Trow

Design Brief
New Sewage Lagoon for the
Hamlet of Arctic Bay

Prepared for:
Government of Nunavut
Department of Community and Government Services
Project Management Division – Baffin Region

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Executive Summary

Trow Associates Inc. were retained by the Department of Community and Government Services, Government of Nunavut to review the existing sewage lagoon and complete the detailed planning design for the construction of a new sewage treatment facility for the Hamlet of Arctic Bay.

The Hamlet's existing sewage treatment facility is located approximately 2 kms to the east of the community, just north of the road to Nanisivik. It is comprised of a single cell lagoon, an ice pack storage area and wetlands. Currently, the existing facility does not meet the storage requirements of the Hamlet, nor does it meet the treatment requirements of the Hamlet's water licence. The new sewage treatment facility shall be required to meet both the 20 year needs of the Hamlet and provide sewage treatment to meet the requirements of the Hamlet's water licence, as issued by the Nunavut Water Board. The projected population for the Hamlet for the year 2029 is estimated at 1312. It is estimated that the annual sewage generated by this population will be approximately 56,029 m^3 per year. To meet these requirements, it is recommended that a new sewage lagoon, with additional treatment through natural wetlands, be constructed in a small valley to the northwest of the existing facility. It is recommended that the sewage lagoon be designed to drain to the northwest towards Victor Bay and that the lands between the sewage lagoon and Victor Bay remain as undisturbed tundra. These lands can be included in the sewage treatment facility as filterstrip wetlands.

The projected effluent quality from the treatment facility, including the sewage lagoon and filterstrip wetlands is estimated as BOD_5 of 18 mg/L and a TSS of 22 mg/L and faecal coliforms of less than 100,000. This level of treatment meets or exceeds the requirements of the Hamlet's water licence.

The project will also require the construction of a new gravel access road from the existing sewage lagoon site to the proposed new site. It is recommended that the road alignment is such that grades are maintained to allow access by a fully loaded sewage truck.

The estimated capital cost for the proposed facility, including the new lagoon, access road and decommissioning of the existing facility is $6,216,500 with a yearly operating and maintenance cost of $58,000.

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1.0 Introduction

Trow Associates Inc. (Trow) were retained by the Department of Community and Government Services (CGS), Government of Nunavut (GN) to complete the detail planning and design for the construction of a new sewage lagoon for the Hamlet of Arctic Bay (Hamlet), Nunavut.

The Hamlet's existing sewage lagoon is located approximately 2 km to the east of the community. It is a comprised of a single cell lagoon, ice pack storage area and wetlands, as shown in Figure 1. The sewage treatment system is bordered to the north by the Hamlet's solid waste disposal site and to the south by the Road to Nanisivik. The existing lagoon was constructed in 1976. It is an online earth lagoon with a reported capacity of approximately 21,000 m^3 and was designed to hold sewage for 365 days with manual discharge. In 2003 the sewage system was expanded to include an ice pack area and modifications to improve the efficiency of the wetlands. Works were based on a project plan prepared by Dillon Consulting Ltd. and presented in the reported entitled *Arctic Bay – Wetlands Treatment Facility: Proposed Project Plan* dated 2002.

In 2002 and 2003 effluent tests carried out by Indian and Northern Affairs cited problems with the effluent quality from the facility. In addition, effluent samples taken in September 2004 did not comply with the requirements under the Hamlet's water licence.

1.1. Background

Background information provided as part of this project included the "*Arctic Bay – Wetlands Treatment Facility: Proposed Project Plan*" completed by Dillon Consulting Ltd. in 2002. This report was the basis for the improvements to the facility undertaken in 2003.

1.2. Scope of Services

The scope of services to be undertaken as part of the detail planning and design for the new sewage lagoon and the decommissioning of the Hamlet's existing sewage treatment facility included the following:

1. A community visit and site investigation.
2. Review of available resources within the Hamlet.
3. Completion of a topographic survey.
4. Completion of a geotechnical investigation and report.
5. Investigate the opportunity to include the wetlands as part of the treatment facility.
6. Develop a plan and design for the construction of a new sewage lagoon to meet the long term requirements of the Hamlet.
7. Prepare a cost estimate for construction and improvement of the new sewage lagoon, including decommissioning of the existing lagoon.

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GOVERNMENT OF NUNAVUT

LOCATION PLAN - ARCTIC BAY SEWAGE LAGOON

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FIG 1

2.0 System Requirements

2.1. General

The proposed sewage treatment facility must meet the long term needs of the Hamlet, as well as the regulatory requirements of the Hamlet's water licence. The "Water and Sewage's Facility Capital Program Standards and Criteria" as provided by the CGS, indicates the design horizon for sewage lagoons is to be between 15 – 20 years. As per the direction of the CGS, the design horizon for this project shall be 20 years, until the year 2029.

2.2. Population

The population projections for this project will be based on "Nunavut: Community Population Projections" as published by the Nunavut Bureau of Statistics. The Nunavut Bureau of Statistics population projections provide projected populations of the Nunavut communities to the year 2020. As a planning horizon for this project is past the current population projections available from the Nunavut Bureau of Statistics, the population projection from 2020 to 2029 are estimated using the average annual growth rate for the Hamlet between the year 2000 and 2020 of 2.04%. The table below summarizes the population projections to the year 2029.

Table 2.1 - Population Projections

Planning Year	Year	Population	Planning Year	Year	Population
	2000	730	6	2015	1019
	2001	747	7	2016	1033
	2002	763	8	2017	1049
	2003	782	9	2018	1065
	2004	801	10	2019	1078
	2005	819	11	2020	1094
	2006	837	12	2021	1116
	2007	855	13	2022	1139
	2008	876	14	2023	1162
0	2009	894	15	2024	1186
1	2010	916	16	2025	1210
2	2011	939	17	2026	1235
3	2012	960	18	2027	1260
4	2013	980	19	2028	1286
5	2014	1003	20	2029	1312

2.3. Sewage Generation

To determine the volume of sewage the facility must treat, the sewage generation rate for the community must be determined. Sewage generation rates are generally assumed to be equal to the water consumption rates for a community, with the water consumption rate being the total of the residential and non-residential water consumption. The "Water and Sewage Facility Capital Program Standards and Criteria" provide the following design values and formulae for estimating the water consumption and therefore the sewage generation rates for communities.

The residential water usage (RWU) for a community is based on the method of water delivery and sewage collection in the community. The per capita water usage rates for the different methods of water delivery and sewage collection are summarized in the Table 2.2.

Table 2.2 - Residential Water Usage

Service Method	Residential Water Usage (RWU)
Trucked water and sewage	90 lpcd
Piped water and sewage	225 lpcd
Piped water supply and truck sewage pump out	110 lpcd
Trucked water delivery and individual septic fields	100 lpcd

The Hamlet of Arctic Bay has a trucked water and sewage system, therefore the RWU for the community from Table 2.2 is equal to 90 lpcd.

The non-residential water usage by a community tends to increase with increases in the population. To determine the Total Community Water Usage the Residential Water Usage is adjusted based on population to provide a Total Water Usage Per Capital. The Total Water Usage Per Capital, including residential and non residential activities are estimated based on the equations in Table 2.3.

Table 2.3 - Total Community Water Usage

Community Population	Total Water Use Per Capita
0 – 2000	RWU x (1.0 + 0.00023 x Population)
2000 – 10,000	RWU x [-1.0 + {0.323 x Ln(Population)}]
Over 10,000	RWU x 2.0

The daily water consumption, and therefore the sewage generated by the community, is equal to the population multiplied by the Total Water Usage Per Capital. Based on the design population of 1312 for the year 2029, and a total water usage per capita rate of 117 lpcd, the daily sewage generation rate is equal to 153,504 lpd. This is equal to a yearly sewage generation rate of 56,029 m^3.

2.4. Regulatory Requirements

The proposed sewage treatment facility will have to meet the effluent quality standards as set out in the Hamlet's water licence. The Hamlet is operating under a valid water licence, licence #NWB3ARC0207 issued on November 1, 2002 by the Nunavut Water Board, as required under the Nunavut Lands Claim Agreement and the Nunavut Waters Act. The effluent quality standards set out in the water licence are summarized in the Table 2.4.

Table 2.4 – Effluent Quality Standards

Parameters	Maximum Average Concentration
BOD_5	100 mg/l
Total suspended solids (TSS)	120 mg/l
Faecal coliforms	1 x 10^6 CFU/dl
Oil and grease	No visible sheen
pH	6 and 9

3.0 Site Investigation

In August 2007 a detailed site investigation was undertaken, including the following:

1. Site inspection
2. Topographic survey
3. Geotechnical investigation
4. Wetlands assessment
5. Environmental Assessment

3.1. Site Inspection

As part of the site investigation an inspection of the existing facility was undertaken. This inspection noted the following:

1. The sewage lagoon constructed in 1976 is not currently being operated by the Hamlet. Sewage is being discharged directly into the ice pack area.
2. The ice pack cell provides very short retention as there appears to be a channel through the containment berm which allows the sewage to be released to the wetlands.
3. Earth berms constructed in the wetlands area are working to create small containment ponds as per the design.
4. CGS representatives presented three alternate sites for the location of the new sewage lagoon.
5. Site 1 was a relatively flat valley which provided good potential for use as a sewage lagoon. The valley drains, both to the northwest towards Victor Bay and to the southeast back towards Admiralty Inlet and the existing sewage treatment facility.
6. The area in between Site A and Victor Bay to the northwest has a large potential wetlands area.
7. Site B was near the end of the valley referred to in Site A.
8. Site B was sloped from the northwest towards the southeast towards Admiralty Inlet and the existing sewage treatment facility.
9. Site C was located northwest of the existing site and has a slope from the north to the south which may be too steep to allow the site to be considered for development of a sewage lagoon.
10. The proposed access road to Sites A and B would have to traverse a relatively steep section, after which the access road would be relatively easy to construct.

3.2. Topographic Survey

A topographic survey of the existing facility, including the existing lagoon, ice pack area and wetlands was undertaken. In addition, a topographic survey for the proposed sites for the new lagoon and the route for the proposed access road was undertaken.

The survey of the existing facility reaffirmed the information provided in the background report with regards to the location and size of the various components of the facility. The existing facility is shown on Figure 2.

The survey crew, in conjunction with the wetlands specialist, mapped out the potential sites as well as the limits of the potential wetlands as shown on Figure 3.

3.3. Geotechnical Investigation

As part of the site investigation, a geotechnical investigation was carried out by Trow. The geotechnical report resulting from this investigation has been issued under a separate cover. The following summarizes the findings and recommendations from this report.

The area of the proposed new lagoon is located in an approximately 70 m to 90 m wide, 500 m long and 7 to 12 m deep valley. A small pond is located in part of the area proposed for construction of the lagoon.

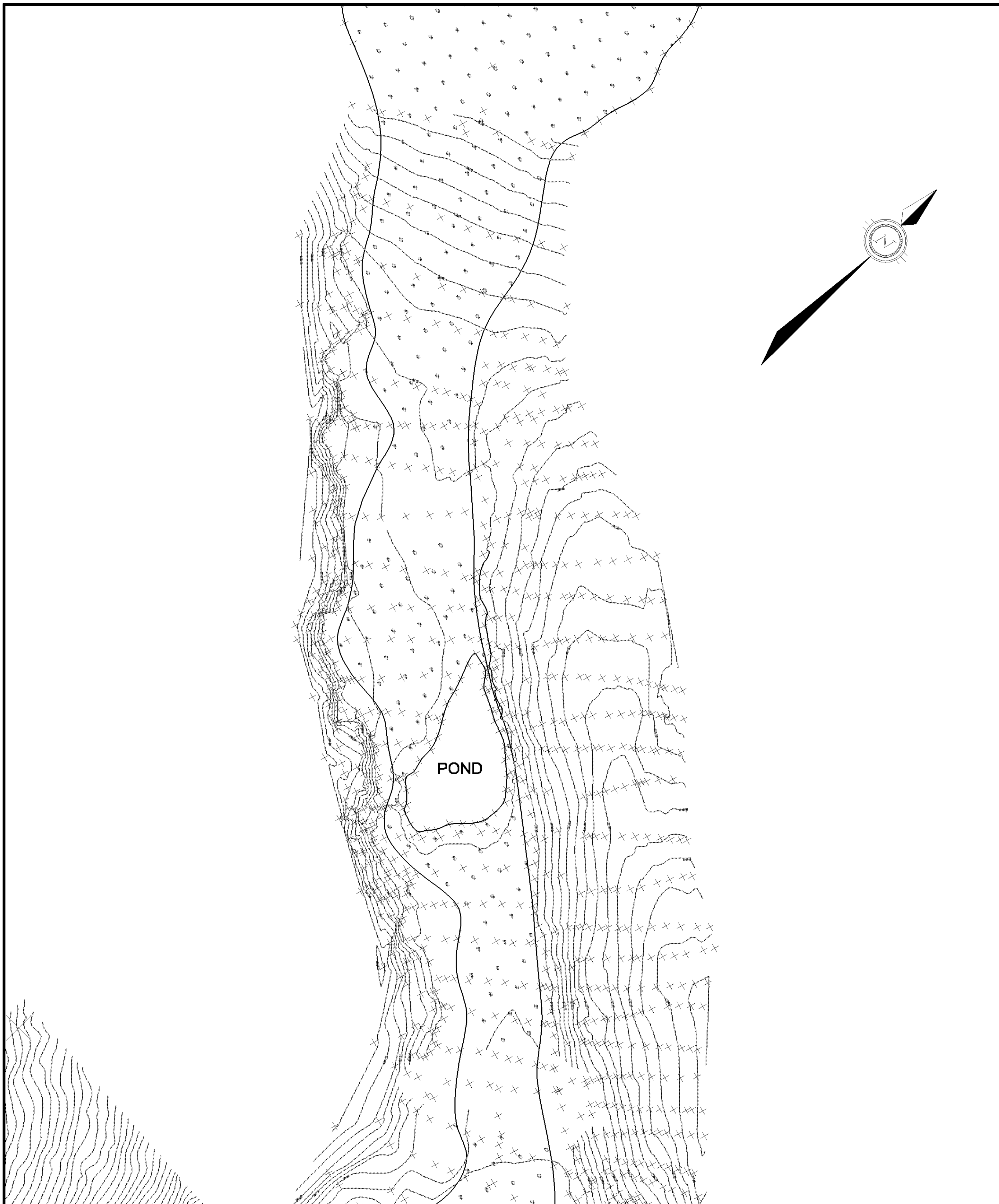
The investigation has revealed that the natural soils are permeable, ice rich layered sand and gravel, silty sand and silty sand till which extend to the bedrock surface. Ice layers, which varied in thickness from 0.5 m to 3.7 m were encountered in the majority of the boreholes drilled at the site. Bedrock was not encountered in any of the boreholes drilled in the valley bottom to a depth of 3.7 m to 5.5 m investigated, with the exception of the borehole located closest to the middle of the valley where rock was encountered at a depth of approximately 3.8m.

The rock sampled at the sides of the valley was found to be generally of poor quality.

Due to the ice rich soils and high permeability of the soils, construction of the conventional permeable berms for the lagoons is not feasibility as they will experience large settlements due to thaw of the underlying soils. The on-site soils are permeable and as such the lagoon berms would have to be lined or an “ice dam” design used to create an impermeable berm.

Installation of synthetic liners in lagoons constructed on ice rich soils are likely to rupture because of the anticipated large settlements. It is recommended that the proposed berms should be constructed as ‘ice dams’, i.e. the soil in the core of the berm and the underlying ice rich soils should be maintained in a permanently frozen state. In this case, the frozen soil would act as a liner. If construction of the dykes as ‘ice dams’ is considered not to be feasible, another more suitable site may have to be located. A geothermal analysis of the proposed berm section should be carried out to determine if the creation of an ice dam is feasible.

The above and other related considerations have been discussed in greater detail in the geotechnical report.



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DATE: 28/01/08			
DRAWN: MMR	TITLE: ARCTIC BAY - TOPOGRAPHIC SURVEY		FIG.2

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DRAWN: MMR	TITLE: POTENTIAL SITES AND WETLANDS		FIG.3

3.4. Wetlands Assessment

Treatment of raw sewage in new sewage lagoon in Arctic Bay will be combined with the utilization of a wetlands treatment as a final polishing. The area to be used as a wetlands for the Arctic Bay treatment facility is a vegetated filterstrip wetland as described below.

The proposed sewage lagoon will be constructed on top of the mountain overlooking the existing lagoons and Admiralty Inlet to the south and Victor Bay to the north. The vegetated area between the new lagoon and Victor Bay will be incorporated into the sewage treatment process as shown in Figure 4. The filterstrip wetland area is 11.2 hectare (approximately 700 m long and between 86 and 202 m wide) with a slope that varies between 6 to 13 %. Treatment of the pre-treated sewage in the filterstrip wetland area will include removal of TSS, BOD, nutrients and pathogens.

The soil in the filterstrip wetland area is comprised of a topsoil layer with peaty and organic content between 15 and 50 cm thick, silty sand and sand and gravel with permafrost at a depth of approximately 1 m in the summer month. This type of soil is suitable for infiltration processes and will facilitate the two main processes of contaminant removal from pre-treated sewage: uptake of contaminants and nutrients by plant roots and degradation by microorganisms in the rhizosphere.

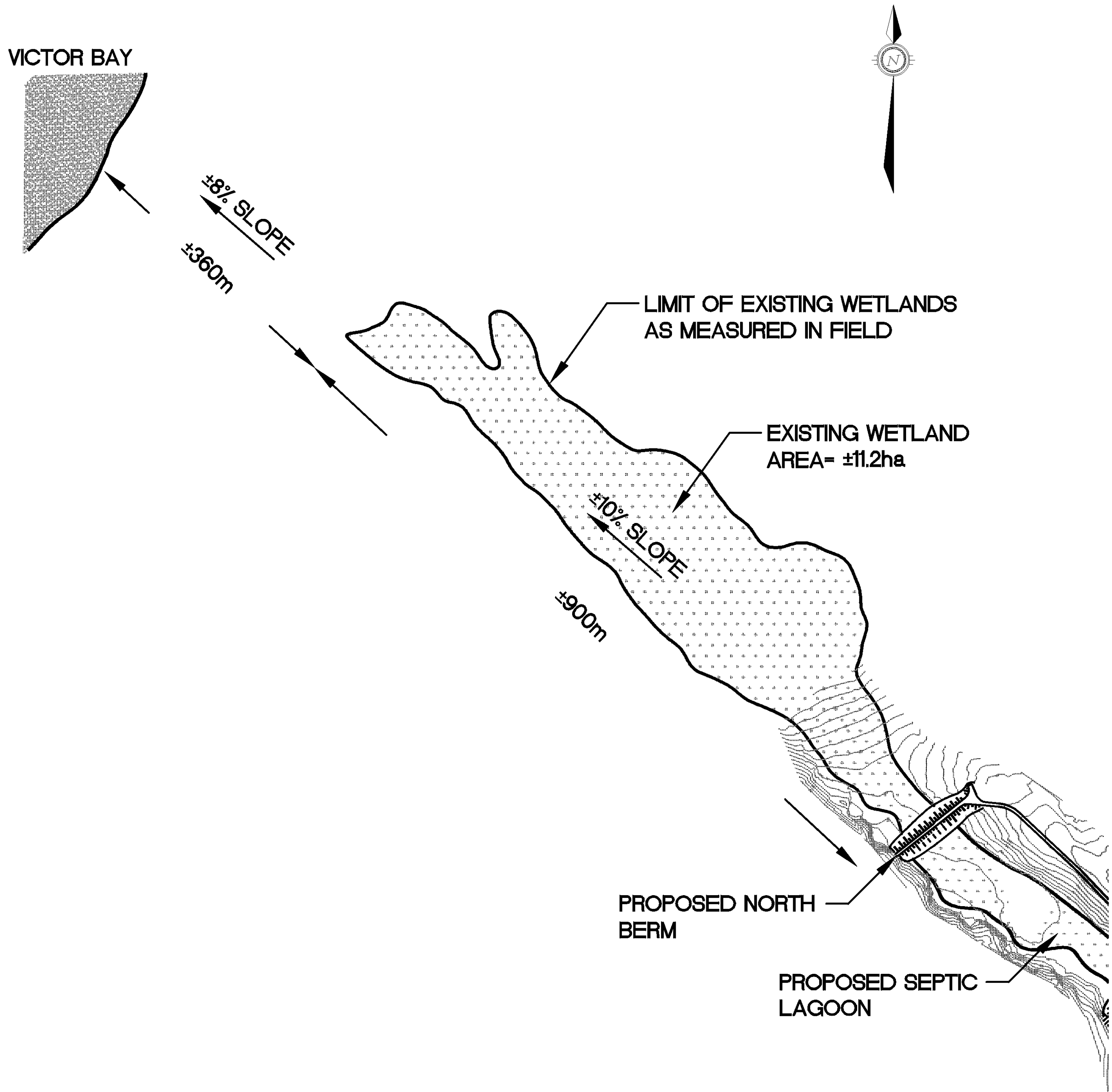
The well established, native vegetation community will be used and alterations or modifications to the plant community composition are not necessary to increase removal of contaminants. The plant species present, which include willows, grasses, sedges and mosses, are suitable for the phytofiltration processes that will reduce BOD and TSS.

3.5. Environmental Assessment

As part of the site investigation, Trow completed an Environmental Assessment Screening under the Canadian Environmental Assessment Act in order to construct a new sewage lagoon, treatment wetland and decommissioning of the existing sewage lagoon. The Environmental Assessment has been issued under a separate cover. The following summarizes the findings of that report.

The Hamlet of Arctic Bay is the proponent of the project and as such triggers the requirement for a screening level environmental assessment for the project under Section 5(1)a of the Canadian Environmental Assessment Act (CEAA). Due to the size and location of the proposed project (leaving a footprint >25 m^2), it cannot be excluded under CEAA, and an environmental assessment as per CEAA must be completed prior to any physical work completed by the proponent. The Hamlet of Arctic Bay is the Responsible Authority (RA).

The existing sewage lagoons are located approximately 2 km east of the Arctic Bay community on the road between Arctic Bay and Nanisivik. The proposed sewage lagoon will be constructed on top of the mountain, overlooking the existing lagoons and Admiralty Inlet to the south and Victor Bay to the north. The vegetated area between the new lagoon and Victor Bay will be



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incorporated into the sewage treatment process. A new access road will be constructed from the existing sewage lagoons to the new lagoon.

Construction of a new sewage lagoon is necessary because the two existing lagoons are too small for the Hamlet and the berms are failing. Trow is designing a new sewage treatment lagoon with a larger capacity which takes growth of the population of Arctic Bay over the next 20 years into consideration. It incorporates a vegetated filterstrip wetland as an additional polishing step using existing native vegetation.

A number of components of the proposed project will interact with Valued Ecosystem Components (VECs) during the construction phase, operating phase and decommissioning of the existing sewage lagoon. A number of interactions may have a negative effect, however, all of the negative effects can be mitigated through mitigation measures, maintenance programs or implementation of health and safety plans. These interactions are short term, localized and do not result in residual negative effects on the environment. The overall and long term effect of the project is positive.

Public consultation with stakeholders has taken place, this included presentations to Council, consultation with Government staff and Public Open Houses. All stakeholders appear to be in favour of the proposed project.

4.0 Alternative Sites

4.1. Alternative Sites

As part of the site visit, representatives of CGS presented three sites as shown on Figure 5. The three sites and their suitability for construction of a sewage lagoon are discussed below.

Site A

Site A is the most isolated of the three options. It is a natural valley between two small hills. The valley could easily be used to construct a sewage lagoon through construction of an earth berm at each end of the valley. To the northwest of the valley is a significant natural wetlands area.

Site B

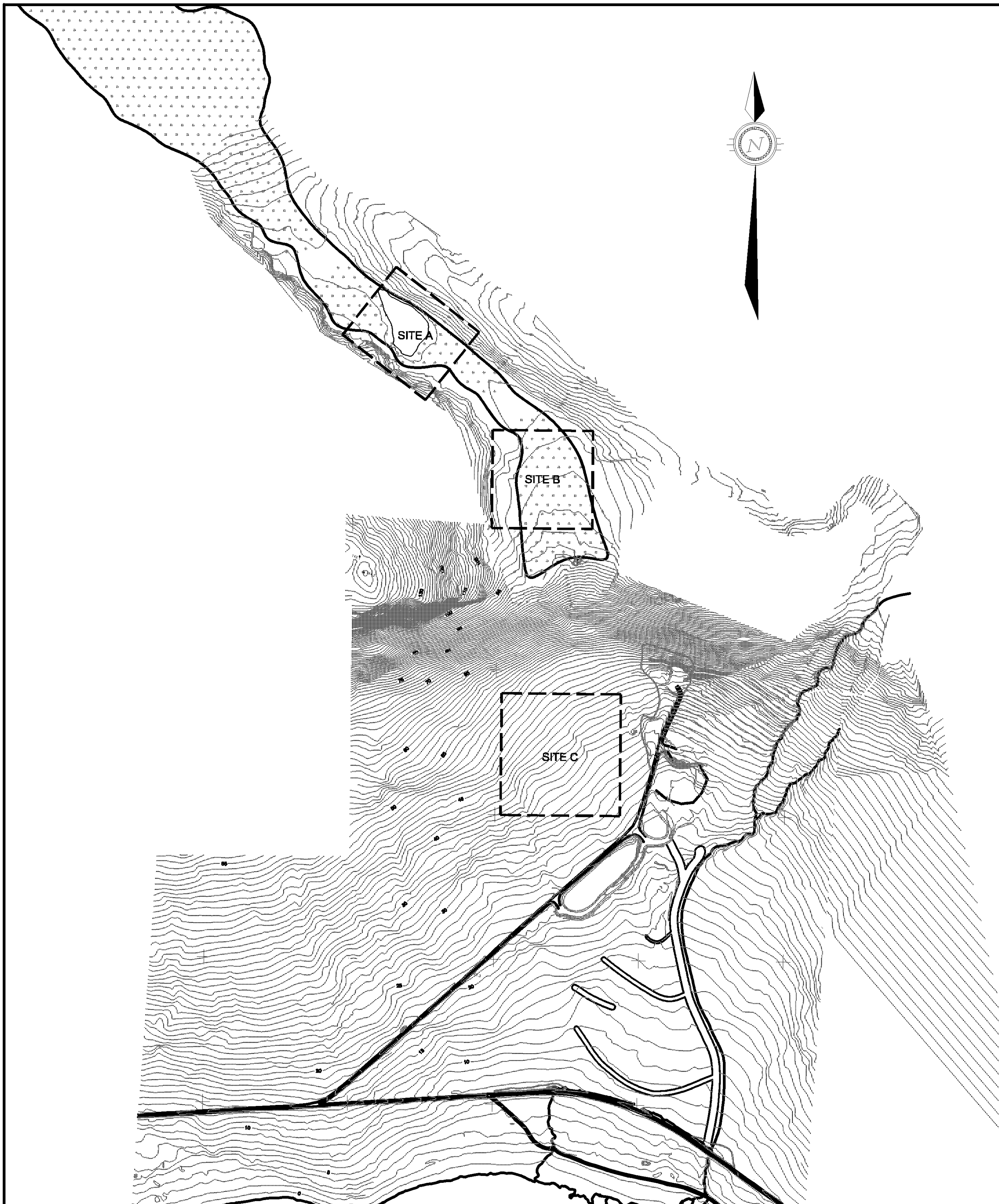
Site B is located closer to the existing facility at the end of the valley which is Site A. The site has a natural slope of 3% across the site which is approximately 200 m wide. This would result in the lower berm being required to be very high. The site also does not take advantage of the natural topography by utilizing the valley sides to form the lagoon as well as Site A does.

Site C

Site C is located to the west of the existing solid waste disposal site and to the northwest of the existing lagoon. It is located on a natural slope which is greater than 10%. This would require the berm on the lower side of the site to be extremely large and, in essence, makes the use of this site for the sewage lagoon impractical.

4.2. Site Evaluation

Sites B and C require extremely large berms be constructed which is not reasonable or feasible. Therefore, Site A is recommended as the preferred site for the construction of the sewage lagoon due to the ability to make use of the natural topography to reduce the capital costs of the facility.



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5.0 Detail Design

5.1. Lagoon System

The proposed sewage lagoon system for Arctic Bay is a single cell storage lagoon providing the storage capacities to store the sewage generated by the Hamlet over one-year. The sewage lagoon will be decanted annually in the late summer or early fall.

The sewage lagoon will be created by the construction of an earth berm on the northwest and southeast ends of the natural valley, referred to as Site A. The berms will be located to provide the greatest area, thereby reducing the depth of sewage and height of the berms.

The lagoon will be decanted to the northwest through the natural wetlands and ultimately effluent will be released to Victor Bay. The alternative of draining to the southeast towards the existing site and Admiralty Inlet is less desirable as it requires effluent to drain back towards a more populated area and an area used for dog sled teams.

5.2. Berm Design

The design of the earth berms for the rehabilitation of the existing sewage lagoon and the proposed new lagoon are based on recommendations from the geotechnical report, and the geothermal report.

5.2.1. Geotechnical Recommendations

A geotechnical report has been prepared based on a geotechnical investigation for the Arctic Bay sewage lagoon expansion and has been issued under a separate cover. Based on the geotechnical investigation the following conclusions and recommendations were put forward.

A slope stability analysis was performed to determine the steepest slopes of the berms that would be stable under prevailing conditions. The analysis assumed that the berms would either be lined or constructed as ‘ice dams’ and that in either case, the underlying foundation soils will be maintained in a constantly frozen state. If the berms are lined, seepage through the berms is not expected. The exception to this is if the liner leaks or if any of the joints fail. If the berms are constructed as ‘ice dams’, the central core of the berms would be maintained in a constantly frozen state. However, the outside and inside slopes of the berms would be subjected to seasonal freezing and thawing. For these reasons, the inside slopes of the berms were analysed for completely submerged case, whereas the outside slopes of the berms were analysed for steady state seepage conditions. Static as well as seismic loading were considered for each case.

The analysis concluded that the inside and outside slopes of the berms would be stable when constructed at a slope of 3H:1V.

The stability of slope analysis has also concluded that if the berms are to be designed for rapid drawdown condition, inside slope of 3.5H:1V would be required for the southeast berm and 4H:1V for the northwest berm.

5.2.2. Geothermal Recommendations

A geothermal analysis of the proposed sewage lagoon design was undertaken by Naviq Consulting Inc. and issued under a separate cover. The purpose of the geothermal analysis was to provide a design of the sewage lagoon's structure for Arctic Bay which would utilize an ice dam design for the berms.

The geothermal modelling showed the seasonal thawing of the lagoon berms was to a maximum depth of about 2 m below the crest. The effects of climate warming were applied to the geothermal model and the depth of seasonal thawing was shown to be relatively insensitive to the effects of climate warming.

The application of an ice dam concept as a primary containment method was not recommended based on the analysis. As an alternative the geothermal model proposed that a liner, or other barrier, be incorporated into the upstream face of the berm and keyed into the permafrost at the toe of the berm. The ice dam in the lagoon berm would form a secondary containment, as well as ensure the liner is keyed into an impermeable surface, i.e. the permafrost.

Due to the generally poor quality of rock along the sides of the proposed lagoon, it is suggested that it may be prudent to install a liner along each side of the valley forming the lagoon. The liner should be keyed into the permafrost or sound rock at the bottom of the side slopes.

No secondary cooling of the berm was currently recommended, however, a monitoring system for ground temperatures and seepage throughout the berm structures was recommended to be implemented. Based on monitoring of the core temperatures of the berm and further potential of seepage, secondary cooling by way of thermosyphon may be required in the future.

5.2.3. Recommended Berm Design

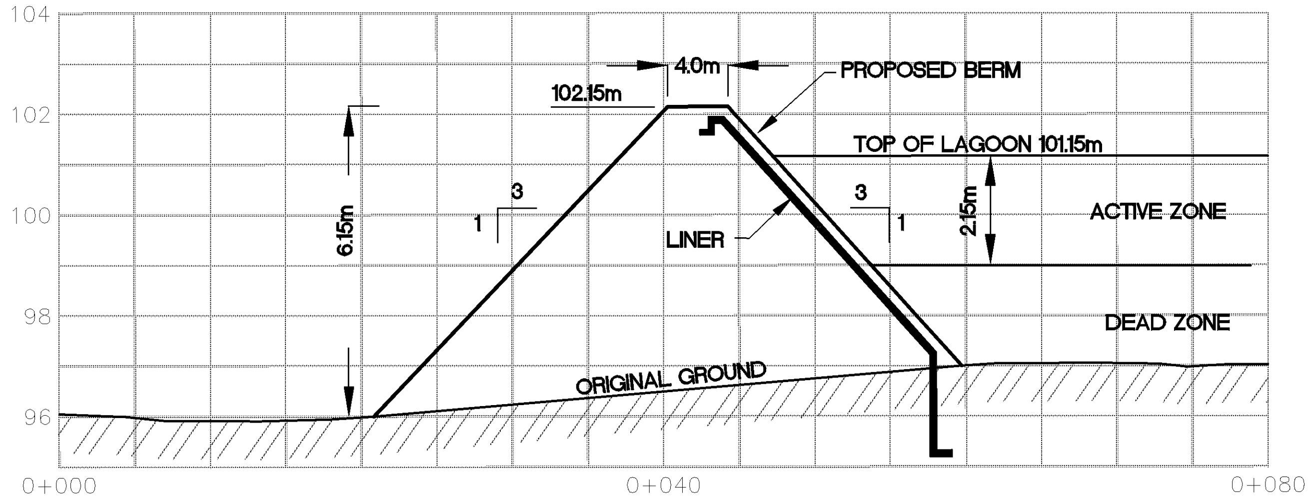
As per the geotechnical recommendations, the proposed berm design is to have a 3H:1V slope on the upstream side and downside of the berm. The berm crest width will be 4 m, except where the top of the berm is utilized for access, either for the decanting process or discharging of the sewer trucks, where it will be 5 m wide to better accommodate vehicles. As per the recommendations of the geotechnical report and geothermal analysis, the berms will be constructed with a liner on the upstream slope to provide an impermeable boundary, with an ice dam providing secondary containment and ensuring the liner is keyed into an impermeable surface, i.e. the permafrost. The typical berm sections are shown in Figures 6.

5.3. Lagoon Size

The proposed sewage lagoon system for Arctic Bay is to be a storage cell system. Storage cell lagoon systems must store the sewage generated from the end of one decanting cycle to the start of the next, plus any runoff which may enter the lagoon from adjacent land.

It is proposed that the Arctic Bay lagoon be decanted over a 30 day period from between mid to late August and mid to late September. Therefore the required storage period for the new sewage lagoon will be for 335 days (approximately 11 months). Based on the projected

NORTH BERM



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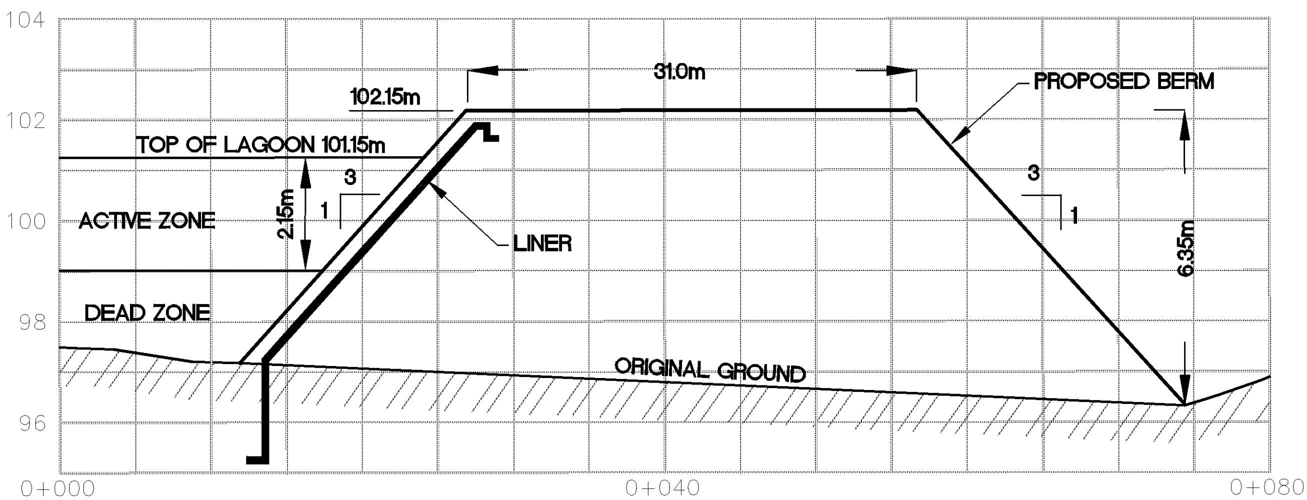
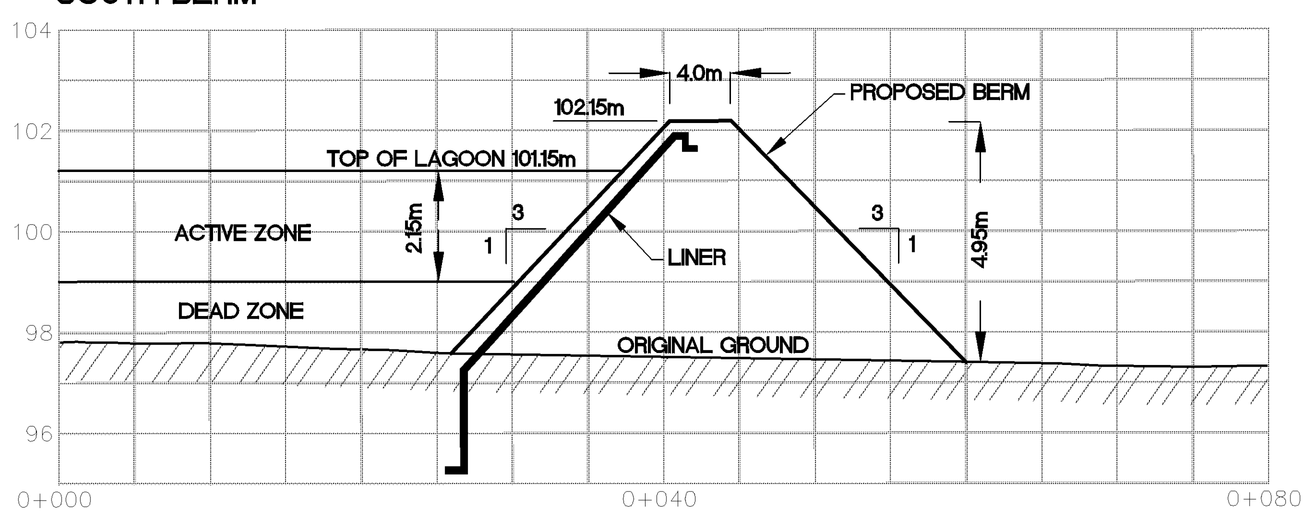


SOUTH BERM



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population of 1,312 and the sewage generation rate of 117 lcpd, the total required storage for sewage is 51,360 m^3. Based on the configuration of the lagoon, the elevation of the surface of the lagoon would be 101.15 m.

The sewage lagoon must also be able to store the volume of precipitation which falls on the lagoon, plus the volume of water that entered the lagoon from runoff from adjacent lands minus losses due to evaporation, evapotranspiration and sublimation. The surface area of the lagoon is approximately 31,500 m^2, and there is an area of 101,000 m^2 that drains into the lagoon. Environment Canada does not provide annual precipitation records for Arctic Bay. The Northwest Territories Data book, 1990/91, published by Outcrop Ltd. reports a total annual precipitation of 118 mm. Based on this value, an average of 3,717 m^3 of precipitation falls on the lagoon, and an additional 11,918 m^3 falls on land, draining into the lagoon for a total potential precipitation input of 15,600 m^3.

A portion of the total precipitation is taken up in evapotranspiration, the sum of the evaporation and plant transpiration from the land. In more temperate climates, the portion of moisture returned to the atmosphere through evapotranspiration is estimated at 40% (Environmental Engineering, Peavy/Rowe/Tchobanoglous 1985). Given the short summer season, and limited vegetation, it is recommended that this value be reduced to 25%.

Standard texts provide methods for the estimation of evaporation. These techniques, both analytical and empirical, require substantial assumptions and input data. This data includes parameters from a long list that can include solar radiation, fraction of radiation reflected and reflected long wave radiation. Confirmation of any methods of estimating evaporation is very challenging. Any estimates of evaporation must be treated in the most cautious of fashions, and it should be accepted that any computation is, at best, an approximation.

Introduction to Hydrology (Viessman et al, 1972, pg 36-38) presents one simplistic method based upon temperature, vapour pressure and wind speed which is data more easily available for similar locations to Arctic Bay. This takes the form:

$$E = C(e_0-e_a)(1+W/10)$$

Where:

E = evaporation (in/day)

e_0 and e_a = vapour pressure at water surface and air (in Hg)

W = wind speed (mph), and

C is a constant (typically 0.36)

As Climate Normals for Arctic bay were not available, Climate Normals for Pond Inlet were used to estimate evaporation. The Climatic Normals for Pond Inlet indicate an average temperature for July of 6.0°C and 4.2˚C for August. Wind speed is reported as 9.7 and 10.3 kph for that same period. If the following conditions are assumed:

Air temperature 5°C (41°F)

Water temperature 3°C (37°F)

Wind Speed 10 mph

Substituting into the relationship provides:

$$E = 0.36(0.26 - 0.22)(1 + 6/10)$$

$$= 0.023 \text{ in/day or}$$

$$= 0.6 \text{ mm/day}$$

On this basis evaporation could total 18 mm per month.

Although the will be additional reduction through sublimation, estimating the reduction is very difficult and therefore it is recommended that the conservative approach be taken, and the reduction through sublimation not be considered.

Applying the assumption that evapotranspiration will reduce precipitation, input to the lagoon by 25% decreases the additional volume that must be stored in the lagoon to 11,700 m^3. This represents an additional depth of 0.404 m. Evaporation over the period of June through August will reduce the stored volume in the lagoon by 18 mm per month for a total of 54 mm. The net increase in lagoon depth when precipitation inputs, evapotranspiration and evaporation are considered is estimate at 0.35 m. Therefore the estimated maximum operating water surface elevation is 101.15 m.

5.4. Decanting Methods

One of the significant challenges in the operation of a sewage lagoon in a northern location is the process of decanting or emptying the lagoon. The three methods that are commonly used are:

1. Seepage cell lagoon design
2. Provision of a discharge pipe through the berm
3. Pumping over the berm

5.4.1. Seepage Cell Design

Many lagoons in the north depend on the permeability of their berms to allow the sewage to seep or leak out during the summer. This method does not allow for the control of the time or rate of decanting. In addition, these berms are more prone to experience partial failure due to erosion piping or settlement from permafrost degradation of the subgrade.

5.4.2. Discharge Pipe

For lagoons that are designed to be impermeable a decanting method must be installed. The installation of a discharge pipe and valve through the berm is common in southern locations with continuous discharge. In storage lagoons in northern locations, the discharge pipe is only used seasonally, and pipe and valve arrangement are installed through a frozen berm. This tends to require the pipe and valve have to be thawed prior to their use which has caused operational concerns, and in some instances has proven impossible.

5.4.3. Pumping

Pumping the effluent from the lagoon is the most operator demanding alternative, however is also the must dependable. It requires the pumps to be installed and removed each year, and during operation must be checked on a regular basis. It also has the added operational cost for fuel. The operation of a pump is a relatively dependable operation, and in the case of failure, a relatively easy system to repair or replace. They also provide a very good method for controlling the time and rate of discharge which is important for lagoons which use a wetlands as a secondary or additional treatment.

5.4.4. Recommended Decanting Method

It is recommended that the pumping be the method used for the decanting of the Arctic Bay Lagoon. The Arctic Bay system includes a wetlands treatment system with the lagoons providing retention and treatment and the wetlands additional treatment or polishing. The performance of the lagoon is dependent on retention time and the wetlands performance is dependent on the time and rate of discharge. Due to the presence of ice rich soil, the geotechnical investigation concluded that the use of seepage cells were not appropriate at this site. In addition, seepage cell construction does not allow for sufficient control over the time and rate of discharge, and therefore are not suitable for this application. The installation of piped discharges poses operational challenges, primarily thawing of the pipe at the time of discharge. They are also more prone to freeze and may not be recoverable which would result in a costly repair or abandonment of the system. Although pumping is the most operator dependent, it provides the best control over the release time and release rate, and is easiest to repair or replace as the system is accessible.

5.5. Sludge Management

Effluent quality will guide when a sludge management program is implemented. Monitoring of the effluent from the lagoon will indicate when the performance of the lagoon starts to degrade. Degradation of the performance of a lagoon is normally caused by sludge accumulation and will be the indicator to desludge the lagoon.

Prior to disposal, the sludge must be tested to ensure the disposal method chosen is safe and environmentally responsible. Sludge removed from the lagoons can be disposed of in a separate cell constructed at the landfill site. The sludge will be covered with granular material and allowed to freeze.

6.0 Sewage Treatment

The proposed Arctic Bay Sewage Treatment Facility will be comprised of a storage lagoon and a vegetated filterstrip wetlands. The treated sewage will be released over a period of 4 weeks late in the summer for further treatment in a downstream wetland. It is desirable that discharge to the wetlands occur at an early date to maximize the opportunity for treatment, prior to the end of warmer weather.

6.1. Influent Characteristics

The characteristics of sewage generated in a community are dependent on the type of installation and sanitary facilities within the community. The Hamlet of Arctic Bay's water and sewage system is comprised of holding tanks and a trucked delivery and collection system. The waste generated from this arrangement is considered to be "Moderately Diluted Wastewater", as per the Cold Climate Utility Manual. Table 6.1 - Characteristics of Basic Wastewater Categories is an excerpt from the Cold Climate Utilities Manual, summarizing the characteristics of moderately diluted wastewater.

Table 6.1 – Characteristics of Waste Water

Parameter	Units	Moderately Diluted
BOD_5	mg/L	460
COD	mg/L	1000
Suspended Solids	mg/L	490

6.2. Sewage Lagoon

There are several removal mechanisms within a sewage lagoon including sedimentation and bio-chemical oxidation. Sedimentation will remove BOD_5 and suspended solids through settling. An annual detention lagoon provides a good opportunity for sedimentation due to the large volume and long detention time. Sedimentation provides typical removals of 35% and 65% of BOD_5 and Suspended Solids respectively in a short time frame (Ontario MOE Guidelines for the Design of Sewage Treatment Works, July 1984, see excerpt in Appendix C). The remaining BOD_5 and suspended solids is in dissolved or colloidal form, and some other removal mechanism must be applied. The natural processes within the lagoon will result in bio-chemical removal of the dissolved and colloidal fraction. The BOD_5 reduction from a lagoon can be predicted using the following first order relationship.

$$C_e = C_i e^{-Kt}$$

Where:

C_e = Effluent concentration (mg/L)

C_1 =Influent concentration (mg/L)

K = BOD_5 removal rate constant (day^{-1})

t = Residence time in lagoon (days)

The rate constant is temperature dependent. The impact of temperature is estimated using the following relationship:

$$K = K_{20}\Theta^{T-20}$$

Where:

K = Rate constant at stipulated temperature (day^{-1})

K_{20} = Rate constant at 20˚C (day^{-1})

Θ = Temperature activity coefficient

T = Temperature (˚C)

The temperature activity coefficient (Θ) for various sewage treatment processes falls in the range of 1.00 to 1.10, with higher values indicating greater sensitivity to changing temperature. Values in the range of 1.04 to 1.10 are reported as typical for aerated lagoons. The lagoon under consideration is a facultative lagoon. A value of 1.08 has been assumed for this coefficient.

The BOD_5 removal rate coefficient for lagoons typically falls in the range of 0.25 to 0.50. Operating conditions for lagoons in harsh climates vary from those in Southern Canada. Specifically, they experience long periods of low activity due to low temperatures and ice cover. The sewage treated has higher than typical strength. There is limited data regarding the performance of lagoons in harsh climates. For these reasons, it was felt appropriate to use a conservative value for the removal rate coefficient. For this analysis a value of 0.10 has been assumed.

Based on the influent characteristics reported in Section 6.1, the influent sewage strength has been assumed to be 460 mg/L BOD_5. Table 6.2 summarizes the treatment levels based on the assumptions stated above for various treatment times, different primary removal rates and a range of temperatures:

Table 6.2 - Effluent BOD_5 Following Bio-Chemical Oxidation

Treatment Time (Days)	Temperatures		
	1°C	2°C	4°C
30	149	141	125
45	105	97	80
60	74	67	52

Based upon the above, 45 days of treatment will provide sufficient treatment to meet the requirements of the Hamlet's water licence for the levels of BOD_5.

This initial removal of suspended solids results in the removal of a portion of the BOD_5. The remaining contaminants are in soluble and colloidal forms. The colloidal materials represent the remaining suspended solids. Subsequent to initial sedimentation, removal is achieved by bio-chemical oxidation. The colloidal fraction is converted into various gasses and microbial cells. The resulting microbial cells settle, further reducing suspended solids through the removal of the colloidal fraction. Typically, suspended solids are reduced to a level comparable to the BOD_5 through the various biological removal mechanisms. This is evidenced by the performance that is typical of lagoons in Southern Canada where effluent quality for seasonal discharge lagoons is reported as 25 mg/L BOD_5 and 30 mg/L suspended solids (Ontario MOE Guidelines for the Design of Sewage Treatment Works, July 1984). For the purpose of estimating the levels of suspended solids at the time of release, the levels will be assumed to be 20% higher than the levels of BOD_5 as per the general performance of lagoons in Southern Canada.

The quality of the effluent released from the sewage lagoon is summarized in Table 6.3.

Table 6.3 – Effluent Quality from the Lagoon

Parameter	Units	Effluent from Lagoon
BOD_5	mg/L	97
TSS	mg/L	172* 116**

*Based solely on reductions from sedimentation
** Includes removal of colloidal fraction of TSS through bio-chemical oxidation

6.3. Wetlands Treatment

Treatment of raw sewage in the new sewage lagoon in Arctic Bay will be combined with the utilization of a vegetated filterstrip wetland as a final polishing step. The proposed sewage lagoon will be constructed on top of the mountain overlooking the existing lagoons and Admiralty Inlet to the south and Victor Bay to the north. The vegetated area between the new lagoon and Victor Bay will be incorporated into the sewage treatment process. The filterstrip wetland area is 11.2 hectare in size (approximately 700 m long and between 86 and 202 m wide) with a slope that varies between 6 to 13 %. Treatment of the pre-treated sewage in the filterstrip wetland area will include removal of TSS, BOD, nutrients and pathogens.

Geotechnical investigations carried out in August 2007 found that the soil in the filterstrip wetland area is comprised of a topsoil layer with peaty and organic content between 15 and 50 cm. thick, silty sand and sand and gravel with permafrost at a depth of approximately 1.5 m in the summer months. This type of soil is suitable for infiltration processes and will facilitate the two main processes of contaminant removal from pre-treated sewage: uptake of contaminants and nutrients by plant roots and degradation by microorganisms in the rhizosphere.

The proposed wetlands area has a well established, native vegetation community that will be used and alterations or modifications to the plant community composition are not necessary to increase removal of contaminants. The plant species present, which include willows, grasses, sedges and mosses are suitable for the phytofiltration processes that will reduce BOD and TSS. Willows are commonly used in phytoremediation processes to remove organic and inorganic contaminants from groundwater, soil and wastewater from sewage lagoons, landfills and acid mine drainage. Sedges and mosses are used in constructed treatment wetlands and are known to contribute to the removal of excess nutrients and contaminants. Mosses in particular are effective in phytofiltration processes for the removal of suspended solids and BOD. The availability of additional nutrients from the pre-treated sewage will result in increased biomass production and growth of the existing vegetation.

The microorganisms found in extreme cold environments, such as the arctic, are extremophiles such as obligate cryophilic/psychrophilic bacteria and archaea which grow and reproduce in temperatures between -20°C and 20°C. These bacteria and archaea are known to grow and reproduce in arctic ice and permafrost. The microbial processes that are involved in the degradation of organic materials are generally carried out by heterotrophic bacteria which use organic compounds as carbon source for energy. Heterotrophic are ubiquitous in soils, particularly in the rhizosphere of plants where organic materials are present. The presence of additional organic material from the pre-treated sewage will result in increased microbial biomass which in turn increases the degradation of organic material.

The estimated performance of the filterstrip wetland is shown in Table 6.4.

Table 6.4: Estimated Reduction in BOD and TSS

Outgoing Concentration from Filterstrip Wetlands	BOD (mg/L)			TSS (mg/L)		
	75	**100**	**145**	**90**	**115**	**175**
Highest	21	28	41	32	41	63
Lowest	6	8	11.6	1.8	2.3	3.5
Average	13.5	18	26	17	22	33

BOD removal is estimated to be 72-92%, with an average reduction of 82% and TSS removal between 64-98 %, with an average reduction of 80.5%. Pathogen removal in the filterstrip wetland is expected to be near 100 % as pathogen survival is very limited outside of host organisms. Nitrogen and phosphate reduction is estimated to be around 80 %. Temperature fluctuations are not expected to change reduction of contaminants or nutrients significantly.

The filterstrip wetland, which will be receiving pre-treated sewage from the newly constructed sewage lagoon, is expected to successfully remove BOD, TSS, pathogens and nitrogen compounds and phosphate before the wastewater enters the ocean. Existing, native vegetation and microorganisms will be the main contributors to the reduction in contaminants and nutrients.

6.4. Sewage System Treatment Summary

The predicted level of treatment provided by the proposed sewage treatment system meets or exceeds the requirements of the Hamlet's water licence. Table 6.5 summarizes the levels of treatment predicted from the sewage treatment system in comparison to the water licence criteria.

Table 6.5 – Summary of Treatment Levels

Parameter	Units	Criteria	Influent	Effluent from Lagoon	Effluent from Wetland[†]
BOD_5	mg/L	100	460	97	18
TSS	mg/L	120	490	172* 116**	33* 22**
FC	#/100ml	1×10^6	1×10^7	1×10^6	<100,000

[†] Based on average treatment levels
* Based solely on reductions from sedimentation
** Includes removal of colloidal fraction of TSS through bio-chemical oxidation

7.0 Monitoring and Compliance Points

7.1. Effluent Monitoring and Compliance

Monitoring the operation of the system will be accomplished through the establishment of seven sampling points, one of which will also be the compliance point. Sampling will provide information regarding the performance of the system and help identify any degradation to the treatment provided. Sampling points will be established at the truck discharge points, the two spillways, and two pump discharges, and at the end of the wetlands. The sampling point at the end of the wetlands shall be the systems compliance point. Table 7.1 provides coordinates of the sampling points, which will be confirmed upon construction by hand held GPS units. A sampling protocol shall be as summarized in Table 7.2.

Table 7.1 – Sampling Points Coordinates

STP#	Description	Latitude	Longitude	Comment
1	Truck Discharge	73° 02’ 27.17”	85° 05’ 10.73”	
2	Lagoon Pump Discharge	73° 02’ 34.07”	85° 05’ 42.96”	
3	End of Wetlands	73° 02’ 52.88”	85° 07’ 05.36”	Compliance Point

Table 7.2 – Sampling Frequency

STP#	Description	Frequency
1	Truck Discharge	Yearly
2	Lagoon Pump Discharge	Twice Yearly – start and end decanting
3	End of Wetlands	Twice Yearly – start and end decanting

7.2. Ground Temperature and Seepage Monitoring

The earth berms, due to the height and retention of fluid, are classified as dams under the Canadian Dam Safety Guidelines, and as such should include ongoing monitoring for stability. As per the recommendations of the geothermal report, a thermistor will be installed in each of the berms to monitor the ground temperatures. Additional thermistor casings will be installed to allow additional monitoring if required. In addition, a series of standpipes will also be installed to monitor for seepage.

The ground temperatures be monitored by a data logger and the data will be collected and reported every three months for the first two years after construction, and three times yearly, after the second year. The standpipes should be monitored yearly, early to mid fall, for the presence of seepage.

8.0 Access Road

To access the site it is required that a new access road, approximately 1.25km long, be constructed from the road to the existing lagoon to the new site. The access road will be comprised of a 7.0m driving surface and a 0.5 m shoulder on each side for a total width of 8.0 m. Due to the relatively steep slope that the proposed road must traverse, it will be required to be aligned across the slope and switch back to the top of the steep section. This proposed alignment provides a maximum grade of approximately 10.4%, and is required to cross a drainage path twice.

To accommodate the stream crossings, two 900 mm diameter CSP culverts are proposed for each crossing. The culvert crossings shall be installed to ensure the culvert inverts are properly buried and in inlets and outlets has sufficient erosion protect.

The stream crossings shall be protected during construction through the installation of silt fencing between the stream and any proposed work.

9.0 Granular Supply

During the site visit in August 2007 Trow staff visited several granular supplies identified by the Hamlet.

These included:

1. The gravel supply currently being used to build a new runway.

2. Small slate quarry located behind residence and the western end of town.

The existing quarry being used for the airport is reportedly near its current boundaries. There appears to be ample supply of material at this site, access to which would require adjustment of the quarry boundary through a new quarry administration agreement. The existing quarry is located near Marcil Lake at the exit to the water fill station.

The Granular Resource Management – 12 Communities, Baffin Region, Nunavut report prepared by Trow in 2004 reported that the Hamlet has three active quarry sites at that time which were nearly depleted and would not meet the Hamlet's needs for road maintenance. The report also identified several large till areas and an area of colluvium located within bedrock outcrops northwest of the Hamlet. The areas are currently inaccessible by road. The study did not extend as far as the current site being used for the new airport, therefore this site was not identified in the study.

A new quarry licence has been issued for to the Hamlet of Arctic Bay which includes sufficient material for the completion of this project. A copy of the license is included in Appendix D.

10.0 Cost Estimate

A Class B Capital Cost Estimate has been prepared for the Arctic Bay Sewage Treatment Facility. The works included in the cost estimate included the following:

1. Construction of a new storage lagoon;
2. Construction of a new access road;
3. Decommissioning of existing facility

A detailed breakdown of the cost estimates is included in Appendix B and includes a 10% contingency allowance. The estimated capital cost for the construction of the Arctic Bay Sewage Treatment Facility, including the works listed above is $5,647,500.

10.1. Operating and Maintenance Costs

One of the characteristics of a sewage lagoon which makes its use in the arctic attractive is the relatively lower operator requirements. For the lagoon system proposed, other than the decanting of the lagoon, regular inspections of the berms, and sampling and testing of the effluent are the main annual operating and maintenance (O&M) costs. For the purpose of analysis the O&M costs for the proposed lagoon, will be assumed to be 1% of the capital cost, not including the cost for decanting the lagoon. The annual O&M costs are estimated to be $58,000 as detailed in Appendix B.

10.2. Life Cycle Costing

The Life Cycle Cost of the proposed facility based on the Capital and O&M costs presented above, based on a 20 year economic life as per the "Water and Sewage Facilities Capital Program: Standards and Criteria" and a discount rate of 8%, "General Terms of Reference for a Community Water and Sanitation Service Study, Appendix A" MACA 1986, is summarized in Table 9.1, and detailed in Appendix B.

Table 9.1 – Life Cycle Cost Summary

Capital Cost	$5,647,500
Present Value of O&M Costs over 20 Years	$569,000
Life Cycle Costs	$6,216,500

11.0 Conclusions and Recommendations

The following summarizes conclusions and recommendations for the preliminary design for the Hamlet of Arctic Bay's new sewage lagoon:

1. The existing sewage treatment facility in Arctic Bay does not meet the long term needs of the Hamlet, nor does it meet the treatment requirements as per the Hamlet's water licence
2. The projected population for the Hamlet of Arctic Bay for the year 2029 is 1,312 persons.
3. The projected sewage generation rate for the 2029, based on the projected population, is 117 lpcd.
4. Three sites were investigated as part of the site visit in 2007, two of these sites were found to be not favourable for the construction of the sewage lagoon due to the slope across the site.
5. The recommended site for the new sewage lagoon for Arctic Bay is located to the north west of the existing facility, in a valley located between two small hills.
6. The sewage lagoon could be developed through the construction of earth berms along the north west and south east ends of the valley.
7. There is an area of undisturbed tundra with an area of 11.2 hectares between the proposed site for the sewage lagoon and Victor Bay to the northwest which will be incorporated into the sewage treatment system as a filterstrip wetlands.
8. A geotechnical investigation of the proposed site revealed large ice lenses beneath the proposed sewage lagoon and proposed locations of the berms.
9. The geotechnical investigation did not reveal bedrock in the middle of the valley within a reasonable distance from the surface.
10. Due to the presence of ice rich soil and ice lenses in the area of the proposed sewage lagoon, it is not recommended that either a seepage cell or fully lined lagoons be used as part of the proposed new sewage lagoon system.
11. Based on the geothermal analysis, it is recommended that lined berms be keyed into the permafrost, utilizing an ice core dam within the berm, the secondary containment can be used for the design of the berms in the creation of the sewage lagoon.
12. The installation of a liner keyed into the permafrost or sound rock is recommended along the south west and north east sided of the valley forming the lagoon.
13. It is recommended that decanting of the lagoon be undertaken yearly through a pumping process. This will provide the best control of time and rate of discharge. The ability to control the time and rate of discharge will allow operators to optimize the level of treatment from the sewage lagoon and the wetlands. Access to the new site will require the construction of an approximate 1.25 km gravel access road from the area of the existing sewage lagoon to the proposed new site.

14. It is recommended that the new sewage treatment facility utilize the existing wetlands between the proposed facility and Victor Bay. This will provide additional treatment of the effluent before it is released into the environment.

15. An environmental assessment undertaken concluded that although there are potentially negative impacts to the project, either due to construction or operation, these can be mitigated through proper design and construction procedures. The project overall provides a net benefit primarily through the improved treatment of the Hamlet's sewage.

16. It is recommended that effluent monitoring be undertaken at the sewage lagoon and at the end of the wetlands, which will be the compliance point for the new sewage treatment facility.

17. As the earth berms are water retaining structures they fall within the dam's safety guidelines and therefore should incorporate a monitoring program.

18. It is recommended that the monitoring program consist of thermistors and standpipes installed within the berms to monitor ground temperatures and seepage within the berms.

19. It is estimated that the capital cost of construction of a new sewage lagoon, the access road and the decommissioning of the existing lagoon will be $5,647,500.

20. The estimated annual operating and maintenance costs for the new facility, including the cost of monitoring and sampling, testing and decanting will be an estimate $58,000 per annum.

21. The overall lifecycle costs over the 20-year design horizon of the facility are estimated at $6,216,500.

22. The estimated final quality of the effluent at the compliance point, i.e. the end of the wetlands is BOD_5 18 mg/L and TSS of 22 mg/L and faecal coliforms of less than 100,000 which meets or exceeds the requirements of the Hamlet's water licence.

Trow Associates Inc.

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Appendix A:
Cost Estimate

Trow Associates Inc. **Class 'B' Cost Estimate**
Arctic Bay Sewage Treatment Facility
OTCD00019054A

Item	Description	Unit	Quantity	Unit Price	Amount
1	Mobilization & Demobilization	L.S.	1	$ 1,000,000.00	$ 1,000,000.00
2	Supply deliver and erect a Project sign.	L.S.	1	$ 5,000.00	$ 5,000.00
	Proposed Lagoon				
3	Supply deliver & install outlet structure c/w, inlet and outlet piping	Ea.	1	$ 90,000.00	$ 90,000.00
4	Supply deliver and install Truck Discharge Structures, including erosion protection	Ea.	1	$ 30,000.00	$ 30,000.00
5	Supply deliver & place granular material to construct new berm	m^3	26,500	$ 40.00	$ 1,060,000.00
6	Supply, deliver and install liner in lagoon berm c/w 150 mm of sand bedding and sand cover	m^2	4,900	$ 55.00	$ 269,500.00
7	Supply, deliver and place granular material to construct 2:1 slope along SW side of lagoon	m^3	2,000	$ 45.00	$ 90,000.00
8	Supply, deliver and install liner along SW side of lagoon c/w 150 mm of sand bedding and sand cover	m^2	5,000	$ 55.00	$ 275,000.00
9	Supply, deliver and install liner along NE side of lagoon c/w 200 mm of sand bedding, 150 mm sand cover and 300 mm general cover material	m^2	7,000	$ 80.00	$ 560,000.00
10	Supply, deliver, place and compact granular material for construction of maintenance road.	m^2	1,000	$ 40.00	$ 40,000.00
11	Supply, deliver and install silt fence	m	900	$ 20.00	$ 18,000.00
12	Supply Deliver and Install boulder barriers	Ea.	80	$ 250.00	$ 20,000.00
13	Supply, deliver and install thermistors casing	Ea.	10	$ 500.00	$ 5,000.00
14	Supply, deliver and install thermistors & data loggers	Ea.	2	$ 2,000.00	$ 4,000.00
15	Supply, deliver and install seepage monitoring tubes	Ea.	10	$ 500.00	$ 5,000.00
16	Install Signage	LS	1	$ 3,000.00	$ 3,000.00
	Proposed Access Road				
17	Excavation, placement of material for roadbed and embankment.	m^3	2,200	$ 25.00	$ 55,000.00
18	Supply, deliver, place and compact material for roadbed embankment.	m^3	17,700	$ 40.00	$ 708,000.00
19	Supply, deliver, place and compact Gran. A	m^3	900	$ 150.00	$ 135,000.00
20	Supply, deliver, place and compact Gran. B	m^3	2,010	$ 100.00	$ 201,000.00
21	Supply, deliver, place road culverts 600 mm dia	m	54	$ 300.00	$ 16,200.00
22	Supply, deliver, place road culverts 900 mm dia	m	77	$ 400.00	$ 30,800.00
23	Supply, Deliver and Install Guide rail	m	500	$ 250.00	$ 125,000.00
24	Supply, Deliver and Install Fencing	m	12	$ 250.00	$ 3,000.00
25	Supply, Deliver and Install gate	Ea.	1	$ 500.00	$ 500.00
				Subtotal	**$ 4,749,000.00**
				10% Contingency	**$ 474,900.00**
				Total	**$ 5,223,900.00**

Item	Description	Unit	Quantity	Unit Price	Amount
1	Mobilization & Demobilization	L.S.	1	$ 25,000.00	$ 25,000.00
2	Excavate top of berm around lagoon and deposit material into lagoon	m^3	375	$ 20.00	$ 7,500.00
3	Excavate top of berm around ice pack area and deposit material into ice pack area	m^3	925	$ 20.00	$ 18,500.00
4	Supply, place and spread general fill in 300mm lifts in the lagoon	m^3	1750	$ 40.00	$ 70,000.00
5	Supply, place and spread general fill in 300mm lifts in the ice pack area	m^3	6600	$ 40.00	$ 264,000.00
				Subtotal	**$ 385,000.00**
				10% Contingency	**$ 38,500.00**
				Total	**$ 423,500.00**

Appendix B:
O&M Cost Estimates and
Life Cycle Cost

Site A

Yearly General O&M

1% of Capital Costs

$5,224,000x 1% = $52,000

Decanting Costs

Fuel	80 litres at $1.25	$100
Operator	2 hours per day @ $75/hr	$150
Miscellaneous		$50
Total		$300
Pumping 20 days	20 x $300	$6,000

Annual O&M Costs

General O&M Costs	$52,000
Decanting Cost	$6,000
Total O&M Costs	**$58,000**

Life Cycle Cost of O&M Costs

@ 8% Discount Rate

Year	Year Cost	Present Value
1	$58,000	$53,704
2	$58,000	$49,726
3	$58,000	$46,042
4	$58,000	$42,632
5	$58,000	$39,474
6	$58,000	$36,550
7	$58,000	$33,842
8	$58,000	$31,336
9	$58,000	$29,014
10	$58,000	$26,865
11	$58,000	$24,875
12	$58,000	$23,033
13	$58,000	$21,326
14	$58,000	$19,747
15	$58,000	$18,284
16	$58,000	$16,930
17	$58,000	$15,676
18	$58,000	$14,514
19	$58,000	$13,439
20	$58,000	$12,444
Total		**$569,453**

Appendix C: Guidelines for the Design of Water and Sewage Treatment Works

With each new plant, or major expansion of an existing plant, the designer is, therefore, requested to economically compare the waste treatment and sludge treatment alternatives before finalizing the overall process.'

Primary sedimentation treatment offers low cost suspended solids and BOD_5 removal, especially in cases where the raw sewage contains a high proportion of settleable solids, as is often the case with sewage containing significant food processing, or similar wastes.

As shown in Table 6.1, primary sedimentation tanks used for phosphorus precipitation with normal strength municipal wastewaters exhibit BOD_5 and suspended solids removals of 65 and 85 per cent, respectively. Without chemical addition for phosphorus removal, the BOD_5 and suspended solids reductions would be 35 and 65 per cent, respectively. With secondary treatment plants, the use of the secondary clarifiers for phosphorus removal has been the most common approach. This has been at least partially due to the reduced chemical requirements when the secondary units are used for phosphorus removal. In view of the potential for increased BOD_5 and suspended solids removals when the primaries are used for phosphorus removal, there may be circumstances when consideration should be given to their use rather than the secondaries for phosphorus removal. Such circumstances might include the following:

- where economic evaluation shows the process to be more cost effective despite the higher chemical costs;

TABLE 6.1

SEWAGE TREATMENT PROCESSES AND TYPICAL EFFLUENT QUALITY

PROCESS	EFFLUENT PARAMETERS (mg/L)			
	TOTAL BOD_5	SS	TOTAL PHOSPHORUS (as P)	FREE AMMONIA (as N)
PRIMARY				
- Without P Removal	110	70	5.0	20
- With P Removal	90	30	1.0	20
CONVENTIONAL A.S.				
- Without P Removal	15	15	3.5	17
- With P Removal	15	15	1.0	17
- With P Removal And Filtration	10	5	0.3	17
- With Nitrification	15	15	3.5	3.0
CONTACT STABILIZATION				
- Without P Removal	20	20	3.5	17
- With P Removal	20	20	1.0	17
EXTENDED AERATION				
- Without P Removal	15	15	3.5	3.0
- With P Removal	15	15	1.0	3.0
- With P Removal And Filtration	5	5	0.3	3.0
CONTINUOUS DISCHARGE LAGOON				
- Without P Removal	25	30	6.0	
- With P Removal	25	30	1.0	
SEASONAL RETENTION LAGOON				
- Without P Removal	25	30	6.0	
- With P Removal By Batch Chemical Dosage	15	20	1.0/0.5	
- With P Removal By Continuous Chemical Dosage	25	30	1.0	
PRE-AERATION LAGOON (Aerobic - Facultative Type)				
- Without P Removal With 4-5 Days Retention Time	60	100	6.0	

NOTE :

1. The above values are based on typical raw sewage with Total BOD_5 = 170 mg/L, Soluble BOD_5 = 50%, SS = 200 mg/L, P = 7 mg/L, NH_4^+ = 20 mg/L.

Appendix D:
Quarry Permit No. 08 703 001
Arctic Bay

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Nunalaani Kavamatkunnilu Hulijutainni
Department of Community and Government Services
Ministère des Services communautaires et gouvernementaux

File No.703-QUA

April 19, 2008

PROJECT MANAGEMENT,
CGS Regional Office
P. O. Box 379
POND INLET, NU
XOA OSO

Attention: JOHN WATSON

QUARRY PERMIT NO. 08-703-001
ARCTIC BAY, NUNAVUT

Enclosed is Quarry Permit no. 08-703-001 as requested in your application dated September 3RD 2007.

Please note that the Permit terms and conditions enclosed are an integral part of the Permit, and compliance with these terms and conditions is equally mandatory. In addition to the attached terms and conditions please note that the Nunavut Impact Review Board has recommended the following:

1. NIRB would like to encourage the proponent to hire local people and services, to the extent possible.

2. The Proponent should ensure that all reasonable public safety procedures are implemented during the life of the operation.

3. NIRB recommends that a final inspection be made by the proponent upon the last load being hauled to ensure the removal of any debris, garbage and the like which might have accumulated along the road and at the site during the work period of this project.

4. NIRB advises proponents to consult with the local residents regarding their activities in the region.

5. All amendment requests deemed by the Nunavut Impact Review Board to be outside the original scope of the project will be considered as a new project.

If you have any questions, please contact our office at 867-897-3621.

Sincerely,

Adule Chris
Regional Community Planner (Baffin Region)

cc. Community Planning & Lands Administration – Hamlet of Arctic Bay

P.O. Box 330, Government of Nunavut, Cape Dorset, X0A 0C0
(867) 897-3621 (867) 897-3633/3632

QUARRY PERMIT NO. 08-703-001

QUARRY PERMIT

PURSUANT TO THE COMMISSIONER'S LAND ACT AND REGULATIONS

FULL NAME OF PERMITEE		MAILING ADDRESS OF PERMITEE
PROJECT MANAGEMENT (GN)	**of**	**P. O. BOX 379 Pond Inlet, Nunavut X0A 0S0**

is hereby authorized to take **340,000** cubic meters of **Pit Run** from four (4) sites located approximately 5 miles from Hamlet of Arctic Bay community site.

(as sketch attached to this permit)

This permit is subject to the following conditions:

1. This permit expires on **May 1, 2009** or when the quantity of material specified in this permit has been quarried or removed, whichever is sooner.
2. This permit does not grant to the Proponent any exclusive right or leasehold interest in the land described above.
3. This permit is not assignable and any assignment of it is of no effect.
4. All quarrying under this permit shall be carried out in accordance with the MINING SAFETY ACT, where that Act applies
5. This permit is issued subject to the provisions of the Commissioner's Land Act and the Commissioner's Land Regulations. This Permit and the terms and conditions annexed are equally binding parts of this Permit. Failure to comply with the provisions of the Act and Regulations, this Permit or the terms and conditions annexed, may result in penalties including the cancellations of the Permit without prior notice to the Permittee.

ISSUED AT	DATE	REGIONAL SUPERINTENDENT
CAPE DORSET, NUNAVUT	18th April, 2008	