22,425	$19,140	$16,386	$14,070
9	2017	$22,874	$0	$22,874	$19,140	$16,071	$13,539
10	2018	$23,331	$18,285	$41,616	$34,140	$28,115	$23,238
11	2019	$23,798	$0	$23,798	$19,140	$15,459	$12,537
12	2020	$24,274	$0	$24,274	$19,140	$15,161	$12,063
13	2021	$24,760	$0	$24,760	$19,140	$14,870	$11,608
14	2022	$25,255	$55,418	$80,673	$61,140	$46,587	$35,682
15	2023	$25,760	$0	$25,760	$19,140	$14,304	$10,749
16	2024	$26,275	$0	$26,275	$19,140	$14,028	$10,343
17	2025	$26,801	$0	$26,801	$19,140	$13,759	$9,953
18	2026	$27,337	$0	$27,337	$19,140	$13,494	$9,577
19	2027	$27,883	$0	$27,883	$19,140	$13,235	$9,216
20	2028	$28,441	$22,289	$50,730	$34,140	$23,153	$15,818
21	2029	$29,010	$63,658	$92,668	$61,140	$40,666	$27,259
22	2030	$29,590	$0	$29,590	$19,140	$12,486	$8,211
23	2031	$30,182	$0	$30,182	$19,140	$12,246	$7,901
24	2032	$30,785	$0	$30,785	$19,140	$12,010	$7,603
25	2033	$31,401	$0	$31,401	$19,140	$11,779	$7,316
		$644,458	$207,895	$852,353	**$653,638**	**$513,668**	**$413,122**

% Usage of Wind Generator	Future Costs			Discounted Cash Flow		
	Annual O&M	Replacements	Total O&M	2%	4%	6%
10	$580,012	$207,895	$787,907	$603,874	$474,214	$381,058
20	$515,567	$207,895	$723,462	$554,110	$434,760	$348,994
30	$451,121	$207,895	$659,016	$504,346	$395,305	$316,930
40	$386,675	$207,895	$594,570	$454,583	$355,851	$284,866
50	$322,229	$207,895	$530,124	$404,819	$316,397	$252,802
60	$257,783	$207,895	$465,678	$355,055	$276,942	$220,738

Option I - Transmission Line with PV Cells and Wind Generator

CAPITAL COSTS

Item	Cost
Transmission Line	$120,000
Battery Bank	$42,000
Inverters	$18,200
PV Cells	$25,000
Wind Generator	$15,000
Shipment	$35,000
Total	$255,200

O&M COSTS

Item	Cost
Electricity	$18,140
Wind Turbine	$1,000
Total	$19,140

O&M COSTS

Item	Cost
Electricity	$18,140
Wind Turbine	$1,000
Total	$19,140

REPLACEMENTS

Item	Cost	Year
Battery Replacement	$42,000	7th, 14th, 21st
Wind Turbine Replacement	$15,000	10th, 20th
Total	$57,000	

DISCOUNTED CASH FLOW

% Usage 1.0

Planning Year	Year	Future Costs			Discounted Cash Flow		
		Annual O&M	Replacements	Total O&M	2%	4%	6%
0	2008	$19,140	$0	$19,140	$19,140	$19,140	$19,140
1	2009	$19,523	$0	$19,523	$19,140	$18,772	$18,418
2	2010	$19,913	$0	$19,913	$19,140	$18,411	$17,723
3	2011	$20,311	$0	$20,311	$19,140	$18,057	$17,054
4	2012	$20,718	$0	$20,718	$19,140	$17,710	$16,410
5	2013	$21,132	$0	$21,132	$19,140	$17,369	$15,791
6	2014	$21,555	$0	$21,555	$19,140	$17,035	$15,195
7	2015	$21,986	$48,245	$70,231	$61,140	$53,369	$46,707
8	2016	$22,425	$0	$22,425	$19,140	$16,386	$14,070
9	2017	$22,874	$0	$22,874	$19,140	$16,071	$13,539
10	2018	$23,331	$18,285	$41,616	$34,140	$28,115	$23,238
11	2019	$23,798	$0	$23,798	$19,140	$15,459	$12,537
12	2020	$24,274	$0	$24,274	$19,140	$15,161	$12,063
13	2021	$24,760	$0	$24,760	$19,140	$14,870	$11,608
14	2022	$25,255	$55,418	$80,673	$61,140	$46,587	$35,682
15	2023	$25,760	$0	$25,760	$19,140	$14,304	$10,749
16	2024	$26,275	$0	$26,275	$19,140	$14,028	$10,343
17	2025	$26,801	$0	$26,801	$19,140	$13,759	$9,953
18	2026	$27,337	$0	$27,337	$19,140	$13,494	$9,577
19	2027	$27,883	$0	$27,883	$19,140	$13,235	$9,216
20	2028	$28,441	$22,289	$50,730	$34,140	$23,153	$15,818
21	2029	$29,010	$63,658	$92,668	$61,140	$40,666	$27,259
22	2030	$29,590	$0	$29,590	$19,140	$12,486	$8,211
23	2031	$30,182	$0	$30,182	$19,140	$12,246	$7,901
24	2032	$30,785	$0	$30,785	$19,140	$12,010	$7,603
25	2033	$31,401	$0	$31,401	$19,140	$11,779	$7,316

	$644,458	$207,895	$852,353	**$653,638**	**$513,668**	**$413,122**

% Usage of Each	Future Costs			Discounted Cash Flow		
	Annual O&M	Replacements	Total O&M	2%	4%	6%
5	$580,012	$207,895	$787,907	$603,874	$474,214	$381,058
10	$515,567	$207,895	$723,462	$554,110	$434,760	$348,994
15	$451,121	$207,895	$659,016	$504,346	$395,305	$316,930
20	$386,675	$207,895	$594,570	$454,583	$355,851	$284,866
25	$322,229	$207,895	$530,124	$404,819	$316,397	$252,802
30	$257,783	$207,895	$465,678	$355,055	$276,942	$220,738
35	$193,337	$207,895	$401,232	$305,291	$237,488	$188,674
40	$128,892	$207,895	$336,787	$255,528	$198,034	$156,610
45	$64,446	$207,895	$272,341	$205,764	$158,579	$124,546

APPENDIX I

Calculations and Cost Analysis

Water Demand Calculations

Assumptions:

Domestic Water Demand (MACA)	100 Lcpd
Population, 2007 (NU Bureau of Statistics)	947 ppl
Population % Yearly Increase	2.415 %
Peak Day Factor, PDF	1.5
Truck Delivery Factor, TDF	1.4
Conversion Factor (Lpd to USgpd)	0.264

LITERS

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Population	970	993	1017	1042	1067	1093	1119	1146	1174	1202	1231	1261	1291	1323	1355	1387	1421	1455	1490	1526	1563	1601	1640	1679	1720	1761
Water Demand per Capita includes Additional for Industrial, Commercial, Institutional (Lcpd):	122.3	122.8	123.4	124.0	124.5	125.1	125.7	126.4	127.0	127.7	128.3	129.0	129.7	130.4	131.2	131.9	132.7	133.5	134.3	135.1	136.0	136.8	137.7	138.6	139.6	140.5
Average Day Demand (Lpd)	118,622	122,022	125,530	129,150	132,886	136,743	140,725	144,836	149,081	153,465	157,994	162,672	167,505	172,499	177,660	182,994	188,508	194,209	200,104	206,200	212,504	219,026	225,774	232,755	239,980	247,458
Additional Water for In-Plant Use	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Total Average Day Demand (Lpd)	**130,484**	**134,224**	**138,083**	**142,065**	**146,175**	**150,418**	**154,798**	**159,320**	**163,989**	**168,812**	**173,793**	**178,939**	**184,255**	**189,749**	**195,426**	**201,294**	**207,359**	**213,630**	**220,114**	**226,819**	**233,755**	**240,929**	**248,351**	**256,031**	**263,978**	**272,203**
Peak Day Demand w/o TDF (Lpd)	177,933	183,033	188,295	193,725	199,330	205,115	211,088	217,254	223,622	230,198	236,991	244,008	251,257	258,748	266,490	274,491	282,762	291,314	300,155	309,299	318,757	328,539	338,660	349,133	359,970	371,186
Additional Water for In-Plant Use	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Total Peak Day Demand w/o TDF (Lpd)	**195,726**	**201,336**	**207,124**	**213,098**	**219,263**	**225,627**	**232,196**	**238,979**	**245,984**	**253,218**	**260,690**	**268,408**	**276,383**	**284,623**	**293,139**	**301,940**	**311,039**	**320,445**	**330,171**	**340,229**	**350,632**	**361,393**	**372,526**	**384,046**	**395,967**	**408,305**
Peak Day Demand w/ TDF (Lpd)	249,106	256,246	263,613	271,215	279,062	287,161	295,523	304,156	313,071	322,277	331,787	341,611	351,760	362,248	373,086	384,288	395,867	407,839	420,218	433,019	446,259	459,955	474,124	488,786	503,958	519,661
Additional Water for In-Plant Use	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Total Peak Day Demand w/ TDF (Lpd)	**274,017**	**281,870**	**289,974**	**298,337**	**306,968**	**315,877**	**325,075**	**334,571**	**344,378**	**354,505**	**364,966**	**375,772**	**386,936**	**398,472**	**410,394**	**422,716**	**435,454**	**448,623**	**462,239**	**476,321**	**490,885**	**505,951**	**521,537**	**537,664**	**554,354**	**571,627**

GALLONS

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Population	970	993	1017	1042	1067	1093	1119	1146	1174	1202	1231	1261	1291	1323	1355	1387	1421	1455	1490	1526	1563	1601	1640	1679	1720	1761
Water Demand per Capita includes Additional for Industrial, Commercial, Institutional (US gpd):	32.3	32.5	32.6	32.7	32.9	33.1	33.2	33.4	33.5	33.7	33.9	34.1	34.3	34.5	34.6	34.8	35.0	35.3	35.5	35.7	35.9	36.1	36.4	36.6	36.9	37.1
Average Day Demand (US gpd)	31,337	32,235	33,161	34,118	35,105	36,124	37,176	38,262	39,383	40,541	41,738	42,973	44,250	45,569	46,933	48,342	49,799	51,305	52,862	54,472	56,138	57,861	59,643	61,487	63,396	65,371
Additional Water for In-Plant Use	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Total Average Day Demand (US gpd)	**34,470**	**35,458**	**36,478**	**37,530**	**38,615**	**39,736**	**40,893**	**42,088**	**43,321**	**44,595**	**45,911**	**47,271**	**48,675**	**50,126**	**51,626**	**53,176**	**54,778**	**56,435**	**58,148**	**59,919**	**61,751**	**63,647**	**65,607**	**67,636**	**69,736**	**71,909**
Peak Day Demand w/o (US gpd)	47,005	48,352	49,742	51,177	52,657	54,186	55,763	57,392	59,075	60,812	62,606	64,460	66,375	68,354	70,399	72,513	74,698	76,957	79,293	81,708	84,207	86,791	89,465	92,231	95,094	98,057
Additional Water for In-Plant Use	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Total Peak Day Demand w/o TDF (US gpd)	**51,705**	**53,187**	**54,716**	**56,294**	**57,923**	**59,604**	**61,340**	**63,132**	**64,982**	**66,893**	**68,867**	**70,906**	**73,013**	**75,189**	**77,439**	**79,764**	**82,168**	**84,653**	**87,222**	**89,879**	**92,627**	**95,470**	**98,411**	**101,454**	**104,603**	**107,863**
Peak Day Demand w/ TDF (US gpd)	65,807	67,693	69,639	71,647	73,720	75,860	78,069	80,349	82,704	85,137	87,649	90,244	92,925	95,696	98,559	101,518	104,577	107,740	111,010	114,392	117,889	121,507	125,250	129,123	133,132	137,280
Additional Water for In-Plant Use	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Total Peak Day Demand w/ TDF (US gpd)	**72,388**	**74,462**	**76,603**	**78,812**	**81,092**	**83,446**	**85,876**	**88,384**	**90,975**	**93,650**	**96,414**	**99,268**	**102,218**	**105,265**	**108,415**	**111,670**	**115,035**	**118,514**	**122,111**	**125,831**	**129,678**	**133,658**	**137,775**	**142,036**	**146,445**	**151,008**

Flow from Truck Fill Station

Days Truckfill Operates out of 7 Days (W): 5 days/week

Truckfill Hours of Operation Avg Day (X): 8 hrs/day

Truckfill Hours of Operation Max Day (X): 10 hrs/day

GALLONS

Flow from Truckfill, AVERAGE DAY:

	2008	2021	2033
Average Day Demand (USgpd)	34,470	50,126	71,909
Truckfill operates W out of 7 days so daily demand is increased to:	48,258	70,177	100,672
Flow from Tank to Truckfill over X hours (USgpm):	**100.5**	**146.2**	**209.7**

Flow from Truckfill, MAX DAY:

	2008	2021	2033
Max Day Demand (USgpd)	51,705	75,189	107,863
Truckfill operates W out of 7 days so daily demand is increased to:	72,388	105,265	151,008
Flow from Tank to Truckfill over X hours (USgpm):	**120.6**	**175.4**	**251.7**

LITERS

Flow from Truckfill, AVERAGE DAY:

	2007	2020	2032
Average Day Demand (Lpd)	130,484	189,749	272,203
Truckfill operates W out of 7 days so Daily Demand is increased to (Lpd):	182,678	265,648	381,085
Flow from Tank to Truckfill over X hours (m^3/hr):	**22.8**	**33.2**	**47.6**

Flow from Truckfill, MAX DAY:

	2007	2020	2032
Max Day Demand (Lpd)	195,726	284,623	408,305
Truckfill operates W out of 7 days so Daily Demand is increased to (Lpd):	274,017	398,472	571,627
Flow from Tank to Truckfill over X hours (m^3/hr):	**27.4**	**39.8**	**57.2**

COST ANALYSIS OF WATER DELIVERY OPTIONS

DESCRIPTION	OPTION	
	Truck	Pipeline
Capital Costs		
1) Pipeline/Transmission Main	$0	$1,200,000
2) Road Access/Turn Around	$325,000	$325,000
3) Intake Pumphouse	$400,000	$400,000
4) Water Treatment Plant	$1,750,000	$1,750,000
5) Heating Station	$0	$100,000
6) Trucks (0 Year)	$200,000	$0
7) Maintenance Garage	$150,000	$0
A. Sub-Total	**$2,825,000**	**$3,775,000**
Operation and Maintenance Costs		
1) Pipeline/Transmission Main	$0	$40,000
2) Road Access/Turn Around	$5,000	$5,000
3) Intake Pumphouse	$50,000	$50,000
4) Water Treatment Plant	$160,000	$160,000
5) Heating Station	$0	$20,000
6) Trucks (0 Year)	$25,000	$0
7) Maintenance Garage	$10,000	$0
B. Sub-Total	**$250,000**	**$275,000**
C. Present Value of O&M	**$2,800,000**	**$3,100,000**
TOTAL PRESENT VALUE (A+C)	**$5,625,000**	**$6,875,000**

COST ANALYSIS OF ACCESS ROAD

ASSUMPTIONS

2005 INDICES FOR YELLOWKNIFE

Geographic Index for Gravel Roads/Ground, Capital Cost	1.12
City Center Index for Gravel Road, O&M Costs	1.02
Remoteness Index for Gravel Roads, Zone 4	1.45

PRICE INDICES

Year	Index
2004/05	100.0
2005/06	101.4
2006/07	103.2
2007/08	105.3

UNIT PRICES FOR ROAD CONSTRUCTION

Description	Unit	Toronto (2005)	Yellowknife (2007)
Unit Price for Capital Cost, Road Construction	$/l.m.	$465.80	$796.55
Unit Price for O&M Cost, Access Road	$/l.m.	$4.49	$6.99

Table 1: Cost Estimate for New Access Road

Site	Distance from Center of Community (km)	Required Length of Access Road (m)	Cost			
			Capital	O&M	Present Value O&M	Total Present Value
1	0.87	550	$438,103	$3,846	$41,579	$479,682
2	1.00	360	$286,759	$2,518	$27,215	$313,974
3	1.25	600	$477,931	$4,196	$45,359	$523,290

Table 2: Present Value of O&M Costs of Access Road for Different Sites

Year	OPTION 1		OPTION 2		OPTION 3	
	Annual O&M Costs	Present Value	Annual O&M Costs	Present Value	Annual O&M Costs	Present Value
2008	$3,846	$3,561	$2,518	$2,331	$4,196	$3,885
2009	$3,846	$3,298	$2,518	$2,158	$4,196	$3,597
2010	$3,846	$3,053	$2,518	$1,999	$4,196	$3,331
2011	$3,846	$2,827	$2,518	$1,851	$4,196	$3,084
2012	$3,846	$2,618	$2,518	$1,713	$4,196	$2,856
2013	$3,846	$2,424	$2,518	$1,587	$4,196	$2,644
2014	$3,846	$2,244	$2,518	$1,469	$4,196	$2,448
2015	$3,846	$2,078	$2,518	$1,360	$4,196	$2,267
2016	$3,846	$1,924	$2,518	$1,259	$4,196	$2,099
2017	$3,846	$1,782	$2,518	$1,166	$4,196	$1,944
2018	$3,846	$1,650	$2,518	$1,080	$4,196	$1,800
2019	$3,846	$1,527	$2,518	$1,000	$4,196	$1,666
2020	$3,846	$1,414	$2,518	$926	$4,196	$1,543
2021	$3,846	$1,310	$2,518	$857	$4,196	$1,429
2022	$3,846	$1,213	$2,518	$794	$4,196	$1,323
2023	$3,846	$1,123	$2,518	$735	$4,196	$1,225
2024	$3,846	$1,040	$2,518	$680	$4,196	$1,134
2025	$3,846	$963	$2,518	$630	$4,196	$1,050
2026	$3,846	$891	$2,518	$583	$4,196	$972
2027	$3,846	$825	$2,518	$540	$4,196	$900
2028	$3,846	$764	$2,518	$500	$4,196	$834
2029	$3,846	$708	$2,518	$463	$4,196	$772
2030	$3,846	$655	$2,518	$429	$4,196	$715
2031	$3,846	$607	$2,518	$397	$4,196	$662
2032	$3,846	$562	$2,518	$368	$4,196	$613
2033	$3,846	$520	$2,518	$340	$4,196	$567
Present Value		**$41,579**		**$27,215**		**$45,359**

COST ANALYSIS OF INTAKE PIPE

ASSUMPTIONS

2005 INDICES FOR YELLOWKNIFE

Geographic Index for Water/Sewer, Capital Cost	1.35
City Center Index for Heated Mains, O&M Costs	1.64
Multipler for Intake Pipe, Polyethylene, Heat-traced & Insulated	3.00
Remoteness Index for Water Mains, Zone 4	1.96

UNIT PRICES FOR INTAKE PIPE

Description	Unit	Cost	
		TO, 2004/05	YK, 2007/08
Water Mains - Heated	l.m.	$3.87	$39.30
Underwater Intake Pipe	l.m.	$265	$2,215
Underground Intake Pipe	l.m.	$332	$2,775
Average Intake Pipe	l.m.	$299	$2,495

Table 3: Cost Estimate for Intake Pipe

Site	Length of Intake Pipe (m)	Costs			
		Capital	O&M	Present Value O&M	Total Present Value
1	45	$112,278	$1,768	$19,116	$131,394
2	40	$99,803	$1,572	$16,992	$116,795
3	50	$124,754	$1,965	$21,240	$145,994

Table 4: Present Value of O&M Costs of Intake Pipe for Different Sites

Year	OPTION 1		OPTION 2		OPTION 3	
	Annual O&M Costs	Present Value	Annual O&M Costs	Present Value	Annual O&M Costs	Present Value
2008	$1,768	$1,637	$1,572	$1,455	$1,965	$1,819
2009	$1,768	$1,516	$1,572	$1,348	$1,965	$1,685
2010	$1,768	$1,404	$1,572	$1,248	$1,965	$1,560
2011	$1,768	$1,300	$1,572	$1,155	$1,965	$1,444
2012	$1,768	$1,204	$1,572	$1,070	$1,965	$1,337
2013	$1,768	$1,114	$1,572	$991	$1,965	$1,238
2014	$1,768	$1,032	$1,572	$917	$1,965	$1,146
2015	$1,768	$955	$1,572	$849	$1,965	$1,062
2016	$1,768	$885	$1,572	$786	$1,965	$983
2017	$1,768	$819	$1,572	$728	$1,965	$910
2018	$1,768	$758	$1,572	$674	$1,965	$843
2019	$1,768	$702	$1,572	$624	$1,965	$780
2020	$1,768	$650	$1,572	$578	$1,965	$722
2021	$1,768	$602	$1,572	$535	$1,965	$669
2022	$1,768	$557	$1,572	$496	$1,965	$619
2023	$1,768	$516	$1,572	$459	$1,965	$574
2024	$1,768	$478	$1,572	$425	$1,965	$531
2025	$1,768	$443	$1,572	$393	$1,965	$492
2026	$1,768	$410	$1,572	$364	$1,965	$455
2027	$1,768	$379	$1,572	$337	$1,965	$422
2028	$1,768	$351	$1,572	$312	$1,965	$390
2029	$1,768	$325	$1,572	$289	$1,965	$361
2030	$1,768	$301	$1,572	$268	$1,965	$335
2031	$1,768	$279	$1,572	$248	$1,965	$310
2032	$1,768	$258	$1,572	$230	$1,965	$287
2033	$1,768	$239	$1,572	$213	$1,965	$266
Present Value		**$19,116**		**$16,992**		**$21,240**

COST ANALYSIS OF POWER LINE

ASSUMPTIONS

2005 INDICES FOR YELLOWKNIFE

Electrical Distribution, Capital Cost	1.40
City Center Index for Transmission & Distribution, O&M Costs	1.25
City Center Index for Street Lights, O&M Costs	1.29
Remoteness Index for Transmission, Distribution & Street Lights	1.46

UNIT PRICES FOR CAPITAL COST FOR POWER LINE

Description	Unit	Cost	
		TO, 2004/05	YK, 2007/08
Transmission Line	km	$107,310	$230,967
Substation	l.s	$249,900	$537,868
Distribution	km	$90,440	$194,657
Street Lighting	ea.	$1,730	$3,724

UNIT PRICES FOR O&M COSTS FOR POWER LINE

Description	Unit	Cost	
		TO, 2004/05	YK, 2007/08
Transmission	km	$1,303	$2,504
Distribution	km	$2,724.46	$5,236
Street Lights	fixture	$127.88	$254

Table 5: Cost Estimate for Power Line

Site	Length of Power Line [km]	Costs			
		Capital	O&M	Present Value O&M	Total Present Value
1	0.56	$238,384	$4,337	$46,878	$285,262
2	0.85	$361,833	$6,582	$71,155	$432,988
3	1	$425,686	$7,744	$83,711	$509,397

Table 6: Present Value of O&M Costs of Power Transmission Line for Different Sites

Year	OPTION 1		OPTION 2		OPTION 3	
	Annual O&M Costs	Present Value	Annual O&M Costs	Present Value	Annual O&M Costs	Present Value
2008	$4,337	$4,015	$6,582	$6,095	$7,744	$7,170
2009	$4,337	$3,718	$6,582	$5,643	$7,744	$6,639
2010	$4,337	$3,443	$6,582	$5,225	$7,744	$6,147
2011	$4,337	$3,188	$6,582	$4,838	$7,744	$5,692
2012	$4,337	$2,951	$6,582	$4,480	$7,744	$5,270
2013	$4,337	$2,733	$6,582	$4,148	$7,744	$4,880
2014	$4,337	$2,530	$6,582	$3,841	$7,744	$4,518
2015	$4,337	$2,343	$6,582	$3,556	$7,744	$4,184
2016	$4,337	$2,169	$6,582	$3,293	$7,744	$3,874
2017	$4,337	$2,009	$6,582	$3,049	$7,744	$3,587
2018	$4,337	$1,860	$6,582	$2,823	$7,744	$3,321
2019	$4,337	$1,722	$6,582	$2,614	$7,744	$3,075
2020	$4,337	$1,595	$6,582	$2,420	$7,744	$2,847
2021	$4,337	$1,476	$6,582	$2,241	$7,744	$2,636
2022	$4,337	$1,367	$6,582	$2,075	$7,744	$2,441
2023	$4,337	$1,266	$6,582	$1,921	$7,744	$2,260
2024	$4,337	$1,172	$6,582	$1,779	$7,744	$2,093
2025	$4,337	$1,085	$6,582	$1,647	$7,744	$1,938
2026	$4,337	$1,005	$6,582	$1,525	$7,744	$1,794
2027	$4,337	$930	$6,582	$1,412	$7,744	$1,661
2028	$4,337	$861	$6,582	$1,308	$7,744	$1,538
2029	$4,337	$798	$6,582	$1,211	$7,744	$1,424
2030	$4,337	$739	$6,582	$1,121	$7,744	$1,319
2031	$4,337	$684	$6,582	$1,038	$7,744	$1,221
2032	$4,337	$633	$6,582	$961	$7,744	$1,131
2033	$4,337	$586	$6,582	$890	$7,744	$1,047
Present Value		**$46,878**		**$71,155**		**$83,711**

SUMMARY OF COST ANALYSIS

Table 7: Cost Summary of Truckfill Distribution System at Different Sites

DESCRIPTION	OPTION		
	1	2	3
Capital Costs			
1) Power Transmission Line	$238,384	$361,833	$425,686
2) Road Access/Turn Around	$438,103	$286,759	$477,931
3) Intake Pipe	$112,278	$99,803	$124,754
4) Intake Pumphouse	$300,000	$300,000	$300,000
5) Water Treatment Plant	$1,750,000	$1,750,000	$1,750,000
6) Trucks (0 Year)	$200,000	$200,000	$200,000
7) Maintenance Garage	$150,000	$150,000	$150,000
A. Sub-Total	**$3,188,766**	**$3,148,394**	**$3,428,370**
Operation and Maintenance Costs			
1) Power Transmission Line	$4,337	$6,582	$7,744
2) Road Access/Turn Around	$3,846	$2,518	$4,196
3) Intake Pipe	$1,768	$1,572	$1,965
4) Intake Pumphouse	$45,000	$45,000	$45,000
5) Water Treatment Plant	$160,000	$160,000	$160,000
6) Trucks (0 Year)	$25,000	$25,000	$25,000
7) Maintenance Garage	$10,000	$10,000	$10,000
B. Sub-Total	**$249,951**	**$250,672**	**$253,905**
C. Present Value of O&M (from Table 8)	**$2,701,968**	**$2,709,757**	**$2,744,705**
TOTAL PRESENT VALUE (A+C)	**$5,890,734**	**$5,858,151**	**$6,173,076**

Table 8: Present Value of O&M Costs for Truck-filled Distribution System at Different Sites

Year	OPTION 1		OPTION 2		OPTION 3	
	Annual O&M Costs	Present Value	Annual O&M Costs	Present Value	Annual O&M Costs	Present Value
2007	$249,951	$231,436	$250,672	$232,104	$253,905	$235,097
2008	$249,951	$214,293	$250,672	$214,911	$253,905	$217,682
2009	$249,951	$198,419	$250,672	$198,991	$253,905	$201,558
2010	$249,951	$183,722	$250,672	$184,251	$253,905	$186,628
2011	$249,951	$170,113	$250,672	$170,603	$253,905	$172,803
2012	$249,951	$157,512	$250,672	$157,966	$253,905	$160,003
2013	$249,951	$145,844	$250,672	$146,265	$253,905	$148,151
2014	$249,951	$135,041	$250,672	$135,430	$253,905	$137,177
2015	$249,951	$125,038	$250,672	$125,398	$253,905	$127,016
2016	$249,951	$115,776	$250,672	$116,110	$253,905	$117,607
2017	$249,951	$107,200	$250,672	$107,509	$253,905	$108,895
2018	$249,951	$99,259	$250,672	$99,545	$253,905	$100,829
2019	$249,951	$91,907	$250,672	$92,172	$253,905	$93,360
2020	$249,951	$85,099	$250,672	$85,344	$253,905	$86,445
2021	$249,951	$78,795	$250,672	$79,022	$253,905	$80,041
2022	$249,951	$72,958	$250,672	$73,169	$253,905	$74,112
2023	$249,951	$67,554	$250,672	$67,749	$253,905	$68,623
2024	$249,951	$62,550	$250,672	$62,730	$253,905	$63,539
2025	$249,951	$57,917	$250,672	$58,084	$253,905	$58,833
2026	$249,951	$53,627	$250,672	$53,781	$253,905	$54,475
2027	$249,951	$49,654	$250,672	$49,797	$253,905	$50,440
2028	$249,951	$45,976	$250,672	$46,109	$253,905	$46,703
2029	$249,951	$42,571	$250,672	$42,693	$253,905	$43,244
2030	$249,951	$39,417	$250,672	$39,531	$253,905	$40,041
2031	$249,951	$36,497	$250,672	$36,603	$253,905	$37,075
2032	$249,951	$33,794	$250,672	$33,891	$253,905	$34,328
Present Value		**$2,701,968**		**$2,709,757**		**$2,744,705**

COST ANALYSIS AT DIFFERENT SITES

ASSUMPTIONS

Capital Costs

Unit Price of Access Road	$480	$/l.m.
Unit Price of Intake Pipe	$3,000	$/l.m.
Unit Price of Power Line	$150	$/l.m.

Operation & Maintenance Costs

Unit Price of Access Road	$7	$/l.m.
Unit Price of Intake Pipe	$40	$/l.m.
Unit Price of Power Line	$7	$/l.m.

Site	Access Road			Intake Pipe			Power Line			Total Cost		
	Length (m)	Capital Cost	O&M Costs	Length (m)	Capital Cost	O&M Costs	Length (m)	Capital Cost	O&M Costs	Capital	O&M	Life Cycle at 4%
1	550	$264,000	$3,850	95	$285,000	$3,800	550	$82,500	$3,850	$631,500	$11,500	$868,557
2	850	$408,000	$5,950	90	$270,000	$3,600	850	$127,500	$5,950	$805,500	$15,500	$1,125,011
3	1100	$528,000	$7,700	100	$300,000	$4,000	1100	$165,000	$7,700	$993,000	$19,400	$1,392,905

DISCOUNTED CASH FLOW

Inflation Rate 0.02

	Year	Site 1				Site 2				Site 3			
		FV O&M Costs	DPV at 2%	DPV at 4%	DPV at 6%	FV O&M Costs	DPV at 2%	DPV at 4%	DPV at 6%	FV O&M Costs	DPV at 2%	DPV at 4%	DPV at 6%
0	2008	$11,500	$11,500	$11,500	$11,500	$15,500	$15,500	$15,500	$15,500	$19,400	$19,400	$19,400	$19,400
1	2009	$11,730	$11,500	$11,279	$11,066	$15,810	$15,500	$15,202	$14,915	$19,788	$19,400	$19,027	$18,668
2	2010	$11,965	$11,500	$11,062	$10,648	$16,126	$15,500	$14,910	$14,352	$20,184	$19,400	$18,661	$17,963
3	2011	$12,204	$11,500	$10,849	$10,247	$16,449	$15,500	$14,623	$13,811	$20,587	$19,400	$18,302	$17,286
4	2012	$12,448	$11,500	$10,641	$9,860	$16,778	$15,500	$14,342	$13,290	$20,999	$19,400	$17,950	$16,633
5	2013	$12,697	$11,500	$10,436	$9,488	$17,113	$15,500	$14,066	$12,788	$21,419	$19,400	$17,605	$16,006
6	2014	$12,951	$11,500	$10,235	$9,130	$17,456	$15,500	$13,795	$12,305	$21,848	$19,400	$17,266	$15,402
7	2015	$13,210	$11,500	$10,038	$8,785	$17,805	$15,500	$13,530	$11,841	$22,285	$19,400	$16,934	$14,820
8	2016	$13,474	$11,500	$9,845	$8,454	$18,161	$15,500	$13,270	$11,394	$22,730	$19,400	$16,609	$14,261
9	2017	$13,744	$11,500	$9,656	$8,135	$18,524	$15,500	$13,015	$10,964	$23,185	$19,400	$16,289	$13,723
10	2018	$14,018	$11,500	$9,470	$7,828	$18,894	$15,500	$12,764	$10,551	$23,648	$19,400	$15,976	$13,205
11	2019	$14,299	$11,500	$9,288	$7,532	$19,272	$15,500	$12,519	$10,152	$24,121	$19,400	$15,669	$12,707
12	2020	$14,585	$11,500	$9,110	$7,248	$19,658	$15,500	$12,278	$9,769	$24,604	$19,400	$15,368	$12,227
13	2021	$14,876	$11,500	$8,934	$6,975	$20,051	$15,500	$12,042	$9,401	$25,096	$19,400	$15,072	$11,766
14	2022	$15,174	$11,500	$8,763	$6,711	$20,452	$15,500	$11,810	$9,046	$25,598	$19,400	$14,782	$11,322
15	2023	$15,477	$11,500	$8,594	$6,458	$20,861	$15,500	$11,583	$8,705	$26,110	$19,400	$14,498	$10,895
16	2024	$15,787	$11,500	$8,429	$6,215	$21,278	$15,500	$11,361	$8,376	$26,632	$19,400	$14,219	$10,484
17	2025	$16,103	$11,500	$8,267	$5,980	$21,704	$15,500	$11,142	$8,060	$27,165	$19,400	$13,946	$10,088
18	2026	$16,425	$11,500	$8,108	$5,754	$22,138	$15,500	$10,928	$7,756	$27,708	$19,400	$13,677	$9,707
19	2027	$16,753	$11,500	$7,952	$5,537	$22,581	$15,500	$10,718	$7,463	$28,262	$19,400	$13,414	$9,341
20	2028	$17,088	$11,500	$7,799	$5,328	$23,032	$15,500	$10,512	$7,182	$28,827	$19,400	$13,156	$8,989
21	2029	$17,430	$11,500	$7,649	$5,127	$23,493	$15,500	$10,309	$6,911	$29,404	$19,400	$12,903	$8,649
22	2030	$17,779	$11,500	$7,502	$4,934	$23,963	$15,500	$10,111	$6,650	$29,992	$19,400	$12,655	$8,323
23	2031	$18,134	$11,500	$7,358	$4,748	$24,442	$15,500	$9,917	$6,399	$30,592	$19,400	$12,412	$8,009
24	2032	$18,497	$11,500	$7,216	$4,568	$24,931	$15,500	$9,726	$6,157	$31,204	$19,400	$12,173	$7,707
25	2033	$18,867	$11,500	$7,077	$4,396	$25,429	$15,500	$9,539	$5,925	$31,828	$19,400	$11,939	$7,416
Present Value		**$387,215**	**$299,000**	**$237,057**	**$192,653**	**$521,899**	**$403,000**	**$319,511**	**$259,662**	**$653,216**	**$504,400**	**$399,905**	**$324,996**

Cost Analysis for Building Heating Options

Inflation Rate	0.02
Location Factor	1.3
Discount Rate	0.06

Heating System	COSTS FOR COVILLE LAKE, 2003				COSTS FOR TALOYOAK, 2007			
	Supply & Installation	Annual Operating	Annual Maintenance	Total Annual O&M	Supply & Installation	Total Annual O&M	DPV of O&M	Life Cycle
Boiler, Oil Fired	$22,500	$10,300	$2,500	$12,800	$31,661	$16,640	$278,760	$310,421
Boiler, Electric	$12,500	$50,800	$1,500	$52,300	$17,590	$67,990	$1,138,995	$1,156,585
Furnace, Oil Fired	$17,000	$8,900	$2,000	$10,900	$23,922	$14,170	$237,381	$261,303
Furnace, Electric	$4,500	$50,000	$750	$50,750	$6,332	$65,975	$1,105,239	$1,111,572
Unit Heaters, Oil Fired	$14,500	$12,500	$1,500	$14,000	$20,404	$18,200	$304,894	$325,297
Unit Heaters, Electric	$7,500	$52,200	$750	$52,950	$10,554	$68,835	$1,153,151	$1,163,705

Planning Year	Year	Future Value (FV) of Annual O&M Costs						Discounted Present Value (DPV) of Annual O&M Costs					
		Boiler Oil Fired	Boiler Electric	Furnace Oil Fired	Furnance Electric	Unit Heaters Oil Fired	Unit Heaters Electric	Boiler Oil Fired	Boiler Electric	Furnace Oil Fired	Furnance Electric	Unit Heaters Oil Fired	Unit Heaters Electric
0	2008	$16,640	$67,990	$14,170	$65,975	$18,200	$68,835	$16,640	$67,990	$14,170	$65,975	$18,200	$68,835
1	2009	$16,973	$69,350	$14,453	$67,295	$18,564	$70,212	$16,012	$65,424	$13,635	$63,485	$17,513	$66,237
2	2010	$17,312	$70,737	$14,742	$68,640	$18,935	$71,616	$15,408	$62,955	$13,121	$61,090	$16,852	$63,738
3	2011	$17,659	$72,152	$15,037	$70,013	$19,314	$73,048	$14,826	$60,580	$12,626	$58,784	$16,216	$61,333
4	2012	$18,012	$73,595	$15,338	$71,413	$19,700	$74,509	$14,267	$58,294	$12,149	$56,566	$15,604	$59,018
5	2013	$18,372	$75,066	$15,645	$72,842	$20,094	$75,999	$13,729	$56,094	$11,691	$54,432	$15,016	$56,791
6	2014	$18,739	$76,568	$15,958	$74,299	$20,496	$77,519	$13,210	$53,977	$11,250	$52,378	$14,449	$54,648
7	2015	$19,114	$78,099	$16,277	$75,785	$20,906	$79,070	$12,712	$51,940	$10,825	$50,401	$13,904	$52,586
8	2016	$19,496	$79,661	$16,602	$77,300	$21,324	$80,651	$12,232	$49,980	$10,417	$48,499	$13,379	$50,602
9	2017	$19,886	$81,254	$16,934	$78,846	$21,751	$82,264	$11,771	$48,094	$10,023	$46,669	$12,874	$48,692
10	2018	$20,284	$82,879	$17,273	$80,423	$22,186	$83,909	$11,327	$46,279	$9,645	$44,908	$12,388	$46,855
11	2019	$20,690	$84,537	$17,619	$82,032	$22,629	$85,588	$10,899	$44,533	$9,281	$43,213	$11,921	$45,087
12	2020	$21,104	$86,228	$17,971	$83,672	$23,082	$87,299	$10,488	$42,853	$8,931	$41,583	$11,471	$43,385
13	2021	$21,526	$87,952	$18,330	$85,346	$23,544	$89,045	$10,092	$41,235	$8,594	$40,013	$11,038	$41,748
14	2022	$21,956	$89,711	$18,697	$87,053	$24,015	$90,826	$9,711	$39,679	$8,270	$38,503	$10,622	$40,173
15	2023	$22,395	$91,506	$19,071	$88,794	$24,495	$92,643	$9,345	$38,182	$7,958	$37,050	$10,221	$38,657
16	2024	$22,843	$93,336	$19,452	$90,570	$24,985	$94,496	$8,992	$36,741	$7,657	$35,652	$9,835	$37,198
17	2025	$23,300	$95,202	$19,841	$92,381	$25,484	$96,386	$8,653	$35,355	$7,368	$34,307	$9,464	$35,794
18	2026	$23,766	$97,106	$20,238	$94,229	$25,994	$98,313	$8,326	$34,021	$7,090	$33,012	$9,107	$34,443
19	2027	$24,241	$99,049	$20,643	$96,113	$26,514	$100,280	$8,012	$32,737	$6,823	$31,767	$8,763	$33,144
20	2028	$24,726	$101,030	$21,056	$98,035	$27,044	$102,285	$7,710	$31,501	$6,565	$30,568	$8,433	$31,893
21	2029	$25,221	$103,050	$21,477	$99,996	$27,585	$104,331	$7,419	$30,313	$6,318	$29,414	$8,114	$30,689
22	2030	$25,725	$105,111	$21,907	$101,996	$28,137	$106,418	$7,139	$29,169	$6,079	$28,304	$7,808	$29,531
23	2031	$26,240	$107,213	$22,345	$104,036	$28,700	$108,546	$6,869	$28,068	$5,850	$27,236	$7,513	$28,417
24	2032	$26,764	$109,358	$22,792	$106,117	$29,274	$110,717	$6,610	$27,009	$5,629	$26,209	$7,230	$27,345
25	2033	$27,300	$111,545	$23,247	$108,239	$29,859	$112,931	$6,361	$25,990	$5,417	$25,220	$6,957	$26,313
Net Present Value		**$560,284**	**$2,289,285**	**$477,117**	**$2,221,438**	**$612,810**	**$2,317,737**	**$278,760**	**$1,138,995**	**$237,381**	**$1,105,239**	**$304,894**	**$1,153,151**

Capital Cost Analysis for WTP

ITEM	2007 Price		
	Without PV & Wind Turbine	**With PV Only**	**With PV & Wind Turbine**
ACCESS ROAD	**$410,000**	**$410,000**	**$410,000**
EXCAVATION & BACKFILL			
Building Pad and Access Insulation	$9,000	$9,000	$9,000
Truck Pad and Access Granular	$70,000	$70,000	$70,000
Ditch Excavation	$500	$500	$500
SUB-TOTAL	**$79,500**	**$79,500**	**$79,500**
FOUNDATION SKID			
Water Treatment Plant	$35,000	$35,000	$35,000
Alternative Energy Source		$10,000	$20,000
SUB-TOTAL	**$35,000**	**$45,000**	**$55,000**
BUILDING ENVELOP			
Water Treatment Plant	$170,000	$170,000	$170,000
Alternative Energy Source		$50,000	$70,000
SUB-TOTAL	**$170,000**	**$220,000**	**$240,000**
PROCESS WATER			
Post Treatment Storage Tank	$10,000	$10,000	$10,000
Intake Pipe, Casing Pump, Raw Water Pump, Pipe, Screen 1	$270,000	$270,000	$270,000
Intake Pipe, Casing Pump, Raw Water Pump, Pipe, Screen 2	$270,000	$270,000	$270,000
Chlorination System	$20,000	$20,000	$20,000
Truckfill System	$40,000	$40,000	$40,000
Piping and Valves	$35,000	$35,000	$35,000
Cartridge Filtration System	$75,000	$75,000	$75,000
SUB-TOTAL	**$720,000**	**$720,000**	**$720,000**
ELECTRICAL			
Standby Generator	$60,000	$60,000	$60,000
Domestic Lighting	$5,000	$5,000	$5,000
Motor Control System	$50,000	$50,000	$50,000
Monitoring and Controls	$40,000	$40,000	$40,000
AES/Wind Generator		$120,000	$170,000
SUB-TOTAL	**$155,000**	**$275,000**	**$325,000**
HVAC & PLUMBING			
Furnace	$25,000	$25,000	$25,000
Plumbing	$40,000	$40,000	$40,000
Air Exchange System	$25,000	$25,000	$25,000
Fuel Oil Tank (5,000 L)	$20,000	$20,000	$20,000
Generator Air Handling System	$25,000	$25,000	$25,000
AE Building Heating		$7,500	$10,000
SUB-TOTAL	**$135,000**	**$142,500**	**$145,000**
OFFICE/LAB/SINK/SPARES	**$75,000**	**$75,000**	**$75,000**
SUB-TOTAL	$1,779,500	$1,967,000	$2,049,500
Engineering 10%	$177,950	$196,700	$204,950
Contingency 15%	$266,925	$295,050	$307,425
Power Transmission Line to Site	$120,000	$120,000	$120,000
TOTAL	**$2,344,375**	**$2,578,750**	**$2,681,875**

Note: Costs shown above were calculated based on a previous WTP that was designed in Colville Lake, NT in 2003

Taloyoak Water System Upgrade Planning Study

Report

April, 2005

Taloyoak Water System
Upgrade Planning Study

Client: Tom Livingston, GGS, GN
GN Project No. 04-4403
Cost Code: 5140008

PN: 043653 - 2000

Gary Strong - Project Manager

Submitted by
Dillon Consulting Limited

File Reference: R:\PROJECTS\DRAFT\043653\Task 2000\Reports\Report - Taloyoak Future Water Requirements.Draft Version.Doc

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(In reply, please refer to)
Our File: 04-3653
GN Project Number: 04-4403

Date: March 18, 2005

Government of Nunavut, Kitikmeot Region
Community and Government Services,
Second floor, Enhokok Centre
Cambridge Bay,
Nunavut, X0B 0C0

Attention: Thomas G. Livingston, BA, B.A.Sc, B.Eng, P.Eng.
Regional Municipal Planning Engineer

Re: Taloyoak Water System – Upgrade Planning Study

Dear Mr. Livingston,

Please find enclosed our report on future planning for the Taloyoak Water System. It is meant to serve as a decision making tool in assessing the various options available for designing a Water treatment Plant/Truck-fill station that meets the requirements of the community.

We've updated this report to your comments, and trust it meets your needs.

Yours Sincerely,

DILLON CONSULTING LIMITED

Gary Strong
Project Manager

Encl.

Dillon Consulting Limited

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APPENDICES
Schematics ands Sketches of the Existing Facilities

EXECUTIVE SUMMARY

The community of Taloyoak is supplied with water from a truck fill station that draws its water from a lake adjacent to the community, namely Water Lake, via a single pump and small pump house. There is a short transmission main between the intake pump house and the Truck fill facility. A portion of the Truckfill system is also located in a privately owned building, the Boothnia Inn. In 2004, the Government of Nunavut, the Department Of Community and Government Services recognized that the Water Supply Facility in Taloyoak would require an upgrade to meet the needs of a growing population.

Taloyoak - Community Population Projections

Year	2000	2005	2010	2015	2020
Total Population	804	904	1,016	1,147	1,294

The water supplied by the proposed water supply system must meet the requirements of the Nunavut Health Act. This act essentially adopts the Guidelines for Canadian Drinking Water Quality (GCDWQ). There is limited available raw water sample data for the Water Lake source. The data collected to date indicates that the raw water source provides water meeting the GCDWQ for all tested parameters. There are pending changes to the GCDWQ related to turbidity. The raw water source will require treatment for turbidity and will need to be disinfected in order to meet the pending guidelines.

It is recommended that a sampling program be initiated to establish the temporal raw water quality of the source lake body. This data is imperative to the future design of any treatment system. Monthly sampling should be completed for the next two years. The sampling frequency should be increased to weekly for the period of the spring melt to capture the worse case water quality conditions. Sampling and analytical parameters to be tested are;

Proposal Testing Program

Type	**Parameters**
Physical	Turbidity, Colour, Suspended Solids, Total Dissolved Solids, pH, Conductivity, Alkalinity, Particle Size
Major Ions	Calcium, Magnesium, Hardness, Sodium, Potassium, Fluoride, Chloride, Sulphate
Metals	Arsenic, Aluminium, Barium, Cadmium, Chromium, Copper, Iron, Mercury, Manganese, Lead, Selenium, Uranium, Zinc
Organics	THM potential

Type	**Parameters**
Microbiological	Total Coliforms, Fecal Coliforms, E coli, Standard Plate Count

The community, in conjunction with C&GS can complete this program.

The existing truckfill facility is located approximately 200 meters from the intake facility. There is the opportunity to combine the intake facility with the Truckfill operation. There needs to be a location study completed as part of the planning and design process.

The intake and truck-fill station will have the following major components:

- Building(s) Foundation
- Building(s) System and Envelop (windows, insulation, sheathing, VDR, air barrier, siding, roofing)
- Building heating system
- Intake Pipes and Pumps (option of 1 intake or 2)
- Intake Pipe Freeze Protection
- Domestic Lighting
- Domestic water supply
- Fire water capacity
- Treatment System (filtration, chlorination, etc)
- Laboratory and testing equipment
- Truckfill controls and metering
- Conveyance Pipes
- Prime Power Supply
- Stand-by power supply
- Monitoring and Alarms
- Spares and Ancillary Components

A preliminary design and detailed design program needs to be completed to fully describe these components. Other aspects of the facility replacement include that need to be addressed include;

- Decommissioning of the existing Plant, this would include the;
  - Intake pump house;
  - Utilidor
  - Truck-fill plant
  - Boothnia Inn connection and pipes
- Developing a construction schedule and strategy to ensure the existing facility can remain inplace until the new system is commissioned

- Over wintering plan for the existing facility after the new facility is commissioned. The owner would like the existing facility to be operational for the first year/first 6 months of the new plants life.
- Reusing existing equipment in the new plant;
  - Water Tanks
  - Boilers and hydronic heating units
  - Buildings – use by Hamlet or power corporate
  - Review of pumps fans and motors for re-use as spares
  - Lights bulbs, balances etc if common to be spares.

1.0 INTRODUCTION

In 2004, the Government of Nunavut, the Department Of Community and Government Services recognized that the Water Supply Facility in Taloyoak would require an upgrade to meet the needs of a growing population. Several issues with the aging facility that is currently in use are identified in a document called Taloyoak Pump House Plan - Briefing Note 1, by Tom Livingston, A/Municipal Engineer, CGS Cambridge Bay. The document indicates that C&GS Projects Division is working closely with the Hamlet of Taloyoak to ensure that both short and long-term solutions are found for the community's potable water supply. The following timetable was also given for providing the Hamlet with a new water system:

Tender for Design Services award date:	Early 2005
Tender for Construction Services award date:	Late 2005
Site Delivery date:	Summer 2006
Project Completion date:	Summer 2007

1.1 Background

The community of Taloyoak is supplied with water from a truck fill station that draws its water from a lake adjacent to the community, namely Water Lake, via a single pump and small pump house. There is a short transmission main between the intake pump house and the Truck fill facility. A portion of the Truckfill system is also located in a privately owned building, the Boothnia Inn. A full description of the system is found in Appendix 6. The system components are aging, and there have been recent problems with freeze up of the transmission main, electrical faults, and water supply rates not meeting the community's needs. See the appendices for a description of these issues.

When constructed the intake pumphouse was located on the shore of the lake. In recent years the level of the lake has risen, so that now the pump house sits about 10 m into the lake upon its raised concrete foundation. A concrete walk way was constructed a number of years ago to allow access to the intake pumphouse.

In mid-August 2004, the floor of the pump house was measured at ten inches above the surface of the water in the lake. The electrical inspector raised concerns that during spring break-up, the water has the potential to rise to above floor level, creating an electrical hazard for personnel working in the pump house. An order to address the electrical hazard was issued to the GN, C&GS. Remedial work was undertaken to raise the level of the pump house floor and provide a safe walkway and address the electrical inspector's concerns.

In addition to the rising water level issue, neither the storage capacity of the tanks in the treatment plant nor the flow rate of water from the intake facility is adequate for the community's present needs. Typically, the hamlet delivery trucks run out of water by mid-afternoon. There is also no provision for dedicated fire-fighting water supply.

Due to the issues identified above, the Government of Nunavut has decided to replace the aging facility with one that will meet the community's long term needs.

1.2 Scope of this Report

The intent of this report is to assess the future requirements of the water supply system for Taloyoak and present design options for a truck-fill station and pump house. Issues addressed in this report include;

- The development of the criteria for the water supply system.
- The water source currently in use meets the Nunavut Public Health Act for Canadian Drinking Water Quality; however, new guidelines are pending for the requirements for turbidity for surface water supply. These draft guidelines are included in **Appendix 7**. Upgrades to the system will be required to meet the new guidelines.
- The assessment of the fire flow regulations for the system, and the ability of the facility to meet accepted fire water storage and flow rates.
- Develop a description of the requirement for a new facility.

2.0 SYSTEM DESIGN STANDARDS

2.1 Design Criteria

At the 20-year design horizon the community population is estimated at 1,460 residents (see below for details on population estimates). The design must meet community water supply needs for 20 years, but water supply planning should consider a 40-year planning period. The primary factors to consider in designing the water treatment plant (WTP) are the population and water use projections. Population projections in this report have been obtained from Statistics Canada and the Nunavut Bureau of Statistics. It is also recommended that consultation with the funding agency and community be conducted prior to finalizing a design population.

For a trucked water system, storage capacity (if necessary) should be determined after an analysis of the trucking pattern of the community and consultation with the hamlet Foreman or supervisor of the WTP. In-town storage is only recommended if the water source is more than 3.2 km from the community or if the loading rate of 1000 L/min cannot be obtained directly from the source.

In the near future, the possibility of a sudden population increase due to industrial development or increased exploration in the surrounding area appears remote. For this reason, there is currently no justification for designing a system for a population greater than the upper limit projected by Statistics Canada and the Nunavut Bureau of Statistics.

Table 2.1 : Taloyoak Population Statistics and Projections

Characteristics	**Taloyoak**
Population in 2003 (1)	795
Population in 2001 (2)	720
Population in 1996 (3)	648
1996 to 2001 population change (%)	11.1

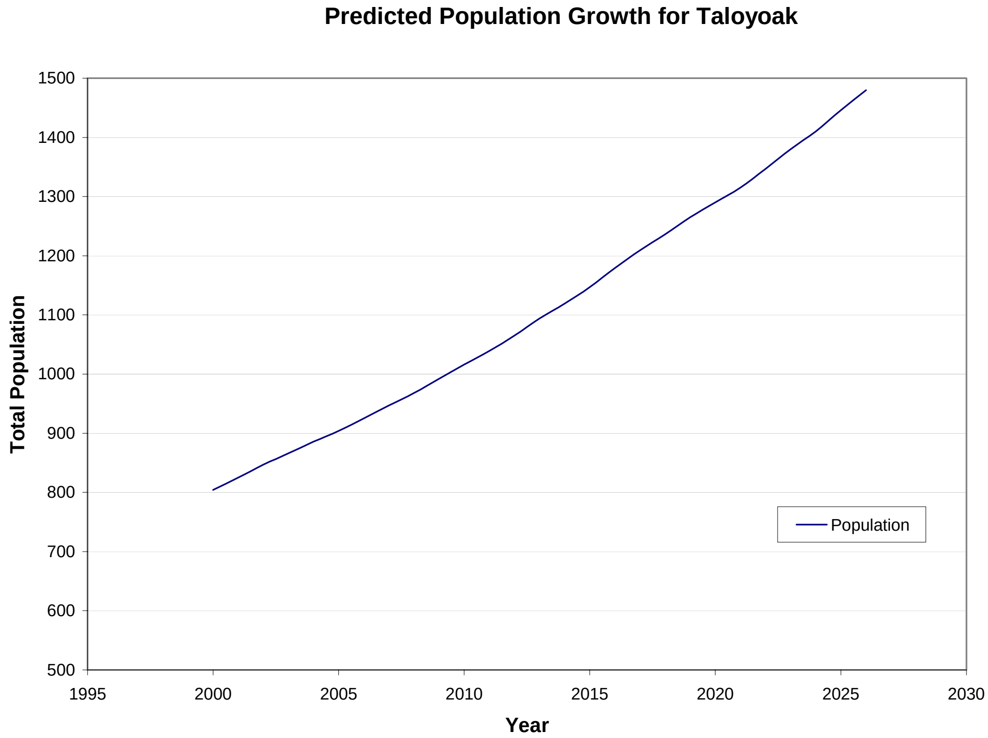
(1). Evaluation & Statistics Division, Department of Executive & Intergovernmental Affairs Nunavut.
(2). Starting with the 2001 Census, some population counts are adjusted in order to ensure confidentiality.
(3). These figures have not been subjected to random rounding.

Table 2.2 : Taloyoak - Community Population Projections

Year	2000	2005	2010	2015	2020
Total Population	804	904	1,016	1,147	1,294

Population projections produced by Statistics Canada and the Nunavut Bureau of Statistics include people in the population who are residents of Nunavut and do not have a home elsewhere in Canada from which they are temporarily absent. Therefore, temporary residents such as construction crews, residents in mining camps, etc. are not included in the population projection. As part of the design of the system, a scan of potential industrial/mining activities is to be undertaken. The design of the facility should address any impacts from these developments.

Figure 2.1



The design criteria for this project will be completed in accordance with the parameters set out by the *"Good Engineering Practices for Northern Water and Sewer Systems, 2004"* These are as follows:

Table 2.3 : Design Criteria

Facility	Design Horizon (Years)	Design Economic Life (Years)	Design Expected Life (Years)
Building	20	20	40
Pumps	10	20	20
Pipelines	20	20	30

Where the:

a) Design horizon is the period used to establish capacity requirements for a facility.
b) Design economic life is the period used in the economic analysis to establish the present value (or equivalent capital cost) of a facility.
c) Design expected life is the practical maximum expected life of a facility assuming no premature failure, destruction or obsolescence.

2.2 Design Standards

The following is a list of the design standards to be used in the development of the water supply system. These are derived from the *"Good Engineering Practices for Northern Water and Sewer Systems, 2004"*, and the "National Building Code" (NBC). Reference to the GNWT, MACA model for the development of water consumption projections is used because it is the only available model for small remote communities serviced by trucked delivery systems.

Table 2.4 : Water Consumption Rates

Water Consumption Rates		**Reference**
Domestic	90 litres per capita per day	MACA
Commercial	0.00023 x population	MACA
Total Consumption per Capita	90 x (1.0 + 0.00023 x pop.)	MACA
Fire Demand	2,000 litres per minute for 60 minute duration (1200,000 L) if storage is required. And Delivery rate of 1,000 L/min at fill point.	Office of the Fire Marshal, Nunavut
Discount Rates	4%	

Environmental Conditions	
Design Minimum Temp.	-45°C [1]
Degree-Days (below 18ºC)	12037 [2]
Snow Load S_S S_R	1.5 kPa [1] 0.1 kPa [1]
Wind Pressures (1/30 kPa)	0.34 kPa [1]
Seismic	Za & Zv > 2

Table 2.5 : Environmental Conditions

1. Supplement to the National Building Code of Canada 1990 Third Revisions and Errata. Values from Cambridge Bay were used because data for Taloyoak was unavailable.
2. Canadian Climate Normals (1961-1990). Yukon and Northwest Territories.
3. Nunavut Fire Marshal's Technical Bulletin FM-019: Seismic Requirements for Post-disaster Buildings

2.3 Design Parameters

The following are items that have been identified as design parameters for the facility:

- The facility must be simple to operate and maintain by local forces with limited equipment, and parts and materials which are available locally.
- Reliability of the facility is extremely important.
- The facility must be efficient and cost effective.
- The truck-fill supply shall have a minimum pumping capacity of 1000 L/min for truck fill.
- All equipment and pipes must be self draining after each use cycle, where practical. When self draining of any major component cannot practically be accommodated, some other means of frost protection should be incorporated.
- All major components must be capable of recovering from a frozen condition, in an operable state, if there is any possibility of freezing.
- Provisions of spares for all equipment is required, particularly components that have bulbs, fuses, relays, timers, etc.
- The first year supply of consumable, such as disinfectant, water testing packets, and cleaning supplies are to be a requirement of the construction contract.
- Provision for standby power generation at the truck-fill station is in accordance with the Office of the Fire Marshals requirement for uninterrupted firewater supply for fire suppression.
- Fuel storage at the truck-fill station must provide for spill containment (if applicable).
- Water supplied from the truck-fill station must be metered.

2.4 Cost Analysis

Throughout this document, there are cost analyses of various options. The analyses have been carried out using the terms described below.

Table 2.6 : Cost Elements

Cost Item	Description
Capital Cost	Cost of construction for the facility
Annual Operation and Maintenance Costs	The cost of operation, which may include manpower, energy requirements, fuel, general maintenance (light bulbs, paint), and equipment replacement
Life Cycle Costs	The calculation of the total facility cost over a 20-Year period. This includes the capital, operations and maintenance costs. The life cycle value is shown as a present value which is calculated at a discount rate of 4%, 8% and 12%.

3.0 FACILITY ASSESSMENT

3.1 Treatment Requirements

The water supplied by the proposed water supply system must meet the requirements of the Nunavut Health Act. This act essentially adopts the Guidelines for Canadian Drinking Water Quality (GCDWQ). There is limited available raw water sample data for the Water Lake source. **Appendix 8** contains the data available at this time. The following table shows a summary of the test data for Water Lake compared to the GCDWQ.

Table 3.1: Water Quality Sampling Results

Parameter	Units			Guideline
		14-Aug-2001	**28 Aug 1998**	
Colour	TCU	<5	10	≤15
pH	pH Units		7.89	6.5-8.5
Total Dissolved Solids	mg/L	98	6	≤500
Turbidity	NTU	**0.5**		See Section 3.1.1
Nitrate + Nitrite as N	mg/L	<0.008		10
Total Organic Carbon	mg/L			
Chloride	mg/L	15		≤250
Fluoride	mg/L			1.5
Potassium	mg/L			
Sodium	mg/L	8.31		≤200
Sulphate	mg/L	4		≤500
Fecal Coliforms	CFU/100mL	<1		0
Total Coliforms	CFU/100mL			Not present in 2 consecutive samples or more than 10% of samples
E. Coli	CFU/100mL			0
Total Cyanide	mg/L			0.2
Aluminum	μg/L			100
Arsenic	μg/L	<1.0		25
Barium	μg/L			1000
Cadmium	μg/L	<0.3	<0.1	5
Chromium	μg/L	<3	<2	50
Copper	μg/L	<2	1.4	≤1000
Iron	μg/L	<30	0.47	≤300
Lead	μg/L	<1	0.2	10
Manganese	μg/L	1		≤50
Selenium	μg/L			10
Uranium	μg/L			20
Zinc	μg/L	<10	<10	≤5000

The data collected to date indicates that the raw water source provides water meeting the GCDWQ for all tested parameters. There are pending changes to the GCDWQ related to turbidity (see the following section). The raw water source will require treatment for turbidity and will need to be disinfected.

It is recommended that a sampling program be initiated to establish the temporal raw water quality of the source lake body. This data is imperative to the future design of any treatment system. Monthly sampling should be completed for the next two years. The sampling frequency should be increased to weekly for the period of the spring melt to capture the worse case water quality conditions. Sampling and analytical parameters to be tested are;

Table 3.2 : Proposal Testing Program

Type	**Parameters**
Physical	Turbidity, Colour, Suspended Solids, Total Dissolved Solids, pH, Conductivity, Alkalinity, Particle Size
Major Ions	Calcium, Magnesium, Hardness, Sodium, Potassium, Fluoride, Chloride, Sulphate
Metals	Arsenic, Aluminium, Barium, Cadmium, Chromium, Copper, Iron, Mercury, Manganese, Lead, Selenium, Uranium, Zinc
Organics	THM potential
Microbiological	Total Coliforms, Fecal Coliforms, E coli, Standard Plate Count

The Department of Community and Government Service may work with the hamlet in the completion of the above program.

3.1.1 New Turbidity Guidelines

The GCDWQ are being revised to include new guidelines for turbidity. The new guidelines will be applicable to all surface water sources, and all ground water sources under the influence of surface water. The proposed guidelines will require that treated water will have turbidity less than 0.1 NTU. Where this is not possible the treated water from filtration will have;

1) For chemically assisted filtration, shall be less than or equal to 0.3 NTU in at least 95% of the measurements made, or at least 95% of the time each calendar month, and shall not exceed 1.0 NTU at any time.

2) For slow sand or diatomaceous earth filtration, shall be less than or equal to 1.0 NTU in at least 95% of the measurements made, or at least 95% of the time each calendar month, and shall not exceed 3.0 NTU at any time.
3) For Membrane filtration, shall be less than or equal to 0.1 NTU in at least 99% of the measurements made, or at least 99% of the time each calendar month, and shall not exceed 0.3 NTU at any time. If membrane filtration is the sole treatment technology employed, some form of virus inactivation should follow the filtration process.

3.1.2 Filtration

Based on the one sample result for turbidity, any treatment technology will likely be able to meet the new turbidity requirements. However, basing the technology section on one sample is not recommended. The design process must include an assessment of the turbidity treatment requirements on the results of the recommended sampling program.

Likely technology candidates for this community will include membrane filtration, cartridge filtration, and chemically assisted pressure sand filtration. The colour results suggest that treatment for colour will not be required; however the results of the proposed sampling program may change this assessment. Treatment for colour will complicate the process system, and would likely impact the recommendation for the technology recommendation for turbidity treatment.

3.1.3 Disinfection

3.1.3.1 Chlorination

The GCDWQ requires that the disinfection process for raw water also have a residual disinfection component. This is achieved through the use of chlorination. A typical residual chlorination level is 0.2 to 1.0 part per million (ppm). Many communities in the north find the taste of chlorine unpleasing, and residual levels are often set at 0.5 ppm. Several chemicals are available for disinfection of domestic water supplies. These include:

- Gaseous Chlorine
- Sodium hypochlorite (liquid)
- Calcium hypochlorite (solid)

Gaseous chlorine requires storage in a separate room that is monitored for chlorine gas emissions. Safety equipment and training is necessary to comply with the Occupational Health and Safety Regulations when chlorine gas is used. The transport of gaseous chlorine is regulated by the Transportation of Dangerous Goods (TDG) and it cannot be transported by passenger air plane. For these reasons, the use of gaseous chlorine is not recommended for small facilities such as the Taloyoak Truck-fill Station.

Sodium hypochlorite is shipped and stored as a liquid. The liquid is subject to freezing, and is to be stored in a heated room (above -10ºC). Sodium hypochlorite used in water treatment is similar to house hold bleach. It is available at 12% available chlorine, whereas bleach is 5% available chlorine. Sodium hypochlorite loses its concentration with time. After 90 days the level of available chlorine drops slowly and may reach a level similar to bleach after 6 months. If the 12% available sodium hypochlorite is diluted to 2% available, the shelf life is significantly extended. The operation of the disinfection system using sodium hypochlorite is relatively simple. The liquid is used directly without mixing. An injection pump is used to inject the liquid into the water as it flows through the truck-fill arm.

Calcium hypochlorite is shipped and stored as a powder, or as “pucks”. There is no concern with freeze protection, and heated storage is not required. Calcium hypochlorite has 65% available chlorine by weight. The powder/puck is mixed with water to make a solution that can be used in the disinfection process. Typically the solution is mixed at a concentration similar to that of sodium hypochlorite (12% available chlorine is typical). The disinfection system for calcium hypochlorite requires a mixing tank, a solution tank, an agitator, and an injection pump.

Both calcium and sodium hypochlorite are commonly used for disinfection in small facilities. The use of calcium hypochlorite is more common in Nunavut. Currently Taloyoak uses calcium hypochlorite. The issues to be addressed in the selection of a disinfectant are:

1. Cost of the optional system
2. Relative ease of use
3. The potential for failure.

3.1.3.2 Cost of System

Sodium hypochlorite, as a liquid, requires a greater volume of disinfectant to be shipped to site than calcium hypochlorite. Based on 12% available chlorine for sodium hypochlorite and 65% available for calcium hypochlorite the required shipping weight of disinfectant and volume to be shipped to site are as follows:

Table 3.3 : Disinfectant Quantity

Disinfectant	Year 0 (2005)	Year 20 (2025)
Calcium Hypochlorite	40 kg	72 kg
Sodium Hypochlorite	216 L (216 kg)	391 L (391 kg)

Sample Calculations are shown in **APPENDIX B.**

The supply and transportation costs associated with each chemical are as follow:

Table 3.4 : Disinfectant Supply Cost

Disinfectant	Supply (Year 0)	Transportation (Year 0)	Total (Year 0)
Calcium Hypochlorite	$229	$130	$359
Sodium Hypochlorite	$164	$704	$868

3.1.3.3 Operation

The mechanical and control systems for either disinfectant are similar. The difference is that calcium hypochlorite requires a mixing tank as well as a solution tank. Typically these are 50 to 100 litre tanks each. They require a floor or bench area of 1.5 m^2. The mixing tank is elevated to allow it to gravity feed into the solution tank. The sodium hypochlorite does not require any additional tanks as it is transported in its own 22 litre container. The mixing tank and agitator require additional space in the building which increases the capital cost of the facility.

The mixing process requires approximately 1 hour of operation time every 2 weeks for the calcium system. Less than 1 hour per month would be required for the sodium system.

3.1.3.4 Chlorine Storage and Safety Requirements

Storage and mixing of chlorine is government through the Nunavut Safety Act. The Electrical inspector of Nunavut has raised concerns with the historic corrosion of electrical equipment in corrosive atmospheres that are generated through improper ventilation of the chlorine mixing and storage areas. The design of the facility must meet all current legislation with respect to the transportation, storage, mixing and use of the selected disinfectant.

3.1.3.5 Risk of Failure

As the two systems are mechanically and electrically similar, the risk of failure for these systems are also similar. There is an additional risk associated with the sodium hypochlorite when there is a power failure. The liquid could freeze during an extended power loss. With the calcium system, the mixed disinfectant will also freeze, however, the remaining powdered calcium hypochlorite would not be damaged.

3.1.3.6 Summary

The use of sodium hypochlorite is operatively more simplistic and user friendly. The difference in supply and transportation costs for these chemicals is appreciable ($700/year more for sodium hypochlorite). The sodium hypochlorite has a risk of freezing in the event of a power outage. In this event, standard household bleach from a local store can be used as a substitute until additional sodium hypochlorite is transported to site. To assess the risk, it is assumed that each year 50% of the sodium hypochlorite is flown to site.

Table 3.5 : Life Cycle Cost of Disinfectant

Item	Sodium Hypochlorite	Calcium Hypochlorite
Supply Cost (Year 1)	$160	$230
Transportation Cost [1] (Year 1)	$700	$14
Operations and Maint. Cost (Year 1)	$290	$540
Total Annual Cost (Year 1)	$1,150	$784
Capital Cost	$800	$920
Life Cycle Cost	$15,800	$10,000

1. the transportation cost for sodium hypochlorite in this analysis is based on half the required volume being transported by air to address storage limits and concentration reduction.

The above analysis uses an 8% discount rate, and indicates that calcium hypochlorite is the more economical system for disinfection.

3.2 Building Location

The existing truckfill facility is located approximately 200 meters from the intake facility. Because of the issues related to the operation of the existing intake facility, a new intake facility is required. This will be built close to the existing intake facility. There is the opportunity to combine the intake facility with the Truckfill operation. An assessment of the following options is required;

Table 3.6 : Facility Options

Option	Description
A) One Intake and Treatment Facility	One facility that will house the intake, process treatment system, truckfill operation, and all ancillary components. Facility likely to be constructed on the shore of the water lake adjacent to the existing intake facility. Location to be confirmed with the community.
B) Separate Intake and Truckfill facility adjacent to the existing facilities.	Replacement of the intake facility with one similar to the existing intake facility with increased pumping capacity. The intake will be located on the shores of the water lake adjacent to the existing facility. Replacement of the Truckfill facility with a process treatment and truck fill facility. This will include all required ancillary equipment. Truckfill operation will be adjacent to the existing facility
B) Separate Intake and Truckfill facility at a new location.	Replacement of the intake facility with one similar to the existing intake facility with increased pumping capacity. The intake will be located on the shores of the water lake adjacent to the existing facility. Replacement of the Truckfill facility with a process treatment and truck fill facility. This will include all required ancillary equipment. Truckfill operation will be at a new location.

Prior to proceeding to the design phase of the facility, the GN should meet with the community to determine if there is a preference for one of the options. The most cost effective option will be option A. If there are no other decision drivers, then option A should be selected for implementation.

4.0 NEW FACILITY COMPONENTS

The description of the facility requirements are provided based on the overall program requirements and are not based on a specific treatment or location option. The intake and truck-fill station will have the following major components:

- Building(s) Foundation
- Building(s) System and Envelop (windows, insulation, sheathing, VDR, air barrier, siding, roofing)
- Building heating system
- Intake Pipes and Pumps (option of 1 intake or 2)
- Intake Pipe Freeze Protection
- Domestic Lighting
- Domestic water supply
- Fire water capacity
- Treatment System (filtration, chlorination, etc)
- Laboratory and testing equipment
- Truckfill controls and metering
- Conveyance Pipes
- Prime Power Supply
- Stand-by power supply
- Monitoring and Alarms
- Spares and Ancillary Components

The following sections will describe the requirements for each component.

4.1 Building Foundation

Typically the Truckfill and water treatment facilities in Nunavut and the NWT are skid mounted buildings founded on granular pads. However, most of the existing facilities have been relatively small buildings (3.0 by 5.0 meters) because there has been no requirement for treatment of the raw water other than the use of disinfection. With the requirement for treatment for turbidity, the building size will need to be increased. The use of a skid mounted building may not be possible, and other foundation types will need to be assessed. Foundation types to be considered are skid mounted foundation on a gravel pad and pile foundation. The use of slab on grade with thermo-siphons could be considered, however it is likely a more expensive option.

It is recommended that a geotechnical investigation be completed once the building size and gravity and seismic loads have been determined. The geotechnical investigation should assess;

- Building foundation type and design
- Intake protection requirements related to mechanical damage from ice scour
- Granular sources available (quality and quantity) for construction of foundation
- Locate or regional availability of equipment needed to construct the various foundation options (ie: pile driver, drilling rigs, concrete mixers, etc)
- Seasonal water table levels, if applicable
- Seasonal safe soil bearing capacity

4.2 Building System and Envelope

Two types of buildings are available for this facility, namely:

- Wood frame, on-site construction.
- Pre engineered, pre fabricated construction.

The wood frame building would be constructed to the standard for truck-fill stations used by the Government of the Nunavut, as follows:

- Wall construction consisting of 38 mm x 140 mm (nominal 2x6) with 150 mm (nominal R-20) of fibreglass batt insulation.
- Walls with torch on vapour barrier on the outside of the plywood sheathing.
- 50 to 100 mm (2" – 4") of extruded insulation on the outside of the torch on membrane (R-10 to R-20). The R value of R40 is considered a minimum for the wall envelope.
- The interior of the walls sheathed with ply wood, and clad with metal siding. (The interior plywood is for convenient equipment installation.)
- Provision of natural lighting using fixed quad-glazed argon (or krypton) filled windows (Southwall Technologies Heat Mirror 88 glazing), with fully-insulated poltruded fibreglass frames. A special provision will be made for a Lexan ™ cover to protect from thrown rocks.
- Roofing provided by a pre manufactured truss, or rafter system. With a torch on membrane covered with extruded insulation and metal roofing system. The R value of the roof to be a minimum of R 40.
- Foundation, and requirements for protection of the permafrost.

In addition, performance criteria, preferred materials or method and logistical considerations for the design and construction of the new facilities are to be in accordance with the GN's Good Building Practices Guidelines, Design Review Stages, and Document Submissions (6/05/03), the GNWT's Public Works and Services Design Standards and Guidelines (October 1996), and Community Government and Transportation Capital Standards and Criteria, (GNWT), July 1993 issue.

The pre manufactured building would be constructed to provide the equivalent insulation value as the wood frame building. Several companies produce these structures (Bally, Cold Stream, Brytex, Butler), and each have a slightly different building design. Typically these buildings have an insulation value of RSI 5.6. (R-32)

The use of on-site construction will typically add $40,000 to $50,000 to the total facility cost. The increase in cost is a result of the required accommodations, flights and additional man hours on-site for down time. Local involvement created by on-site construction will be approximately 120 man days. (30 days of construction for 4 workers).

4.3 Intake Pipe and Pumps

The process piping is required to deliver 1000 L/min of treated water to the truck-fill discharge point for truck delivery for fire fighting purposes. The GN has used both single intake and dual intakes in previous projects. The estimated cost for intake construction is $2,500 per linear meter. The additional cost for the second intake will be dependant of the location of the intake facility, and the bathymetry[1] of the lake. A site survey of the proposed location is required to determine the intake profile and required length. If possible the bathymetry should be completed off the ice to provide accurate survey results.

The standard detail for these intakes and intake casing is as follows:

- The intake pump is housed within a stainless steel skid that allows for pump extraction.
- The skid has a stainless steel aircraft cable attached. The cable leads the length of the raw water pump pipe. The cable is used to extract the pump for maintenance and repairs.
- The raw water pump pipe from the pump will be 100 mm HDPE DR 17 pipe. The pipe is sized to handle the proposed flow of 1,000 L/min.
- The casing pipe will be HDPE DR32 300 mm diameter. The pipe size needs to be confirmed that it will meet the needs of the 1,000 L/min pump.

[1] The measurement of the depth of bodies of water

- The casing pipe will have 50 mm of ridge foam insulation. The outer jacket will be 2- counter wound layers of heat tape.
- Drain-back strategies when pump is not running
- Concrete weights will be used to counter the buoyancy of the intake casing. Reinforcing bar loops will be embedded in the concrete, and the exact positions of these weights will be located by GPS data, and recorded.
- The casing will be buried in the near shore section, and covered by a minimum of 1.0 meters of clean backfill.
- Two heat trace will be installed on the raw water pump pipe. The heat trace cables will be installed in a 19 mm copper tube and attached to the raw water pump piping with packing tape or Tyvek Tuck tape.
- All heat trace will be installed with controllers, monitors and alarms.
- Stainless steel intake screen
- The exact position of the pump will be located via GPS data and recorded

4.4 Domestic Electrical and Water Requirements

All electrical distribution and panels are to be water tight installations. There have been problems in water supply building with corrosive atmospheres because of the presence of the chlorine injection systems. The water supply facilities also have high humidity and water condensation collection that is created by the presence of pipes and vessels carrying cold water. Condensation is often present on process piping.

There is a need for a domestic water supply system to provide the facility operator with water for mixing chorine, cleaning the facility, and completing water testing and plant optimization work. A small amount of water storage is required. One hundred litres of water storage is required for domestic purposes. Hot water is not essential, however the provision of hot water aids in the operator’s activities related to cleaning the facility and maintaining the water testing equipment in clean order.

4.5 Treatment System

As outlined in section 3.1 there is a requirement for treatment of the turbidity and for disinfection. Disinfection is to be by sodium hypochlorite. Turbidity treatment technology needs to be selected after additional sampling of the raw water source has been completed. The selection of the treatment technology will also affect the requirements for water storage in the facility. Three operating philosophies are possible.

- Minimize the treatment unit size. This will result in a lower capital costs associated with the treatment unit, but increase the capital costs of the storage requirement. This case uses a treatment time of 20 hours per day, based on a 20 year design horizon, and a 5 day per week delivery system.
- Operate the treatment unit for 8 hours per day based on a 20 year design horizon, and a 5 day per week delivery system. Using an 8 hour treatment cycle allows the plant to operate only during normal working hours of the water treatment plant operator.
- Minimize the storage requirements. In some cases this makes the overall system less complex.

The storage requirement for balancing storage is based on delivery of water to the community on a 5 day per week cycle, based on a 10 hour delivery day. Daily water supply is calculated as follows;

20 year design population = 1457people
Per Capita consumption = 120 Lcd
Daily Consumption = 174,840 L
Weekly demand = 174,840 L x 7 days = 1,223,880L
Daily delivery (based on 5 day delivery) = 1,223,880 L/ 5 days = 244,776 L (round to 245,000L)

The following table outlines the required treatment rate and balancing storage for each scenario

Scenario	Treatment Flow Rate	Balancing Storage Requirement	Commentary
Treatment time of 20 hours per day	245,000/20 hrs/60 min. = 203 L/min	245,000 – 203*10* 60 = 123,000 L	Typically this provides for the most flexibility in treatment technologies, and the lowest capital cost scenario. Has storage buffer if treatment process is being maintained and is offline.
Treatment time of 8 hours per day	245,000/8 hrs/60 min. = 510 L/min	Assume 3 – 9,000 L trucks = 13,800 L**	Process units can become large and costly.

			Limited buffer in storage to allow for down time on the process units.
Treatment rate set to Truckfill rate	1000 L/min	Nil	For conventional treatment this option results in high capital costs, and large process units.

** With the process rate on an 8 hour day, there are times (immediately after lunch, first thing in the am, and during back wash) where several trucks can re-fill in a short period of time, and the process is not running. Sufficient water storage to re-fill the Hamlets trucks, with the process "off" is required.

Fire Storage

The Nunavut Fire Marshal requires that 120,000 litres of fire fighting water be stored in addition to any domestic requirements. However, with the intake and Truckfill system located on the shores of the water supply the need for fire fighting storage does not exist, provided;

- There is stand-by power to allow for the fire flow to occur in a power outage,
- There is redundancy in the intake system. (two intakes)

During the pre-design phase this needs to be confirmed with the Office of the Fire Marshal. A review of the cost of fire storage versus the cost of then provision of a second intake to address the fire supply requirements needs to be assessed during the preliminary design phase.

Process Water

This is water required for back washing the process units. This is a requirement for most conventional treatment systems, namely; direct filtration, slow sand filtration and coagulation and mixed media filtration systems. Membrane filtration units also require back wash water. Cartridge filters require water for washing the filters, usually this is completed manually.

Dead Storage

In any tankage system, there is a portion of the tank that is not available for use. This is normally the bottom of the tank, located below the obvert of the tank outlet pipe. A value of 10% is used for this storage volume.

Storage Tanks

The tanks will have the following components:

- An inlet for incoming water and an equalization pipe and valve between the tanks.
- An outlet for truck fill with a pump and controls.
- An overflow that will spill overflow water to the exterior of the building. In the case of the above ground tank this will be an overflow pipe and down spout within the building connected to a pipe that penetrates the building envelop. The pipe will have a bird screen to protect the inlet from debris and animals. The outlet will be directed into an erosion protected drainage channel that leads to the local ditch. The over flow pipe on the underground reservoir will penetrate the concrete wall and lead underground to the local ditch. A bird screen will protect the outlet of the pipe.

Laboratory Testing Equipment

The laboratory equipment as listed in the following table will be provided for the operator's use.

Table 4.1 Laboratory Equipment

Item	Quantity	Description	Hach Catalog No.
1	1	Hach DR890 portable colorimeter complete with Procedures Manual	48470-00
2	1	Hach DR890 hard-sided case	49425-00
3	1	Hach 2100P portable turbidimeter complete with Instrument and Procedure Manual	46500-00
4	1	2100P Battery Eliminator 120 V North American plug	46079-00
5	6	Silicon Oil, 15 ml SCDB	1269-36
6	6	Sample cell oiling cloth	47076-00
7	2	Sample cells (6 pack) (1 in. round glass, 10 ml, w. cap)	24347-06
8	2	Sample cell (6 pack) (1 in. round glass, 10 ml, w. cap)	24276-06
9	2	Sample cells (6-pack) (1 in. round glass, 10 ml, 20 ml w. cap)	24019-06
10	2	Holder / rack to hold sample cells. 6	
11	1	Beakers, polypropylene, 100 ml (12-pack)	1080-72
12	1	Beakers, polypropylene, 250 ml (6-pack)	1080-76
13	1	Beakers, polypropylene, 1000 ml (3-pack)	1080-83
14	2	Graduated cylinder, 100 ml, polypropylene	1081-42
15	2	Graduated cylinder, 500 ml, polypropylene	1081-49
16	2	Graduated cylinder, 1000 Ml, polypropylene	1081-53
17	2	Wash bottle, polypropylene, 500 ml	620-11
18	2	Thermometer with nylon case, -5 to 45ºC	26763-00
19	20	Dynalon HDPE sample bottles	D00022
20	1	Hach FerroVer iron reagents (100)	21057-69
21	1	Hach LR manganese reagents (100)	22433-00
22	5	Hach Total chlorine reagents (100)	21055-69
23	15	Hach Free chlorine reagents (100)	21056-69
24	1	Hach color standard kit	26353-00
25	20	Brush, test tube	6900
26	10	Syringe, Luer – Lock Tip, plastic, disposable, 1 ml with 0.1ml divisions)	12263-00
27	1	bottle (4 L) of general laboratory cleaner (phosphate free)	

4.6 Truck-fill Controls and Metering

The truck-fill control has been established according to the Government of Nunavut for similar facilities in other small communities. The truck-fill control system will have the following components:

- Truck-fill control with one customer key lock. This will have a flow accumulator to record cumulative flows. The control will be on the truck-fill arm, with a start and stop switch, and a timer.
- Flow rate indicator.
- Flow sensor installed in the truck-fill pipe to control the flow accumulator.
- Flow switch to interlock with the pump and chlorine pump to avoid damage to the equipment or excessive chlorine injection into an empty line.
- All measurements for the metering are to be in SI units (litres).
- The accumulators, flow indicator, and miscellaneous control devices will be located in a main control panel inside the pumphouse.

4.7 Conveyance Piping

The process piping will consist of the following:

- An intake screen, submersible pump on 100 mm HDPE DR17 piping, contained within a 300 mm HDPE DR17 casing. The casing will be insulated with 50 mm of polyurethane foam and will be heat traced. The intake piping will enter the truck-fill station and terminate with a flange connection just inside the truck-fill station wall.
- PVC Schedule 40 piping with Victaulic system connections from the intake to the truck-fill discharge point.
- 19 mm copper piping for the domestic water supply
- Nylon tubing for the chlorine injection system.

4.8 Prime Power

Prime power can be obtained from either Nunavut Power Corporation's power plant, or an on-site diesel electric generator. Typically, the use of grid power generated by the Power Corporation is the source of prime power.

The estimated steady-state power requirements of the truck-fill station are:

Power (kW)

Truck-fill Pump	6.0
Intake Pump	6.0
Building Heat	0.5
Heat Trace	1.0
Lighting	1.0
Treatment train	2.0
Backwash pumps	8.0
Chemical Feed Pumps	0.1
TOTAL	24.6 kW

4.8 Standby Power

Standby power is required for several reasons;

- Provision of un-interrupted water for fire fighting
- Provision of back up power to provide freeze protection to the facility during power outages
- Provide continual power to the control system to prevent program loss.

The first two requirements can be met by a stand by power generation unit. The last item requires a local UPS for the control panels.

4.9 Freeze Protection

4.9.1 Building Heat

To review the various heating systems for the water treatment plant, three separate systems were evaluated: a) a boiler system, b) a furnace system, and c) a combination of overhead unit heaters. The building assumed consisted of one large room and a smaller one for stand-by power (i.e., generator). No allowance has been made for the impact of the water storage impact on the building heating. An assessment of the heat sink created by the water storage system is required as part of the final design.

a) Boiler System

This system is comprised of a hot water boiler, which feeds the overhead unit heaters. A Heat Recovery Ventilator (HRV) exhausts stale air from the building and brings fresh air into the building. As it does this, the heat from the stale air is transferred to the cold air brought into the building.

b) Furnace System

This system uses a furnace combined with an HRV to supply both warmed and fresh air to all rooms in the building.

c) Unit Heaters

This system is comprised of a ceiling or wall-mounted unit heater which supply the rooms with warm air. A HRV will supply fresh air to the building. For the oil fired system, as the smallest oil unit heater is the size of the one used to heat the entire building, a separate electric unit heater is necessary to keep the generator room just above freezing (5ºC).

Table 4.2: System Comparison

System	Supply & Installation Costs	Annual Operating Costs	Annual Maintenance Costs	Total Annual Costs	Life Cycle Costs 4%	6%	8%
Boiler – oil fired	$22,500	$10,300	$2,500	$12,800	$197,000	$157,000	$128,000
Boiler – electric	$12,500	$50,800	$1,500	$52,300	$724,000	$651,000	$515,000
Furnace – oil fired	$17,000	$8,900	$2,500	$11,400	$172,000	$140,000	$114,000
Furnace – electric	$4,500	$50,000	$750	$50,750	$693,000	$632,000	$500,000
Unit Heaters – oil fired	$14,500	$12,500	$1,500	$14,000	$205,000	$173,000	$139,000
Unit Heaters – electric	$7,500	$52,200	$750	$52,950	$728,000	$660,000	$521,000

Power and fuel rates used in the above assessment are $2.50/kWhr and $1.00/L fuel.

In general, the supply and installation costs for the electricity powered systems are all lower than the oil fired systems. However, due to the high cost of electricity, the operating costs for the electricity-based systems are all approximately three to four times that of the oil systems. This makes the electricity-based systems unfeasible for this type of application.

In comparing the oil systems to one another, taking into account the entire supply and installation, operating, and maintenance costs, the furnace system appears to be the least costly system. This is mainly due to its low electricity requirement. The furnace has a low horsepower fan which saves on the annual electrical requirements. In addition, the fan in the furnace allows the HRV fan to stop when the furnace is running, thereby resulting in some electrical savings.

Electricity requirements for the boiler system include the circulating pumps, the HRV fan, and the fans in each of the overhead unit heaters.

The unit heater system also requires electricity to power the fans on each of the overhead unit heaters and HRV. However, it is the electric unit heater in the stand-by power room that requires additional power to maintain the room's temperature above freezing.

As such, the oil-fired furnace system is the most feasible option for this building.

Fuel storage for the furnace and the stand-by power generation unit will be stored in one 5,000 L double walled tank. The furnace will require approximately 2,500 L of fuel per year. The remaining fuel would be available for the operation of the generator.

4.9.2 Intake Casing and Intake Pipe

The intake casing and intake pipe must be protected from freezing. This will be accomplished by electric heat trace cable installed adjacent to the outside of the intake pipe. The cable will be 15 W/m constant wattage with temperature setting so it will not damage the HDPE pipe. Two lengths of cable will be installed on the raw water pipeline. Under normal operation, only one of the raw water pipeline heat trace cables will operate. The second raw water pipeline cable is a back-up in case of failure of the first cable. Automatic controls will be used. The cable will be removable.

4.9.3 Truck fill Arm

A method must be used to protect the truck fill arm from freezing and to recover the pipe if it freezes. Various methods have been used in past designs, including insulation and heat trace cable. A key to successfully avoiding freezing of the treatment facility pipe is to ensure that it drains quickly and completely after use. The truck fill pipe will be installed with a 4% or greater slope back into the building. The pipe will be stainless steel and insulated with the provision for heat trace cable conduit. Freezing of the pipe is unlikely, due to the draining system, however, the provision to allow for easy installation of a heat trace and switch is recommended. A switch will be located near the wall penetration of the building at the Truckfill arm.

4.10 Monitoring and Alarms

The truck-fill building will have the following monitoring and control system. The system will have two (2) levels of alarms: major and minor. Minor alarms will cause a green alarm light to activate, and a horn to sound at the pumphouse. Major alarms will activate a red alarm light and sound a horn and will dial out to the Facility Operator and Hamlet emergency numbers through an auto-dialer system. The alarms for this system are set as follows:

Major
Intake pump failure
Low building temperature
Power off – stand-by generator failure
Very low fuel level

Minor
High building temperature
Treatment facility pump failure
Power off – stand-by power on
Process plant failure
Low fuel level

4.11 System Spares

The following is a list of spares, replacement parts, and ancillary components that will be included.

Table 4.3 Spare Parts

Spare Components	Parts
Pumps (intake and process pumps)	1 Pump complete with power cable. 1 spare of each type
Sodium Hypochlorite (liquid made from solid pucks) Feed System, and Chemical Pumps	Rebuild kits for chemical pump. 2 chlorine flow switches. 2 chemical feed pumps. 2 chlorine mixing pumps and 1 spare Nylon tubing.
Eyewash	1 spare container of solution.
Lighting – exterior and interior	6 spare lamps each type. 1 case of all fluorescent lamps of each type and size

Spare Components	Parts
Distribution Panel	2 breakers of each size and type.
Terminal Blocks	1 set of blocks for each size and type installed including end caps, end plates, cross connectors and tear-off markers.
Fuses	Unless noted elsewhere, 12 spares for each type required in facility.
Valves	Rebuild kits (2 each) for each type and size. To include all gaskets. 1 spare of each type of valve.
Motor Starters	2 of each type of pilot light and over load heaters. 1 of each type of coil and contact.
Control Devices	2 push button, 6 pilot light and 2 lens type. 1 spare flow display/totalizer. 1 spare flow sensor.
Alarm Panel	1 alarm annunciator.
6 of each Fuses or Mini-breaker	2 of each relay and timer. 1 of each relay and timer base.
Fan Belts	1 for each type
Fuel Filters	12 month supply
Oil Filters	12 month supply
Thermostats	1 spare of each type of thermostat.
Heat Trace	Spare controller Spare thermostat
Fire Extinguisher	per room.
Miscellaneous	sodium hypochlorite, and testing chemicals. Timers

Miscellaneous Equipment

1. Fire Extinguisher: Ansul A20E, Class ABC, UL listed, 9 kg capacity, external nitrogen cartridge Foray powder with wall mounting brackets. Mount on wall near exterior door.
2. Goggles & Respirator
3. Gloves: Twelve (12) Fisher 11-394-30, large, extra long, heavyweight rubber gloves, 19 mm by 380 mm length.
4. Apron: One (1) Fisher 01-357 double coated abrasion resistant, rubberized cloth apron.
5. Push Broom.
6. Mop.

7. Mop Bucket and Wringer.
8. Dust Pan.
9. Garbage Can: One (1) 100 L, galvanized, with cover.
10. Floor Cleaner.
11. Lighting: Two (2) fluorescent tubes and One (1) low temperature ballasts.
12. Storage Cabinet:
    Combination shelving/wardrobe unit.
    Two (2) doors.
    Four (4) half shelves.
    Pre-finished in grey.
13. Laboratory equipment for completing bench tests. To include 1 years supply of reagents.
14. Eye wash station and first aid kit.
15. 1.2 m (4 ft.) long, by 0.9 m (36 in.) high bench
16. Stool
17. Laundry-type tub near bench
18. Instant hot water heater.

4.11 Miscellaneous Issues

Successful proponent will be working closing with the regional engineer in the implementation of the project.

Other aspects of the facility replacement include that need to be addressed include;

- Decommissioning of the existing Plant, this would include the;
    - Intake pump house;
    - Utilidor
    - Truck-fill plant
    - Boothnia Inn connection and pipes
- Developing a construction schedule and strategy to ensure the existing facility can remain inplace until the new system is commissioned
- Over wintering plan for the existing facility after the new facility is commissioned. The owner would like the existing facility to be operational for the first year/first 6 months of the new plants life.
- Reusing existing equipment in the new plant;
    - Water Tanks
    - Boilers and hydronic heating units
    - Buildings – use by Hamlet or power corporate

- Review of pumps fans and motors for re-use as spares
- Lights bulbs, balances etc if common to be spares.

5.0 SUMMARY AND IMPLEMENTATION

The community of Taloyoak is supplied with water from a truck fill station that draws its water from a lake adjacent to the community, namely Water Lake, via a single pump and small pump house. There is a short transmission main between the intake pump house and the Truck fill facility. A portion of the Truckfill system is also located in a privately owned building, the Boothnia Inn. In 2004, the Government of Nunavut, the Department Of Community and Government Services recognized that the Water Supply Facility in Taloyoak would require an upgrade to meet the needs of a growing population.

Taloyoak - Community Population Projections

Year	2000	2005	2010	2015	2020
Total Population	804	904	1,016	1,147	1,294

The water supplied by the proposed water supply system must meet the requirements of the Nunavut Health Act. This act essentially adopts the Guidelines for Canadian Drinking Water Quality (GCDWQ). There is limited available raw water sample data for the Water Lake source. The data collected to date indicates that the raw water source provides water meeting the GCDWQ for all tested parameters. There are pending changes to the GCDWQ related to turbidity. The raw water source will require treatment for turbidity and will need to be disinfected in order to meet the pending guidelines.

It is recommended that a sampling program be initiated to establish the temporal raw water quality of the source lake body. This data is imperative to the future design of any treatment system. Monthly sampling should be completed for the next two years. The sampling frequency should be increased to weekly for the period of the spring melt to capture the worse case water quality conditions. Sampling and analytical parameters to be tested are;

Proposal Testing Program

Type	Parameters
Physical	Turbidity, Colour, Suspended Solids, Total Dissolved Solids, pH, Conductivity, Alkalinity, Particle Size
Major Ions	Calcium, Magnesium, Hardness, Sodium, Potassium, Fluoride, Chloride, Sulphate
Metals	Arsenic, Aluminium, Barium, Cadmium,

Type	**Parameters**
	Chromium, Copper, Iron, Mercury, Manganese, Lead, Selenium, Uranium, Zinc
Organics	THM potential
Microbiological	Total Coliforms, Fecal Coliforms, E coli, Standard Plate Count

The community, in conjunction with C&GS can complete this program.

The existing truckfill facility is located approximately 200 meters from the intake facility. There is the opportunity to combine the intake facility with the Truckfill operation. There needs to be a location study completed as part of the planning and design process.

The intake and truck-fill station will have the following major components:

- Building(s) Foundation
- Building(s) System and Envelop (windows, insulation, sheathing, VDR, air barrier, siding, roofing)
- Building heating system
- Intake Pipes and Pumps (option of 1 intake or 2)
- Intake Pipe Freeze Protection
- Domestic Lighting
- Domestic water supply
- Fire water capacity
- Treatment System (filtration, chlorination, etc)
- Laboratory and testing equipment
- Truckfill controls and metering
- Conveyance Pipes
- Prime Power Supply
- Stand-by power supply
- Monitoring and Alarms
- Spares and Ancillary Components

A preliminary design and detailed design program needs to be completed to fully describe these components. Other aspects of the facility replacement include that need to be addressed include;

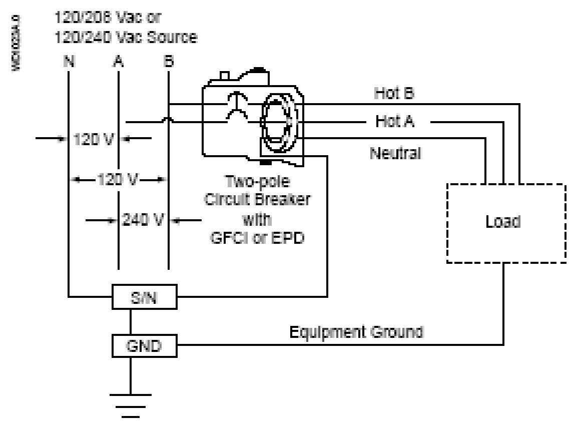
- Decommissioning of the existing Plant, this would include the;
    - Intake pump house;
    - Utilidor
    - Truck-fill plant

    - Boothnia Inn connection and pipes
- Developing a construction schedule and strategy to ensure the existing facility can remain inplace until the new system is commissioned
- Over wintering plan for the existing facility after the new facility is commissioned. The owner would like the existing facility to be operational for the first year/first 6 months of the new plants life.
- Reusing existing equipment in the new plant;
    - Water Tanks
    - Boilers and hydronic heating units
    - Buildings – use by Hamlet or power corporate
    - Review of pumps fans and motors for re-use as spares
    - Lights bulbs, balances etc if common to be spares.

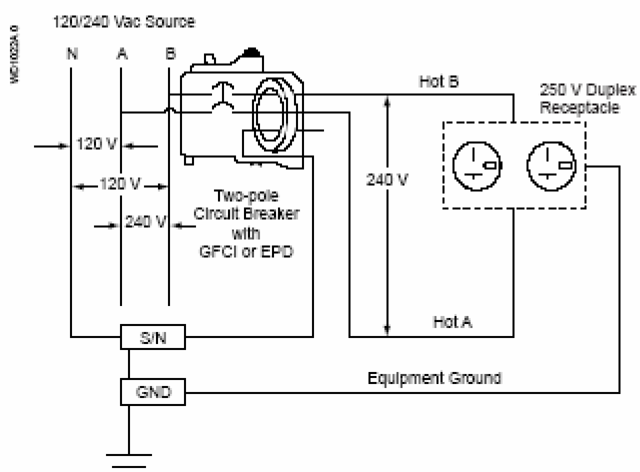
APPENDIX #1
GFI Breaker Drawings

GFI Breaker Drawings

The following diagrams illustrate a Two Wire Connection and a Three Wire Connection, for GFI Breakers. It may be the case, and further investigation is required, that the GFI has been connected in the two wire mode, when, for this application it should be a three wire connection.



Three-wire 120/240 Vac or 208Y/120 Vac Circuits



Two-wire 240 Vac or 208 Vac

APPENDIX #2
Taloyoak Pump Model
Existing Plant

Taloyoak Pump Model

The following tables and chart, models the Taloyoak water system using the Hazen-Williams method based on data obtained from the current system. Absolute accuracy can not be guaranteed, but the there is reasonable agreement between the predicted behaviour and observed data.

The model was created to aid in new pump selection. It predicts the pressure at the Intake Pump House on the supply line, and the flow rates. Two operating modes were modeled, pumping to the tank, and pumping in recirculation mode (tank valve closed). Three new pumps have been compared against the existing pump. The following Myers Ranger series (Pentair Pump Group) Pump data was used:

1. SS30-50: 3.0hp – 30gpm
2. SS50-50: 5.0hp – 50gpm
3. SS50-80: 5.0hp – 80gpm

The results of the model indicate the correct pump is the SS30-50; however the Hamlet has already purchased a **SS50-50. There is considerable reason to believe that this pump will over-pressurize the line. During the recirculation mode the model predicts pressures of 180psi at the intake pump house.** This may or may not cause an immediate line rupture, but does increase the risk of a rupture at some point. In all possibility it will cause a hose to blow off at a joint where hose clamps are used.

(It now looks as thought the Hamlet intends to not to use their 5 Hp pump, but purchase a 3 Hp instead).

The other concern with the 5.0hp pump is the pump starter (not controller) is rated at 3.0hp. There is, however, a 30 amp breaker and no thermal overloads, so the present system may handle the bigger load, but in the long term the starter (including the timer) would have to be up-rated.

If the pump does deliver excessive pressure, the Supplier is relatively certain that the 5.0hp motor can be swapped for a 3.0hp unit. This would be preferable to a pressure regulating valve as, in general, the energy costs of using an inefficient pump outweigh, by a considerable margin, the cost of purchasing the correct pump. There is the possibility of mounting a pressure relief valve that allows water to circulate back down the intake casing. If tank fill rate exceeds cost considerations, this latter option may be the way to go. (Since the initial release of this appendix, the advantages of using a presser relief valve with the 5.0 Hp pump (and also the 3.0 Hp pump), have become more apparent. We now recommend that a pressure relief valve should be installed).

In the short term we would suggest the following:

1. Since the pump is on site it may as well be given a trial: the model prediction may be incorrect, **but only after installing the pressure relief valve.** This valve should be set to relive the pressure at 5 to 10 PSI above the operating pressure when the tank is filling, but not above 150 PSI.

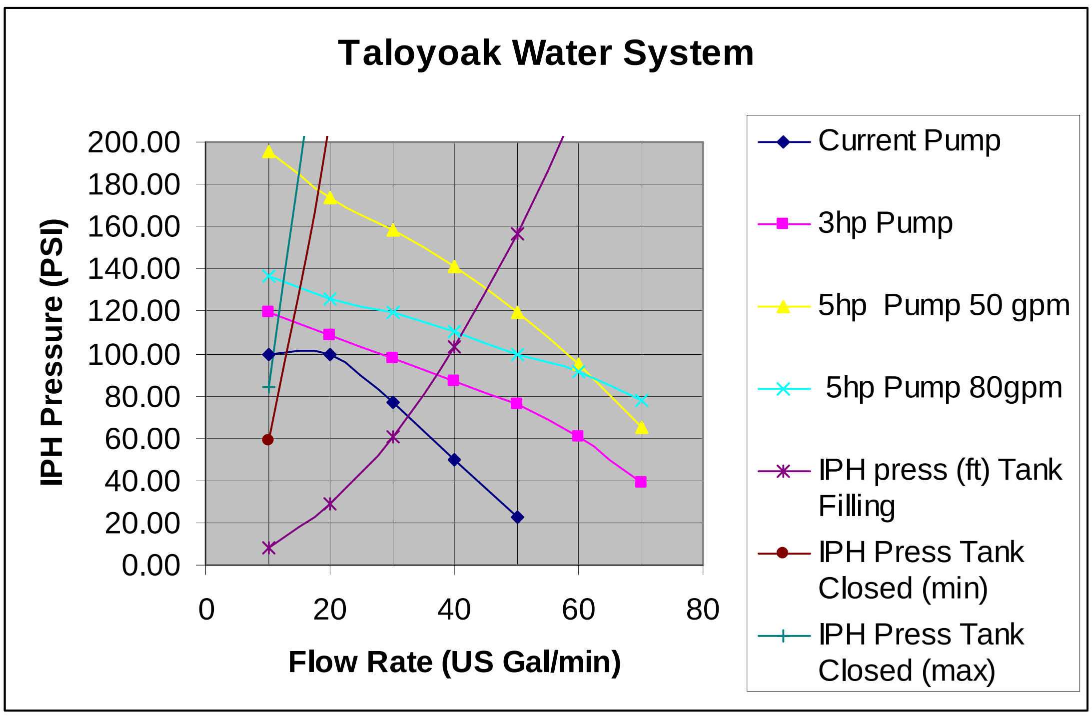
2. The following data should be monitored during the pump trial, and recorded for each mode of operation
    a. IPH Supply Pressure
    b. WTP Supply Pressure
    c. WTP Return Pressure
    d. Flow rate into the tank
    e. Pump Amperage (and temperature of the contactor)

   We would suggest that the trial be stopped if the IPH Supply pressure exceeds 150 psi. We have no knowledge of the system's maximum operating pressure. It may give this data in the O&M manual. Originally we assumed that the max. pressure was 100 psi, but after examining the system, we believe 150 psi is not an unreasonable guess. What is certain, is the system has not run in excess of 100 psi, at least in the recent past, because that is all the current pump will deliver. The system may hold together at higher pressures but it really becomes a lottery. If failure occurs at a joint with a hose clamp, little is lost; however, rupturing some other part of the line could take a while to repair. It should also be noted that the IPH pressure gauge is rated at 0 to 150 psi. Over pressurizing it will cause non-reversible damage. It can be isolated, but then the pressure will not be known. A higher rated gauge could be fitted prior to the test. Similarly, care should be taken not to over pressurize the gauges in the WTP.

3. The high pressure problem will occur when the system is in recirculation mode, so when the pump is started, both the ¾" and 1¼" feeds to the tank should be open.
4. Slowly, and while in radio contact with the IPH, these valves can be closed to simulate the tank valve closing.
5. Even if the system will run with the tank valves closed, it is still highly likely a problem will occur when the tank solenoid valve closes, because this is not a gradual operation. As we recommended verbally while in Taloyoak, it would be better if the tank valve were a motor operated ball valve, rather than a solenoid valve, so the closing action was gradual. The response of the system to the operation of the tank solenoid valve must be tested. This can be accomplished by manually manipulating the level switch.
6. If the system passes the above listed tests the water system's operation should be carefully monitored for several days, because all the piping will be under greater pressure.

	Taloyoak Water System Predicted Operating Points							
	Tank Filling				Recirculation Mode - Tank Open			
	Existing Pump	3 hp Pump	5hp - 80	5hp - 50	Existing Pump	3 hp Pump	5hp - 80	5hp - 50
IPH psi	70	88	108	130	98	115	133	180
Total Flow Rate (gpm)	32	37	41	45	13	14	16	18
Tank only Flow Rate (gpm)	21	31	35	39				
% Increase	0%	43%	63%	84%				

Pump & System Curves - Taloyoak IPH (psi)							
Gal per Min	Current Pump	3hp Pump	5hp Pump 50 gpm	5hp Pump 80gpm	IPH press (ft) Tank Filling	IPH Press Tank Closed (min)	IPH Press Tank Closed (max)
10	100.00	119.22	195.09	136.56	7.93	58.52	84.36
20	100.00	108.38	173.41	125.72	28.63	211.24	304.50
30	76.56	97.54	158.24	119.22	60.66	447.57	645.18
40	49.37	86.71	140.90	110.55	103.33	762.48	1099.13
50	22.18	75.87	119.22	99.71	156.21	1152.64	1661.55
60		60.69	95.38	91.04	218.95	1615.57	2328.87
70		39.02	65.03	78.03	291.28	2149.32	3098.28



APPENDIX #3
Taloyoak Water System Fill Rates
Existing Plant

Taloyoak Water System Fill Rates

Storage Capacity	Size (Imp. Gal)	Size (Litres)	
Tank #1	4500	20457	
Tank #2	4500	20457	
Tank #3	5000	22730	
Total	14000	63645	
Tanker Capacity (litres)	9000		
Daily Usage (litres)	102000		
Number of Tanker Loads per Day	11.3		
Water required in excess of storage per day (litres)	38355		
	Existing Pump	3.0 Hp Pump	5.0 Hp Pump
Flow rate estimates (l/min)	81	116	149
Time required to deliver excess water (Hrs)	7.9	5.5	4.3
Note 1: Existing flow rate has decreased since Summer visit because of change to return configuration			

APPENDIX #4

Taloyoak Intake Pump Starter Panel

Existing Plant

Taloyoak Intake Pump Starter Panel

At the time of writing this, there are two intake pumps under consideration for Taloyoak: a 5.0Hp and a 3.0Hp. The situation is not clear cut. At present, we have agreed with Bob Hoddinott, that he will install a pressure relief valve and test the 5.0Hp pump.

The existing motor starter (not to be confused with the pump controller), is rated for 3.0Hp. For testing purposes, the existing switch gear should suffice. Once the pump size is confirmed, replacement gear can be specified.

The existing panel is quite dated and is due for replacement. Any replacement is complicated by the timer for the flow and pressure switch.

There is, in the IPH, two new starter panels rated at 3.0 HP. They do contain timers and we believe that they were designed as a straight swap for the existing starter panel. The components in these new starters are as follows:

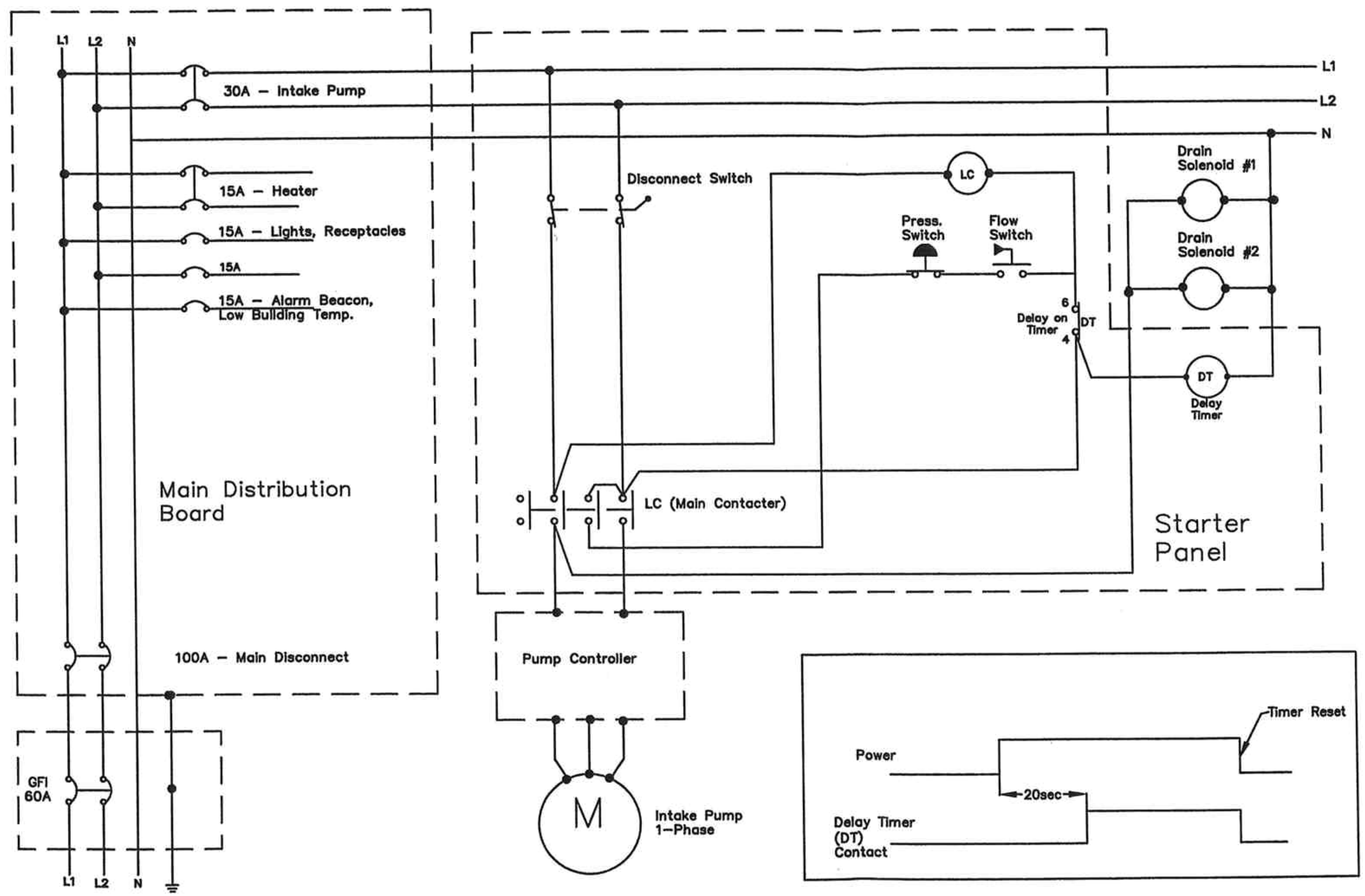
1. Existing Contactor: Telemecanique LC1 D25.
2. Required up-rated Contactor for 5.0Hp motor: Telemecanique LC1 D32.
3. The Intake pump is not fitted with overload protection. For that reason, the following overload relays should be ordered and fitted:
    a. 5.0 Hp – LRD1532 (3)
    b. 3.0 Hp – LRD 1522 (3)
    c. Direct Connection Kit - LAD7C2

Confirm these numbers with supplier prior to ordering.

4. Omron Timer: H3G – 8C: this is a DPDT Delay On Timer, which is functionally the same as the existing timer.
5. The Square D 30A Breaker in the Distribution Board should be up-rated to 35 or 40 amps.

Provided these new starter panels are upgraded as recommended, they should work as intended. An electrician will be required to do the installation.

APPENDIX #5
Taloyoak IPH Electrical Drawing
Existing Plant



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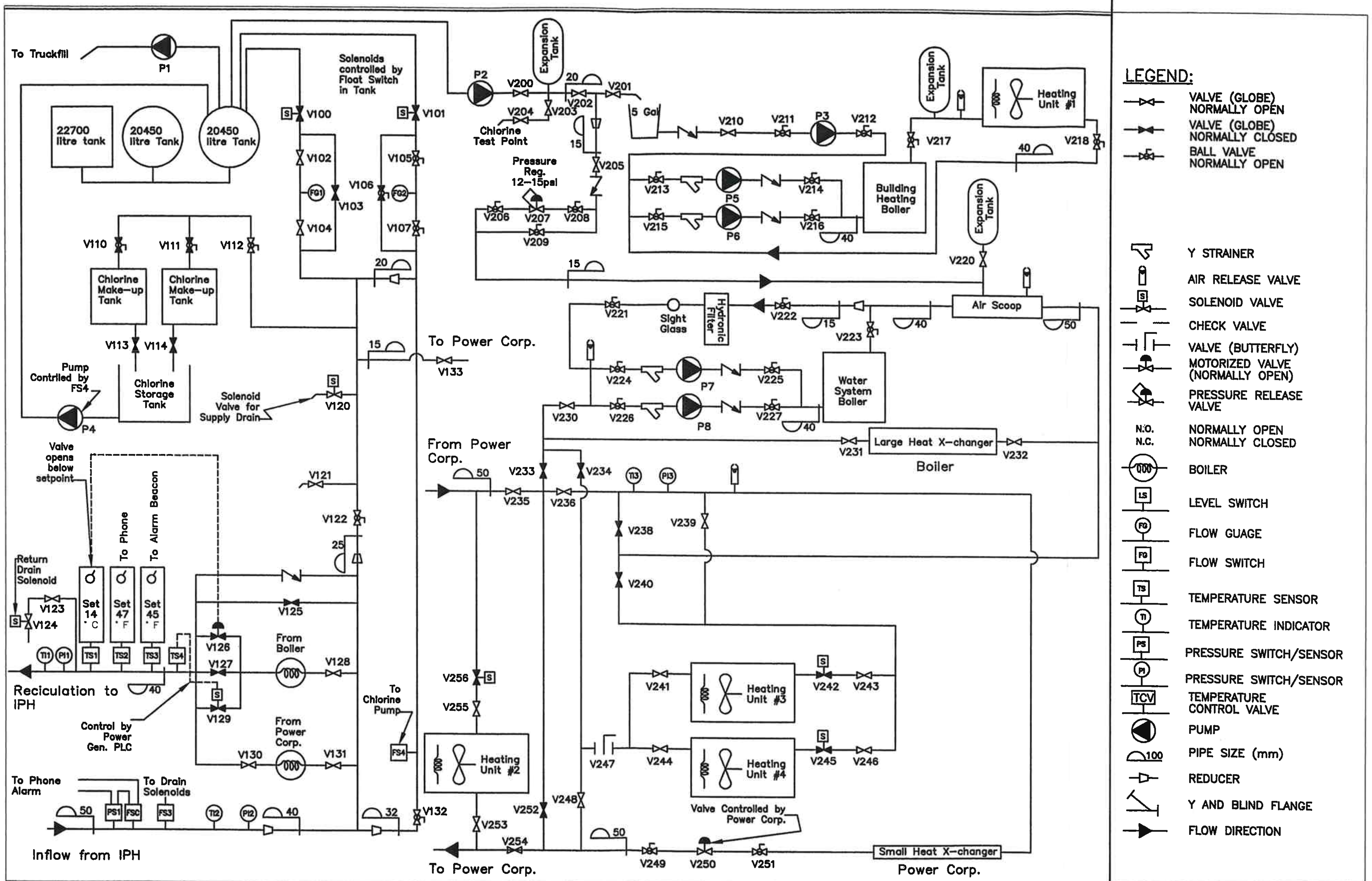
DILLON CONSULTING

PROJECT	WATER WORKS AND WATER SUPPLY TALOYOAK, NUNAVUT	PROJECT NUMBER	04–3653
		DATE	December 2004
TITLE	INTAKE PUMP HOUSE (IPH) Electrical Schematic	FIGURE NUMBER	201

APPENDIX #6

Taloyoak Water System Schematics

Existing Plant



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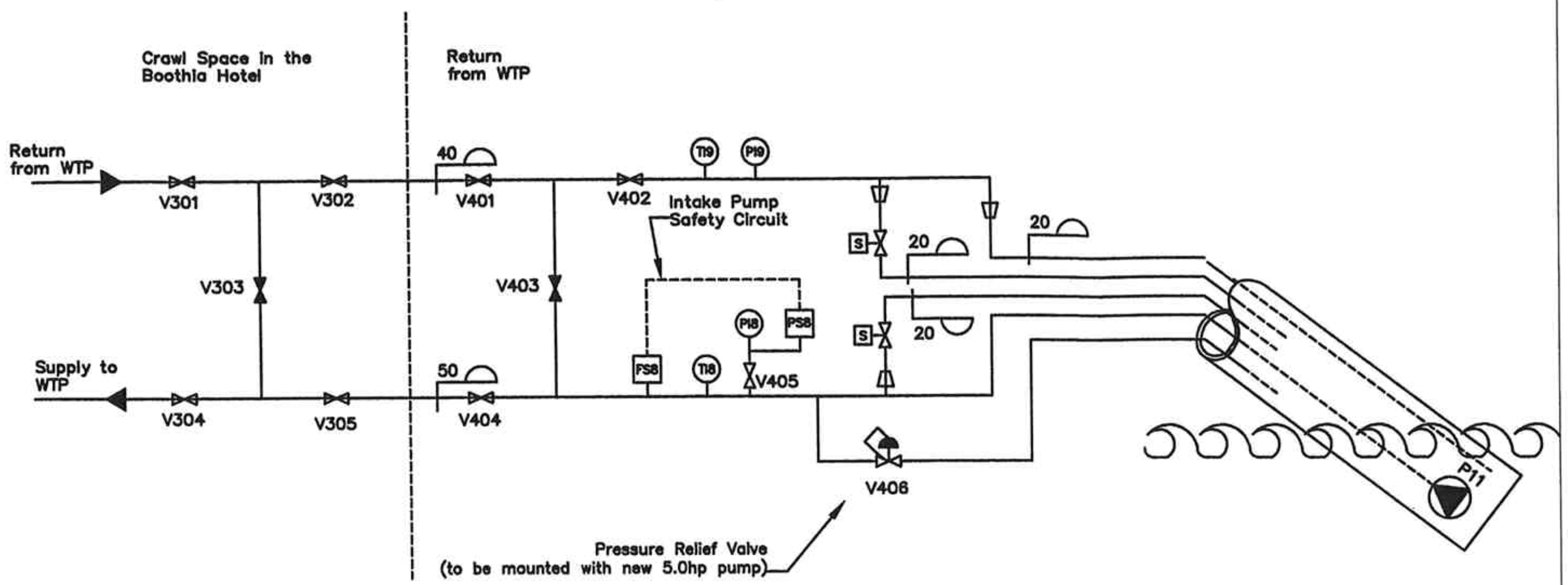
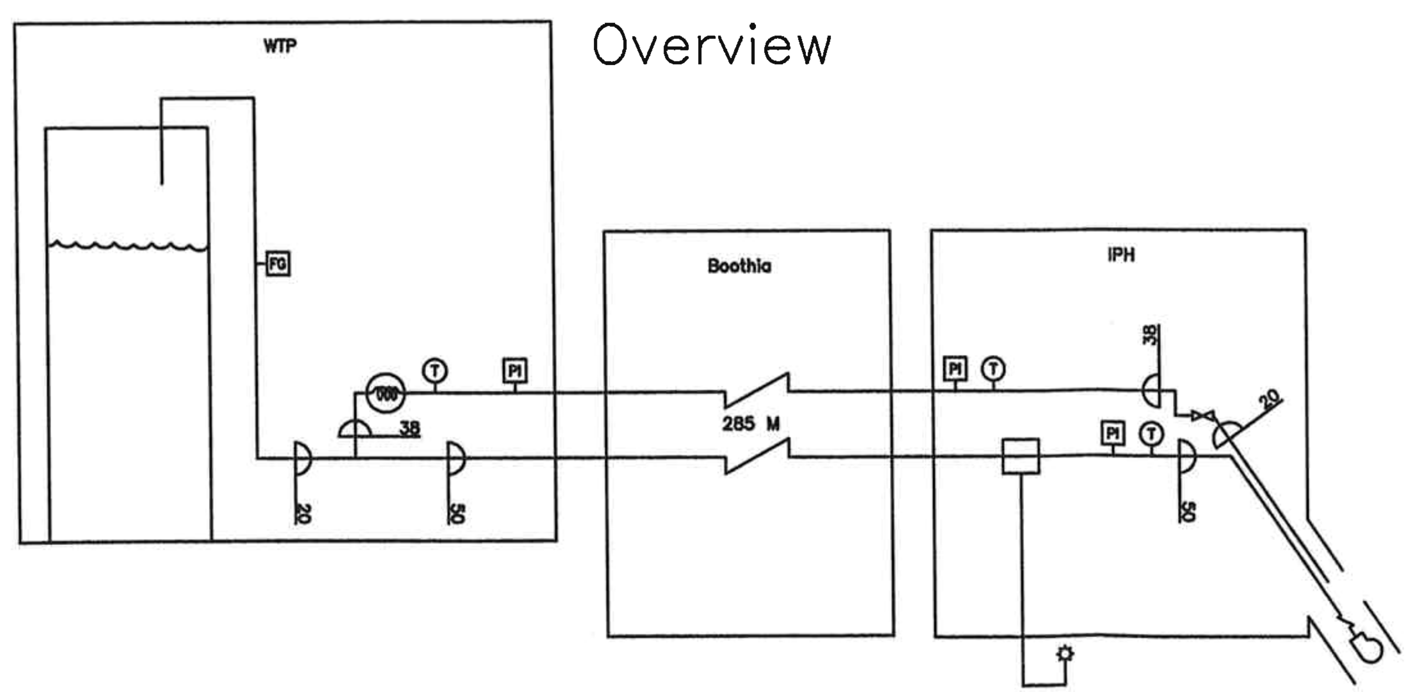
DILLON CONSULTING

PROJECT	WATER WORKS AND WATER SUPPLY TALOYOAK, NUNAVUT
TITLE	PROCESS WATER FLOW SCHEMATIC Water Treatment Plant (WTP)
PROJECT NUMBER	04–3653
DATE	Jan 2005
FIGURE NUMBER	102

Intake Pump House



Overview



LEGEND:

- VALVE (GLOBE) NORMALLY OPEN
- VALVE (GLOBE) NORMALLY CLOSED
- BALL VALVE NORMALLY OPEN
- Y STRAINER
- AIR RELEASE VALVE
- SOLENOID VALVE
- CHECK VALVE
- VALVE (BUTTERFLY)
- MOTORIZED VALVE (NORMALLY OPEN)
- PRESSURE RELEASE VALVE
- N.O. NORMALLY OPEN
- N.C. NORMALLY CLOSED
- BOILER
- LS LEVEL SWITCH
- FG FLOW GUAGE
- FG FLOW SWITCH
- TS TEMPERATURE SENSOR
- TI TEMPERATURE INDICATOR
- PS PRESSURE SWITCH/SENSOR
- PI PRESSURE SWITCH/SENSOR
- TCV TEMPERATURE CONTROL VALVE
- PUMP
- 100 PIPE SIZE (mm)
- REDUCER
- Y AND BLIND FLANGE
- FLOW DIRECTION

EDIT DATE: 03 Jan 2005 ACAD FILE: 41tmh g:\cad\043653\taloyoak_schem.dwg

DILLON CONSULTING

PROJECT	WATER WORKS AND WATER SUPPLY TALOYOAK, NUNAVUT
TITLE	PROCESS WATER FLOW SCHEMATIC Intake Pump House & Overview
PROJECT NUMBER	04–3653
DATE	Jan 2005
FIGURE NUMBER	101

APPENDIX #7
Guidelines for Canadian Drinking Water Quality

APPENDIX 'I'

-

**GUIDELINES FOR CANADIAN DRINKING WATER QUALITY (GCDWQ)
NEW TURBIDITY GUIDELINE**

Turbidity

Table of Contents

Turbidity

1.0 Guideline

Waterworks systems that use a surface water source or a groundwater source under the direct influence of surface water should filter the source water to meet the following health-based turbidity limits, as defined for specific treatment technologies. Where possible, filtration systems should be designed and operated to reduce turbidity levels as low as possible, with a treated water turbidity target of less than 0.1 NTU at all times. Where this is not achievable, the treated water turbidity levels from individual filters:

*1.01 For **chemically-assisted filtration**, shall be less than or equal to **0.3 NTU** in at least 95% of the measurements made, or at least 95% of the time each calendar month, and shall not exceed 1.0 NTU at any time.*

*2. For **slow sand or diatomaceous earth filtration**, shall be less than or equal to **1.0 NTU** in at least 95% of the measurements made, or at least 95% of the time each calendar month, and shall not exceed 3.0 NTU at any time.*

*3. For **membrane filtration**, shall be less than or equal to **0.1 NTU** in at least 99% of the measurements made, or at least 99% of the time each calendar month, and shall not exceed 0.3 NTU at any time. If membrane filtration is the sole treatment technology employed, some form of virus inactivation* should follow the filtration process.*

It is not expected that all water supplies will be able to meet this revised turbidity guideline immediately. Therefore, supplementary treatment should be considered in the interim to ensure delivery of safe drinking water.

2.0 Executive Summary

Particles of matter are naturally suspended in water. These particles can be clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms. Turbidity is a measurement of how light scatters when it is aimed at water and bounces off the suspended particles. It is not a measurement of the particles themselves. In general terms, the cloudier the water, the more the light scatters and the higher the turbidity.

The best means of reducing turbidity and safeguarding a drinking water supply is to apply a multiple-barrier approach (i.e., source to tap) to protect drinking water. The focus of this approach is to look at the entire drinking water supply, identify potential and existing hazards and then develop strategies to deal with each of the hazards.

Treatment plants can reduce turbidity by filtering particles out of the water. All filtration systems should be designed and operated to reduce turbidity levels as low as possible. The treated water turbidity target is 0.1 NTU at all times. However, even though effective filtration can be accomplished using any one of a number of technologies, the actual levels of turbidity

* Some form of virus inactivation is required for all technologies. The difference is that chemically assisted, slow sand and diatomaceous earth filters are credited with log virus reductions and membrane filters receive no credit.

achieved will vary from technology to technology. For this reason, the turbidity guideline is broken down by type of technology.

The most important consideration when dealing with turbidity is to make sure the levels remain low and fairly constant over time. Concerns are most likely to result from a spike in the level of turbidity, due either to an increase in the amount of particulate matter in the source water (e.g., from heavy rains) or to a breakdown in the treatment process (e.g., inadequate coagulation, a ruptured filter). Because it might otherwise be difficult to notice a spike in turbidity when only one filter in a plant is not working properly, the guideline applies to each individual filter within a filtration system.

2.1 Health Considerations

It is important to control turbidity in public water supplies for both health and aesthetic reasons. Suspended matter can contain toxins such as heavy metals and biocides and can also harbour microorganisms, protecting them from disinfection. Recent research has correlated turbidity levels with treated water supplies being contaminated with *Giardia* and *Cryptosporidium*. These microorganisms can cause outbreaks of illness. As such, turbidity may be used as a health parameter to indicate the safety of water leaving a filtration system. Because turbidity can affect the microbiological quality of drinking water, this guideline should be read in conjunction with the bacteriological guidelines. Excessive turbidity may also be associated with unpleasant tastes and odours.

In addition, high turbidity can lead to an increase in the amount of disinfection by-products that form in treated water. Trihalomethanes (THMs), for instance, are a group of chemical compounds that form when chlorine reacts with organic material in water. By filtering out the organic matter to reduce turbidity, treatment plants also reduce the amount of THMs that may form in the water. For more information on these disinfection by-products, see the THMs guideline and supporting document.

The nature of turbidity and its health implications vary with the type of source water. Turbidity in surface water and groundwater that comes into contact with surface water (referred to as groundwater under the direct influence of surface water), however, is generally organic in nature and may contain toxins, harbour pathogens or lead to the formation of THMs. Turbidity in secure groundwater supplies (i.e., not under the influence of surface water) is generally non-organic and should pose no health threat. The health-based guideline and target for turbidity therefore apply only to surface water sources and groundwater under its influence.

2.2 Analytical and Treatment Considerations

Turbidity is easy and inexpensive to measure. In addition to being an indicator for determining the relative safety of drinking water, it is a useful tool for assessing the performance of water treatment processes.

Turbidity is measured in nephelometric turbidity units, or NTU, using a device called a turbidimeter. Modern turbidimeters can make measurements of 0.1 NTU or lower. Levels of turbidity in raw waters can range from 1.0 NTU to more than 1000.0 NTU. Levels vary at individual locations over time.

A number of studies indicate that properly designed and well-operated conventional, chemically assisted and direct filtration water treatment plants can readily achieve a safe finished water with turbidity levels lower than 0.2 NTU. Meeting the guideline level of 0.3 NTU for these systems should be straightforward. Slow sand and diatomaceous earth filtration plants can consistently achieve a safe finished water with turbidity levels of less than 1.0 NTU. Membrane filtration plants can consistently achieve finished water turbidity of less than 0.1 NTU. For all filtration technologies, these limits are achievable and expected in 95–99% of measurements, but a target of 0.1 NTU should be sought at all times.

3.0 Application of the Guideline

The health-based turbidity guideline applies to drinking water produced by systems that use either a surface water source or a groundwater source under the direct influence of surface water. The guideline is applied to individual filter turbidity. However, good operating practices suggest that both the individual filter turbidity and the combined filter turbidity should be continuously monitored. Drinking water taken from pristine sources may be exempt from the filtration requirements if it meets all of the criteria outlined below (see "Criteria for Exclusion of Filtration in Waterworks Systems").

Surface water is defined as all waters open to the atmosphere and subject to surface runoff. Groundwater under the direct influence of surface water is defined as "any water beneath the surface of the ground with (i) significant occurrence of insects or other macro-organisms, algae, organic debris, or large-diameter pathogens such as *Giardia lamblia*, *Cryptosporidium*, or (ii) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions."[1] Key issues that should be considered when determining whether groundwater is under the influence of surface water are given in Appendix A.

The health-based turbidity guideline does not apply to secure groundwater sources, i.e., those not under the direct influence of surface water. Turbidity in these cases is non-organic, should pose no health threat and should not hinder disinfection. However, for effective operation of the distribution system , it is good practice to ensure that water entering the distribution system has low turbidity levels of around 1.0 NTU.

3.1 Monitoring Turbidity Levels

For *chemically assisted filtration* (i.e., continuous feed of a coagulant with mixing ahead of filtration), source water turbidity levels should be measured at least once per calendar day directly in front of where the first treatment chemical is applied. Treated water turbidity levels from individual filters should be continuously measured (with an on-line turbidimeter) at intervals no longer than 5 minutes apart at a point upstream of the combined filter effluent line or the clear water tank.

For *slow sand or diatomaceous earth filtration*, water turbidity levels from individual filters should be continuously measured (with an on-line turbidimeter) at intervals no longer than 5 minutes apart at a point upstream of the combined filter effluent line or the clear water tank. However, the frequency of monitoring may be reduced to one grab sample per day if it can be demonstrated that this frequency gives a reliable measure of filter performance.

For *membrane filtration*, treated water turbidity levels from individual filters should be continuously measured (with an on-line turbidimeter) at intervals no longer than 5 minutes apart at a point upstream of the combined filter effluent line or the clear water tank. An individual membrane filter may be defined as a unit or group of membrane stacks or cartridges within a train that may be valved and isolated from the rest of the system for testing and maintenance. Process designs should include a minimum of two parallel trains, if practical. Consideration should be given to installing on-line turbidity meters to analyse the water unique to each "individual" filter.

3.2 Use of Alternative Filtration Technology by Waterworks Systems

A waterworks system can use a filtration technology other than the technologies stipulated if, in combination with disinfection, it reliably achieves at least a 3-log reduction of *Giardia lamblia* cysts and *Cryptosporidium* oocysts and a 4-log reduction of viruses. Pilot studies or equivalencies from other jurisdictions should demonstrate that the technology meets these criteria.

3.3 Criteria for Exclusion of Filtration in Waterworks Systems

Filtration of a surface water source or a groundwater source under the direct influence of surface water may not be necessary if *all* of the following conditions are met:

1. Overall inactivation is met using a minimum of two disinfectants:
   - ultraviolet irradiation or ozone to inactivate cysts/oocysts;
   - chlorine (free chlorine) to inactivate viruses; and
   - chlorine or chloramines to maintain a residual in the distribution system.

   Disinfection should reliably achieve at least a 99% (2-log) reduction of *Cryptosporidium* oocysts,* a 99.9% (3-log) reduction of *Giardia lamblia* cysts and a 99.99% (4-log) reduction of viruses. If mean source water cyst/oocyst levels are greater than 10/1000 L, more than 99% (2-log) reduction of *Cryptosporidium* oocysts and 99.9% (3-log) reduction of *Giardia lamblia* cysts should be achieved. Background levels for *Giardia lamblia* cysts and *Cryptosporidium* oocysts in the source water should be established by monitoring as described in the most recent "Protozoa" guideline document, or more frequently during periods of expected highest levels (e.g., during spring runoff or after heavy rainfall).
2. Prior to the point where the disinfectant is applied, the number of *Escherichia coli* bacteria in the source water does not exceed 20/100 mL (or, if *E. coli* data are not available, the number of total coliform bacteria does not exceed 100/100 mL) in at least 90% of the weekly samples from the previous 6 months.
3. Average daily source water turbidity levels measured at equal intervals (at least every 4 hours), immediately prior to where the disinfectant is applied, are around 1.0 NTU but do not exceed 5.0 NTU for more than 2 days in a 12-month period.

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* Studies on human volunteers have demonstrated that *Cryptosporidium* oocysts are less infectious than *Giardia* cysts by about one order of magnitude.

Source water turbidity also does not show evidence of protecting microbiological contaminants.

4. A watershed control program (e.g., protected watershed, controlled discharges, etc.) is maintained that minimizes the potential for faecal contamination in the source water.

3.4 Considerations for Groundwater Systems

In keeping with the multi-barrier approach to drinking water quality management, systems using secure groundwater sources should:

1. Ensure that groundwater wells are properly constructed, are located in areas where there is minimum potential for contamination and have appropriate wellhead protection measures in place. These source protection measures protect public health by reducing the risk of the drinking water source becoming contaminated.
2. Ensure that treatment is sufficient to achieve 4-log reduction of viruses by disinfection. It is important to confirm that elevated turbidity levels will not compromise the disinfection process.
3. Maintain a chlorine residual throughout the distribution system and ensure that water quality is monitored and maintained. Well-designed and well-operated distribution systems are key to providing safe, clean drinking water to consumers.

4.0 Identity and Sources in the Environment

The sources and nature of turbidity are varied and complex and are influenced by the physical, microbiological and chemical characteristics of water. In surface waters and groundwater under the direct influence of surface water, turbidity can vary significantly over time, which has important implications for drinking water treatment processes and the microbiological safety of the drinking water. Particulate matter is frequently a source of nutrients for microorganisms and can protect microorganisms from both chemical and ultraviolet light disinfection. Particles contributing to turbidity may also carry undesirable chemical contaminants such as heavy metals. Turbidity can seriously affect the safety and acceptability of drinking water to consumers.

4.1 Description of Turbidity

Turbidity is a "measure of the relative clarity of water."[2] Turbidity in water is caused by suspended and colloidal matter, such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. However, turbidity is not a direct measure of suspended particles suspended in the water. It is, rather, a measure of the scattering effect that such particles have on light. A directed beam of light remains relatively undisturbed when transmitted through absolutely pure water, but even the molecules in a pure fluid will scatter light to a certain degree. *Standard Methods for the Examination of Water and Wastewater* defines turbidity as an "expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the sample."[3]

In samples containing suspended solids, the manner in which water interferes with light transmittance is related to the size, shape and composition of the particles in the water and to the wavelength (colour) of the light that falls on the particles (incident light).[4] A minute particle absorbs the incident light falling on it and then re-radiates the light in all directions.

The detection, measurement and visual perception of turbidity are influenced by a number of factors. Particle size has an impact on the direction in which light is scattered and on the intensity of scattered light of differing wavelengths (colours). The shape of the particle also influences light scattering, as does the refractive index of the water and the colour of the particles.

Light scattering intensifies as particle concentration increases. However, as scattered light strikes more and more particles, multiple scattering occurs, and absorption of light increases. When particulate concentration exceeds a certain point, detectable levels of both scattered and transmitted light drop rapidly, marking the upper limit of measurable turbidity. By decreasing the path length of light through the sample, the number of particles between the light source and light detector is reduced, extending the upper limit of turbidity measurement.

Because several factors affect the intensity of light scattering, it is not possible to relate scattered light measurements directly to the number or weight of suspended solids in a given volume of water with any accuracy. Direct correlations can be made only if such factors as the size, distribution, shape, refractive index and adsorptive capacity of the suspended solids causing the turbidity remain constant; this can be achieved only in a laboratory and is therefore impractical and unnecessary in most cases.[4]

4.2 Sources

Levels of turbidity in raw water can range from less than 1.0 NTU to more than 1000.0 NTU. The particles that cause turbidity in water range in size from colloidal dimensions (approximately 10 nm) to diameters of the order of 0.1 mm and can be divided into three general classes: clays, organic particles resulting from decomposition of plant and animal debris, and fibrous particles from asbestos minerals.[5] Clay particles generally have an upper diameter limit of about 0.002 mm, but can be as large as 0.02 mm. Biological organisms may also cause turbidity.

Particulate material in natural waters is mostly made up of eroded soil particles from the surrounding area. Coarser sand and silt fragments are at least partially coated with organic material. Clay particles are composed of clay minerals, usually phyllosilicates, as well as non-clay material, such as iron and aluminum oxides and hydroxides, quartz, amorphous silica, carbonates and feldspar.[5] Clays and organic particles are often found together as a "clay organic complex."[5] To a certain extent, it is artificial to treat the organic (humic) component in isolation from the inorganic component when considering the behaviour of suspended matter. However, humic substances have a much higher adsorptive capacity than clays (870 meq/100 g and 80 100 meq/100 g, respectively[6]); the effect of humic components likely predominates in many instances.

Other particles in raw water and drinking water supplies include the group of naturally occurring hydrated silicate minerals with fibrous structures known as asbestos; inorganic precipitates, such as metal (iron or manganese) oxides and hydroxides; and biological organisms, such as algae, cyanobacteria, zooplankton, and filamentous or macrobacterial growths.[7,8] Due to the numerous types of source particles and their implications in the treatment process, raw water quality monitoring for turbidity should be done at least daily, and preferably more often.

5.0 Relationship between Turbidity and Other Water Quality Parameters

Table 1 summarizes some of the relationships between the source of turbidity and water quality/treatment implications.

Table 1: Turbidity and implications for water quality and water treatment

Source of turbidity	Possible water quality/chemistry implications	Treatment implications
Inorganic particles (silt, clay, natural precipitants, e.g., $CaCO_3$, MnO_2, Fe_2O_3, etc.)	- raise/lower pH and alkalinity - source of micronutrients - affect zeta potential - source of metals and metal oxides - cloudy/turbid appearance - affect taste	- major influence on coagulation, flocculation and sedimentation design - harbour/protect microorganisms
Organic particles (decomposed plant and animal debris, humic substances)	- source of energy and nutrients for microorganisms - cause colour - impart taste and odour - serve as precursors for the formation of chlorinated or ozonated compounds - possess ion exchange and complexing properties that include association with toxic elements and micropollutants - affect pH - affect zeta potential	- high disinfectant demand - potential to form chlorinated organics - potential to form ozonation by-products - high coagulant dose - reduce clarifier overflow rates - increase flocculation/sedimentation times - harbour/protect microorganisms - reduce filter runs - can compete with pollutant compounds for adsorption sites in activated carbon adsorption - can precipitate in the distribution systems
Biological organisms (algae, cyanobacteria, zooplankton, filamentous or macrobacterial growth)	- impart taste and odour - potential source of toxin (microcystin-LR) - disease transmission - corrode tanks, pipes, etc. - stain fixtures - cause aesthetic problems due to sloughing of growths from tanks, filters, reservoirs and distribution system	- plug filters - high disinfectant demand - need multiple barriers to ensure effective microbial inactivation - flotation may be more effective than sedimentation - microbial inactivation required

5.1 Microbiological Characteristics

5.1.1 Relationship between Turbidity and the Presence of Pathogenic/Non-pathogenic Organisms

The microbiological quality of drinking water can be significantly affected by turbidity. Microbial growth in water is most extensive on the surfaces of particles and inside loose flocs, both naturally occurring and those formed during treatment(see section "Treatment Technology"). This growth occurs because nutrients adsorb to surfaces, allowing bacteria to grow more efficiently than when in free suspension.[9,10] Similarly, river silt has been shown to readily adsorb viruses.[11]

Studies of distribution systems have shown conflicting findings with respect to turbidity and microorganisms. Haas *et al.*[12] noted that increased values of pH, temperature and turbidity were associated with increased concentrations of microorganisms. Heterotrophic plate count (HPC, formerly known as standard plate count) increases that parallel increases in turbidity have been found at turbidity levels lower than 2.0 NTU.[13] Similarly, work by Goshko *et al.*[14] found positive correlations between HPCs and turbidities in the 0.83–8.89 NTU range. On the other hand, a study reported by Reilly and Kippin[15] suggested that turbidity around 1.0 NTU does not affect the frequency with which either coliforms or HPC organisms occur in the analysis.

In water with turbidities ranging from 3.8 to 84.0 NTU, Sanderson and Kelly[16] found coliform organisms even after the water was treated with chlorine (free chlorine residuals between 0.1 and 0.5 mg/L after a minimum contact time of 30 minutes).

Huck *et al.*,[17] in their investigation of *Cryptosporidium* removal by granular media filtration, noted that an increase in turbidity associated with suboptimal coagulation and breakthrough at the end of filtration runs resulted in deterioration in oocyst reduction, even at turbidity levels less than 0.3 NTU. Utilities should therefore carefully consider the effects of reducing coagulant dosage. To avoid breakthrough, plants should specify a maximum head loss and filter run times and should consider using particle counters to monitor for early breakthrough.

5.1.2 Effect of Turbidity on Disinfection

Particulate matter (e.g., organic, inorganic, higher microorganisms) can protect bacteria and viruses from the effects of disinfection. LeChevallier *et al.*,[18] studying the efficiency of chlorination in killing coliforms in unfiltered surface water supplies, found a negative correlation with turbidity. A derived model predicted that an increase in turbidity from 1.0 to 10.0 NTU would result in an eight-fold decrease in the disinfection efficiency at a fixed chlorine dose. A study by Hoff,[19] which examined the efficiency of disinfection at turbidities of 1.0 and 5.0 NTU on poliovirus and sewage effluent coliforms, found that viruses and coliforms that adsorbed to organic matter were more resistant to disinfection than those that adsorbed to inorganic material such as clay and aluminum phosphate. For organic particulates, a reduction of turbidity from 5.0 to 1.0 NTU reduced the concentrations of disinfectant-resistant organisms approximately five-fold.

Hoff and Geldreich[20] reiterated that particulate characteristics have a significant impact on protection effects. Studies with ozone by Sproul *et al.*[21] confirmed that alum and bentonite afforded little protection to a variety of test organisms at 1.0 and 5.0 NTU, whereas faecal material and, in particular, human epithelial carcinoma cells did provide protection. Chlorine dioxide studies by Scarpino *et al.*[22] suggested that temperature and turbidity affected the rate of inactivation of bentonite-adsorbed poliovirus. At 25°C, turbidities in excess of 2.29 NTU reduced inactivation rates.

Free-living nematodes are relatively common in North American municipal water supplies. Nematodes of the Rhabditae family are known to ingest pathogenic bacteria and viruses and hence are able to protect these pathogens from chlorine disinfection.[23] Studies indicate that more nematodes are found in higher-turbidity raw and treated waters.[24,25] In a study of the San Francisco water supply, coliform organisms were detected at chlorine levels of 0.35 mg/L or greater. Crustaceans apparently harboured the coliforms; on passing through a spigot, the crustaceans ruptured, and viable coliforms were released.[26] In laboratory tests, various clays and humic acid were shown to protect *Klebsiella aerogenes* from ultraviolet light disinfection.[27]

Chlorine (as hypochlorous acid) reacts readily with organic matter containing unsaturated bonds, phenolic groups and nitrogen groups, giving rise to taste- and odour-producing compounds[28] and trihalomethanes (THMs).[29] Hence, waters with high turbidity from organic sources may give rise to a substantial chlorine demand. This could result in reductions in the free chlorine residual in distribution systems as protection against possible recontamination. For Ottawa River plants, Otson *et al.*[30] noted that increased pre-chlorination dosage requirements were strongly correlated with increases in turbidity. In Oregon surface waters, chlorine demand had a positive correlation with both turbidity and total organic carbon levels.[18] The resultant model suggested a 180% increase in chlorine demand for a turbidity increase from 1.0 to 5.0 NTU.

In the United States, well-operated slow sand filtration plants may be allowed to have higher turbidity in filter effluents if there is no interference with disinfection and the turbidity level never exceeds 5.0 NTU.[31] Non-interference with disinfection may be assumed if the finished water meets the coliform maximum contaminant level and if there are fewer than 10 HPC bacteria per millilitre during times of highest turbidity.[31]

5.1.3 *Effect of Turbidity on Microbial Enumeration*

The presence of turbidity may interfere with the quantification of bacteria and viruses. Bacteria are enumerated by counting the number of visible colonies that form on nutritive media when bacterial cells are incubated on the media for a fixed period of time. This process assumes that each colony represents one cell; however, a single colony could emanate from a particle containing many bacterial cells adsorbed on its surface. Fewer cells than were actually present would then be recorded. This phenomenon would also lead to an underestimation of bacterial numbers with the most probable number technique.

Geldreich *et al.*[32] noted that turbidity in a potable water sample may make membrane filtration impractical because of the volume of water the filter can pass, the character of the suspended material and the thickness of the deposit on the surface of the membrane. Although crystalline or siliceous materials may not be a problem, other substances may clog filter pores or cause a confluent growth to develop during incubation, hampering microbial enumeration. Coliform masking has been observed with membrane filters, with false-negative results occurring 17, 45 and more than 80% of the time for turbidities of less than or equal to 1.0, 5.0 and more than 10.0 NTU, respectively.[18,33] Additional studies suggested that levels of turbidity *per se* (up to approximately 10.0 NTU) did not greatly affect coliform discovery, although associated non-coliform bacteria seriously inhibited detections.[34]

Viruses can also be adsorbed on or within particulate matter and may be very difficult to remove; 1% recovery is not unusual.[35] A review of virus detection methods concluded that no simple and accurate system for enumerating viruses in highly turbid waters was available.[36]

5.1.4 Relationship between Turbidity Removal and Microbial Quality of Treated Water

Historically, filtration has been shown to substantially block disease-causing organisms from entering into the drinking water supply.[34] During coagulation, protozoa, bacteria and viruses, along with other sources of turbidity, become trapped in the floc and are removed by the filter.[37,38] However, sometimes floc breaks through filter beds; such breakthroughs have been shown to be accompanied by an increase in virus penetration, even though the turbidity of the finished water remained below 0.5 NTU.[35]

Studies have shown a correlation between decreased filtrate turbidity (down to 0.1 NTU) and reduced bacterial and algal counts.[39] Increases in the turbidity of filter effluent can signal the potential for increasing passage of unwanted organisms, even if the turbidity in the effluent is less than 1.0 NTU. For example, increasing concentrations of *Giardia* cysts can occur with turbidity increases of only 0.2–0.3 NTU.[40,41]

The Pennsylvania Department of Environmental Protection, in its 1996 Regulatory Basics Initiative Program report,[42] gave its view of the relationship between turbidity and pathogen occurrence in finished filtered water. It stated that a relationship exists between turbidity spikes and *Giardia* breakthrough such that a stable filter with low turbidities that experiences a 0.1 NTU increase in turbidity can experience a 10- to 50-fold increase in cyst breakthrough from disturbance of the media.

In evaluating plant performance using endospores, researchers found that the log reduction of spores was similar in magnitude to the individual reduction of turbidity, total particles and particles in the *Cryptosporidium* oocyst size range. More important, spore removal closely paralleled particle and turbidity removal in response to coagulant dosage under all the water quality conditions examined.[43]

In examining relationships between turbidity and parasites, it was found that for every log removal of turbidity, a 0.89-log removal was achieved for *Giardia* and *Cryptosporidium*.[44] Conversely, increases in filtrate turbidity paralleled increases in the risk of *Cryptosporidium* breaking through the filter due to floc material breaking through that contained, or was associated with, oocysts. These increases occurred even with efficient chemical coagulation. It is therefore reasonable to assume that during the filter "ripening" period at the beginning of a run, when turbidity is often greater than normal for the filter, the risk of *Cryptosporidium* breakthrough is higher.[45]

Table 2 shows average potential removal credits estimated for *Giardia lamblia*, *Cryptosporidium* and viruses, when treated water meets the prescribed turbidity limits. The log reduction credits outlined in Table 2 are based on the mean or median removal established by the U.S. Environmental Protection Agency (EPA) as part of the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).[46] Facilities that do not meet the requirements, or facilities that believe they can achieve a higher log credit than is automatically given, can be granted a log reduction credit based on a demonstration of performance by the appropriate regulatory agency.

Table 2: *Giardia lamblia*, *Cryptosporidium* and virus potential reduction credits for various technologies

Technology	Cyst/oocyst credit[c]	Virus credit
Conventional filtration[a]	3.0 log	2.0 log
Direct filtration[a]	2.5 log	1.0 log

Technology	Cyst/oocyst credit[c]	Virus credit
Slow sand or diatomaceous earth filtration[a]	3.0 log	2.0 log
Micro- and ultrafiltration, nanofiltration and reverse osmosis[b]	Removal efficiency demonstrated through challenge testing and verified by direct integrity testing	No credit for micro- and ultrafiltration; for nanofiltration and reverse osmosis, removal efficiency demonstrated through challenge testing and verified by direct integrity testing

[a] Conventional/direct/slow sand/diatomaceous earth filtration should be followed by free chlorination to obtain additional virus credit.

[b] Micro- and ultrafiltration should be followed by free chlorination for the inactivation of viruses.

[c] Depending on cyst/oocyst levels in source water, additional treatment is required using ultraviolet light, ozone, chlorine or chlorine dioxide (refer to protozoa/virological quality supporting documents for the level of inactivation required and the CT/IT tables for various disinfectants).

5.2 Chemical Characteristics

Because of their adsorption capacity, suspended particulates have the ability to entrap undesirable organic and inorganic compounds; as such, an indirect relationship exists between turbidity and the chemical characteristics of these compounds in water. Most important in this respect is the organic or humic component of turbidity.

Humic substances are able to bind substantial amounts of metals and hydrous oxides together, forming complexes. An excellent review of metal–humate complexes, the mechanism of their formation and their properties is provided by Schnitzer and Kahn.[47] The ability of a number of natural waters in Ontario to complex copper has been demonstrated, with complexing capacities of up to 2.35 µmol Cu/L (0.149 mg/L) being reported.[48] A wide variety of heavy metal ions were found to be complexed in sediments of the Ottawa and Rideau rivers. A positive correlation between the unit surface area of the sediment and the concentration of adsorbed metal ions was observed.[49] In a study of mercury sorption and desorption characteristics of Ottawa River sediments, it was found that sorption rates were higher for organic-rich sands. Desorption of mercury was difficult, with less than 1% of the mercury being leached during a 7-hour contact period.[50] The strength of some metal–humate complexes may lead to negative errors in the analytical measurement of trace metals in natural water samples if turbidity exists.[51]

One method that is used to remove undesirable metal ions during water treatment is adsorption with activated carbon. This process is aided by the presence of organic matter.[52] Organic molecules are also adsorbed by natural organic matter. DDT, for example, is solubilized in 0.5% sodium humate solution by a factor of at least 20 over its solubility in pure water.[53] Herbicides such as 2,4-D, paraquat and diquat can be adsorbed onto clay/humic acid particulates, the adsorption being greatly influenced by metal cations present in the humic material.[54] The presence of turbidity, therefore, might also interfere with the detection of biocides in water samples.

Chlorination of water containing organic matter such as humic acids can produce THMs, a group of chemical compounds that includes chloroform, bromodichloromethane, chlorodibromomethane and bromoform. The Canadian drinking water guideline for THMs is based on the known health effects associated with chloroform. Morris and Johnson[55] observed a relationship between raw water turbidity and THM concentration in finished Iowa City water. In laboratory tests, Stevens and co-workers[56] found that THM production was reduced if the water was filtered prior to chlorination. Harms and Looyenga[57] also reported that raw water turbidity was positively correlated with chloroform concentration in a South Dakota water supply. Strategies for addressing turbidity have implications related to controlling the potential formation of THMs, including the removal of organic matter, the use of alternative disinfectants, disinfectant application points and dosages, and the use of activated carbon.[58]

For plants using aluminum salts as coagulants, highest particulate aluminum concentrations (>200 µg/L) were measured when the turbidity was greater than 0.5 NTU.[59] The results of the study suggest that filtered water turbidity should be less than 0.1 NTU to minimize particulate aluminum concentrations that contribute to residual aluminum.[59]

At the asbestos levels commonly found in drinking water (of the order of 10^4–10^6 fibres/L),[60] very little, if any, correlation has been observed between turbidity and asbestos concentration.[2,61,62] However, a general but non-linear relationship has been reported at high levels of asbestos (10^9–10^{11} fibres/L).[63] Further studies on treatment efficiencies for asbestos removal have resulted in a recommendation by Logsdon and co-workers[64,65] that plants designed for asbestos removal should produce filtered waters with turbidities of 0.1 NTU or lower. McGuire *et al.*[66] suggested that this objective would help but not necessarily guarantee low asbestos counts (<10^6 fibres/L). Boatman[67] reported that turbidity could impede asbestos analyses because of restricted filter volumes. Asbestos-cement pipes are used in some localities to transport drinking water, and it has been demonstrated that water with an aggressivity index of less than 10 can cause the release of asbestos fibres into the drinking water.[68]

5.3 Physical Characteristics

A considerable body of evidence suggests that a large part of colour in water arises from colloidal particles. These tiny particles have physical and chemical properties that allow them to stay suspended in the water, rather than settling down or dissolving. Black and co-workers[69,70] used electrophoretic studies to demonstrate the predominantly colloidal nature of colour in water; it has been claimed that about 50% of colour is due to a "colloidal fraction" of humic substances.[71] True colour is therefore defined as the colour of water from which turbidity has been removed.[2]

The relationship between high turbidity, in both raw and filtered water, and taste and odour has long been recognized.[72] Algal growths, actinomycetes and their debris also contribute to taste and odour problems.[7] At 5.0 NTU and above, there is an increasing visual detection, which many consumers find unacceptable.

6.0 Analytical Methods

Turbidity is measured using the nephelometric method. Nephelometry determines turbidity using the intensity of scattered light. Table 3 lists four nephelometric methods that meet the criteria of the American Water Works Association/American Public Health Association (AWWA/APHA) or the U.S. EPA and one International Organization for Standardization (ISO) criterion for determining turbidity in drinking water.

Table 3: Recognized analytical methods for measuring turbidity in drinking water[a]

Method	Citation	Description
Nephelometric	AWWA/APHA 2130B[3]	Tungsten lamp@2200–3000°K and one or more perpendicular detectors (& filters) with spectral response peak of 400–600 nm; light path ≤10 cm
Nephelometric	U.S. EPA 180.1[73]	Tungsten lamp@2200–3000°K and one or more perpendicular detectors (& filters) with spectral response peak of 400–600 nm; light path ≤10 cm
Optical	ISO 7027[74]	Tungsten lamp (& filters), diode or laser as radiation source at 860 nm (or 550 nm if sample is colourless) with a perpendicular detector and aperture angle 20–30°
Great Lakes Instruments (GLI)	U.S. EPA GLI 2[75]	Two perpendicular 860-nm light sources alternately pulse each 0.5 seconds, & two perpendicular detectors alternately measure "reference" and "active" signals
Hach Filter Trak	U.S. EPA 10133[76]	Laser diode @660 nm at 90° to detector/receiver (light path ≤10 cm), which may use photo-multiplier tube and fibre-optic cable; range is 0–1000 mNTUs

[a] Additional methods may be approved before this guideline is revised/updated in the future.

Nephelometric turbidity instrumentation varies in design, range, accuracy and application. The design of nephelometric instruments should take into account the physics of scattered light. As noted in a previous section ("Identity and Sources in the Environment"), the size, shape and concentration of the particles affect the intensity pattern and distribution of the scattered light. Small particles less than one-tenth of the light wavelength will scatter light uniformly in both forward and backward directions. As the particle size approaches and exceeds the wavelength of the incident light, more light is transmitted in the forward direction. Because of this intensity pattern, the angle at which the light is measured is a critical factor; the current international standards have determined the most appropriate angle to be 90 degrees.[74] As noted above, as the concentration of particles increases, more particles reflect the incident light, which increases the intensity of the scattered light. As the concentration exceeds a certain point determined by the specific optical characteristics of the process, the particles themselves begin to block the transmission of the scattered light. The result is a decrease in the intensity of the scattered light. The intensity at which various wavelengths of light are reflected or absorbed is also determined by the colour of the liquid and the reflecting surface. Industry standards require nephelometers to operate in the visible or infrared ranges: 400–600 and 800–900 nm, respectively.[77]

All these factors, along with the optical geometry of a particular instrument, cause measured values between instruments to vary widely; thus, criteria for instrument design have been developed to minimize these variables. Manufacture of turbidimeters is guided by recommendations provided by the U.S. EPA[78] and the ISO (ISO 7027).[74]

Using special experimentation methods with a quartz iodine light source, the nephelometric response of exhaustively filtered de-ionized water has been shown to be

0.022–0.003 NTU.[79] Air bubbles and dirty sample tubes can cause false high readings for turbidity; very turbid samples or samples with colour due to dissolved substances will give low readings.[3,80]

For a finished water turbidity goal of 0.1 NTU, rigorous standard operating procedures and a high level of quality control are required; a small numeric change may result in a large percent change.[81,82] However, according to the U.S. EPA's *Analytical Methods for Turbidity Measurement* (180.1 and GLI 2) and *Standard Methods for the Examination of Water and Wastewater* (2130B), the sensitivity of nephelometers is such that turbidity differences of 0.02 NTU or less can be detected in waters having a turbidity of less than 1.0 NTU.[3,73,75] All three methods cite "reporting to the nearest 0.05 NTU where the turbidity range is 0–1.0 NTU." Thus, the practical lower limit of the standard nephelometric method can be considered to be 0.1 NTU.

Laser turbidimeters have recently entered the market. The manufacturers claim that these instruments are far more sensitive than the standard turbidimeters, purporting to accurately measure in the mNTU range. The U.S. EPA has approved a laser turbidity method, "Method 10133, Determination of Turbidity by Laser Nephelometry."[76] Currently, laser turbidimeters are not widely used in the industry.[83]

Turbidity, as defined by the above methods, is a non-scientific measure of particle concentration. Electronic particle counters are now available that are capable of accurately counting and recording the number of particles as a function of size (often in the 1–150 μm range). Although there is a general relationship between particle counts and turbidity (below 1.0 NTU), a firm correlation does not exist.[84–86]

A simple conversion factor relating particle counting and turbidity measurements is not possible because the two techniques differ fundamentally in terms of discernment. Particle counting measures two characteristics of particulates: particle number and particle size. Samples with identical clarity can be distinguished on the basis of these two features; one sample may contain many small particles, whereas another may contain few large particles. Turbidity, on the other hand, cannot distinguish between two samples of identical clarity and different particulate composition.[87]

Particle counters are an excellent tool for optimizing treatment processes and for detecting the onset of filter breakthrough. Particle counters are restricted to performance verification only, and no limit is set as a maximum acceptable concentration for the number of particles in the treated water.

7.0 Treatment Technology

Turbidity is reduced by removing particles from the water through filtration. Adequate filtration can be achieved by a variety of technologies: chemically assisted filtration, slow sand filtration, diatomaceous earth filtration, membrane filtration or an alternative proven filtration technology.

7.1 Chemically Assisted Filtration

The chemically assisted filtration process generally includes chemical mixing, coagulation, flocculation, sedimentation (or dissolved air flotation) and rapid gravity filtration. Aluminum and ferric salts are used as primary coagulants. Cationic and anionic polymers are most commonly used as flocculation aids, and both, along with non-ionic polymers, have been used as filter aids. The coagulants and polymers are used to destabilize the generally negatively charged colloidal particles, which allows aggregation to occur via chemical and van der Waals interactions.[88,89] The resulting (much larger) particles are filtered out when the water passes through sand beds or other single-, dual- or mixed-media granular filters. In systems where the combined water from all filters is monitored continuously, this treatment process is capable of producing water with a turbidity of less than 0.3 NTU; turbidities of less than 0.2 NTU have been demonstrated to be achievable on an ongoing basis. Filter loading rates generally range from 3.0 to 12.0 m/h.[90,91]

Changes in alkalinity, colour, turbidity and orthophosphate concentrations affect coagulation reactions and the properties and rate of settling of resulting floc particles. Temperature affects efficiency by influencing the rate of chemical reactions and the viscosity of water, thereby affecting the particle settling velocity and the filter backwash rate. The lower the temperature of the water, the more difficult it is to treat the water.

All filtration plants should provide for continuous monitoring of the effluent turbidity from each individual filter, as well as for continuous monitoring of the combined filtered water turbidity from all filters. Continuous monitoring is required because short-term turbidity spikes represent a process failure and potential health risk. Peak turbidity levels in the filtered water are a particular concern immediately after filter backwashing; therefore, all filters should be designed so that the filtered water immediately after filter backwashing is directed into a waste stream ("filter-to-waste" provision). When operating the filters, every effort should be made to minimize the magnitude and duration of turbidity spikes.[92]

Discharge of filter backwash water into a raw water reservoir should not be permitted unless the filter backwash water receives off-line treatment or is returned to a location upstream of the coagulant dosage point, so that all processes of a conventional or direct filtration plant are employed. The off-line treatment may be acceptable depending on the method used to treat the backwash water.

Following filtration, turbidity in a waterworks may increase if any of the following occur:

- coagulants escape into the filtered water;
- dissolved metals oxidize;
- bacteria and other microflora grow;
- chemicals are added for stability or corrosion control;
- deposited materials (especially in low-flow parts of the system) are resuspended; or
- pipes corrode or lines break.[93,94]

Uncovered distribution system reservoirs may also lead to increased turbidities, mainly by encouraging biological production.[95,96]

In 1989, the American Water Works Association Research Foundation sponsored a study that identified design provisions and operational practices at high-rate filtration plants. For the study, researchers chose 21 plants that were successful in producing finished water with turbidity of less than 0.2 NTU.[91] In choosing the participating plants, consideration was given to geographic coverage as well as diversity of raw water types and treatment processes. In a different study, the Pennsylvania Department of Environmental Protection undertook performance evaluations of 150 surface water treatment plants that used filtration from 1988 to 1990 and found that a goal of 0.2 NTU was achievable for most plants.[97] An internal report, prepared in 1995 for the same department, also found that filtration plants can readily achieve finished water with turbidities of less than 0.5 NTU and that most plants can achieve less than 0.2 NTU.[90] In pilot tests involving treatment of Boston's low-turbidity surface water supply with dissolved air flotation, the turbidity goal of 0.1 NTU was met in more than 90% of the runs.[98] Operational studies at specific plants have indicated that low turbidities in plant effluent are readily achievable when competent operations are in place.[99,100] In another study, it was demonstrated that well-operated conventional treatment plants or direct filtration plants that produce water with low turbidity (less than 0.5 NTU) can achieve up to a 3-log reduction of *Giardia* cysts and up to a 2-log reduction of viruses.[101] The same study demonstrated that source waters with low raw water turbidity require filter effluent turbidities to be substantially lower than 0.5 NTU in order to effectively remove *Giardia* cysts and viruses.

The U.S. EPA's 1997 Notice of Data Availability for Interim Enhanced Surface Water Treatment Rule (IESWTR) shows that systems serving more than 10 000 people are able to meet low turbidity limits. The same study indicated that chemically assisted filtration is able to achieve a 2-log reduction of *Cryptosporidium* through filtration.[102,103] The U.S. EPA has now concluded that conventional treatment plants in compliance with the IESWTR or LT1ESWTR achieve an average of 3-log reduction of *Cryptosporidium*. Direct filtration plants achieve an average of 2.5-log reduction of *Cryptosporidium*.[46]

7.2 Slow Sand Filtration

In slow sand filtration, filter effectiveness depends on the formation of schmutzdecke, which is a layer of bacteria, algae and other microorganisms on the surface of the sand, and the formation of a biopopulation within the sand bed. Raw water passes through the sand bed, where physical, chemical and biological mechanisms remove contaminants. The most important removal mechanism has been attributed to the biological process. No chemicals are added, nor is there a need to backwash.

Researchers have observed variation in the ability of slow sand filters to reduce turbidity. Fox *et al.*[104] found that when water was filtered at 0.12 m/h, after an initial ripening period had allowed the biopopulation to become established on new sand, the treated water turbidity was consistently less than 1.0 NTU. Raw water turbidity ranged from 0.2 to 10.0 NTU. Cleasby *et al.*[105] reported that typical effluent turbidity was 0.1 NTU for raw water, with turbidity ranging from lower than 1.0 to 30.0 NTU, except during the first 2 days after scraping of the schmutzdecke. Pyper[106] observed slow sand filtered water with turbidity of 0.1 NTU or lower 50% of the time and 1.0 NTU or lower 99% of the time; raw water turbidity in this study ranged from 0.4 to 4.6 NTU. Slezak and Sims[107] reported that nearly half of the 27 slow sand filtration plants they surveyed produced filtered water turbidity of 0.4 NTU or lower; at the same time, 15% of the plants produced water with an average turbidity of 1.0 NTU or higher. Consistent 3-log reductions of particles sized from 2 to 4 µm upwards were also observed in this study. The size range of 7–12 µm is considered to be representative of the size of *Giardia* cysts. Bellamy *et al.*[108] studied the water treatment efficiency of slow sand filtration to ascertain removal of

Giardia cysts, total coliform bacteria, HPC bacteria, particles and turbidity. Results showed that slow sand filtration is an effective water treatment technology. Using a biologically mature filter, *Giardia* cyst removal was virtually 100%; total and faecal coliform removal was approximately 99%; particle removal averaged 98%; HPC bacteria removal ranged from negative to 99%, depending on the influent concentration; and turbidity removal ranged from 0 to 40%.[103] The U.S. EPA has now concluded that slow sand filtration plants in compliance with the IESWTR or LT1ESWTR achieve an average of 3-log reduction of *Cryptosporidium*.[46]

Slow sand filtration is appropriate for use when raw water turbidities are relatively low (e.g., <10.0 NTU).

As is the case with chemically assisted filtration, a "filter-to-waste" feature should be provided so that the filtered water immediately after filter cleaning is directed into a waste stream.

7.3 Diatomaceous Earth Filtration

Diatomaceous earth filters operate by passing water through a thin layer of diatomaceous earth about 3 mm thick supported on a septum or filter element. To prevent turbid water from clogging the filter, a small amount of diatomaceous earth is continually added as body feed to maintain a permeable filter cake. Once the head loss across the filter cake becomes too great or the filter cake begins to slough, the filter is removed from service and the filter cake is washed and reused. New precoat is applied, and the cycle starts again.

Diatomaceous earth filtration has been shown to attain excellent removal of *Giardia* cysts over a broad range of operating conditions. Cyst removals exceeding 99%, and often 99.9%, were reported by Lange *et al.*[109] for filtration rates of 2.4–9.6 m/h and for temperatures from 3.5 to 15°C. Logsdon *et al.*[110] reported that when sufficient diatomaceous earth and body feed were used, removal of 9-µm radioactive beads was nearly always 99.9% or higher. The same study reported that 11 filter runs were made with *Giardia muris* cysts at filtration rates of 2.2–3.5 m/h. Cyst removal exceeded 99% in all runs and exceeded 99.9% in five of the runs. The U.S. EPA has now concluded that diatomaceous earth filtration plants in compliance with the IESWTR or LT1ESWTR achieve an average of 3-log reduction of *Cryptosporidium*.[46]

Diatomaceous earth filtration is appropriate and effective in treating waters with low turbidity. Logsdon *et al.*[110] reported that turbidity reductions of 56–78% were attained with diatomaceous earth when raw water turbidity ranged from 0.95 to 2.5 NTU. Pyper[106] reported an average turbidity reduction of 75% with an effluent quality of 0.5 NTU.

As is the case with chemically assisted filtration, a "filter-to-waste" feature should be provided so that the filtered water immediately after filter backwashing is directed into a waste stream.

7.4 Membrane Filtration

Four membrane treatment processes are currently used in the water industry, and all involve pressure-driven semi-permeable membranes. The most appropriate type of membrane depends on a number of factors, including targeted materials to be removed, source water quality characteristics, treated water quality requirements, membrane pore size, molecular weight cut-off, membrane materials and system/treatment configuration.[111] The four processes are:

1. *Reverse osmosis*: a high-pressure membrane treatment process originally developed to remove salts from brackish water;
2. *Nanofiltration*: a low-pressure reverse osmosis process for the removal of larger cations (e.g., calcium and magnesium ions) and/or organic molecules;
3. *Ultrafiltration*: a lower-pressure membrane process characterized by a wide band of molecular weight cut-off and pore sizes for the removal of dissolved organics and particulates; and
4. *Microfiltration*: a low operating pressure membrane process used to remove particulates, including pathogenic cysts.[111,112]

Reverse osmosis and nanofiltration are very effective for absolute removal of cysts, bacteria and viruses.[112] Ultrafiltration (pore size 0.01 µm) and microfiltration (pore size 0.1 µm) are effective for absolute removal of *Giardia* cysts and partial removal of bacteria and viruses.[113] Filtrate turbidity can be achieved consistently at or below 0.1 NTU.[114,115]

Prefiltration and/or the addition of a scale-inhibiting chemical may be required to protect membranes from plugging effects, fouling and/or scaling.

If membrane filtration is the sole treatment technology in use, then a form of virus inactivation should be incorporated into the treatment train after the filtering process.

A "filter-to-waste" feature should be provided for initial start-up and commissioning of the membrane system and for emergency diversion in the event of a membrane integrity breach.

8.0 Health Considerations

8.1 Microbial

The most important health-related effect of turbidity is probably its ability to protect microorganisms from disinfection. Turbidity, which has been shown to be correlated with the contamination of water supplies by *Giardia* and *Cryptosporidium*,[116] serves as a surrogate measure for indicating the risk of contamination by these pathogens. A dramatic increase in turbidity levels at one of the Milwaukee water treatment plants (levels many times higher than those of the preceding 14 months) was associated with the outbreak of cryptosporidiosis in April 1993, when more than 400 000 people developed symptomatic gastrointestinal infections as a consequence of exposure to contaminated drinking water.[117] An outbreak of giardiasis in Rome, New York, where an unfiltered but chlorinated water supply was used, has been cited as illustrating the problem of particulates possibly protecting pathogens and interfering with marginal disinfection.[62] In another incident, high turbidities (>4.0 NTU), resulting from poor plant operation coupled with a malfunctioning chlorinator, were considered as causal factors in an outbreak of giardiasis.[39]

In most water treatment plants, *Giardia* removal is a physical process involving coagulation, flocculation and filtration; chlorine contact times alone are insufficient to result in complete destruction or removal.[118] Monitoring turbidity can therefore be a useful indicator of plant performance, including cyst removal. Studies have shown that small increases in turbidity (about 0.2 NTU) can result in significant passage of *Giardia* cysts.[40] It has been suggested that 0.1 NTU should be set as a goal or objective for treated water.[39,40,118,119] Giardiasis problems have, however, occurred where turbidity limits have been met, and it should not be assumed that achieving a turbidity limit will by itself prevent waterborne disease.[41,120]

A study in Philadelphia by Schwartz *et al.*,[115] which asserted a correlation between levels of turbidity and hospital admissions of elderly residents with gastrointestinal illnesses, highlights the fact that meeting the turbidity limits does not necessarily mean that disease can be prevented. The authors found that an increase in the weighted average turbidity of approximately 25% (0.035 NTU) was associated with a 9% increase in hospital admissions of elderly residents with gastrointestinal illness 9–11 days after exposure, even though the recorded average turbidities were well below the regulated limits. A similar study by Aramini *et al.*[121] has demonstrated a relationship between reported gastrointestinal illness and turbidities in excess of 1.0 NTU, the previous Canadian health-based drinking water guideline. Using a generalized additive model, the authors demonstrated that excess turbidities during the period 1992–1998 could explain 2.1%, 0.8% and 0.9% of emergency-associated, gastroenteritis-related physician visits by persons residing within the three water distribution areas, respectively. In addition, 1.3%, 0.2% and 0.3% of gastroenteritis-related hospitalizations of persons residing in the same three areas were explained by variations in turbidity. It is evident from these studies that change in turbidity levels in drinking water is a potential indicator for breakthrough of pathogenic organisms and increased consumer risk.

Hudson,[122] using 1953 data on infectious hepatitis and raw water turbidity for 12 U.S. cities, observed that infectious hepatitis incidence was greater with higher turbidity. A similar relationship appeared to exist between turbidity and cases of poliomyelitis, although this finding was based on a smaller sample.[122] Shaffer *et al.*[123] reported detection of poliovirus in waters with chlorine concentrations greater than 1 mg/L and turbidities less than 1.0 NTU, which indicates that protection from disinfection occurs even at very low turbidity levels. Although a study of 16 U.S. cities in 1961 failed to reveal a clearly defined relationship between hepatitis incidence and finished water turbidity, the authors stated that, because of the many factors involved, it should not be inferred that there is none.[124] The infectious hepatitis epidemic in Delhi, India, occasioned by the massive contamination of the raw water source of a treatment plant by sewage, was also accompanied by a significant increase in raw water turbidity. Even though chlorination was practised, it was apparently insufficient to inactivate the infectious hepatitis virus.[125] The protection from disinfection offered by organic or cellular material in particular has been reported in other studies.[19,21]

8.2 Chemical

Particulate matter in water is not usually a potential chemical hazard in itself, but may have indirect effects.[5] The concentrations of both heavy metal ions and biocides are usually much higher in suspended solids than in water. The possibility therefore exists that when such contaminated particles enter a different environment, such as the stomach, release of the pollutants could occur, with potentially deleterious effects.

The metal–ligand binding in humate complexes can be represented by the equation[47]:

$$M^{n+} + H_mA \rightleftharpoons M_mA_n + mH$$

where:

- M^{n+} = the metal ion
- H_mA = humic acid
- M_mA_n = the metal complex.

If, for instance, the hydrogen ion concentration is increased by stomach acid, the equilibrium will be displaced in favour of the free ion and the undissociated humic acid.

Similarly, the absorption of some herbicides, in particular s-triazine compounds, by soil organic matter has been demonstrated to be pH dependent. Maximum absorption occurs at pH levels in the vicinity of the respective pK values of the herbicides (i.e., pH levels of about 4–6). Lowering or raising the pH decreases absorption and hence may lead to the release of free herbicides.[47]

9.0 Other Considerations

Excessive turbidity has often been associated with unacceptable tastes and odours. Turbidity in excess of 5.0 NTU also becomes visually apparent and may be objected to by consumers. In some cases, if the level of turbidity is not lowered to reduce the organic loading in advance of applying certain chemicals, it may lead to other health concerns (e.g., the formation of THMs).

As noted above, turbidity measurement does not indicate the type, number or mass of particles. However, because of the ease of analysis and relative inexpensiveness of the equipment, it is a very useful tool to assess the performance of water treatment processes — especially for conventional surface water systems. Moreover, turbidity can serve to signal potential contamination problems or difficulties within a distribution system. Drinking water should be aesthetically pleasing. Every effort should be made to keep the turbidity as low as possible by flushing and cleaning the pipelines. For aesthetic purposes, turbidity should not exceed 5.0 NTU within the distribution system, especially at the point of consumption.

10.0 Rationale

Turbidity is a characteristic of all water supplies. In surface waters and groundwaters under the influence of surface water, turbidity is a concern for both health and aesthetic reasons. In these waters, the particulate matter that creates turbidity can contain toxins, harbour microorganisms and interfere with disinfection. In addition, organic matter in the water can react with disinfectants such as chlorine to create by-products. These by-products may cause adverse health effects.

While turbidity may be measured in secure groundwater supplies (i.e., not under the direct influence of surface water), it is not a concern in treated water from these sources provided it does not hinder disinfection. It is good practice to ensure that water entering the distribution system from a secure groundwater supply has a low turbidity level around 1.0 NTU.

Turbidity is effectively reduced through filtration, using one of a number of common technologies. The most important consideration when dealing with turbidity is to reduce its level as low as possible and minimize fluctuation. For this reason, while the target is to reduce turbidity levels to below 0.1 NTU at all times, it is considered acceptable for treatment plants to achieve the following levels based on the type of technology used. The levels of turbidity in treated water:

1. For chemically assisted filtration, should be less than or equal to 0.3 NTU in at least 95% of the measurements made, or at least 95% of the time each calendar month, and should not exceed 1.0 NTU at any time.
2. For slow sand or diatomaceous earth filtration, should be less than or equal to 1.0 NTU in at least 95% of the measurements made, or at least 95% of the time each calendar month, and should not exceed 3.0 NTU at any time.
3. For membrane filtration, should be less than or equal to 0.1 NTU in at least 99% of the measurements made, or at least 99% of the time each calendar month, and should not exceed 0.3 NTU at any time. If membrane filtration is the sole treatment technology employed, some form of virus inactivation should follow the filter process.

Most problems associated with turbidity are caused when the level of turbidity in the treated water spikes. Spikes can occur when the natural levels of particulate matter increase in the source water, when the filtration rate increases or when an individual filter breaks down. In order to quickly figure out that a filter is malfunctioning and to identify which one it is, this guideline applies to individual filters within a system.

Turbidity measured to be less than 5.0 NTU is not discernible to the naked eye, but at higher levels the particulate matter in water may cause colour, taste and odour concerns for consumers. For this reason, utilities should try to maintain the level of turbidity in the distribution system to below 5.0 NTU. An aesthetic objective has not been set in order to avoid confusion with the health-related guideline.

11.0 References

1. U.S. Environmental Protection Agency. National Primary Drinking Water Regulations: Final Rule. Fed. Regist., 54(124): 27485–27541 (1989).

2. Sadar, M.J. Understanding turbidity science. Technical Information Series, Booklet II. Hach Co., Loveland, CO (1996).

3. American Public Health Association/American Water Works Association/Water Environment Federation. Standard methods for the examination of water and wastewater. 20th edition. American Public Health Association, Washington, DC (1995).

4. Hach, C.C., Vanous, R.D. and Heer, J.M. Understanding turbidity measurement. 1st edition. Technical Information Series, Booklet II. Hach Co., Loveland, CO (1982).

5. National Academy of Sciences. Drinking water and health. Chap. IV. U.S. National Research Council, Washington, DC (1977).

6. Narkis, N. and Rebhun, M. The mechanism of flocculation processes in the presence of humic substances. J. Am. Water Works Assoc., 67: 101 (1975).

7. Mackenthun, K.M. and Kemp, L.E. Biological problems encountered in water supplies. J. Am. Water Works Assoc., 62: 520 (1970).

8. Kay, G.P., Sykora, J.L. and Burgess, R.A. Algal concentration as a quality parameter of finished drinking waters in and around Pittsburgh, Pa. J. Am. Water Works Assoc., 72: 162 (1980).

9. Brock, T.D. Principles of microbial ecology. Prentice-Hall, Englewood Cliffs, NJ. p. 72 (1966).

10. Stotzky, G. Influence of clay minerals on microorganisms. III. Effect of particle size, cation exchange capacity, and surface area on bacteria. Can. J. Microbiol., 12: 1235 (1966).

11. Berg, G. Removal of viruses from sewage, effluents, and waters. 2. Present and future trends. Bull. W.H.O., 49: 461 (1973).

12. Haas, C.N., Meyer, M.A. and Paller, M.S. Microbial alterations in water distribution systems and their relationship to physical-chemical characteristics. J. Am. Water Works Assoc., 75: 475 (1983).

13. Snead, M.C., Olivieri, V.P., Kruse, C.W. and Kawata, K. Benefits of maintaining a chlorine residual in water supply systems. EPA-600/2-80-010. U.S. Environmental Protection Agency, Washington, DC, June (1980).

14. Goshko, M.S., Minnigh, H.A., Pipes, W.O. and Christian, R.R. Relationships between standard plate counts and other parameters in water distribution systems. J. Am. Water Works Assoc., 75: 568 (1983).

15. Reilly, J.K. and Kippin, J.S. Relationship of bacterial counts with turbidity and free chlorine in two distribution systems. J. Am. Water Works Assoc., 75: 309 (1983).

16. Sanderson, W.W. and Kelly, S. Comments following a paper by N.A. Clarke *et al.*, reference 85.

17. Huck, P.M, Coffey, B.M., Emelko, M.B., Maurizo, D.D., Slawson, R.M., Anderson, W.B., Van Den Oever, J., Douglas, I.P. and O'Melia, C.R. Effects of filter operation on *Cryptosporidium* removal. J. Am. Water Works Assoc., 94(6): 97–111 (2002).

18. LeChevallier, M.W., Evans, T.M. and Seidler, R.J. Effect of turbidity on chlorination efficiency and bacterial persistence in drinking water. Appl. Environ. Microbiol., 42: 159 (1981).

19. Hoff, J.C. The relationship of turbidity to disinfection of potable water. Evaluation of the microbiology standards for drinking water. EPA-570/9-78-OOC. U.S. Environmental Protection Agency, Washington, DC. p. 103 (1978).

20. Hoff, J.C. and Geldreich, E.E. Comparison of the biocidal efficiency of alternative disinfectants. J. Am. Water Works Assoc., 73: 40 (1981).

21. Sproul, O.J., Buck, C.E., Emerson, M.A., Boyce, D., Walsh, D. and Howser, D. Effects of particulates on ozone disinfection of bacteria and viruses in water. EPA-600/2-79-089. U.S. Environmental Protection Agency, Washington, DC, August (1979).

22. Scarpino, P.V., Brigano, F.A.O., Cronier, S. and Zink, M.L. Effect of particulates on disinfection of enteroviruses in water by chlorine dioxide. EPA-600/2-79-054. U.S. Environmental Protection Agency, Washington, DC, July (1979).

23. Chang, S.L., Woodward, R.L. and Kabler, P.W. Survey of free-living nematodes and amebas in municipal supplies. J. Am. Water Works Assoc., 52: 613 (1960).

24. Mott, J.B., Mulamoottil, G. and Harrison, A.D. A 13-month survey of nematodes at three water treatment plants in southern Ontario, Canada. Water Res., 15: 729 (1981).

25. Tombes, A.S., Abernathy, A.R., Welch, D.M. and Lewis, S.A. The relationship between rainfall and nematode density in drinking water. Water Res., 13: 619 (1979).

26. Tracy, H.W., Camarena, V.M. and Wing, F. Coliform persistence in highly chlorinated waters. J. Am. Water Works Assoc., 58: 1151 (1966).

27. Bitton, G., Henis, Y. and Lahav, N. Effect of several clay minerals and humic acid on the survival of *Klebsiella aerogenes* exposed to ultraviolet irradiation. Appl. Microbiol., 23: 870 (1972).

28. Sawyer, C.N. and McCarty, P.L. Residual chlorine and chlorine demand. In: Chemistry for sanitary engineers. 2nd edition. Chap. 21. McGraw-Hill, Toronto (1967).

29. Rook, J.J. Chlorination reactions of fulvic acids in natural waters. Environ. Sci. Technol., 11: 478 (1977).

30. Otson, R., Williams, D.T. and Bothwell, P.D. Comparison of trihalomethane levels and other water quality parameters for three treatment plants on the Ottawa River. Environ. Sci. Technol., 15: 1075 (1981).

31. U.S. Environmental Protection Agency. Guidance manual for compliance with filtration and disinfection requirements for public water systems using surface water sources. Section 5.3.2. Washington, DC.

32. Geldreich, E.E., Allen, M.J. and Taylor, R.H. Interferences to coliform detection in potable water supplies. In: Evaluation of the microbiology standards for drinking water. EPA-570/9-78-OOC. U.S. Environmental Protection Agency, Washington, DC. p. 13 (1978).

33. Seidler, R.J. and Evans, T.M. Project summary: Persistence and detection of coliforms in turbid finished drinking water. EPA-600/S2-82-054. U.S. Environmental Protection Agency, Washington, DC, August (1982).

34. Herson, D.S. and Victoreen, H.T. Hindrance of coliform recovery by turbidity and non-coliforms. EPA-600/2-80-097. U.S. Environmental Protection Agency, Washington, DC, August (1980).

35. Robeck, G.G., Clarke, N.A. and Dostal, K.A. Effectiveness of water treatment processes in virus removal. J. Am. Water Works Assoc., 54: 1275 (1962).

36. Fenters, J.D. and Reed, J.M. Viruses in water supply. J. Am. Water Works Assoc., 69: 328 (1977).

37. Clarke, N.A., Berg, G., Kabler, P.W. and Chang, S.L. Human enteric viruses in water: source, survival and removability. Adv. Water Pollut. Res., 2: 523 (1964).

38. Foliguet, J.M. and Doncoeur, F. Élimination des enterovirus au cours du traitement des eaux d'alimentation par coagulation/floculation/filtration. Water Res., 9: 953 (1975).

39. Logsdon, G.S. and Lippy, E.C. The role of filtration in preventing waterborne disease. J. Am. Water Works Assoc., 74: 649 (1982).

40. Logsdon, G.S., Thurman, V.C., Frinot, E.S. and Stoecker, J.G. Evaluating sedimentation and various filter media for removal of *Giardia* cysts. J. Am. Water Works Assoc., 77: 61 (1985).

41. Cleasby, J.L. Slow sand filtration and direct in-line filtration of a surface water. In: Proceedings of the American Water Works Association Seminar on Innovative Filtration Techniques, Las Vegas, NV. p. 1 (1983).

42. Pennsylvania Department of Environmental Protection. Regulatory Basics Initiative Program report. Office of Policy and Communication, Harrisburg, PA (1996).

43. Rice, E.W., Fox, K.R., Miltner, R.J., Lytle, D.A. and Johnson, C.H. Evaluating plant performance with endospores. J. Am. Water Works Assoc., 88(9): 122–130 (1996).

44. LeChevallier, M.W. and Norton, W.D. Examining relationships between particle counts, and *Giardia* and *Cryptosporidium* and turbidity. J. Am. Water Works Assoc., 84(12): 54–60 (1992).

45. Hall, T., Pressdee, J., Gregory, R. and Murray, K. *Cryptosporidium* removal during water treatment using dissolved air flotation. Water Sci. Technol., 31(3–4): 125–135 (1995).

46. U.S. Environmental Protection Agency. National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule — toolbox guidance manual. June. pp. 1–8 (2003).

47. Schnitzer, M. and Kahn, S.U. Humic substances in the environment. Marcel Dekker, New York, NY (1972).

48. Chau, Y.K. and Lum-She-Chan, K. Measurement of complexing capacity of lake waters. In: Humic substances, their structure and function in the biosphere. D. Povoledo and H.L. Golterman (eds.). Pudoc, Wageningen, The Netherlands. p. 11 (1975).

49. Oliver, B.G. Heavy metal levels of Ottawa and Rideau river sediments. Environ. Sci. Technol., 7: 135 (1973).

50. Ramamoorthy, S. and Rust, R.R. Mercury sorption and desorption characteristics of some Ottawa River sediments. Can. J. Earth Sci., 13: 530 (1976).

51. Gardiner, J. The chemistry of cadmium in natural water: 1. A study of cadmium complex formation using the cadmium specific-ion electrode. Water Res., 8: 23 (1974).

52. Culp, G.L. and Culp, R.L. New concepts in water purification. Van Nostrand Reinhold, Toronto. p. 221 (1974).

53. Wershaw, R.L., Burcar, P.J. and Goldberg, M.C. Interaction of pesticides with natural organic material. Environ. Sci. Technol., 3: 271 (1969).

54. Kahn, S.U. Adsorption of 2,4-D from aqueous solution by fulvic acid/clay complex. Environ. Sci. Technol., 4: 236 (1974).

55. Morris, R.L. and Johnson, L.G. Agricultural runoff as a source of halomethanes in drinking water. J. Am. Water Works Assoc., 68: 492 (1976).

56. Stevens, A.A., Slocum, C.J., Seeger, D.R. and Robeck, G.G. Chlorination of organics in drinking water. J. Am. Water Works Assoc., 68: 615 (1976).

57. Harms, L.L. and Looyenga, R.W. Preventing haloform formation in drinking water. EPA-600/2-80-091. U.S. Environmental Protection Agency, Washington, DC, August (1980).

58. American Water Works Association. Treatment techniques for controlling trihalomethanes in drinking water. Denver, CO (1982).

59. Driscoll, C.T. and Letterman, R.D. Factors regulating residual aluminum concentrations in treated waters. Envirometrics, 6: 287–309 (1995).

60. Department of National Health and Welfare. A national survey for asbestos fibres in Canadian drinking water supplies. 79-EHD-4. Environmental Health Directorate, Ottawa (1979).

61. Logsdon, G.S. and Symons, J.M. Removal of asbestiform fibers by water filtration. J. Am. Water Works Assoc., 69: 499 (1977).

62. Symons, J.M. and Hoff, J.C. Rationale for turbidity maximum contaminant level. Presented at the 3rd American Water Works Association Water Quality Technology Conference, Atlanta, GA, December (1975).

63. Lawrence, J. and Zimmerman, H.W. Asbestos in water: mining and processing effluent treatment. J. Water Pollut. Control Fed., 49: 156 (1977).

64. Logsdon, G.S., Evavold, G.L., Patton, J.L. and Watkins, J. Filter plant design for asbestos fiber removal. Am. Soc. Civ. Eng. J. Environ. Eng. Div., 109: 900 (1983).

65. Logsdon, G.S., Symons, J.M. and Sorg, T.J. Monitoring water filters for asbestos removal. Am. Soc. Civ. Eng. J. Environ. Eng. Div., 107: 1297 (1981).

66. McGuire, M.J., Bowers, A.E. and Bowers, D.A. Optimizing large-scale water treatment plants for asbestos-fiber removal. J. Am. Water Works Assoc., 75: 364 (1983).

67. Boatman, E.S. Analyzing asbestos fibres in water by means of transmission electron microscopy. J. Am. Water Works Assoc., 74: 533 (1982).

68. Farren, E.F., Buelow, R.W., Thurnau, R.C., Gardels, M., Sorrell, R.K., Snyder, P. and Dressman, R.C. Water quality deterioration in the distribution system. Presented at the 5th American Water Works Association Water Quality Technology Conference, Kansas City, MO, December (1977).

69. Black, A.P. and Willems, D.G. Electrophoretic studies of coagulation for removal of organic colour. J. Am. Water Works Assoc., 53: 589 (1961).

70. Black, A.P. and Christman, R.F. Characteristics of coloured surface waters. J. Am. Water Works Assoc., 55: 753 (1963).

71. Pennanen, V. Humus fractions and their distribution in some lakes in Finland. In: Humic substances, their structure and function in the biosphere. D. Povoledo and H.L. Golterman (eds.). Pudoc, Wageningen, The Netherlands. p. 207 (1975).

72. Atkins, P.F. and Tomlinson, H.D. Evaluation of daily carbon chloroform extracts with CAM. Water Sewage Works, 110: 281 (1963).

73. U.S. Environmental Protection Agency. Method 180.1. EPA/600/R-93/100. Cincinnati, OH (1993).

74. International Organization for Standardization. International Standard 7027. Geneva (1999).

75. GLI International Inc. GLI Method 2. Milwaukee, WI (no date).

76. U.S. Environmental Protection Agency. Hach Filter Trak Method 10133, Determination of turbidity by laser nephelometry. Revision 2.0. Fed. Regist., 67(209), 40 CFR §141.74, 29 October (2002). Description can be obtained from Hach Co., Loveland, CO.

77. Murren, C. Clear thinking on turbidity. Meas. Control, 26: 83–85 (1993).

78. U.S. Environmental Protection Agency. U.S. Code of Federal Regulations, Title 40, Protection of the Environment, Part 141, Section 74 (a)(1) (1989).

79. Eichner, D.W. and Hach, C.C. How clear is clear water. Water Sewage Works, 118: 299 (1971).

80. Traversy, W.J. Turbidity. In: Methods for chemical analysis for waters and wastewaters. Water Quality Division, Inland Waters Branch, Department of Fisheries and Forestry, Ottawa. p. 167 (1971).

81. Burlingame, G.A., Pickel, M.J. and Roman, J.T. Practical applications of turbidity monitoring. J. Am. Water Works Assoc., 90(8): 57–69 (1998).

82. Milstead, J.R., Motley, E.M. and Chiang, V.P. Expectations vs. reality. Proceedings of the American Water Works Association Water Quality Technology Conference, New Orleans, LA (1995).

83. Voss, K. Personal communication. City of Calgary (2003).

84. Beard, J.D. and Tanaka, T.S. A comparison of particle counting and nephelometry. J. Am. Water Works Assoc., 59: 533 (1977).

85. Gammie, L. Particle counting and turbidity in water treatment. In: Proceedings of the 36th Annual Convention, Western Canada Water and Sewage Conference, September (1984).

86. McTigue, N., LeChevallier, M., Arora, H. and Clancy, J. National assessment of particle removal by filtration. American Water Works Association Research Foundation, Denver, CO (1998).

87. Hargesheimer, E.E., Lewis, C.M. and Yentsch, C.M. Evaluation of particle counting as a measure of treatment plant performance. American Water Works Association Research Foundation, Denver, CO (1992).

88. Stumm, W. and O'Melia, C.R. Stoichiometry of coagulation. J. Am. Water Works Assoc., 60: 514 (1968).

89. Stumm, W. and Morgan, J.J. Chemical aspects of coagulation. J. Am. Water Works Assoc., 54: 971 (1962).

90. Cosonery, P.J. Summaries of yearly performance of Pennsylvania's surface water treatment plants. Internal report for the Pennsylvania Department of Environmental Protection, Harrisburg, PA (1995).

91. Cleasby, J.L., Dharmarajah, A.H., Sindt, G.L. and Baumann, E.R. Design and operation guidelines for optimization of the high-rate filtration process: plant survey results. American Water Works Association Research Foundation, Denver, CO (1989).

92. U.S. Environmental Protection Agency. Interim Enhanced Surface Water Treatment Rule. U.S. Code of Federal Regulations Parts 9, 141, and 142 (1998).

93. Stinson, K.B. Treated water forever pure? Water Eng. Manage., 129: 34 (1982).

94. Johnson, M.L. and Doe, P.W. Designing and constructing the Trap Falls water treatment plant. J. Am. Water Works Assoc., 75: 124 (1983).

95. Committee Report. Deterioration of water quality in large distribution reservoirs (open reservoirs). J. Am. Water Works Assoc., 75: 313 (1983).

96. Silverman, G.S., Nagy, L.A. and Olson, B.H. Variations in particulate matter, algae and bacteria in an uncovered, finished drinking water reservoir. J. Am. Water Works Assoc., 75: 191 (1983).

97. Consonery, P.J. and Greenfield, D.N. Filter plant performance evaluation: a summary of procedures and results. Internal report for the Bureau of Water Supply and Community Health, Pennsylvania Department of Environmental Protection, Harrisburg, PA (1991).

98. Johnson, B.A., Gong, B., Bellamy, W. and Fran, T. Pilot plant testing of dissolved air flotation for treating Boston's low turbidity water supply. Water Sci. Technol., 31(3–4): 83–92 (1995).

99. Atherton, T. and Goss, J. Low turbidity water from fast processes. Water Eng. Manage., 128: 40 (1981).

100. Morand, J.M. and Young, M.J. Performance of packaged water treatment plants for small communities. In: Proceedings of the American Water Works Association Seminar on Innovative Filtration Techniques, Las Vegas, NV. p. 129 (1983).

101. Logsdon, G.S. Comparison of some filtration processes appropriate for *Giardia* cyst removal. Presented at Calgary *Giardia* Conference, Calgary, Alberta, 23–25 February. Drinking Water Research Division, U.S. Environmental Protection Agency (1987).

102. U.S. Environmental Protection Agency. National Primary Drinking Water Regulations: Interim Enhanced Surface Water Treatment Rule Notice of Data Availability; Proposed Rule. Fed. Regist., 62(212): 59500–59501 (1997).

103. U.S. Environmental Protection Agency. National Primary Drinking Water Regulations: Long Term 1 Enhanced Surface Water Treatment and Filter Backwash Rule; Proposed Rule. Fed. Regist., 65(69): 19063–19068 (2000).

104. Fox, K.R., Miltner, R.J., Logsdon, G.S., Dicks, D.L. and Drolet, L.F. Pilot plant studies of slow-rate filtration. J. Am. Water Works Assoc., 76(12): 62–68 (1984).

105. Cleasby, J.L., Hilmoe, D.J. and Dimitracopoulos, C.J. Slow sand and direct in-line filtration of a surface water. J. Am. Water Works Assoc., 76(12): 44–45 (1984).

106. Pyper, G.R. Slow sand filter and package treatment plant evaluation: Operating costs and removal of bacteria, *Giardia* and trihalomethanes. EPA/600/2-85/052. U.S. Environmental Protection Agency, Cincinnati, OH (1985).

107. Slezak, L.A. and Sims, R.C. The application and effectiveness of slow sand filtration in the United States. J. Am. Water Works Assoc., 76(12): 38–43 (1984).

108. Bellamy, W.D., Silverman, G.P. and Hendricks, G.W. Filtration of *Giardia* cysts and other substances. Vol. 2. Slow sand filtration. EPA 600/2-85/026. U.S. Environmental Protection Agency, Cincinnati, OH (1985).

109. Lange, K.P., Bellamy, W.D., Hendricks, D.W. and Logsdon, G.S. Diatomaceous earth filtration of *Giardia* cysts and other substances. J. Am. Water Works Assoc., 78(1): 76–84.

110. Logsdon, G.S., Symons, J.M., Hoye, R.L., Jr. and Arozarena, M.M. Alternative filtration wetlands for removal of *Giardia* cysts and cyst models. J. Am. Water Works Assoc., 73(2): 111–118.

111. Jacangelo, J.G. The development of membrane technology. International Report (IR3). Water Supply: Rev. J. Int. Water Supply Assoc., 9(3/4) (1991).

112. Taylor, J.S., Duranceau, S.J., Barrett, W.M. and Goigel, J.F. Assessment of potable water membrane applications and research needs. Prepared for the American Water Works Association Research Foundation, Denver, CO (1990).

113. Jacangelo, J.G., Laine, J.M., Carns, K.E., Cummins, E.W. and Mallevialle, J. Low pressure membrane filtration for removing *Giardia* and microbial indicators. J. Am. Water Works Assoc., 83(9): 97–106 (1991).

114. Clark, M.M. Ultrafiltration of lake water: Optimization of TOC removal and flux: influence and removal of organics in drinking water. Lewis Publishers, Boca Raton, FL (1992).

115. Schwartz, J., Levin, R. and Goldstein, R. Drinking water turbidity and gastrointestinal illness in the elderly of Philadelphia. J. Epidemiol. Community Health, 54(1): 45–51 (2000).

116. LeChevallier, M.W., Norton, W.D. and Lee, R.G. Occurrence of *Giardia* and *Cryptosporidium* spp. in surface water supplies. Appl. Environ. Microbiol., 199(57): 2610–2616 (1991).

117. Morris, R.D., Naumova, E.N., Levin, R. and Munasinghe, R.L. Temporal variation in drinking water turbidity and disguised gastroenteritis in Milwaukee. Am. J. Public Health, 86(2): 237–239 (1996).

118. Lin, S.D. *Giardia lamblia* and water supply. J. Am. Water Works Assoc., 77: 40 (1985).

119. American Water Works Association. AWWA statement of policy: quality goals for potable water. J. Am. Water Works Assoc., 60: 1317 (1968).

120. Committee Report. Waterborne disease in the United States and Canada. J. Am. Water Works Assoc., 73: 528 (1981).

121. Aramini, J., McLean, M., Wilson, J., Holt, J., Copes, R., Allen, B. and Sears, W. Drinking water quality and health care utilization for gastrointestinal illness in Greater Vancouver. Canada Communicable Disease Report 26-24. Health Canada, Ottawa, 15 December (2000).

122. Hudson, H.E. High-quality water production and viral disease. J. Am. Water Works Assoc., 54: 1265 (1962).

123. Shaffer, P.T.B., Metcalf, T.G. and Sproul, O.J. Chlorine resistance of poliovirus isolants recovered from drinking water. Appl. Environ. Microbiol., 40: 1115 (1980).

124. Taylor, F.B., Eagen, J.H., Smith, H.F.A., Jr. and Coene, R.F. The case for water-borne infectious hepatitis. Am. J. Public Health, 56: 2093 (1966).

125. Dennis, J.M. 1955–56 infectious hepatitis epidemic in Delhi, India. J. Am. Water Works Assoc., 51: 1288 (1959).

126. Eckert, C. Personal communication. Alberta Environment (2003).

Appendix A: Determining if Groundwater Is Under the Direct Influence of Surface Water[126]

Determining whether groundwater is under the influence of surface water is a complex process. While there is considerable variation in the circumstances that may result in groundwater becoming contaminated with surface water, some key issues that should be considered include the following:

Geology

- ❑ What are the characteristics of the aquifer deposit (i.e., lithology, stratigraphy and structure)?
- ❑ How was the deposit created (i.e., geomorphology)?
- ❑ What is the age of the deposit?
- ❑ Is it a confined, semi-confined or unconfined aquifer?
- ❑ If the aquifer was created during a recent geologic event (i.e., alluvial deposits/post-glaciation), is it likely to be connected to an existing surface water body? Is it susceptible to land surface use and influences? What are the consequences? What is the level of risk?
- ❑ If the aquifer was created during an ancient geologic event (i.e., unconsolidated deposits or bedrock deposits/pre-glaciation), is it likely to be connected to an existing surface water body? Is it susceptible to land surface use and influences? What are the consequences? What is the level of risk?
- ❑ What are the effects of local topography (e.g., mountains, foothills, plains)?
- ❑ What are the effects of local geology and geologic events (i.e., facies changes, complex geology, glaciation)?

Hydrogeology

- ❑ Do the aquifer characteristics (i.e., hydraulic head, intrinsic permeability, hydraulic conductivity, transmissivity, storitivity) imply direct surface water and/or land surface influence(s)?
- ❑ Is there evidence of local surface water "discharge/recharge" to/from the aquifer?
- ❑ What is the direction of groundwater flow (i.e., hydraulic gradient)?
- ❑ What is the consequence of pumping groundwater from the aquifer (cone of influence)? Is there a change in gradient?

Hydrochemistry

- ❑ Is there evidence of water quality similarities between the aquifer and surface water (i.e., chemistry, temperature, bacterial count)?
- ❑ Is there evidence through environmental isotope analysis (^{3}H, ^{14}C, ^{18}O, ^{2}H)?
- ❑ What is the chemical age of the groundwater (i.e., mineralization)? How does it compare with that of the local surface water?
- ❑ Is there evidence of a hydrochemical facies change?
- ❑ What is the level of bacterial contamination in the aquifer?

Land use issues

- ❑ What types of local land use are there (e.g., agricultural, industrial, municipal, recreational)?

Soil horizon

- ❑ What type of soil is there?

Tools for making the assessment

- ❑ Cross-sections, isopach maps, topographic maps and geological maps
- ❑ Aquifer pumping test, groundwater modelling and groundwater monitoring (observation wells, piezometers), soil percolation tests
- ❑ Local water balance exercises (groundwater vs. surface water recharge/discharge)
- ❑ Isotope analysis

APPENDIX #8
Water Sample Results

04-4653-2000

04-4403

Nunavut

Community and Government Services
Government of Nunavut (Kitikmeot Region)
P.O. Bag 200, Cambridge Bay, NU X0B 0C0

To: **Gary Strong, P.Eng.**
Dillon Consulting Ltd.
Suite 303-4920 - 47 th. Street
Yellowknife, NT X1A 2P1
Phone: (867) 920-4555
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From: Tom Livingston, P.Eng.
tlivingston@gov.nu.ca
Phone: (867) 983-4156
Fax: (867) 983-4123
Date: 17-Mar-05
Pages (including cover): 3

☐ Urgent ☑ For Review ☐ Please Comment ☐ Please Reply ☐ Please Recycle

Project Number: 04-4403
Project Title: Pump House/Elect Panel/Water Supply Study Taloyoak

Re: Water Quality Results

Comments: Hi, Gary,

Here are the two INAC reports: Aug, 1998 and Aug, 2001

Sincerely,

Tom Livingston, P.Eng.

Indian and Northern Affairs Canada | Affaires indiennes et du Nord Canada

INAC, Nunavut District Office
P.O. Box 100
Iqaluit, NU
X0A 0H0

tel.: (867) 975-4275
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Your file Votre référence

Our file Notre référence
unlicenced

October 19, 2001.

Louis M. Primeau
Senior Administrative Officer
Hamlet of Taloyoak
P.O. Box 8
Taloyoak, NU X0E 1B0

August 14, 2001 Municipal Water Use Inspection - Report

Firstly, I wish to thank Bob Hammond and Sampson Ittungna for their much appreciated time and assistance provided during the tour of the Hamlet's water use and waste disposal facilities. Attached for your records is the Municipal Water Use Inspection Report pertaining to the August 14, 2001 inspection; overall, the facilities appear efficiently managed. Nonetheless, the following considerations were noted and ought to be addressed:

- **Water supply:** Several improvements to the water intake and supply facilities have been undertaken in the recent past, and as such no concerns were noted with the water supply system. However, uneasiness over the proximity of commercial and residential buildings was voiced during the inspection, and it was suggested that signs outlining Water Lake as the municipal potable water supply be posted in efforts to limit the level of activity in the immediate area. This being said, the attached analytical results relating to a sample taken in the vicinity of the intake facility (figure 1) indicate that all tested parameters meet the *Guidelines for Canadian Drinking Water Quality*.

- **Sewage disposal:** The considerable volume of the sewage treatment facility (figure 2), coupled to the extensive vegetation growth along the path of discharge from the site (figure 3), seemingly provides adequate sewage effluent treatment. Accordingly, the attached analytical results relating to a sample collected at the outlet of the sewage disposal facility reveal that tested parameters comply with the *Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life*, save for pH (field value of 10.1 versus the 9.0 threshold). Nevertheless, the Microtox sample, which constitutes a reliable toxicity indicator (IC_{50}), shows that half of light-producing bacteria were inhibited by a sample concentration of 21.6%, whereas 50% and over is considered non-toxic. Thus, in an attempt to pinpoint the cause of the toxicity attributed to the sewage effluent discharge, a wider range of parameters will be sampled during the next municipal water use and waste disposal inspection.

- **Solid waste disposal:** Household combustible wastes are regularly burnt and periodically covered (figure 4); however, since the solid waste disposal facility is unfenced, windblown wastes are nonetheless noticeable beyond the perimeter of the site. Consequently, it was mentioned that a fencing project had been approved during the previous year, and that the required materials were awaited on the summer's sealift. At the time of the inspection, no flowing leachate was noted, although an apparent path of runoff from the toe of the facility could be observed (figure 5). Further, bulky metal wastes (figure 6) and hazardous materials such as batteries are segregated from the combustible wastepile and set aside for eventual disposal.

In related matters, the quantity of waste oil stored on-site poses some concerns in terms of possible deposits of waste into waters. Indeed, ground staining was visible at the waste oil storage area (figure 7). In particular, the storage site of the P-50 heating oil recovered from Spill 98-094 (figure 8) implies the potential for significant hydrocarbon contamination; in fact, signs of recent spillage were noted during the inspection (figure 9). In this regards, it was underlined at the time of the inspection that the hamlet cannot absolve itself from all responsibilities since the material recuperated from Spill 98-094 is stored within the footprint of the municipal solid waste disposal facility. Therefore, the hamlet may wish to consider means of waste oil disposal beneficial to both parties involved.

- **Non-compliance of Act or Licence:** The Hamlet does not currently hold the Water licence it requires under the *Northwest Territories Waters Act* and the *Nunavut Land Claims Agreement* for its municipal water use and waste disposal. Consequently, a licence application form was provided during the inspection, and the Inspector points out that INAC and/or other agencies can provide assistance in order to facilitate its prompt submission to the Nunavut Water Board.

Please feel free to contact me at (867) 975-4298 or lavalleep@inac.gc.ca should any questions/comments arise.

Sincerely,

Philippe Lavallée
Water Resources Officer
INAC, Nunavut District

c.c. - Nunavut Water Board, Gjoa Haven
- CG&T, Cambridge Bay (Sherif El-Attar)
- Kitikmeot Health & Social Services, Cambridge Bay (Robert Phillips)
- EC Environmental Protection, Yellowknife (Anne Wilson)

Indian and Northern Affairs Canada / Affaires Indiennes et du Nord Canada

MUNICIPAL WATER USE INSPECTION FORM

Date: 2001/08/14 **Licensee Rep. (Name/Title):** Bob Hammond / Maintenance Director
Sampson Ittungna / Head Mechanic, acting-Foreman

Licensee: Hamlet of Taloyoak **Licence No.:** unlicenced

WATER SUPPLY

Source(s): Water Lake **Quantity used:** recorded @ truck delivery

Owner:/Operator: Hamlet

Indicate: A - Acceptable U - Unacceptable NA - Not Applicable NI - Not Inspected

Intake Facilities: A **Storage Structure:** A **Treatment Systems:** A **Chemical Storage:** A

Flow Meas. Device: NA **Convey. Lines:** A **Pumping Stations:** A

Comments: No concerns noted with the well-maintained water intake and supply facilities. New fiberglass storage tank recently commissioned. Replacement of copper conveyance line has solved recurring freeze-up problems. Continuous water circulation; flow is diverted back to the source when storage capacity is topped. Chlorination in use.

WASTE DISPOSAL

Sewage: **Sewage Treatment System (Prim./Sec/Ter.):** primary; discharge overland to ocean

Natural Water Body: x **Continuous Discharge (land or water):**

Seasonal Discharge: x **Wetlands Treatment:** x **Trench:**

Solid Waste: **Owner/Operator:** Hamlet

Landfill: **Burn & Landfill:** x **Other:**

Indicate: A - Acceptable U - Unacceptable NA - Not Applicable NI - Not Inspected

Discharge Quality: sampled **Decant Structure:** NA **Erosion:** A

Discharge Meas. Device: none **Dyke Inspection:** NA **Seepages:** NA

Dams, Dykes: NA **Freeboard:** NA **Spills:** none reported

Construction: NA **O&M Plan:** NA **A&R Plan:** NA

Periods of Discharge: A **Effluent Discharge Rate:** not measured

Comments: Considerable vegetation growth noticeable along the path of discharge from the sewage disposal facility. Bulky metal and hazardous wastes are segregated from household wastes at the unfenced solid waste disposal facility. Combustible wastes are burnt regularly, then pushed towards the toe of the dump; wastepile covered on a roughly annual basis. No flow of leachate observed along the likely path of runoff from the solid waste disposal facility. Signs of spillage at the waste oil storage site. Substantial quantity of P-50 heating oil recovered from Spill 98-049 stored along the fringe of the solid waste disposal facility; some signs of recent spillage noted. Bermed landfarming facility for hydrocarbon-contaminated soil also present.

FUEL STORAGE

Owner/Operator:

Indicate: A - Acceptable U - Unacceptable NA - Not Applicable NI - Not Inspected

Berms & Liners: **Water within Berms:** **Evidence of Leaks:**

Drainage Pipes: **Pump Station & Catchment Berm:**

Pipeline Condition: **Not Applicable:** x **Condition of Tanks:**

SURVEILLANCE NETWORK PROGRAM (SNP)

Samples Collected **Hamlet:** raw water to be sampled later in the summer

INAC: raw water @ Water Lake, sewage discharge @ outlet of second lake

Signs Posted **SNP:** not applicable **Warning:** none

Records & Reporting: not applicable

Geotechnical Inspection: not applicable

Non-Compliance of Act or Licence: Community is unlicenced.

Philippe Lavallée
Inspector's Name

[signature]
Inspector's Signature

Taiga Environmental Laboratory
4601-52nd Ave., Box 1500, Yellowknife, NT. X1A 2R3
Tel: (867)-669-2788
Fax: (867)-669-2718

- CERTIFICATE OF ANALYSIS -

Prepared For: Nunavut District Office DIAND, Operations ***Attn:*** Philippe Lavalllee

Sample ID: raw water **Taiga Sample ID:** 212069

Client Project: **Sample Type:** raw water **Received Date:** 15-Aug-01

Location: Teloyoc **Sampling Date:** 14-Aug-01

Report Status: **Final** ***Approved by:***

Lab Section	Test Parameter	Result	Units	Detection Limit	Analysis Date
Major Ions	Sodium	8.31	mg/L	0.02	15-Aug-01
Microbiology	Coliforms, Fecal	<1	CFU/100mL	1	15-Aug-01
Nutrients	Ammonia as N	0.013	mg/L	0.005	30-Aug-01
	Biological Oxygen Demand	<2	mg/L	2	15-Aug-01
	Nitrate+Nitrite as N	<0.008	mg/L	0.008	21-Aug-01
Physicals	Colour	<5		5	15-Aug-01
	Solids, Total Dissolved	98	mg/L	10	04-Sep-01
	Turbidity	0.5	NTU	0.1	15-Aug-01
Subcontract	Chloride	15.0	mg/L	0.1	13-Sep-01
	Sulphate	4	mg/L	0	13-Sep-01
Total Metals	Arsenic	<1.0	µg/L	1	07-Sep-01
	Cadmium	<0.3	µg/L	0.3	21-Aug-01
	Chromium	<3	µg/L	3	21-Aug-01
	Cobalt	<1	µg/L	1	21-Aug-01
	Copper	<2	µg/L	2	21-Aug-01
	Iron	<30	µg/L	30	20-Aug-01

Report Date: Monday, September 24, 2001

Taiga Environmental Laboratory
4601-52nd Ave., Box 1500, Yellowknife, NT. X1A 2R3
Tel: (867)-669-2788
Fax: (867)-669-2718

- CERTIFICATE OF ANALYSIS -

Prepared For: Nunavut District Office DIAND, Operations ***Attn:*** Philippe Lavalllee

Sample ID: Sewage Discharge **Taiga Sample ID:** 212070

Client Project: **Sample Type:** sewage **Received Date:** 15-Aug-01

Location: Teloyoc **Sampling Date:** 14-Aug-01

Report Status: **Final** ***Approved by:***

Test Parameter	Result	Units	Detection Limit	Analysis Date
Physicals				
Solids, Total Suspended	170	mg/L	3	04-Sep-01
Nutrients				
Ammonia as N	0.103	mg/L	0.005	30-Aug-01
Biological Oxygen Demand	52	mg/L	2	15-Aug-01
Nitrate+Nitrite as N	0.031	mg/L	0.008	21-Aug-01
Phosphorous, Total	3.29	mg/L	0.004	26-Sep-01
Microbiology				
Coliforms, Fecal	<10	CFU/100mL	10	16-Aug-01
Subcontracted Tests				
Phenols	<2	µg/L	2	13-Sep-01

Field Data (01/08/14) sewage
Temperature: 12.5 °C
Conductivity: 782 µS/cm
pH: 10.1 **Time:** 13:26

Report Date: Wednesday, October 03, 2001

Taiga Environmental Laboratory
4601-52nd Ave., Box 1500, Yellowknife, NT. X1A 2R3
Tel: (867)-669-2788
Fax: (867)-669-2718

- CERTIFICATE OF ANALYSIS -

Prepared For: Nunavut District Office DIAND, Operations ***Attn:*** Philippe Lavalllee

Sample ID: raw water **Taiga Sample ID:** 212069

Total Metals	Lead	<1	µg/L	1	21-Aug-01
	Manganese	1	µg/L	1	21-Aug-01
	Mercury	<0.01	µg/L	0.01	13-Sep-01
	Nickel	2	µg/L	1	21-Aug-01
	Zinc	<10	µg/L	10	21-Aug-01

Field Data (01/08/14) raw water
Temperature: 14.5 °C
Conductivity: 205 µS/cm
pH: 8.3 **Time:** 12:19

Report Date: Monday, September 24, 2001

REPORT OF TOXICITY USING MICROTOX

COMP...NY/LOCATION: **Taloyoak Lagoon Discharge**

Sample Collected By: Philippe Lavallee

Date/Time Sampled: August 14, 2001 13:26

Date/Time Received: August 15, 2001

Date/Time Test Start: August 15, 2001

Sample Type: Elutriate
Sampling Method: Grab

Method: ***Environment Canada Laboratories SOP#830.0 Revision 1, for Microtox Testing in Compliance with November 1992: Biological Test Method: Toxicity Test Using Luminescent Bacteria Photobacterium phosphoreum), November 1992, EPS 1/RM/24.***

Environment Canada has conducted testing on the material sampled according to its own Microtox standards and procedures. The data proceeding from that testing is intended as a preliminary screening tool only, and cannot be used for any other purpose. This data is provided on the condition that it not be used in any report that is intended for public or official use.

RESULTS: **TOXIC - IC_{50} Concentration: 21.6%** **(Toxic 0 to 50%)**

TEST ORGANISMS:
Species: Vibrio fisheri (Photobacterium phosphoreum)
Test Apparatus: Model 500 Analyzer

TEST SUBSTANCE/CONDITIONS

pH of Sample: (No pH adjustment)

Sample Appearance: no colour adjustment

Lot # of Osmotic Adjusting Solution: OAS007

Lot # of Reconstitution Solution: RSN099Y

Lot # of Diluent: DIL034L

TEST METHODS AND CONDITIONS

Test Start Date/Time: August 15, 2001 / 01:47 PM

Test Method: Basic 45% Test, 15 minute incubation.

QUALITY CONTROL

Reference Toxicant: Zinc Sulfate Standard

IC_{50} - 15 minutes mg/L: 2.4 mg/L

Reagent Lot #: ACV026-6

IC_{50} Confidence Range: 1.6 to 3.6 mg/L

TEST ANALYST: Ron Bujold

INITIAL: RB

Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

DIAND Nunavut District
Box 100
Iqaluit, NT
XOA OHO

RECEIVED
DEC 1 1 1998
DEPT. OF MUNICIPAL COMMUNITY AFFAIRS
Your file Votre référence

Our file Notre reference

NWB3TAL

November 30, 1998

Mr. David Irquit
A/Senior Administrative Officer
Hamlet of Taloyoak
Taloyoak, NT
X0E 1B0

Dear Mr. Irquit;

Water Management Inspection; August 25, 1998
and Results of Water Samples Collected.

1. Please find enclosed the inspection report prepared as a result of the water management inspection carried out on August 25, 1998. In addition, also enclosed are the analytical results of water samples collected during the inspection.

2. As the Hamlet has now applied for a water licence, my main concern has been addressed. There remain only some operational problems which the Hamlet can work to resolve.

3. To summarize the inspection report, the areas that the Hamlet is asked to address relate to:

   - placing a fence (with appropriate warning signs) along the shore of the water lake where the community is close. The purpose of the fence would be to reduce wind blown garbage and traffic from impacting on the quality of the water supply.

   - obtaining a waste oil furnace to dispose of the accumulated waste oil.

   - placing a thin granular cap on the dump on an annual basis to reduce wind blown material and to improve on the aesthetics and health & safety aspects of the site.

   - warning signs are required at the dump and sewage waste disposal sites.

4. With respect to the analytical results of water samples collected during the inspection, I collected three samples. One set was raw potable water, one set was sewage effluent (where it enters the ocean) and the final set was runoff from the dump (leachate). There were no concerns with the raw water. The sewage effluent sample returned very low levels of ammonia and suspended solids. This likely indicates that there is significant natural treatment of sewage before it discharges into the ocean.

5. If you have any questions about the inspection report or about the analytical results, please do not hesitate to contact me at the above address or by phone at (867)979-4405.

Sincerely,

Paul Smith
Water Resources Officer
Nunavut District

cc. - Nunavut Water Board, Gjoa Haven
- DIAND Water Resources, YK
- Kojo Kumi, MACA, Cambridge Bay
- Bob Philips, Environmental Health, Yellowknife

TAIGA ENVIRONMENTAL LABORATORY
Dept. Indian Affairs & Northern Development
4601-52 nd Ave., Box 1500
Yellowknife, NT. X1A 2R3
Tel. (867) 669-2788
Fax: (867) 669-2718

To: NUNAVUT
WATER RESOURCES, NAP, DIAND
BOX 100

IQALUIT X0A 0H0
Att'n: PAUL SMITH

LAB# 981428

SAMPLE INFORMATION

Our Lab#: 981428
Your Sample ID: SEWAGE EFFLUENT
Sample Matrix: SEWAGE

PROJECT: INSPECTION

Collection:
Location: TALOYOAK
Date: 8/25/1998
By: P.Smith

Received Date: Aug-28-1998
Report Date: 11-Sep-98
Approved By:

- SAMPLE ANALYSIS REPORT -

Lab#	Test	Result	Units	Detection Limit	Analysis Date	Analytical Method
981428						
	Tot-Suspended-Solids	4	mg/L	3	9/10/1998	grav
	Ammonia-N	0.013	mg/L	0.002		007562
	Tot-Cadmium(ICP-MS)	L0.1	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Cobalt(ICP-MS)	0.3	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Chromium(ICP-MS)	2.6	ug/L	2.0	9/2/1998	ICP-MS
	Tot-Copper(ICP/MS)	3.2	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Iron(AA)	0.590	mg/L	0.020	9/1/1998	ICP-MS
	Tot-Manganese(ICP-MS)	36.8	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Nickel(ICP-MS)	2.6	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Lead(ICP-MS)	L0.2	ug/L	0.2	9/2/1998	ICP-MS
	Tot-Zinc(ICP-MS)	23.2	ug/L	10.0	9/2/1998	ICP-MS

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Fax: (867) 669-2718

To: NUNAVUT
WATER RESOURCES, NAP, DIAND
BOX 100

IQALUIT X0A 0H0
Att'n: PAUL SMITH

LAB# 981430

SAMPLE INFORMATION

Our Lab#: 981430
Your Sample ID: RAW WATER
Sample Matrix: WATER

PROJECT: INSPECTION

Collection:
Location: GJOA HAVEN
Date: 8/24/1998
By: P.Smith

Received Date: Aug-28-1998
Report Date: 11-Sep-98
Approved By: [signature]

- SAMPLE ANALYSIS REPORT -

Lab#	Test	Result	Units	Detection Limit	Analysis Date	Analytical Method
981430						
	pH	7.89	pH	0.05	8/28/1998	010301
	Colour	10		5.0	8/28/1998	02021
	Conductivity	265	uS/cm	0.3	9/4/1998	02041
	Alkalinity	89.2	mg/L	0.3	9/4/1998	010101
	Tot-Suspended-Solids	6	mg/L	3	9/10/1998	grav
	Tot-Cadmium(ICP-MS)	L0.1	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Cobalt(ICP-MS)	0.1	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Chromium(ICP-MS)	L2	ug/L	2.0	9/2/1998	ICP-MS
	Tot-Copper(ICP/MS)	1.4	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Manganese(ICP-MS)	8.9	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Iron(AA)	0.470	mg/L	0.020	9/1/1998	ICP-MS
	Tot-Nickel(ICP-MS)	0.7	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Lead(ICP-MS)	0.2	ug/L	0.2	9/2/1998	ICP-MS
	Tot-Zinc(ICP-MS)	L10	ug/L	10.0	9/2/1998	ICP-MS

TAIGA ENVIRONMENTAL LABORATORY
Dept. Indian Affairs & Northern Development
4601-52 nd Ave., Box 1500
Yellowknife, NT. X1A 2R3
Tel. (867) 669-2788
Fax: (867) 669-2718

To: NUNAVUT
WATER RESOURCES, NAP, DIAND
BOX 100
IQALUIT X0A 0H0
Att'n: PAUL SMITH

LAB# 981431

SAMPLE INFORMATION

Our Lab#: 981431
Your Sample ID: DUMP LEACHATE
Sample Matrix: WATER

PROJECT: INSPECTION

Collection:
Location: GJOA HAVEN
Date: 8/24/1998
By: P.Smith

Received Date: Aug-28-1998
Report Date: 11-Sep-98
Approved By: [signature]

- SAMPLE ANALYSIS REPORT -

Lab#	Test	Result	Units	Detection Limit	Analysis Date	Analytical Method
981431						
	Tot-Suspended-Solids	34	mg/L	3	9/10/1998	grav
	Ammonia-N	27.6	mg/L	0.002		007562
	Tot-Mercury(water)	L0.01	ug/L	0.01	8/31/1998	080314
	Tot-Cadmium(ICP-MS)	2.1	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Cobalt(ICP-MS)	1.9	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Chromium(ICP-MS)	8.2	ug/L	2.0	9/2/1998	ICP-MS
	Tot-Copper(ICP/MS)	84.2	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Manganese(ICP-MS)	534	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Iron(AA)	5.84	mg/L	0.020	9/1/1998	ICP-MS
	Tot-Nickel(ICP-MS)	17.8	ug/L	0.1	9/2/1998	ICP-MS
	Tot-Lead(ICP-MS)	54.1	ug/L	0.2	9/2/1998	ICP-MS
	Tot-Zinc(ICP-MS)	1260	ug/L	10.0	9/2/1998	ICP-MS

Taloyoak Water System Site Investigation And Remedial Action Plan

Report

Monday, December 13, 2004

Taloyoak Water System
Site Investigation
And Remedial Action Plan

Client: Tom Livingston, G&GS, GNU

PN: 043653 - 3000

Tim Hubbard - Project Manager

Submitted by

Dillon Consulting Limited

File Reference: R:\PROJECTS\DRAFT\043653\Task 3000\Report - Taloyoak Water Main Freeze Ups.Doc

(In reply, please refer to)
Our File: 04-3653

Date: Monday, December 13, 2004

Government of Nunavut, Kitikmeot Region
Community and Government Services,
Second floor, Enhokok Centre
Cambridge Bay,
Nunavut, X0B 0C0

Attention: Thomas G. Livingston, BA, B.A.Sc, B.Eng, P.Eng.
Regional Municipal Planning Engineer (Acting)
Project Officer

Re: Taloyoak Water System Site Investigation and Remedial Action Plan

Dear Mr. Livingston,

Please find enclosed our report on a recent site visit to Taloyoak.

Yours Sincerely,

DILLON CONSULTING LIMITED

Timothy M Hubbard
Project Engineer

Encl.

DILLON CONSULTING

4920
47th Street
Suite 303
Box 1409
Yellowknife
Northwest Territories
Canada
X1A 2P1
Telephone
(867) 920-4555
Fax
(867) 873-3328

Dillon Consulting Limited

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APPENDICES

EXECUTIVE SUMMARY

During the month of November, the Hamlet of Taloyoak experienced several freeze-ups on its water main. As per the instructions of Tom Livingston, Project Officer for the Government of Nunavut, Community and Government Services, Dillon Consulting Limited (Dillon) was retained to travel to Taloyoak to rectify the situation. Present during the site trip were Tim Hubbard (Dillon), Andy Herrera (Electrician – Kitnuna), Terry Tregidgo (Mechanical Services – Northland Plumbing & Heating).

Dillon was on site for a period of one week. Several control components were found to be faulty. These faulty components were causing the intake pump to stop. Sometimes when trips occurred, there was no response from the Hamlet maintenance staff to the call-out alarms. The line is designed to drain in the event of no flow, but the solenoid valves designed to allow the water to drain were faulty, and even when these valves are functioning, there are portions of the line that do not appear to drain. The combination of these circumstances was responsible for the line freeze-ups.

The faulty components were replaced or eliminated from the circuit and the pump stoppages have not reoccurred to date.

Attention was also focused on verifying that water system malfunctions always receive a response.

Since my visit there has been one malfunction with the pump (not a trip), but it was responded to by the Hamlet staff and the pipeline did not freeze-up.

One of the components to be removed was the 60 Amp GFI breaker. S. Edgerton, the S.A.O., does not wish to have this component reintroduced into the system until the weather is such that freeze-ups are not a possibility.

The Hamlet is also purchasing a new pump. There has been a degree of uncertainty as to what size pump they intend to install. This uncertainty has led to some difficulty in writing the report, as the situation is still under consideration.

1. INTRODUCTION

On November 22nd, 2004, Tom Livingston, Project Officer for the Government of Nunavut, Community and Government Services, contacted Dillon Consulting Limited (Dillon) and spoke with Timothy M. Hubbard, Mechanical Engineer. The Hamlet of Taloyoak was experiencing severe problems with their water transmission system, and had experienced several freeze-ups over the past weeks.

Dillon was asked to mobilize to Taloyoak and assist the Hamlet in re-establishing a reliable water transmission system. Dillon would be assisted in this work by Andy Herrera (Electrician – Kitnuna), Terry Tregidgo (Mechanical Services – Northland Plumbing & Heating), and the Hamlet Maintenance Personnel (Directed by Bob Hoddinott). Dillon was also asked to collect information on the system so that the following documentation could be produced:

1. A current set of Schematic Drawings
2. A revised O&M Manual.
3. A Request for Tender (RFT) for a short term upgrade to increase the capacity of the system.
4. A Request for Proposal (RFP), for the design of an entirely new water transmission and treatment system.

Dillon was on site from November 25th 2004 to December 1st, 2004. In that time, a number of problems were identified on the system, the majority of which were rectified. Upon departure, the water system had been thoroughly tested and was fully operational, although there were several maintenance items outstanding. Also, a major element of the electrical control system, the Ground Fault Interrupter Breaker, has been temporarily disconnected because there were strong indications that it may have been unreliable.

2. Daily Log

2.1 Day 1 – November 25th 2004

Arrived in Taloyoak by midday. Inspected the system and found that the flow meter was non-operational. Had Little Mike strip it down and discovered the turbine was blocked by pieces of corrosion, probably iron oxide. Cleaned and reassembled the meter and found that it functioned.

Determined that the flow rate to the tank had decreased by 12% (89.4 l/min to 78.7 l/min) since an August 17th visit. Tracked this problem down to the tank-fill solenoid valve, which was not opening correctly, and to a change in the return line.

It was a concern that an intake pump trip could be induced by simulating the tank full condition. This was a definite change in the system's response since the previous visit.

2.2 Day 2 – November 26th 2004

Determined that the flow switch was causing the pump to trip when the system was in tank full mode. Took this sensor out of the control loop and continued to test system. Found that the system was less sensitive to tripping, but it did trip occasionally. Took the small GFI breaker out of the circuit and was no longer able to induce pump trips.

Two of the drain solenoids had also failed.

Tested the alarm dialler by stopping the pump and confirmed that it dialled out.

2.3 Day 3 – November 27th 2004

Discovered the pump had stopped during the night and the line was frozen. It was reported that the large GFI had tripped. Spent remainder of day involved in the efforts to thaw the line.

The four legs of the water system were in the following condition:

IPH to Boothia:	Supply Line Open
IPH to Boothia:	Return Line Lightly Frozen
Boothia to WTP:	Supply Line Heavily Frozen
Boothia to WTP:	Return Line Lightly Frozen

State of the solenoid valves:

IPH Supply Line:	Solenoid Valve OK
IPH Return Line:	No Solenoid Valve – but this line is open to drain
WTP Supply Line:	Solenoid failed – line does not drain
WTP Return Line:	Solenoid Valve OK

As one would expect, there is a reasonable correspondence between the degree of ice in the lines and the state of the drain solenoids; however, it is disturbing that the lines with working solenoids and the line open to drain had any ice at all. This suggests that the drain system is less than 100% effective. This is further confirmed by the presence of wet/dry vacuum cleaners at each end of the line, which are used to clear the lines of water and test for blockages. The vacuum release valves in the Boothia allow air into the system, and can be monitored when testing.

At all times the intake pump was kept running. This was simply to circulate water in the intake pipe and casing, so as to prevent freezing.

There were some existing valves under the Boothia that allowed partial manipulation of the pipe lines. This system was modified so that any of the four legs could be isolated and, so that it would be possible to cross link the legs.

At 9:00pm a warm water feed was run from the WTP to the IPH through the following legs:

WTP to Boothia: Return Line
Boothia to IPH: Supply Line

This warm water was drained down the intake casing.

Bob (Hamlet Maintenance Supervisor), Terry (Plumber), Andy (Electrician) and Tim kept a watch on the pump overnight.

2.4 Day 4 – November 28th 2004

In the morning, it was noticed that the intake pump supply breaker tripped. This is not a GFI breaker. Over the course of the next hour, this breaker tripped two more times. It had been assumed that this was a 30 amp breaker, but close inspection revealed that it was actually rated at 20 amps. The pump was drawing between 19 and 19.5 amps. Previous to this, there had been no trips on this breaker, but the pump house was considerably warmer than usual because of the warm water feed from the WTP. It was felt that this high ambient temperature was enough to cause this heavily loaded breaker to trip.

Time was spent searching for a 30 amp breaker but it wasn't possible to find one that was suitable for the panel. As a temporary measure, two 20 amp breakers were wired in parallel.

In the afternoon, it was determined all the lines were free of ice and the decision was made to put the system back into operation. Within several minutes of pumping water, it was reported that the main GFI breaker had tripped. This was reset and pumping continued until it became apparent that there was a significant leak in the line.

The line was drained down and vacuumed so that it was completely free of water.

The pump was put back into recirculation mode.

A watch was kept on the pump through the night.

2.5 Day 5 – November 29th 2004

It was discovered that the line had broken immediately behind the WTP, inside the Power Corporation compound. At this point, the line contains two 90° bends and is copper tube rather than HDPE, which is the material used for the rest of the line.

Hamlet employees worked to repair the damage despite a relatively severe blizzard.

A test on the Intake Pump was carried out, and it was found to be delivering water at an acceptable pressure and flow rate.

On the electrical side, it was determined to replace the distribution board in the IPH, as we could not find a breaker to fit the existing board.

A modification was made to the Pressure/Flow protection circuit that prevented the pump cycling on and off in a highly destructive fashion.

2.6 Day 6 – November 30th 2004

The repair of the line was completed and a new distribution board was installed in the pump house.

The main (60 amp) GFI breaker was bypassed and the 100 amp main breaker on the new board was used as the main disconnect. This wiring modification is not intended to be permanent, but as the Hamlet staff have been reporting trips on this GFI breaker since it's installation and it was reported that it had tripped twice during the visit - on one occasion causing the line to freeze - it was felt that if the Hamlet were to have a reliable water supply, disconnecting it was the only available option.

There are several possible scenarios as to why the GFI is tripping:

1. The GFI is an incorrect model for the application (See Appendix 1).
2. The GFI is incorrectly hooked up (See Appendix 1).

Note: Items 1&2 do not seem to be high probability factors, but are added for completeness. These possible issues can be eliminated with a further inspection.

3. There is an actual ground fault on the system. The installation of a new pump should cure this fault, if it exists.
4. The GFI breaker is faulty.
5. GFI breakers can be accidentally tripped by motors and capacitors, because these devices can cause momentary current imbalances between phases, as they store or discharge energy. The single phase motor in the Taloyoak intake pump is run from a control panel that contains large capacitors. A new pump may cure this problem, or it may be that it is not possible to operate a 1-phase pump with a GFI breaker.
6. It should be noted that, to date, Dillon has not witnessed this breaker trip, and we are assuming a problem exists because Hamlet employees have reported that it does trip.

In any case, Scotty Edgerton is anxious that work on the GFI breakers be suspended until the summer, as the Hamlet can not afford to have the system freezing up.

From an electrical safety point of view the system is less secure, but it has run in this configuration for many years. Both the electrician, Andy Herrera and Dillon were comfortable with the pump circuit in its current configuration as a temporary measure, but feel a GFI should be reinstalled once the weather is warm enough that nuisance trips can occur and be eliminated without the grave consequences of depriving the hamlet of their water supply.

A new flow switch was wired into the intake pump protection circuit.

By mid-afternoon, the system had been repaired and we again started to pump from the IPH to the WTP. A series of tests where carried out in order to see if we could trip the pump and to verify the operating procedures. At no time were we able to trip the pump.

The alarm system was tested again and it was found that the dialler could not be set into readiness mode. An alarm was the reason for this problem. Investigation determined that the nipple to the Pressure Switch was blocked, so that we were permanently getting a low pressure alarm to the dialler. The nipple was serviced, and the pressure switch functioned properly, as did the dialler.

This problem with the pressure switch was not present on Day 2, November 26th, 2004 when we first tested the dialler. Had it been present, it would not have been possible to set the dialler.

2.7 Day 7 – December 1st 2004

The system ran properly overnight and Dillon departed Taloyoak.

3. Interim Performance

On December 3rd, we received a report that the Intake Pump had failed. On the morning of December 4th, it was reported that the Hamlet Staff had pulled the pump, and it was functioning again. Apparently the alarm went off in the early morning of December 3rd. Bob Hoddinott responded, and could not detect water flow at the IPH. He called in Little Mike, and the system was drained and vacuumed out. On the following day the pump was pulled. Either as part of the removal operation or at some point before, the intake pipe had become separated from the pump. A new pipe was connected and the pump was re-installed.

At present the pump is operating but, the delivery is surging. A new 5 Hp pump was purchased. This pump is due to be installed early in the New Year. We have reservations as to whether this is a suitable pump for the system in its present configuration, and have presented detailed information on the subject in Appendix #2. If the system is modified to include a pressure relief valve, it will allow water to bypass the main loop. When it is in recirculation mode the system will, in all probability, run with the 5.0 Hp pump.

4. Planning for the Future

While the present system is reaching the end of its working life, there is no reason why it can not continue to deliver adequate service to the community for some years to come. Dillon has undertaken to produce CAD schematics of the system (appended) and are working towards an updated O&M manual. This will aid the Hamlet in maintaining the system.

In a previous report it was noted that the water system tends to run dry at about 3:00 pm . Various options for increasing the system capacity were discussed, including increasing the storage and increasing the delivery rate to storage. As an outcome of this most recent visit, Dillon was to generate a Request for Tender (RFT), for work that would increase the capacity of the system. Inspection revealed that the Hamlet has already completed much of this work. A 1¼" line has been run in parallel to the existing 3/4" that feeds the tank. This pipe enlargement, combined with the 5.0 Hp pump, should result in a capacity increase sufficient to meet the Hamlet's needs for the next few years (See Appendices 2 & 3).

In the longer term, a new system is required. Tom Livingston prepared a document called Taloyoak Pump House Plan - Briefing Note 1, with the following timetable for providing the Hamlet with a water new system:

Tender for Design Services award date:	Early 2005
Tender for Construction Services award date:	Late 2005
Site Delivery date:	Summer 2006
Project Completion date:	Summer 2007

5. Conclusions:

The water system in Taloyoak is showing its age. Although the maintenance staff are adept at mechanical repairs, the electrical and control elements are less within their expertise. Also, there does not appear to be a program of planned maintenance; thus, the control elements are not tested on a scheduled basis. This being the case, there were multiple elements that were causing the system to stop operating.

There are multiple reasons as to why the 60 amp GFI breaker may be tripping. This component became an issue towards the end of the visit and it became difficult to do as much investigation as would have been liked, because by then, the focus of the work was concerned solely with making the system run reliably. It is less than desirable that this component has been removed from the circuit, but we concur with Mr. S. Edgerton's opinion that it is best not to re-introduce it until the weather is such that we do not risk a freeze-up if it trips.

The period of intense focus on the water system gave Bob Hoddinott, an opportunity to become familiar with its operation. We believe his presence will make the Hamlet more secure from a water system failure.

The 5.0 Hp pump can be installed, but only in conjunction with a Pressure Relief Valve. This pressure relief valve will allow a proportion of water to bypass the main transmission loop while the system is in recirculation mode. (It now looks as thought the Hamlet intends not to use their 5 Hp pump, but purchase a 3 Hp instead. We have advised by email that a Pressure Relief Valve may still be required).

The Hamlet employees have revised their method of response to alarms from the water system. Provided that alarms are responded to, malfunctions on the water system only require maintenance on the faulty component and do not result in costly freeze-ups.

6. Recommendations:

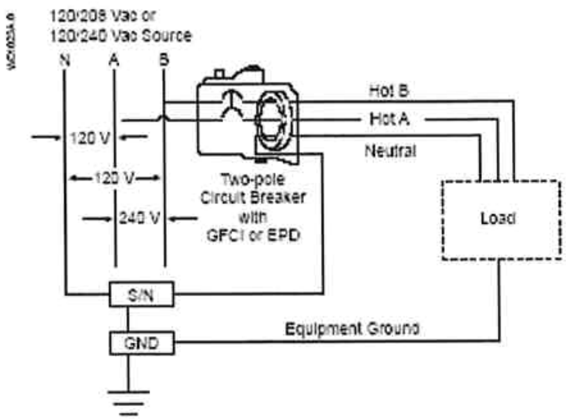
1. Replace and verify that the 60A GFI breaker is working once the weather is such that there is no possibility of the system freezing if this breaker happens to trip.
2. Test the new 5.0 Hp intake pump on the system, but only in conjunction with a Pressure Relief Valve (see drawing 101) and Appendix 2.
3. It may be possible to test the 5.0 Hp pump with the existing switch gear but this will need to be upgraded (see Appendix 4).
4. At least monthly, during the winter, test that the dialler alarm system is working by stopping the intake pump.
5. Do bi-yearly tests on all system control and alarm elements. Once in the spring, so that faulty elements can be replaced and tested during the summer, and once at the start of winter to verify the systems integrity prior to the danger months.

APPENDIX #1

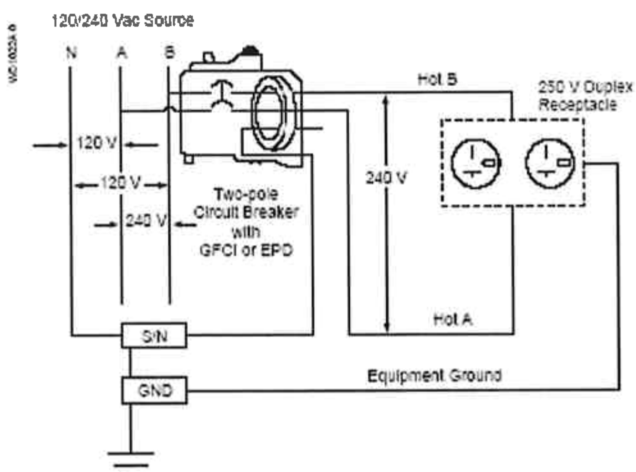
GFI Breaker Drawings

GFI Breaker Drawings

The following diagrams illustrate a Two Wire Connection and a Three Wire Connection, for GFI Breakers. It may be the case, and further investigation is required, that the GFI has been connected in the two wire mode, when, for this application it should be a three wire connection.



Three-wire 120/240 Vac or 208Y/120 Vac Circuits



Two-wire 240 Vac or 208 Vac

APPENDIX #2

Taloyoak Pump Model

Taloyoak Pump Model

The following tables and chart, models the Taloyoak water system using the Hazen-Williams method based on data obtained from the current system. Absolute accuracy can not be guaranteed, but the there is reasonable agreement between the predicted behaviour and observed data.

The model was created to aid in new pump selection. It predicts the pressure at the Intake Pump House on the supply line, and the flow rates. Two operating modes were modeled, pumping to the tank, and pumping in recirculation mode (tank valve closed). Three new pumps have been compared against the existing pump. The following Myers Ranger series (Pentair Pump Group) Pump data was used:

1. SS30-50: 3.0hp – 30gpm
2. SS50-50: 5.0hp – 50gpm
3. SS50-80: 5.0hp – 80gpm

The results of the model indicate the correct pump is the SS30-50; however the Hamlet has already purchased a **SS50-50. There is considerable reason to believe that this pump will over-pressurize the line. During the recirculation mode the model predicts pressures of 180psi at the intake pump house.** This may or may not cause an immediate line rupture, but does increase the risk of a rupture at some point. In all possibility it will cause a hose to blow off at a joint where hose clamps are used.

(It now looks as thought the Hamlet intends to not to use their 5 Hp pump, but purchase a 3 Hp instead).

The other concern with the 5.0hp pump is the pump starter (not controller) is rated at 3.0hp. There is, however, a 30 amp breaker and no thermal overloads, so the present system may handle the bigger load, but in the long term the starter (including the timer) would have to be up-rated.

If the pump does deliver excessive pressure, the Supplier is relatively certain that the 5.0hp motor can be swapped for a 3.0hp unit. This would be preferable to a pressure regulating valve as, in general, the energy costs of using an inefficient pump outweigh, by a considerable margin, the cost of purchasing the correct pump. There is the possibility of mounting a pressure relief valve that allows water to circulate back down the intake casing. If tank fill rate exceeds cost considerations, this latter option may be the way to go. (Since the initial release of this appendix, the advantages of using a presser relief valve with the 5.0 Hp pump (and also the 3.0 Hp pump), have become more apparent. We now recommend that a pressure relief valve should be installed).

In the short term we would suggest the following:

1. Since the pump is on site it may as well be given a trial: the model prediction may be incorrect, **but only after installing the pressure relief valve.** This valve should be set to relive the pressure at 5 to 10 PSI above the operating pressure when the tank is filling, but not above 150 PSI.

2. The following data should be monitored during the pump trial, and recorded for each mode of operation

    a. IPH Supply Pressure

    b. WTP Supply Pressure

    c. WTP Return Pressure

    d. Flow rate into the tank

    e. Pump Amperage (and temperature of the contactor)

    We would suggest that the trial be stopped if the IPH Supply pressure exceeds 150 psi. We have no knowledge of the system's maximum operating pressure. It may give this data in the O&M manual. Originally we assumed that the max. pressure was 100 psi, but after examining the system, we believe 150 psi is not an unreasonable guess. What is certain, is the system has not run in excess of 100 psi, at least in the recent past, because that is all the current pump will deliver. The system may hold together at higher pressures but it really becomes a lottery. If failure occurs at a joint with a hose clamp, little is lost; however, rupturing some other part of the line could take a while to repair. It should also be noted that the IPH pressure gauge is rated at 0 to 150 psi. Over pressurizing it will cause non-reversible damage. It can be isolated, but then the pressure will not be known. A higher rated gauge could be fitted prior to the test. Similarly, care should be taken not to over pressurize the gauges in the WTP.

3. The high pressure problem will occur when the system is in recirculation mode, so when the pump is started, both the ¾" and 1¼" feeds to the tank should be open.

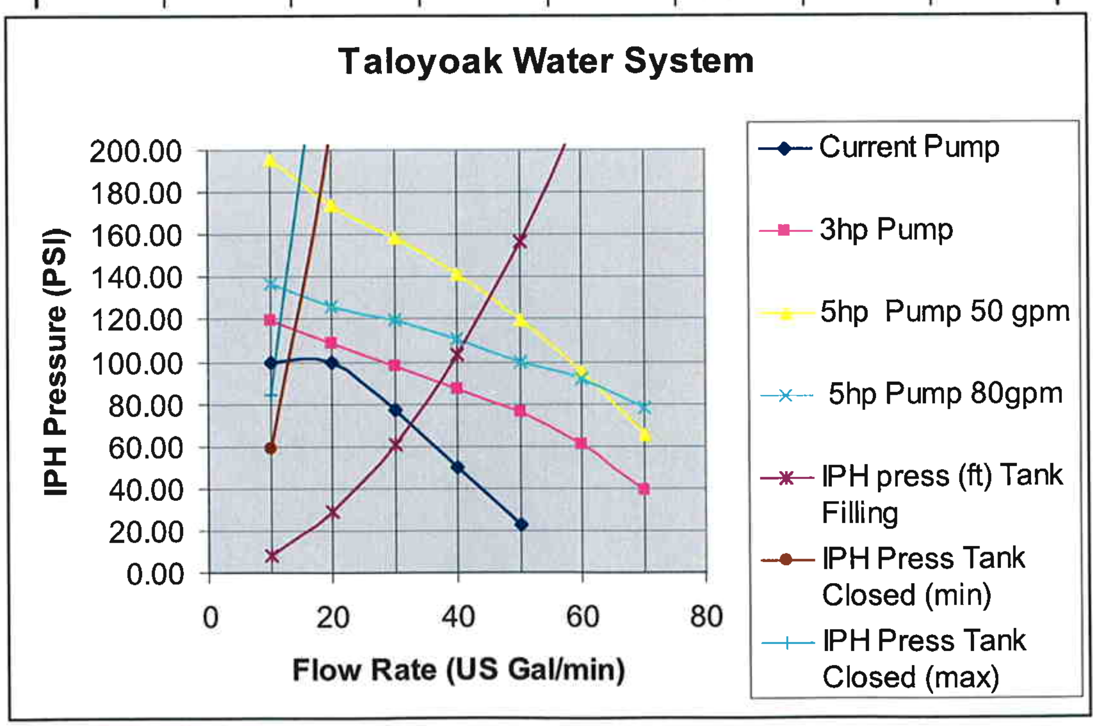
4. Slowly, and while in radio contact with the IPH, these valves can be closed to simulate the tank valve closing.

5. Even if the system will run with the tank valves closed, it is still highly likely a problem will occur when the tank solenoid valve closes, because this is not a gradual operation. As we recommended verbally while in Taloyoak, it would be better if the tank valve were a motor operated ball valve, rather than a solenoid valve, so the closing action was gradual. The response of the system to the operation of the tank solenoid valve must be tested. This can be accomplished by manually manipulating the level switch.

6. If the system passes the above listed tests the water system's operation should be carefully monitored for several days, because all the piping will be under greater pressure.

	Taloyoak Water System Predicted Operating Points							
	Tank Filling				Recirculation Mode - Tank Open			
	Existing Pump	3 hp Pump	5hp - 80	5hp - 50	Existing Pump	3 hp Pump	5hp - 80	5hp - 50
IPH psi	70	88	108	130	98	115	133	180
Total Flow Rate (gpm)	32	37	41	45	13	14	16	18
Tank only Flow Rate (gpm)	21	31	35	39				
% Increase	0%	43%	63%	84%				

Pump & System Curves - Taloyoak IPH (psi)							
Gal per Min	Current Pump	3hp Pump	5hp Pump 50 gpm	5hp Pump 80gpm	IPH press (ft) Tank Filling	IPH Press Tank Closed (min)	IPH Press Tank Closed (max)
10	100.00	119.22	195.09	136.56	7.93	58.52	84.36
20	100.00	108.38	173.41	125.72	28.63	211.24	304.50
30	76.56	97.54	158.24	119.22	60.66	447.57	645.18
40	49.37	86.71	140.90	110.55	103.33	762.48	1099.13
50	22.18	75.87	119.22	99.71	156.21	1152.64	1661.55
60		60.69	95.38	91.04	218.95	1615.57	2328.87
70		39.02	65.03	78.03	291.28	2149.32	3098.28



APPENDIX #3

Taloyoak Water System Fill Rates

Taloyoak Water System Fill Rates

Storage Capacity	Size (Imp Gal)	Size (Litres)	
Tank #1	4500	20457	
Tank #2	4500	20457	
Tank #3	5000	22730	
Total	14000	63645	
Tanker Capacity (litres)	9000		
Daily Usage (litres)	102000		
Number of Tanker Loads per Day	11.3		
Water required in excess of storage per day (litres)	38355		
	Existing Pump	3.0 Hp Pump	5.0 Hp Pump
Flow rate estimates (l/min)	81	116	149
Time required to deliver excess water (Hrs)	7.9	5.5	4.3
Note 1: Existing flow rate has decreased since Summer visit because of change to return configuration			

APPENDIX #4

Taloyoak Intake Pump Starter Panel

Taloyoak Intake Pump Starter Panel

At the time of writing this, there are two intake pumps under consideration for Taloyoak: a 5.0Hp and a 3.0Hp. The situation is not clear cut. At present, we have agreed with Bob Hoddinott, that he will install a pressure relief valve and test the 5.0Hp pump.

The existing motor starter (not to be confused with the pump controller), is rated for 3.0Hp. For testing purposes, the existing switch gear should suffice. Once the pump size is confirmed, replacement gear can be specified.

The existing panel is quite dated and is due for replacement. Any replacement is complicated by the timer for the flow and pressure switch.

There is, in the IPH, two new starter panels rated at 3.0 HP. They do contain timers and we believe that they were designed as a straight swap for the existing starter panel. The components in these new starters are as follows:

1. Existing Contactor: Telemecanique LC1 D25.
2. Required up-rated Contactor for 5.0Hp motor: Telemecanique LC1 D32.
3. The Intake pump is not fitted with overload protection. For that reason, the following overload relays should be ordered and fitted:
    a. 5.0 Hp – LRD1532 (3)
    b. 3.0 Hp – LRD 1522 (3)
    c. Direct Connection Kit - LAD7C2

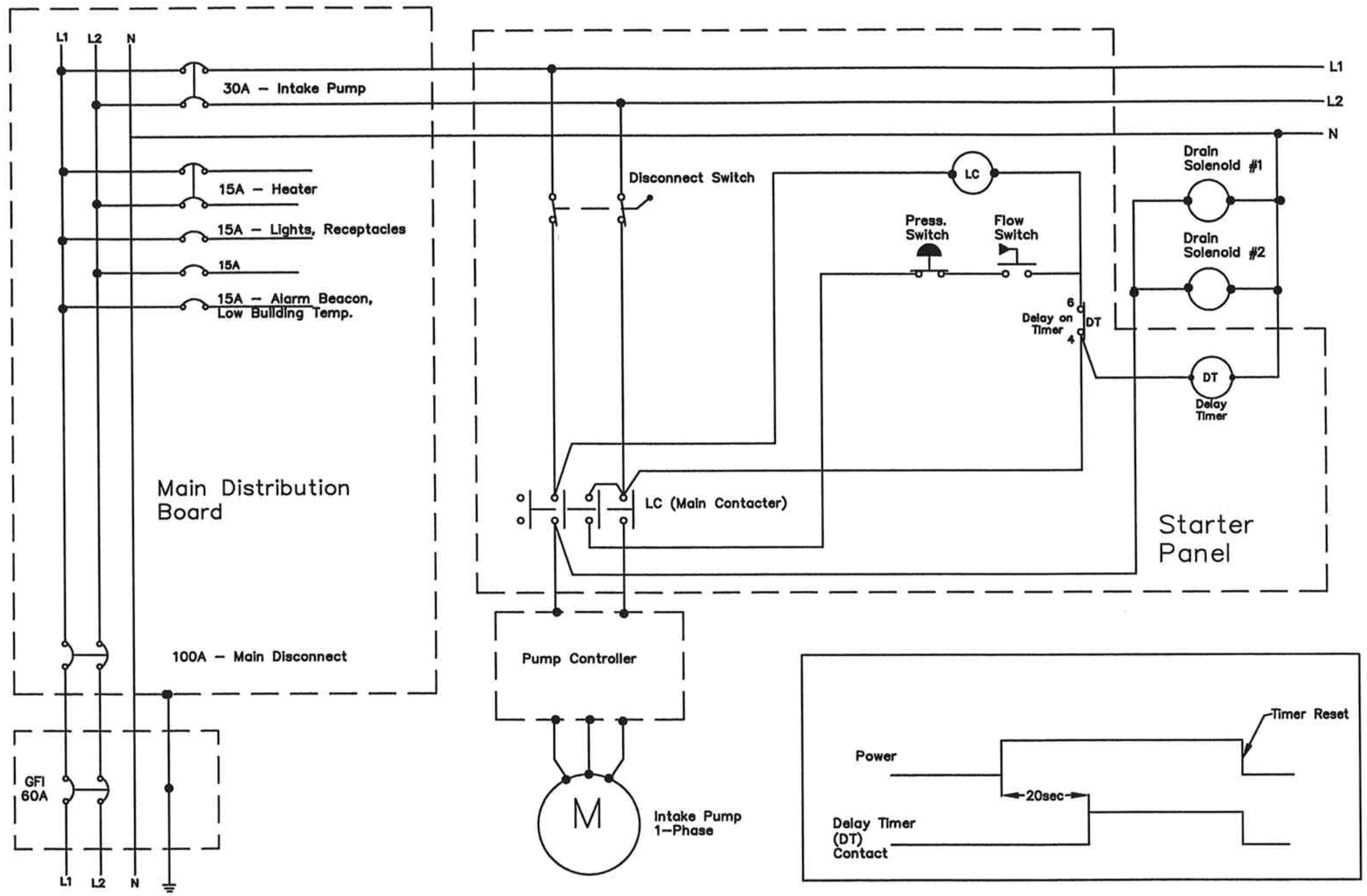
Confirm these numbers with supplier prior to ordering.

4. Omron Timer: H3G – 8C: this is a DPDT Delay On Timer, which is functionally the same as the existing timer.
5. The Square D 30A Breaker in the Distribution Board should be up-rated to 35 or 40 amps.

Provided these new starter panels are upgraded as recommended, they should work as intended. An electrician will be required to do the installation.

APPENDIX #5

Taloyoak IPH Electrical Drawing



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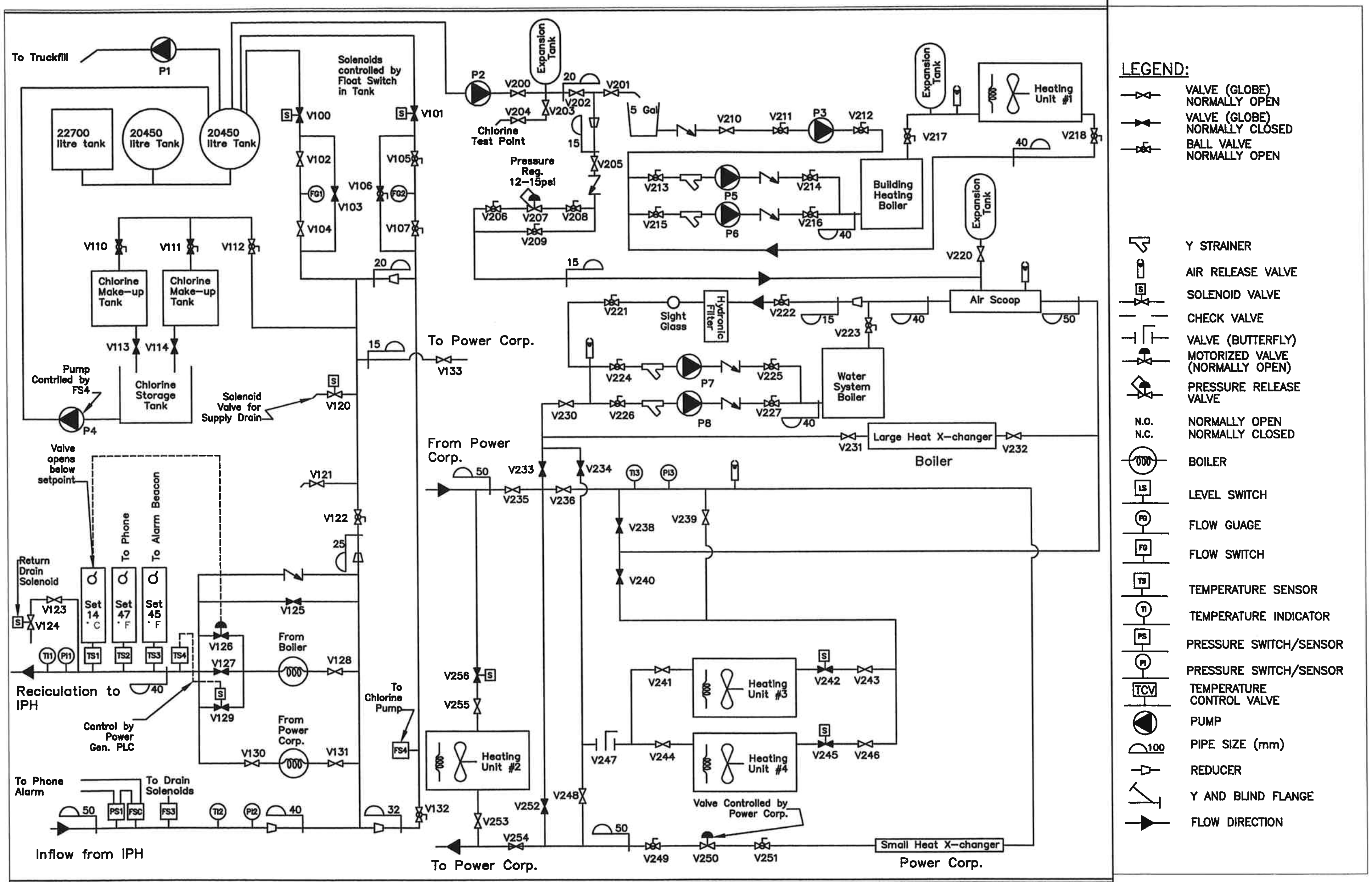
DILLON CONSULTING

PROJECT	WATER WORKS AND WATER SUPPLY TALOYOAK, NUNAVUT
TITLE	INTAKE PUMP HOUSE (IPH) Electrical Schematic
PROJECT NUMBER	04–3653
DATE	December 2004
FIGURE NUMBER	201

APPENDIX #6

Taloyoak Water System Schematics



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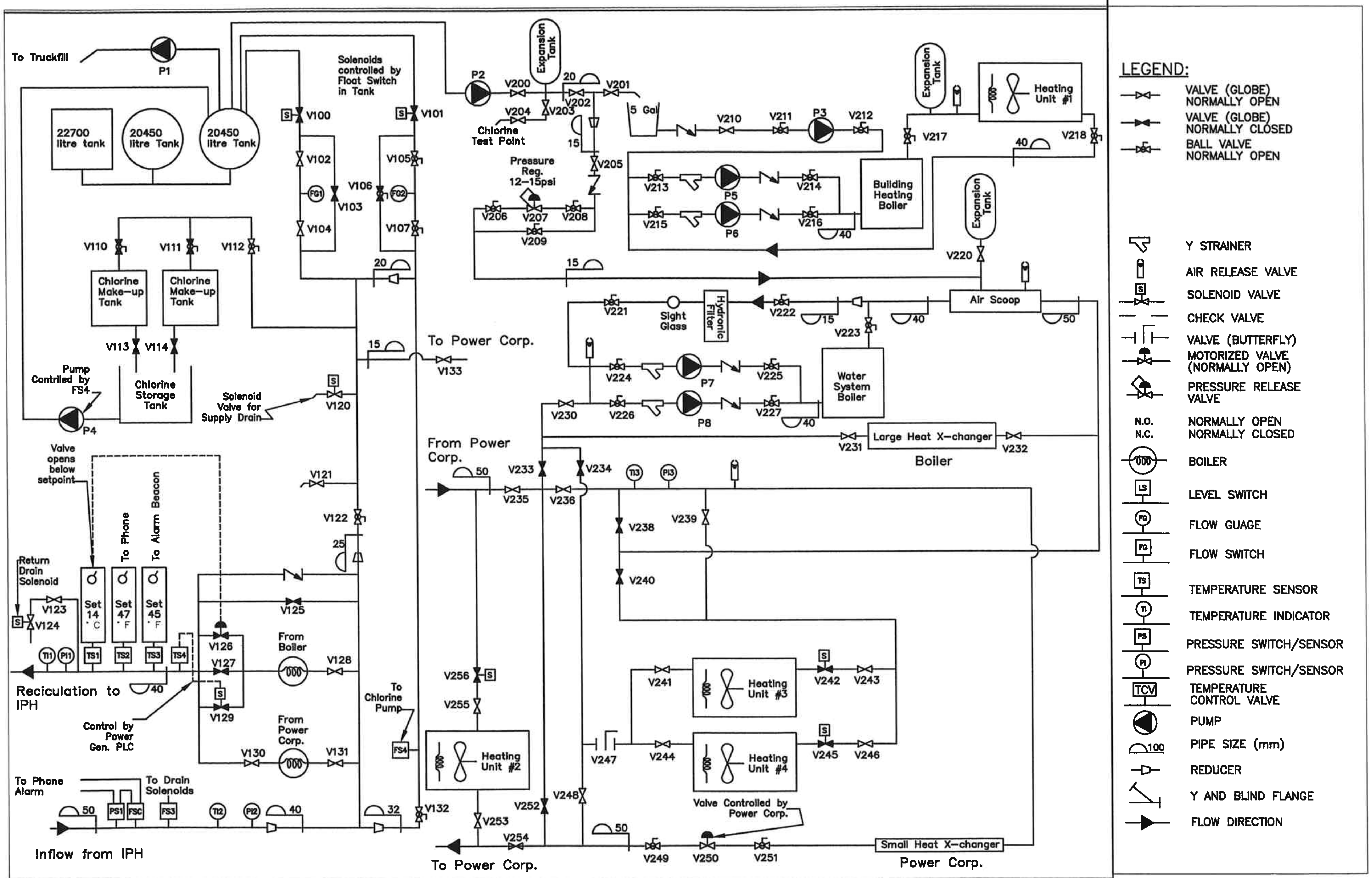
DILLON CONSULTING

PROJECT	WATER WORKS AND WATER SUPPLY TALOYOAK, NUNAVUT
TITLE	PROCESS WATER FLOW SCHEMATIC Water Treatment Plant (WTP)
PROJECT NUMBER	04-3653
DATE	Jan 2005
FIGURE NUMBER	102



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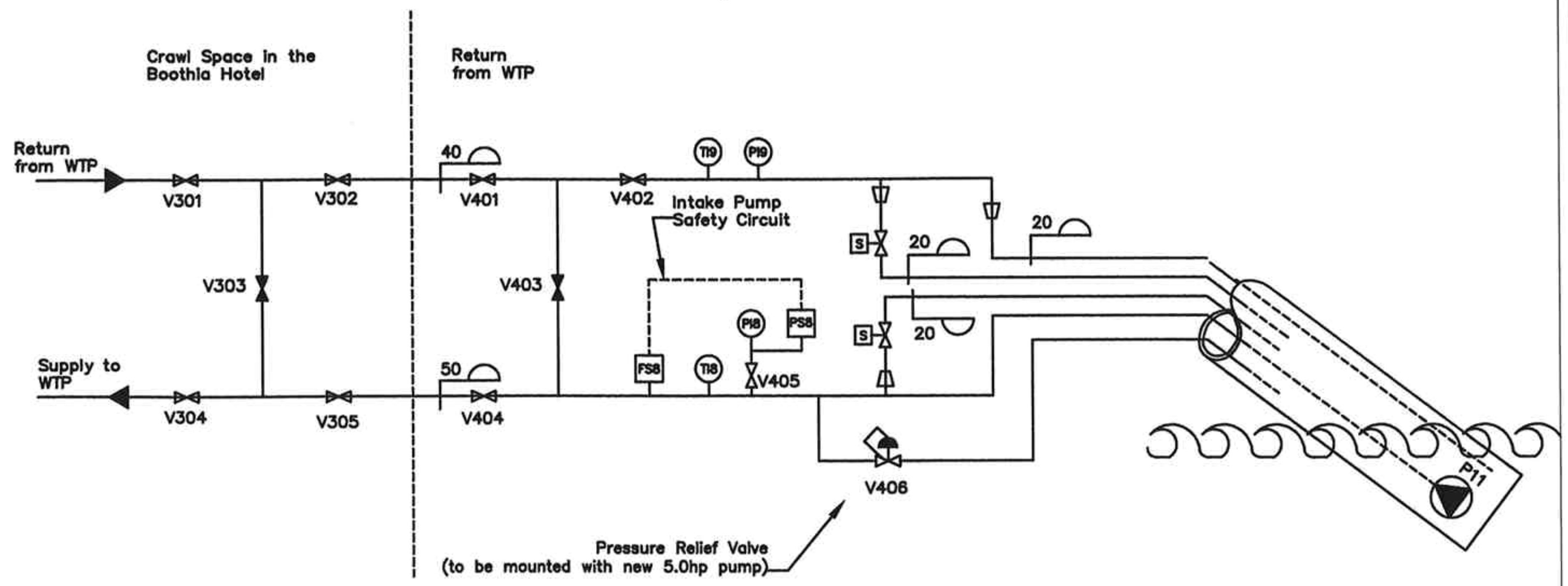
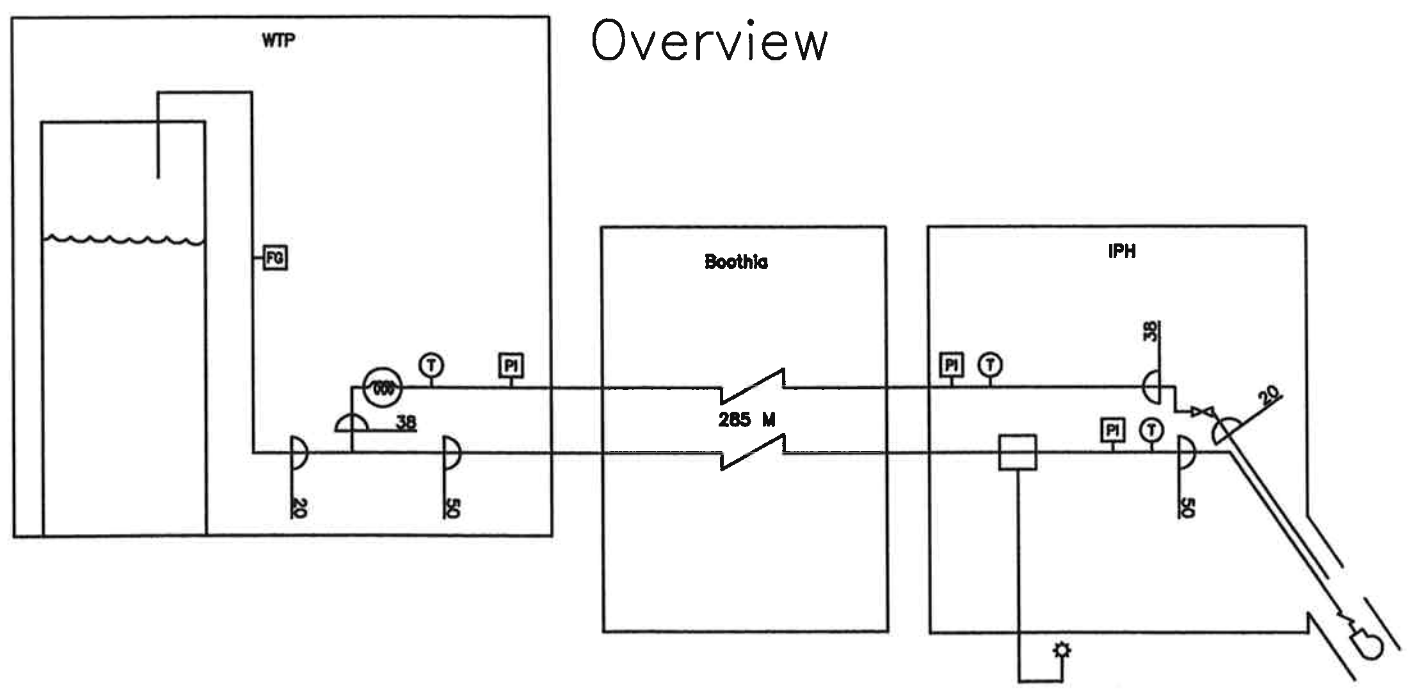
DILLON CONSULTING

PROJECT	WATER WORKS AND WATER SUPPLY TALOYOAK, NUNAVUT	PROJECT NUMBER	04-3653
		DATE	Jan 2005
TITLE	PROCESS WATER FLOW SCHEMATIC Water Treatment Plant (WTP)	FIGURE NUMBER	102

Intake Pump House



Overview



LEGEND:

VALVE (GLOBE) NORMALLY OPEN	
VALVE (GLOBE) NORMALLY CLOSED	
BALL VALVE NORMALLY OPEN	
Y STRAINER	
AIR RELEASE VALVE	
SOLENOID VALVE	
CHECK VALVE	
VALVE (BUTTERFLY)	
MOTORIZED VALVE (NORMALLY OPEN)	
PRESSURE RELEASE VALVE	
N.O.	NORMALLY OPEN
N.C.	NORMALLY CLOSED
BOILER	
LEVEL SWITCH	
FLOW GUAGE	
FLOW SWITCH	
TEMPERATURE SENSOR	
TEMPERATURE INDICATOR	
PRESSURE SWITCH/SENSOR	
PRESSURE SWITCH/SENSOR	
TEMPERATURE CONTROL VALVE	
PUMP	
PIPE SIZE (mm)	
REDUCER	
Y AND BLIND FLANGE	
FLOW DIRECTION	

EDIT DATE: 03 Jan 2005 ACAD FILE: 41tmh g:\cad\043653\taloyoak_schem.dwg

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PROJECT
WATER WORKS AND WATER SUPPLY
TALOYOAK, NUNAVUT

TITLE
PROCESS WATER FLOW SCHEMATIC
Intake Pump House & Overview

PROJECT NUMBER 04-3653
DATE Jan 2005
FIGURE NUMBER 101