# Government of Nunavut

## Design Brief

**Project Name**
Optimization of the Wastewater Facility
Igloolik, Nunavut

**Project Number**
OTT-00019838-A0

**Prepared By:**

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**Date Submitted**
November 2014

# Government of Nunavut

## Design Brief
## Optimization of the Wastewater Facility - Igloolik, Nunavut

**Type of Document:**
Final

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Igloolik Wastewater Treatment Facility

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**Date Submitted:**
November 19, 2014

PERMIT TO PRACTICE
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NT/NU Association of Professional Engineers and Geoscientists

# Table of Contents

# List of Appendices



# List of Tables

# List of Figures

**Page**

# 1 Introduction

**Exp** Services Inc. (**exp**) was retained by the Department of Community & Government Services (CGS), Government of Nunavut (GN) to complete the detail planning and design for the rehabilitation of the existing sewage lagoon for the Hamlet of Igloolik (Hamlet), Nunavut.

The existing sewage lagoon is located approximately 1.3 km north of the community and adjacent to the Hamlet's solid waste site as shown on Figure 1-1. Effluent from the existing facility flows approximately 450 metres to the northeast towards Turton Bay. The land between the existing sewage lagoon and Turton Bay is undeveloped tundra.

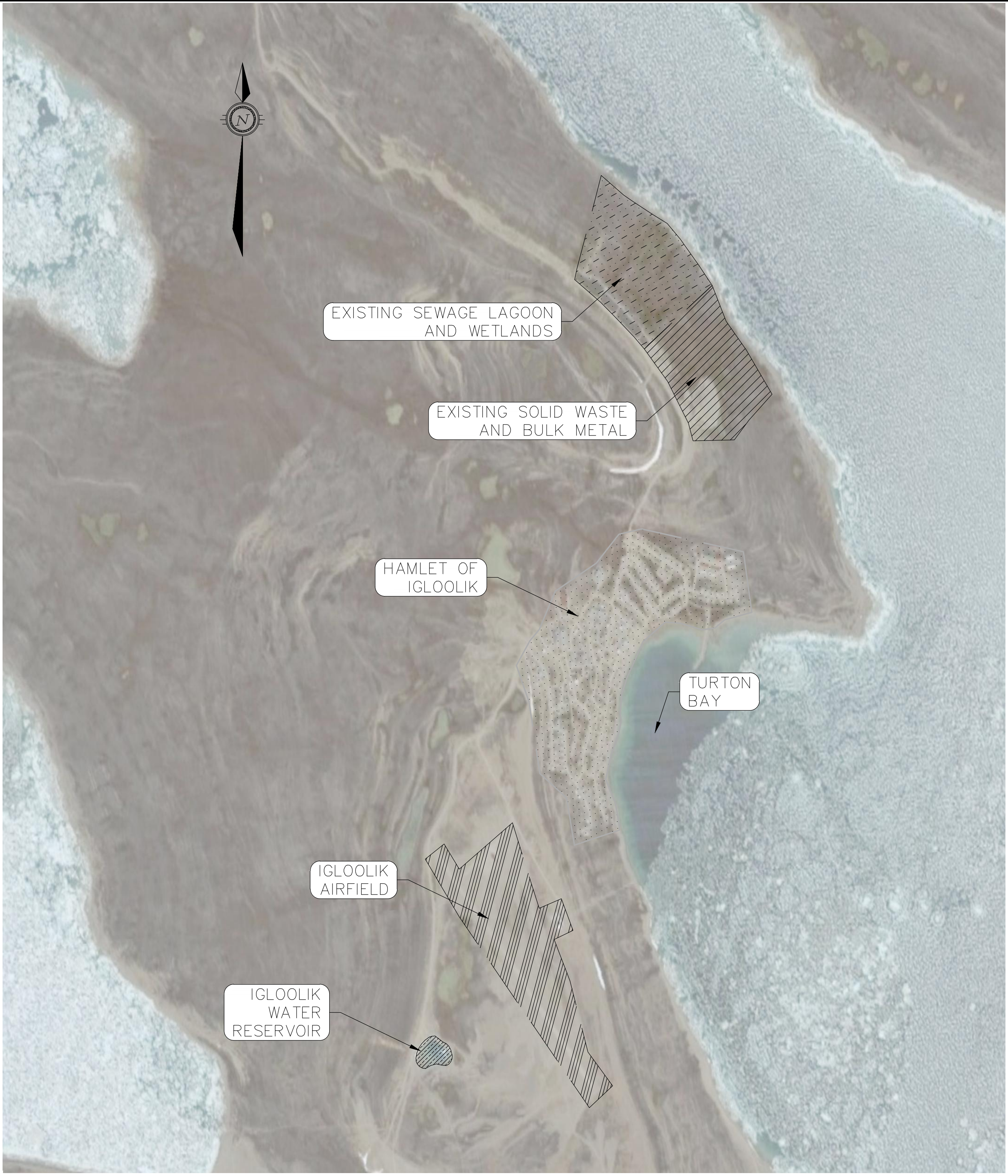
It is estimated that the existing lagoons have a capacity of approximately 42,000 $m^3$. The required sewage storage requirement for 2014 is estimated to have been approximately 75,000 $m^3$. Therefore the existing sewage lagoon does not meet the current or future storage requirements for the Hamlet.

The intent of this project is to upgrade the sewage treatment facility to meet the needs of the Hamlet for 20 years, and to fulfill the requirements of the water licence 3BM-IGL0911 dated July 10, 2009. This will be achieved by rehabilitating and expanding the existing sewage lagoon system.

## 1.1 Scope of Services

The scope of services to be undertaken as part of the detail planning and design for the expansion and/or rehabilitation of the Hamlet's sewage treatment facility includes 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 system as part of the treatment facility.
6. Develop a plan and design for the rehabilitation of the existing sewage lagoon.
7. Develop a plan and design for the construction of a new sewage lagoon to meet the long term requirements of the Hamlet.
8. Prepare a cost estimate for construction and improvement of the new sewage lagoon, including rehabilitation (if applicable) of the existing lagoon.





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| scale 1:4000 | CLIENT: HAMLET OF IGLOOLIK | project no. OTCD00019838 |
| date NOV. 2014 | | |
| drawn by MJT | TITLE: LOCATION PLAN | FIG 1-1 |

# 2 System Requirements

## 2.1 General

The proposed sewage treatment facility for the Hamlet 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 Facility Capital Program Standards and Criteria" as provided by the CGS, indicates that the design horizon for sewage lagoons is to be between 15 and 20 years. As per the direction of the CGS, the design horizon for this project shall be 20 years, until the year 2036.

## 2.2 Population

The population projections for this project will be based upon Baffin Community Projections as published by the Nunavut Bureau of Statistics, June 24, 2010. The Nunavut Bureau of Statistics population projections provide projected populations of the Nunavut communities to the year 2036. The table below summarizes the population projections to the year 2036.

**Table 2.1: Population Projections**

| Planning Year | Year | Population | Planning Year | Year | Population |
|---|---|---|---|---|---|
| | 2014 | 1760 | 10 | 2026 | 2098 |
| | 2015 | 1784 | 11 | 2027 | 2129 |
| 0 | 2016 | 1811 | 12 | 2028 | 2161 |
| 1 | 2017 | 1839 | 13 | 2029 | 2193 |
| 2 | 2018 | 1867 | 14 | 2030 | 2226 |
| 3 | 2019 | 1894 | 15 | 2031 | 2260 |
| 4 | 2020 | 1922 | 16 | 2032 | 2294 |
| 5 | 2021 | 1949 | 17 | 2033 | 2329 |
| 6 | 2022 | 1976 | 18 | 2034 | 2364 |
| 7 | 2023 | 2005 | 19 | 2035 | 2397 |
| 8 | 2024 | 2035 | **20** | **2036** | **2431** |
| 9 | 2025 | 2067 | | | |

## 2.3 Sewage Generation

To determine the volume of sewage the facility must treat, the sewage generation rate must first be established. Sewage generation rates are generally assumed to be equal to the water consumption rates for a community, with the water consumption rate being the combined total of the residential and non-residential water consumption. The Water and Sewage Facility Capital Program Standards and Criteria, as published by the Government of the N.W.T., provide the 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 upon the method of water delivery and sewage collection in the community. The litres per capita per day (lpcd) water usage rates for the different methods of water delivery and sewage collection are summarized in 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 |

The Hamlet 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 the population. To determine the total community water usage, the RWU is adjusted based on population to provide Total Water Usage per Capita (TWUC). The TWUC, including residential and non-residential activities is estimated based on the equations in Table 2.3.

**Table 2.3: Total Community Water Usage**

| Community Population | Total Water Use Per Capita |
|---|---|
| 0 – 2,000 | RWU x (1.0 + 0.00023 x Population) |
| 2,000 – 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 based on the design population of ***2431*** for the year ***2036***, and the TWUC is calculated to be:

TWUC = RWU x [(0.323 x ln(Population)-1]
= 90 x [0.323 x ln(2431) -1]
= 90 x [1.499]
= 136.63 lcpd or **137 lpcd**

Based on a TWUC rate of 137 lpcd, the daily sewage generation rate, estimated for the year 2036, for the entire community of Igloolik is equal to 333,047 litres per day (lpd). This is equal to a yearly sewage generation rate of **121,562m$^3$**.

## 2.4 Regulatory Requirements

Currently the Hamlet is not operating under a valid water licence. It is important that a water licence be obtained otherwise the Hamlet will be in contravention of the Nunavut Land Claims Agreement (NLCA) and the Nunavut Waters Act.

Table 2.4 – Effluent Quality Standards, illustrates anticipated maximum concentrations and acceptable values from previous water licences in Nunavut.

**Table 2.4: Effluent Quality Standards**

| Parameters | Maximum Average Concentration |
|---|---|
| $BOD_5$ | 120 mg/L |
| Total suspended solids (TSS) | 180 mg/L |
| Faecal coliforms | < or = to 1 x $10^6$ CFU/100 mL |
| Oil and grease | No visible sheen |
| pH | 6 and 9 |

# 3 Site Investigation

In 2009, a detailed site investigation was undertaken, including the following:

- Site inspection (July 14 to 17, 2009)
- Topographic survey (September 21 to 24, 2009)
- Geotechnical investigation (October 28 to November 3, 2009)
- Wetlands Assessment (September 21 to 24, 2009)
- Environmental Assessment (September 21 to 24, 2009)

## 3.1 Site Inspection

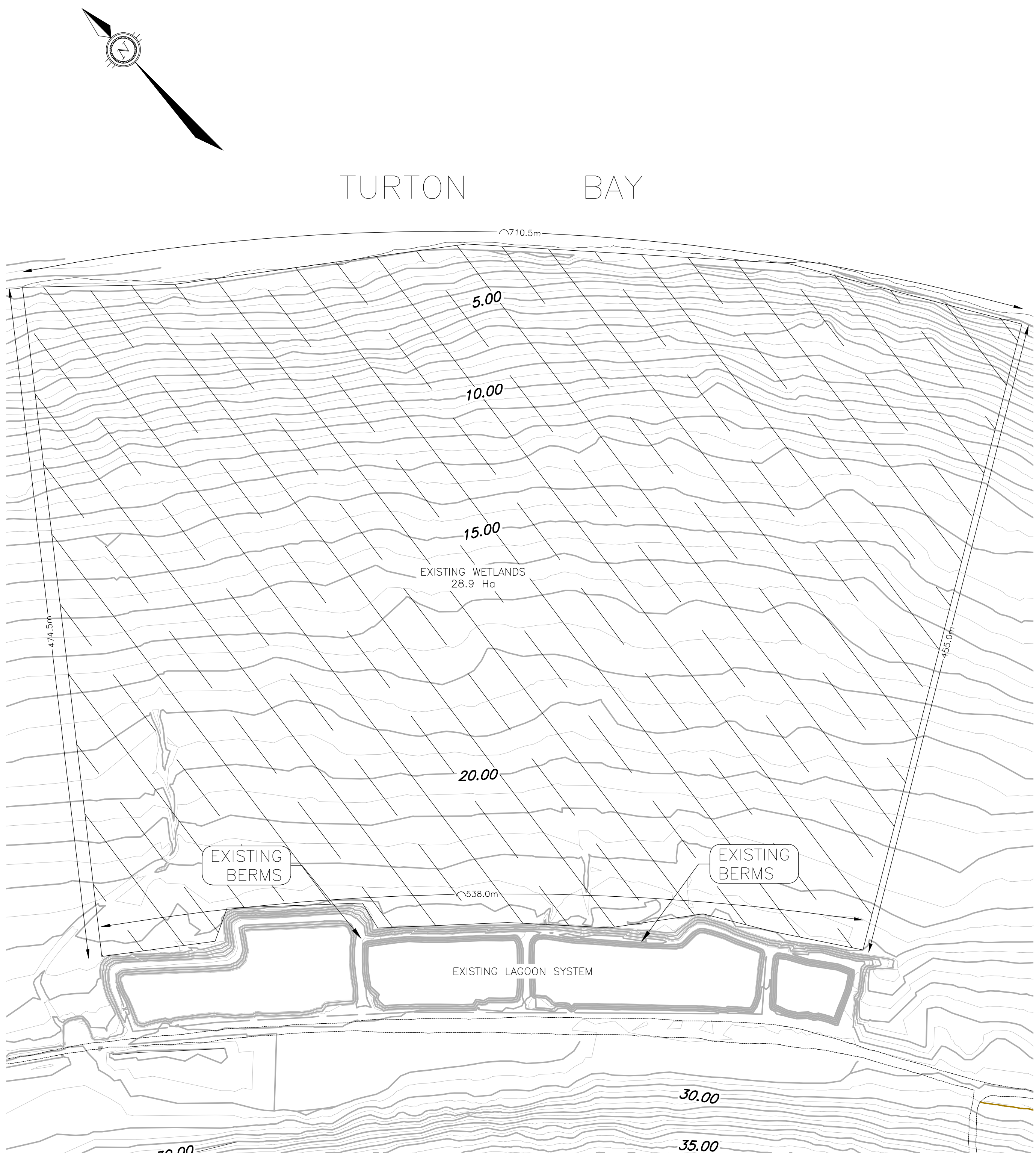
As part of the site investigation an inspection of the existing facility was undertaken. This inspection noted the following:

- The existing sewage lagoon system is comprised of four (4) separate cells which are not linked hydraulically.
- Each of the four cells has independent truck discharge locations.
- The existing discharge locations are in a poor state of repair and do not have a sewage discharge chute.
- Indications of slope instability are evident along the existing berms.
- There are indications of localized areas of piping.
- There is seepage from the lagoon along the northeast berm.
- There is a potential wetlands area hydraulically downstream of the lagoon, between the existing lagoons and Turton Bay.
- The area to the south is occupied by the Hamlet's bulky metals waste site; there is no opportunity to expand the sewage lagoon system in this direction.
- There is an existing drainage course on the northern boundary of the site.

## 3.2 Topographic Survey

A topographic survey of the existing facility, including the existing lagoon cells, honey-bag dump and wetlands was undertaken. In addition, a topographic survey for the proposed extension to the site for the new lagoon was also conducted.

The typical characteristics of the existing lagoon (based on the topographic survey) are shown in Table 3.1, and the existing topography and layout of the lagoon is shown in Figure 3-1: Existing Lagoons.





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| scale: 1:4000 | CLIENT: HAMLET OF IGLOOLIK | project no. OTCD00019838 |
| date: NOV. 2014 | | |
| drawn by: MJT | TITLE: EXISTING LAGOONS | FIG 3–1 |

**Table 3.1: Dimension of Existing Lagoons**

| | Existing Lagoons |
|---|---|
| Dimensions | 55 m x 530 m |
| Side Slopes | Range from:<br>1.0 H : 1 V<br>1.9 H : 1 V |
| Top of Dyke Width | 1.0m to 2.5m |

The topographic survey of the area for the proposed expansion of the sewage treatment facility indicates a slope across the site of approximately 2.5%-9.0%, generally in a northeast direction from the existing access road through to Turton Bay. The survey also located the small watercourse on the western boundary of the lagoon.

The survey crew, in conjunction with the wetlands specialist, mapped out the limits of the existing wetlands treatment, as well as the limits of the potential wetlands. Currently, approximately 28.9 hectares of tundra are being utilized for wetlands treatment.

## 3.3 Geotechnical Investigation

As part of the site investigation, a geotechnical investigation was carried out by **exp**. The geotechnical report resulting from this investigation was issued on March 16$^{th}$, 2010 under a separate cover. The following summarizes the findings and recommendations from this report:

The field investigations revealed that the soils on the site are ice poor and are low in salinity. The report also found an absence of ice layers (or seams) within the soil cores retrieved. Numerous problems are being experienced with existing lagoons which have been designed as exfiltration lagoons. Based on the estimated permeability of the tested soil, it was concluded that the on-site soils are not impervious and are considered permeable. Consequently, if these soils are to be used for construction of the berms, the proposed lagoon would have to be lined; it is then recommended that the new lagoon be designed as an impervious lagoon, with a Polymetric Geomembrane or equivalent (as referenced in the geothermal report).

The existing lagoons have been designed as exfiltration lagoons. These lagoons are experiencing a number of problems as follows:

- The crest width of the berms of lagoons 1 to 3 is narrow. It varies from 1.0 m to 2.5 m. As a result, these lagoons are not accessible to vehicular traffic which leads to maintenance difficulties.
- The existing berm slopes are very steep. They vary from 1 horizontal to 1 vertical to 1.9 horizontal to 1 vertical. As a result, these slopes are prone to localized failures and require extensive maintenance.
- The berms have been constructed with locally available materials which vary from sand and gravel clayey silt, sandy silt to sandy silt till. The heterogeneous nature of the available materials has resulted in pockets which are more permeable. As a result, these pockets become preferred paths for flow of the effluent, which results in erosion of the soil and the conduit becoming larger with time and may lead to eventual failure of the berms due to piping.
- The seepage of effluent through the berms results in filtration of the effluent. As a result, the fines in the effluent are deposited in the voids of the soil. Gradually these voids fill with fines and prevent further seepage of the effluent. This results in build-up of excessive pore pressures which eventually results in localized slope failures.

- Given the prevailing environmental conditions, the discharge of the effluent from the lagoons can take place during 2 to 3 months of the year only, i.e. during the summer months, approximately from June to August. As a result, all the effluent is not discharged from the lagoons which results in greater reduction in the available capacity of the lagoons for storage of the effluent.

For the above reasons, design of the lagoons as exfiltration lagoons is not recommended.

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

In August of 2014, the site was visited by a Geotechnical Technician from **exp**, and the site was reported as unchanged, and therefore the findings and recommendations of the 2010 report are deemed to remain applicable.

## 3.4 Wetlands Assessment

In conjunction with the rehabilitated and expanded sewage lagoons, wetland treatment will be utilized to provide further treatment to the sewage prior to release to the environment. The area to be used as wetlands for the Igloolik treatment facility is a vegetated filterstrip wetland as described in the report *Vegetated Filterstrip Wetland Assessment,* issued under a separate cover.

The proposed sewage lagoon will be constructed next to the existing lagoon. The area between the lagoons (existing and proposed), and the ocean will be incorporated into the sewage treatment process as shown in Figure 3-2: Wetlands. The existing wetlands area is approximately 28.9 hectares in size (approximately 470 m long and 615 m wide) with an average slope of 2.5 to 9.5%. The proposed wetlands vary in size based on the alternatives and are further discussed in Section 5. However, the wetlands will be of adequate size and of similar slope compared to the existing wetlands. 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 Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS).

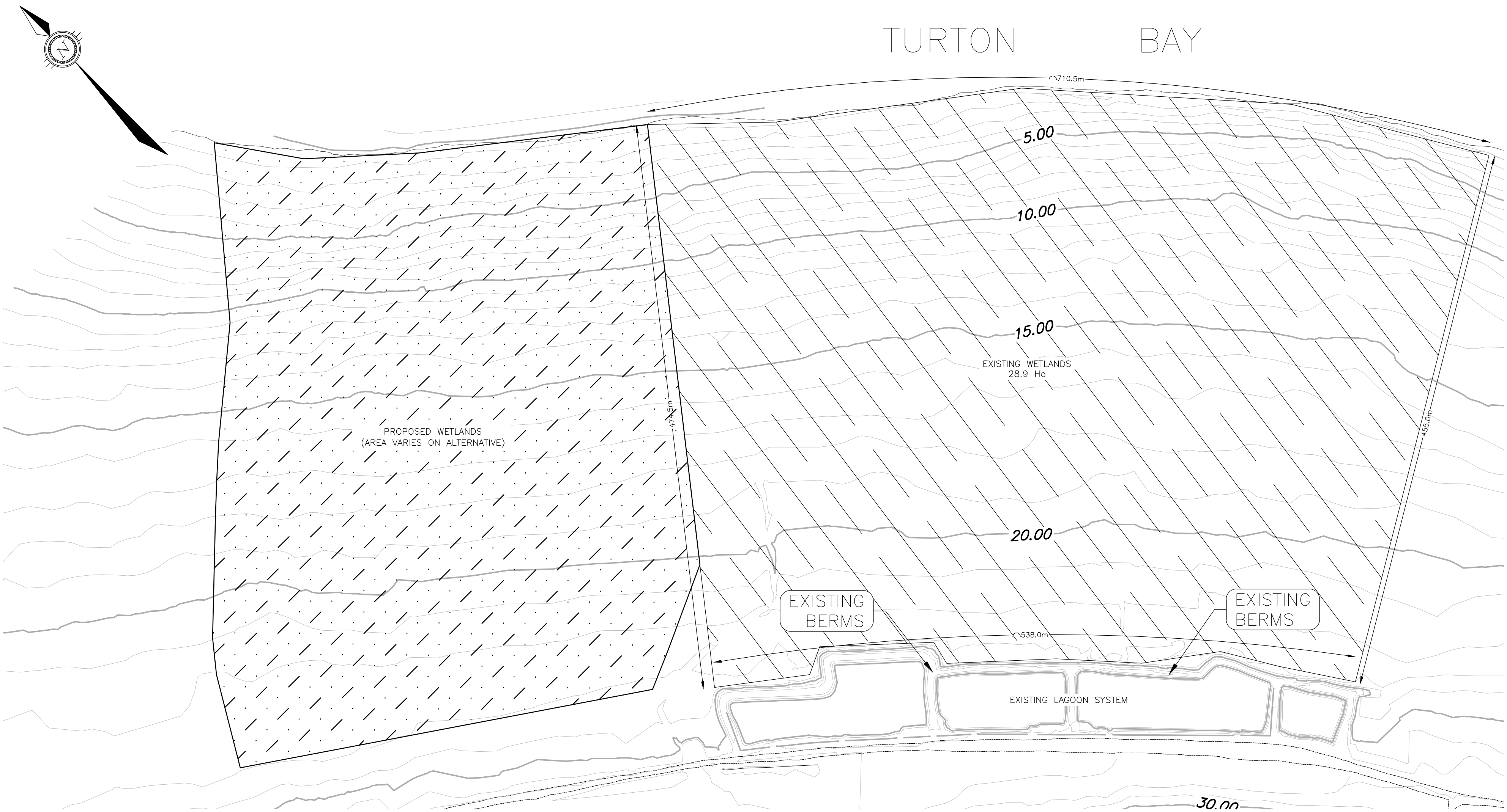
## 3.5 Environmental Assessment

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

The Hamlet 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 GN is the Responsible Authority (RA).

The new sewage lagoon will be designed for the calculated capacity required to sustain Igloolik's sewage requirements for the projected Hamlet's growth in 2036 and will incorporate a native vegetated filterstrip wetland as an additional polishing step. A number of interactions may have a negative effect, however, all of the negative effects can be reduced through mitigation measures, maintenance programs or the 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.

A meeting with Hamlet Council took place in August of 2009; beyond this consultation no other public participation was considered because the project has no negative effect on the public and is confined to the site. No other consultation with other jurisdictions was undertaken.

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| scale: 1:5000 | CLIENT: HAMLET OF IGLOOLIK | project no. OTCD00019838 |
| date: NOV. 2014 | TITLE: WETLANDS | FIG 3–2 |
| drawn by: MJT | | |

# 4 Detail Design

## 4.1 Lagoon Size

The proposed sewage lagoon system for Igloolik shall 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, and also account for the projected population growth. In addition, the lagoon system must be able to store the precipitation that either falls in, or drains into the lagoon, minus the effects of evaporation.

It is anticipated that the decanting of the Igloolik system will begin in mid to late August and continue until mid to late September over a period of 30 days. Therefore, the required storage for the new sewage lagoon will be for a 335 day period (approximately 11 months). Based on the projected population of 2431 people in the year 2036 and an anticipated sewage generation rate of 137 lcpd, the total required 11 month storage is 111,571m$^3$.

The Canadian Normals as published by Environment Canada provide an annual precipitation of 275 mm for Igloolik. This table can be viewed in Appendix D. According to the website, “precipitation in the tables is the water equivalent of all types of precipitation.” This definition includes snowfall. The precipitation results in an average volume of approximately 16,250 m$^3$ which falls into the lagoon(s). This is based on a surface area of approximately 57,000 m$^2$.

Standard textbooks 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.

The textbook Introduction to Hydrology by Viessman et. al, (1972) presents one simplistic method based upon temperature, vapour pressure and wind speed which is data generally available for locations such as Igloolik. 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)

The Climate Normals for Igloolik indicate an average temperature for July of 7.0°C and 4.9˚C for August. Wind speed is reported as 12.7 and 15.3 kph for that same period. If the following conditions are assumed:

Air temperature 6°C (43°F)

Water temperature 3°C (37°F)

Wind Speed 14 kph (8.4 mph)

Substituting into the relationship provides:

$$E = 0.36(0.26 – 0.22)(1 + 8.4/10)$$

$$= 0.027 \text{ in/day or}$$

$$= 0.7 \text{ mm/day}$$

On this basis evaporation could total 21 mm per month. Evaporation over the period of June through August will reduce the stored volume in the lagoon by a total of 63 mm or approximately 3,600 $m^3$.

The total 11 month volume of storage to be provided by the sewage lagoons is equal to the volume of effluent, plus precipitation minus the evaporation (111,571 $m^3$ + 16,250 $m^3$ - 3,600 $m^3$) for a total of approximately 124,220 $m^3$.

## 4.2 Earth Berm Design

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

### 4.2.1 Geotechnical Recommendations

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

#### 4.2.1.1 New Lagoon Cell

The new lagoon cell is to be designed as an impervious cell. A slope stability analysis was performed to determine the steepest slopes of the berms that would be stable under prevailing conditions and provide a minimum factor of safety of 1.5 for static loading conditions, and a minimum factor of safety of 1.1 for seismic loading conditions. The inside slopes of the berms were analysed for fully submerged condition whereas the outside slopes of the berms were analysed for steady state seepage conditions. Static as well as seismic loading was considered for each case. The analysis revealed that the slopes would have an adequate factor of safety if the inside and outside berm slopes are constructed at an inclination of 3H:1V and 3.25H:1V respectively. It is noted that the computed slopes would be stable provided that the berms are not overtopped and are not subjected to ‘rapid drawdown’ condition.

#### 4.2.1.2 Rehabilitation of Existing Lagoon Berms

The remediation of the existing lagoons would necessitate widening the crest of these berms so that they are accessible to vehicular traffic and constructing the berms with stable side slopes. In addition, these lagoons should be converted from exfiltration lagoons to impervious (lined) lagoons. It is recommended that the minimum crest width of the rehabilitated berms should be 4 m to enable access to vehicular traffic. A slope stability analysis was performed to determine the steepest slopes of the berms that would be stable under prevailing conditions and provide a minimum factor of safety of 1.5 for static loading conditions, and a minimum factor of safety of 1.1 for seismic loading conditions. The inside slopes of the berms were analysed for fully submerged conditions, whereas the outside slopes of the berms were analysed for steady state seepage conditions. Static as well as seismic loading was considered for each case. The analysis revealed that the slopes will have an adequate factor of safety if the inside and outside berm slopes are constructed at an inclination of 3H:1V and 3.25H:1V respectively. It is noted that the computed slopes would be stable provided that the berms are not overtopped, and are not subjected to ‘rapid drawdown’ conditions. This work should be carried out under the full time supervision of a geotechnician working under the direction and supervision of a geotechnical engineer.

### 4.2.2 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 Igloolik, which proposes to utilize an impermeable liner within the lagoon’s berm containment structure.

The geothermal modeling shows that while there may be significant thawing under the containment area (particularly in the climate warming case), the overall lateral containment of the frozen mass surrounding the containment area should be adequate to confine or restrict any seepage. Seepage will also be likely impeded by the presence of unweathered bedrock at depth.

Selection of the liner material requires careful consideration as the industry is moving away from high density polyurethane (HDPE) and geosynthetic clay liners (GCL), as both systems have reportedly experienced performance issues in cold temperature applications. A favourable alternative (gaining favour in such locations as Prudhoe Bay, Alaska) is *polymeric geomembranes*, which may include thermoplastic polyurethane. Polyether polyurethane materials are reported to provide good low temperature properties.

The geothermal analyses have assumed that the lagoon berms will be constructed without any perforations or apertures. It is recommended that no drainage pipes or vertical access manholes be installed through or in the berm structure.

### 4.2.3 Recommended Berm Design

The proposed design for the rehabilitated and new lagoon cells is for impervious cells. The options for the creation of an impervious structure are:

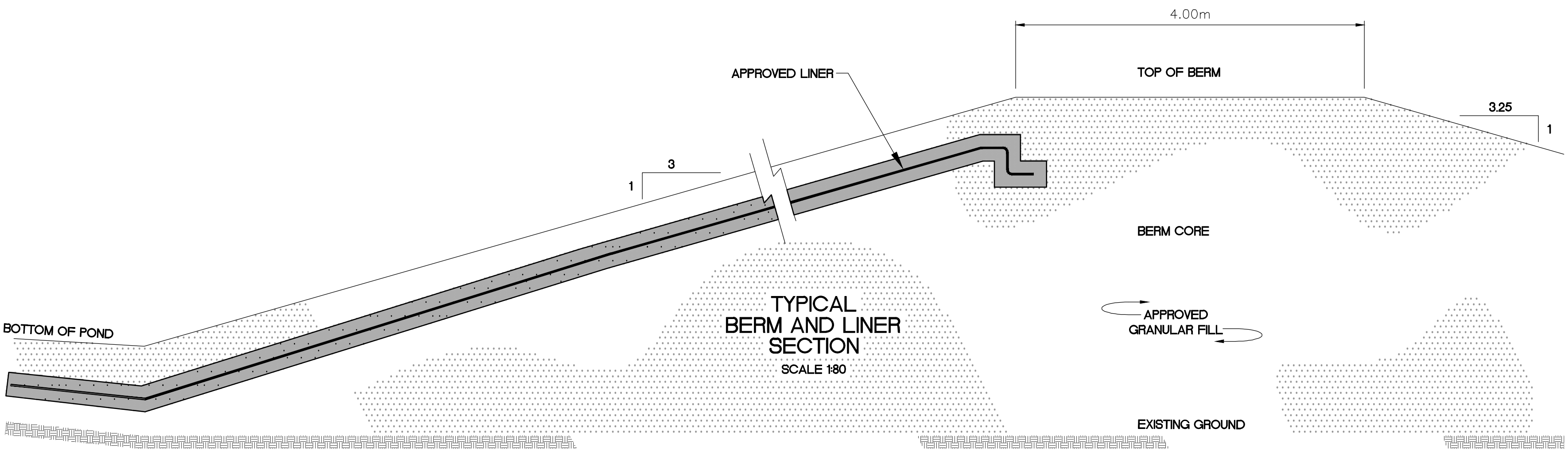
- A fully lined lagoon.
- A liner installed in the berms keyed into the permafrost.

The fully lined lagoon is the traditional approach to making a sewage lagoon impervious. The disadvantages to this approach are liner integrity if the liner experiences an unstable base and the possibility of uplift forces due to buoyancy caused by pore pressures under the liner.

Keying the liner into the permafrost is an alternative that makes use of the impervious characteristic of the permafrost to form the impervious boundary along the bottom of the lagoon, and the liner to form the imperious boundary in the berms. This system is dependent on being able to key the liner into the permafrost. The system is generally the most attractive when a fully lined system is not feasible due to ice rich soils or high buoyancy forces.

As the soils conditions are not ice rich and adverse buoyancy forces will not be present, it is recommended that the entire lagoon be fully lined with an appropriate impermeable layer satisfying both geotechnical and geothermal recommendations.

As per the geotechnical recommendations, the proposed berm design is to have a 3H:1V slope on the upstream side of the berm with a 3.25H:1V slope on the downside of the berm. The berm crest width will be 4 m. 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. The typical berm sections are shown in Figure 4-1.

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| scale: 1:80 | CLIENT: HAMLET OF IGLOOLIK | project no. OTCD00019838 |
| date: NOV. 2014 | | |
| drawn by: IPC | TITLE: TYPICAL BERM SECTION | FIG 4–1 |

## 4.3 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

### 4.3.1 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 the erosion of the piping or settlement from permafrost degradation of the subgrade.

### 4.3.2 Discharge Pipe

For lagoons that are designed to be impermeable a decanting method must be installed. The installation of a discharge pipe 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 the pipe and valve arrangements are installed through a frozen berm. This may result in the decanting structure to freeze and thus require that the pipe and valve to be thawed prior to their use. This has caused operational concerns, and in some instances has proven impractical.

### 4.3.3 Pumping

Pumping the effluent from the lagoon is the most operator demanding alternative, however, it is also the most dependable. It requires that the pumps are 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. Pumping also provides 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.

### 4.3.4 Recommended Decanting Method

The Igloolik system includes sewage lagoons providing retention and treatment and wetlands treatment systems providing additional treatment and/or polishing. The performance of the wetlands is dependent on the time and rate of discharge.

One of the causes for concern identified in the Geotechnical Report with the existing lagoons was due to the seepage of effluent and the gradual build-up of excessive pore pressure. Also, seepage cell construction does not allow for sufficient control over the time and rate of discharge, and therefore is not suitable for this application.

The installation of piped discharges poses operational challenges, primarily the 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. Also, the Geothermal Report does not recommend the use of pipe discharge through the berm. This report stated:

> "…the operation of impermeable liners and perforations or apertures within the berm structure is generally incompatible. That is, where drainage pipes or access manholes are installed in the lagoon containment structure and these features penetrate the liner, an opportunity of leakage and seepage will be present. Therefore, the design of the structure should avoid the installation of drainage pipes, access manholes and other potential seepage points."

Pumping over the berm is the most operator dependent, but it also provides the best control over the release time and release rate, and is the easiest to repair or replace (as the system is accessible). It is therefore recommended that pumping over the berm be the preferred method of decanting.

## 4.4 Sludge Management

One of the main mechanisms of treatment in a sewage lagoon is the settlement of solids. The accumulation of solids is referred to as sludge. To ensure the sludge is not released to the environment, the design of the sewage lagoon must allow for storage of the sludge (settled solids).

There is very limited data regarding the operational behaviour of lagoons in arctic environments. Due to this lack of data, various assumptions were used to develop an estimate of sludge accumulation rates and are summarized as follows:

1. Individual suspended solids contribution is assumed to be 90 grams/capita/day. This is based upon the rate of suspended solids typically found in municipal sewage.
2. A complex set of mechanisms is responsible for removal of contaminants in a lagoon. These mechanisms include sedimentation, aerobic oxidation and anaerobic sludge volume reduction, which reduce the solids contribution from influent sewage. The biological processes also create solids in the forms of bio-mass (bio-solids). It has been assumed that the net outcome of the various biological processes that both create and reduce solids leads to a rate of sludge contribution at the same rate as the individual suspended solids contribution.
3. The sludge that accumulates in the lagoon is made up of sedimented suspended solids and a large amount of water. These solids remain undisturbed in the bottom of the lagoon for several years. This provides the opportunity for gravity thickening of these solids over a protracted period of time. For the purposes of these calculations it has been assumed that an ultimate sludge density of 10% will be achieved.
4. The suspended solids, which accumulate in the lagoon cell, have a very low density and these solids are easily re-suspended. Thus, localized areas of high velocity should be avoided to reduce the risk of re-suspension of accumulated sludge.

The preceding assumptions lead to an annual per capita rate of sludge accumulation of 32.85 kg that represents a per capita volume of 0.329 $m^3$. The total accumulated sludge over the 20 year life of the proposed lagoons, is 14,558 $m^3$ as shown in Table 4.1.

The depth of sludge accumulation is based on an ultimate sludge density of 10% (assumption #3). Thickening of the sludge to this density by gravity will occur over a protracted time period; therefore the storage zone within the lagoon must be greater than the estimated storage volume to account for the un-thickened sludge.

That portion of the lagoon, which is described as the sludge storage zone, also serves to separate accumulated sludge from the general contents of the lagoon. During the process of decanting of the lagoon contents, the target is removal of the treated wastewater while retaining the stored sludge in the lagoon cell. Thus, a buffer should be provided below the decanting pipe to insure that localized high velocities do not re-suspend the settled suspended solids. Placing the inlet of the decanting structure a suitable distance above the sludge will ensure the decanting process does not disturb the settling sludge.

**Table 4.1 – Sludge Accumulation**

| Year | Population | Yearly Sludge | Accumulated Sludge | Year | Population | Yearly Sludge | Accumulated Sludge |
|---|---|---|---|---|---|---|---|
| 2016 | 1811 | 596 | 596 | 2027 | 2129 | 700 | 7,762 |
| 2017 | 1839 | 605 | 1,201 | 2028 | 2161 | 711 | 8,473 |
| 2018 | 1867 | 614 | 1,815 | 2029 | 2193 | 721 | 9,194 |
| 2019 | 1894 | 623 | 2,438 | 2030 | 2226 | 732 | 9,926 |
| 2020 | 1922 | 633 | 3,071 | 2031 | 2260 | 744 | 10,670 |
| 2021 | 1949 | 641 | 3,712 | 2032 | 2294 | 755 | 11,425 |
| 2022 | 1976 | 650 | 4,362 | 2033 | 2329 | 766 | 12,191 |
| 2023 | 2005 | 660 | 5,022 | 2034 | 2364 | 778 | 12,969 |
| 2024 | 2035 | 670 | 5,692 | 2035 | 2397 | 789 | 13,758 |
| 2025 | 2067 | 680 | 6,372 | **2036** | **2431** | **800** | **14,558** |
| 2026 | 2098 | 690 | 7,062 | | | | |

To allow for these factors, an allowance of 0.5 m greater than the required depth of storage should be provided for sludge storage. Sludge volume is not calculated as part of the active storage volume of the lagoon.

Although the sewage lagoons are designed to accommodate 20 years accumulation of sludge the 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 de-sludge the lagoon. The proposed sewage lagoon system is a multi-cell system, which will allow individual cells to be desludged while the active storage is continued to be provided.

Prior to disposal, the sludge must be tested to ensure that 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 current facility (referred to as Cell #4. It is recommended that the sludge undergo at least one freeze-thaw cycle before it is deposited into the landfill. The proposed rehabilitation of the existing lagoons includes the conversion of Cell #4 into a sludge holding and disposal cell.

As part of the rehabilitation of the existing lagoons, the sludge accumulated in the lagoons will be removed and deposed of in Cell 4 prior to the start of the rehabilitation and expansion of the existing cells.

# 5 Lagoon Alternatives

The total projected storage requirements for the Igloolik sewage lagoon system will be required to provide 11 months of storage until the year of 2036, or approximately 111,570 $m^3$ of storage as per Section 4.1. An additional allowance of 12,650 $m^3$ of storage is required to allow for precipitation and evaporation for a total of approximately 124,220 $m^3$ of active storage.

The expansion of the existing facility is restricted by the:

- Access road and the bulky metal waste site and the domestic waste site to the southwest,
- Presence of Turton Bay (Foxe Basin) to the northeast,
- Proximity to the existing community to the south/southeast

Therefore, the alternatives for expanding/replacing the existing sewage lagoon are limited to the following.

## Alternative 1

Alternative 1 proposes to construct a new sewage lagoon to the west of the existing lagoons. The eastern boundary of the new lagoon and the western boundary of the existing lagoons would be separated in order to allow for drainage through the existing swale/channel located to the west of the existing lagoon.

With an approximate volume of 124,220 $m^3$, the proposed lagoon will supply the total required sewage detention for the Hamlet for the projected growth until the year 2036. Refer to Figure 5-1: Alternative 1, for illustration.

## Alternative 2

Alternative 2 is for the rehabilitation of the existing lagoons and the construction of a new cell to the west of the existing sewage lagoons. The rehabilitation of the existing lagoons will be through grading the berms from the upstream toe at a slope of 3V:1H with a berm top width of 4 m and graded back down to existing grades at a slope of 3.25V:1H. The project would be phased with the new lagoon being constructed in the first phase and the existing lagoons being rehabilitated as part of phase 2. The newly constructed lagoon would be able to handle the Hamlet's annual sewage generation while the next phase of the job is constructed.

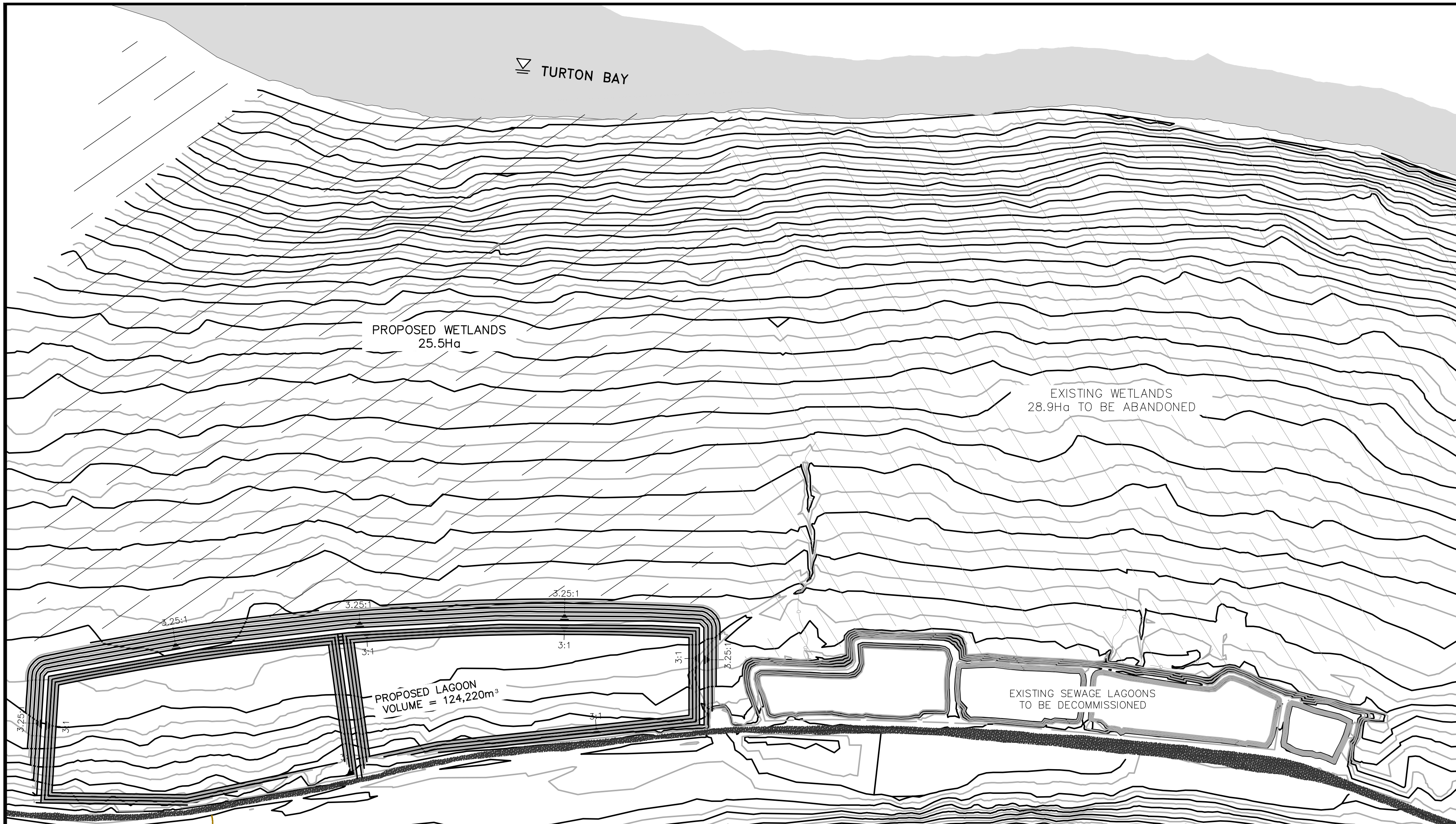
All lagoon cells, after construction, will work in parallel (individual detention). The capacity of the rehabilitated lagoons would provide 85,000 $m^3$ and the new cell would provide an additional 39,220 $m^3$ of storage to provide the required storage. Refer to Figure 5-2: Alternative 2, for illustration.

The eastern boundary of the new lagoon and the western boundary of the existing lagoons would be separated in order to allow for drainage through the existing swale/channel located to the west of the existing lagoon.

## Alternative 3

Alternative 3 proposes a similar operation to that of Alternative 2. A new sewage lagoon will be constructed to the west of the existing sewage lagoons. Once complete and in use, this sewage lagoon will operate during the rehabilitation of the existing sewage lagoons. The newly constructed lagoon would be able to handle the Hamlet's annual sewage generation while the next phase of the job is constructed.

The rehabilitation of the existing sewage lagoons will create two large cells in the place of the existing cells. The berms along the northeast side (towards Turton Bay) will be relocated to the northeast and designed at the proposed slope and criteria. The project would be phased with the new lagoon being constructed in the first phase and the existing lagoons being rehabilitated as part of phase 2.





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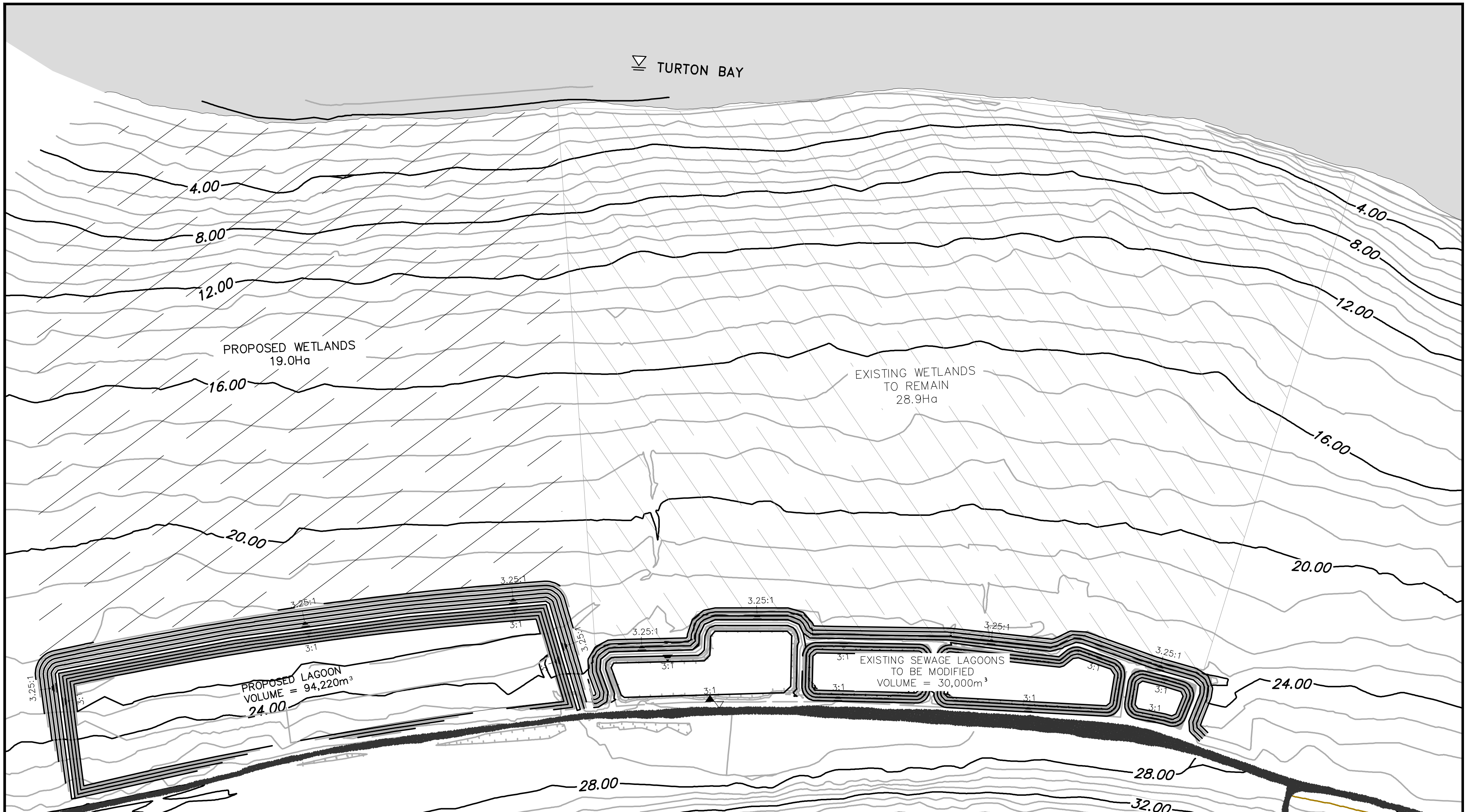
| scale | CLIENT: | project no. |
|---|---|---|
| 1:5000 | HAMLET OF IGLOOLIK | OTCD00019838 |
| date NOV. 2014 | TITLE: | |
| drawn by MJT | ALTERNATIVE No. 1 | FIG 5-1 |

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| | | |
|---|---|---|
| scale 1:5000 | CLIENT: HAMLET OF IGLOOLIK | project no. OTCD00019838 |
| date NOV. 2014 | TITLE: ALTERNATIVE No. 2 | FIG 5-2 |
| drawn by MJT | | |

All lagoon cells, after construction, will work in parallel (individual detention). The capacity of the rehabilitated lagoons would provide 67,220 $m^3$ of storage, the new cell would provide an additional 57,000 $m^3$ for a total of 124, 220 $m^3$ of active storage. Refer to Figure 5-3: Alternative 3, for illustration.

The eastern boundary of the new lagoon and the western boundary of the existing lagoons would be separated in order to allow for positive drainage through the existing drainage swale/channel located to the west of the existing lagoon.

## 5.1 Evaluation Process

The evaluation of the 3 alternatives put forth will be undertaken utilizing a decision matrix. The decision matrix is a tool which evaluates each of the alternatives against a predetermined set of criteria which are in turn weighted due to importance in the decision process. The alternative which receives the highest total score is deemed to be the recommended or preferred alternative. A pre-screen of alternatives is generally undertaken to eliminate any alternatives that do not meet the minimum requirements of the facility. These minimum requirements are referred to as “must” criteria. Any alternative that does not meet the minimum requirements of the “must” criteria will be eliminated from further consideration.

The second set of criteria that the alternatives are rated against is referred to as “want” criteria. The “want” criteria are weighted based on their importance to the decision-making process. Each alternative is then rated between 1 and 10 against these criteria. The product of the alternatives rating and the criteria’s weight is the weighted score for the alternative against that criterion. The sum of the weighted scores is the total score for each alternative. The alternative with the highest total weighted score is deemed the preferred or recommended alternative.

### 5.1.1 “Must” Criteria

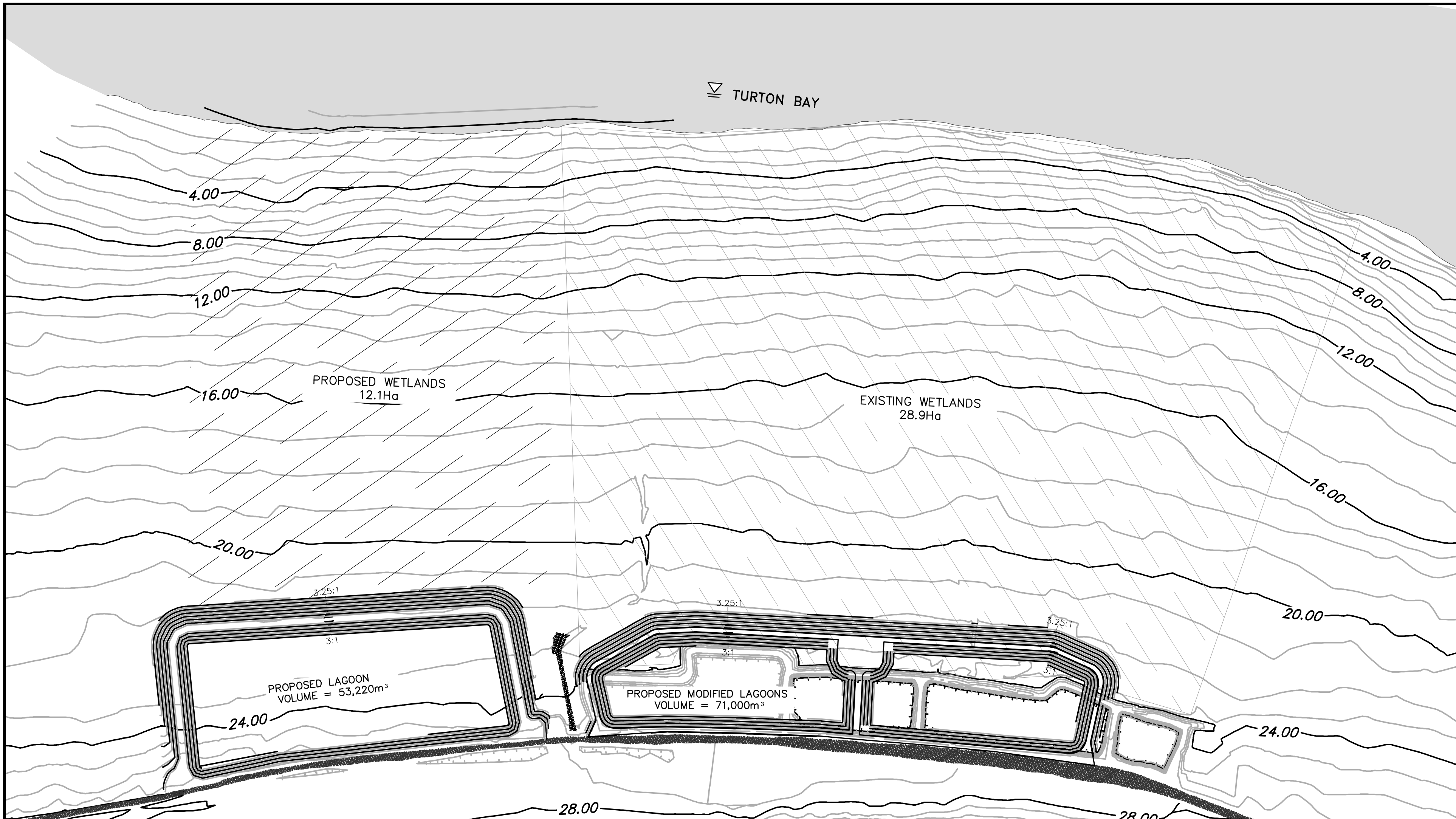
For the evaluation of the Igloolik sewage lagoon system the “must” criteria are listed below:

- Ability to meet the Hamlet’s requirements: the facility must be required to meet the projected storage requirements of the Hamlet as set forth in Section 4.1.
- The alternative must be required to meet the regulatory requirements as set out in the Hamlet’s water licence and summarized in Section 2.4.

### 5.1.2 “Want” Criteria

The evaluation of the Igloolik sewage lagoon system is based on the following “want” criteria and weighting:

- Capital Cost: an objective of the project is to minimize capital cost (criterion weight – 10)
- Life Cycle Cost: the system should minimize the life cycle costs of the facility, including the capital and the operating and maintenance costs (criterion weight – 10)
- Decanting Operation: the system should be simple to operate and minimize the requirements of the operation and maintenance staff of the Hamlet (criterion weight – 7)
- Truck Discharge Operations: the system should incorporate an easy safe truck discharge location (criterion weight – 5)
- Granular Requirements: The Hamlet has limited available granular material, therefore the demand on this material should be minimized with the design of the new system (criterion weight – 3)
- Level of Treatment: all systems must meet the minimum treatment requirement of the regulatory requirements, however improved treatment levels are seen to be beneficial (criterion weight – 3)

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|---|---|---|
| scale 1:5000 | CLIENT: HAMLET OF IGLOOLIK | project no. OTCD00019838 |
| date NOV. 2014 | | |
| drawn by MJT | TITLE: ALTERNATIVE No. 3 | FIG 5-3 |

## 5.2 Evaluation of Alternatives

### 5.2.1 "Must" Criteria

The two criteria that the Igloolik sewage lagoon system must meet are the ability to meet the Hamlet's requirements, i.e. to meet the needs of the projected population of the Hamlet in the year 2036 and meet the regulatory requirements of the Hamlet's water licence as set out by the Nunavut Water Board.

The 3 alternatives can all be designed to meet the required storage for the projected population for the year 2036 and therefore meet the requirements of the Hamlet. In addition, all three alternatives presented would provide a storage lagoon system providing 11 months of storage, followed by treatment in the existing wetlands between the lagoon site and Turton Bay (Foxe Basin). It is therefore anticipated that all three 3 options shall be able to provide sufficient treatment to meet the requirements of the Hamlet's water licence.

Based on the above, all three alternatives meet the "must" criteria put forth for the evaluation of alternatives.

### 5.2.2 Assessment of Alternatives

The three alternatives for the expansion of the Igloolik sewage lagoon were assessed against the "want" criteria presented in Section 5.1.2. The results of the assessment are summarized in the following sections.

#### 5.2.2.1 Capital Costs (Weight 10)

Class C cost estimates were prepared for the three alternatives and are presented in detail in Appendix A. The capital cost, as well as the score for each alternative and the weighted score are summarized in Table 5.4.

**Table 5.4: Capital Costs**

| Alternative | Capital Cost | Score |
|---|---|---|
| **Alternative 1** | | |
| Phase 1 - New Cell | $6,456,000 | |
| Phase 2 - Decommissioning | $1,326,063 | |
| **Total** | **$7,782,063** | 8 |
| **Alternative 2** | | |
| Phase 1- New Cell Construction | $4,768,094 | |
| Phase 2 - Rehabilitation of Existing | $2,632,563 | |
| **Total** | **$7,400,657** | 9 |
| **Alternative 3** | | |
| Phase 1- New Cell Construction | $4,007,338 | |
| Phase 2 - Reconstruction of Existing | $3,390,500 | |
| **Total** | **$7,397,838** | 10 |

#### 5.2.2.2 Life Cycle Costs (Weight 10)

Life cycle costs include the estimated capital cost along with the estimated operational and maintenance costs over the life of the facility in present day dollars. A detailed breakdown of the operation and maintenance costs and the life cycle costs of the alternatives is included in Appendix B. The life cycle costs and score for each alternative are summarized below in Table 5.5.

**Table 5.5: Life Cycle Costs**

| Alternative | Life Cycle Cost | Score |
|---|---|---|
| Alternative 1 | $8,547,878 | 8 |
| Alternative 2 | $8,127,199 | 9 |
| Alternative 3 | $8,124,380 | 10 |

#### 5.2.2.3 Decanting Operations (Weight 7)

One of the features of the sewage lagoon which make them attractive for use in northern communities is the relatively low operator requirements. Sewage lagoons are very simple to operate with the sampling and monitoring protocol and the annual decanting of the lagoon being the main operating requirements. Simplifying the decanting operation is considered a main component of simplifying the operational requirements.

**Alternative 1** incorporates the use of a new proposed sewage lagoon cell as a primary lagoon and the abandonment and decommissioning of the existing lagoons. Only the proposed lagoon requires decanting in the fall and therefore the decanting process will include a one-time set up and monitoring and disassembly of the pumping system. This alternative is easiest to operate and therefore scores **10** for Decanting Operations.

**Alternative 2** includes the remediation of the existing 4 sewage lagoon cells and incorporates them with the proposed sewage lagoon cell. Remediating the existing cells reduces the required size of the new lagoon; however, it requires that both the existing cells and the new cell be decanted in the fall. The discharge arrangement would require multiple pump set ups. This is more complicated than the single pumping operation possible with a primary cell or common area for pumping as in Alternative 1. This alternative scores **6** for Decanting Operations.

**Alternative 3** proposes to construct a new sewage lagoon and later reconstruct the existing 4 sewage lagoons into 2 modified cells. This would leave 3 sewage lagoons for the Hamlet’s sewage system. It is intended that all cells would be decanted in the fall and therefore the decanting process would include 3 pumping operations. This alternative is easier than Alternative 2 but more complex that Alternative 1, and therefore scores **8** for Decanting Operations.

#### 5.2.2.4 Truck Discharge Operations (Weight 5)

All three alternatives feature similar Truck Discharge characteristics. The all have multiple discharge locations allowing more than one truck to discharge at a time and the discharges are orientated in a different direction. Therefore all the alternatives will have the same score of 7.

#### 5.2.2.5 Granular Requirements (Weight 3)

The Hamlet does not have an extensive supply of granular material and therefore minimizing the demand of this project on the Hamlet’s supply is beneficial. The granular requirements of the 3 alternatives, as well as their score are presented in Table 5.6.

**Table 5.6: Granular Requirements**

| Alternative | Granular Requirements | Rating |
|---|---|---|
| Alternative 1 | 75,000 $m^3$ | 6 |
| Alternative 2 | 68,000 $m^3$ | 8 |
| Alternative 3 | 62,000 $m^3$ | 10 |

#### 5.2.2.6 Level of Treatment (Weight 3)

Although all alternatives must meet the minimum level of treatment set forth in the Hamlet's water licence, improved sewage treatment is seen as a positive characteristic for the alternatives. All of the lagoons operate as storage lagoons and provide 335 days of storage, therefore similar treatment is anticipated from all three lagoon systems. All three alternatives do incorporate a natural wetlands as part of the proposed treatment stream, and the loading rates of the wetlands may have an effect on treatment levels.

**Alternative 1** is the simplest alternative and replaces the existing sewage lagoon with a new lagoon that has the smallest wetland therefore the highest loading rate. Alternative 1 scores a **7** for level of treatment.

**Alternative 2** is the most complex to construct but has the largest wetland area resulting in the lowest loading rate. Alternative 2 scores a **10** for level of treatment.

**Alternative 3** is similar to alternative 2, however the wetlands is slightly smaller resulting in a slightly higher loading rate. Alternative 3 scores a **9** for level of treatment.

#### 5.2.2.7 Evaluation of the Alternatives

The rating of the alternatives against the criteria, as detailed above, are brought forward and summarized in Table 5.7 which also summarizes the weighting of the criteria and generates a weighted score for each alternative.

**Table 5.7: Weighted Scores**

| Criteria | Weight | Alternative 1 | | Alternative 2 | | Alternative 3 | |
|---|---|---|---|---|---|---|---|
| | | Score | Weighted Score | Score | Weighted Score | Score | Weighted Score |
| Capital Cost | 10 | *8* | 80 | *9* | 90 | *10* | 100 |
| Life cycle cost | 10 | *8* | 80 | *9* | 90 | *10* | 100 |
| Decanting Operations | 7 | *10* | 70 | *6* | 42 | *8* | 56 |
| Truck Discharge Operations | 5 | *7* | 35 | *7* | 35 | *7* | 35 |
| Granular Material | 3 | *6* | 18 | *8* | 24 | *10* | 30 |
| Low Level Treatment | 3 | *7* | 21 | *10* | 30 | *9* | 27 |
| Total Score | | | 304 | | 311 | | 348 |
| **Ranking** | | | **3** | | **2** | | **1** |

## 5.3 Analysis Summary

As shown in Table 5.7, Alternative 3 was rated #1 and therefore is the recommended and preferred alternative for the expansion of the Igloolik sewage lagoon. This alternative provides the lowest capital cost, life cycle costing, and demand on aggregate material. It is recommended that the preliminary design be based on Alternative 3 as the preferred alternative.

# 6 Sewage Treatment

Based on the selection of Alternative 3, the proposed Igloolik sewage lagoon system will be comprised of three storage lagoons and vegetated filterstrip wetlands. The treated sewage will be released over a period of 30 days, late in the summer, for further polishing in downstream wetlands. It is desirable that discharge to the wetlands occur during this time 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 upon the type of installation and sanitary facilities within the community. The Hamlet'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 Wastewater is an excerpt from the Cold Climate Utilities Manual, summarizing the characteristics of moderately diluted wastewater.

**Table 6.1: Characteristics of Wastewater**

| Parameter | Units | Moderately Diluted |
|---|---|---|
| $BOD_5$ | mg/L | 460 |
| 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 and typically provides 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 a 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)

$C_i$ = Influent concentration (mg/L)

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

$t$ = Residence time in lagoon (days)

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

$\Theta$ = Temperature activity coefficient

T = Temperature (˚C)

The temperature activity coefficient ($\Theta$) for various sewage treatment processes falls in the range of 1.00 to 1.10, with higher values indicating greater sensitivity to changing temperatures. 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 is from the initial sedimentation which also results in the removal of a portion of the $BOD_5$. The remaining contaminants are insoluble 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 gases 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 estimated 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*<br>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 Igloolik will be combined with the utilization of a vegetated filterstrip wetland as a final polishing step. The filterstrip wetland area is 42.8 hectare in size with a slope that varies between 2.5 to 9.5 %. The existing wetland area is 28.9 hectare in size (between 463 m and 476 m long and 703 m wide) and the proposed wetland area is 13.9 hectare in size (between 426 and 477 m long and 330 m wide)

The geotechnical investigations carried out in November 2009 by **exp** found that the soil in the filter strip wetland area is comprised of silty sand to sandy silt with permafrost at approximately 1 m depth. 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. 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 -20ºC and 20ºC. These bacteria and archaea are known to grow and reproduce in arctic ice and permafrost (Friedmann, 1994, Rivkina et al., 2000, Junge et al., 2004). The microbial processes that are involved in the degradation of organic materials are generally carried out by heterotrophic bacteria which use organic compounds as a carbon source for energy. Heterotrophic bacteria 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. Removal rates are based on comparable site conditions from literature reviews (Doku and Heinke, 1993, Nunez et al., 1995, Kadlec and Knight, 1996, Franti, 1997, Cameron et al., 2003, US EPA, 2006, Woerner and Lorimor, 2008).

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%.

**Table 6.4: Estimated Reduction in BOD and TSS**

| Outgoing Concentration from Filterstrip Wetlands | BOD (mg/L) | | | TSS (mg/L) | | |
|---|---|---|---|---|---|---|
| | 75 | 100 | 125 | 80 | 105 | 135 |
| Highest | 21 | 28 | 35 | 29 | 38 | 49 |
| Lowest | 6 | 8 | 10 | 1.6 | 2 | 3 |
| Average | 13.5 | 18 | 22.5 | 16 | 20.5 | 26 |

Pathogens present in sewage include fecal coliforms and *E. coli* which have a limited life span outside of their host organism (warm blooded animals). It is expected that 90% of pathogens will be removed during treatment in the lagoon. The numbers of remaining pathogens will be further reduced in the filter strip wetland because of the unfavourable conditions which will not allow the pathogens to grow and reproduce. Numbers of pathogens from sewage are expected to be very low at the monitoring point at the end of the filter strip wetland area and therefore pathogen removal in the filter strip wetland is expected to be as high 100% as pathogen survival is very limited outside of host organisms. However, it should be noted that animals frequent the area and animal feces may contribute to total fecal coliforms and *E. coli* numbers.

Nitrogen and phosphate are expected to receive high rates of nutrient reduction, particularly of nitrogen compounds as they are utilized by plants.

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 is expected to meet or exceed the requirements of the new Hamlet's water licence (once obtained) at the end of the wetlands. Table 6.5 summarizes the levels of treatment predicted from the sewage treatment system in comparison to the previous Nunavut Water licence criteria.

**Table 6.5: Summery of Treatment Levels**

| Parameter | Units | Criteria | Influent | Effluent from Lagoon | Effluent from Wetland† |
|---|---|---|---|---|---|
| $BOD_5$ | mg/L | 120 | 460 | 97 | 18 |
| TSS | mg/L | 180 | 490 | 172*<br>116** | 33*<br>22** |
| FC | #/100ml | $1 \times 10^6$ | $1 \times 10^7$ | < or = to $1 \times 10^6$ | <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 Granular Supply

**Exp** reviewed the report entitled "Granular Source Survey and Spill Contingency Plan" prepared by Arktis Piusitippaa Inc., identifying granular supplies in and around the Hamlet. Granular supplies identified in this report included:

E1 Existing granular source area partially exploited. Located approximately 2.0 km N of the community, NW from the existing sewage lagoon

E2 Existing granular source area partially exploited. Located approximately 700 m N of the community, immediately south of the existing solid waste site.

E3 Existing granular source area partially exploited. Located immediately west of the community and west from the Hamlet garage

E4 Existing granular source area partially exploited. Located approximately 2.7 km southwest from the community, south of the existing airport runway

E5 Existing granular source area partially exploited. Located approximately 2.7 km southwest from the community, between the existing water reservoir and South Lake.

N1 New potential granular source area Located approximately 1.0 km N of the community and immediately south from the existing sewage lagoon

N2 New potential granular source area. Located approximately 1800m southwest from the community and immediately east from the access road to the airport.

N3 New potential granular source area. Located approximately 1.0 km southwest from the community and immediately east from the access road to the airport and east of the fuel storage facility.

N4 New potential granular source area. Located approximately 4.0km south from the community and south from the airport runway

Of the 9 potential deposits identified 3 deposits E2, E3 and E4 were deemed for community use and it is felt that these deposits should be left to meet the Hamlet's annual granular needs. One deposit E5 was deemed a waste rock pile from the construction of the existing potable water reservoir and therefore unsatisfactory material for berm works. Deposit E1 has an estimated volume available of 52,000 $m^3$ and deposits N1, N2, N3 and N4 have an estimate volume between 49,000$m^3$ - 273,000 $m^3$ of material. It is estimated that 62,000 $m^3$ of material will be required to complete the proposed works. The granular source E1 and N1 appear to have ample supply of granular material for the construction of a new sewage lagoon and rehabilitation of the existing sewage lagoon.

# 8 Cost Estimate

A Class C Capital Cost Estimate has been prepared for the Igloolik Sewage Treatment Facility. The works included in the cost estimate include the following:

- Construction of a new storage lagoon (including the liner and granular material)
- Rehabilitation of the existing sewage lagoon to be utilized as a primary cell during the summer months
- Construction of a diversionary berm adjacent to the existing drainage course on the west side of the wetlands area
- Upgrades to the existing influent locations
- Replacement CSP culverts for the existing drainage course

A detailed breakdown of the cost estimate is included in Appendix A and includes a 20% contingency allowance. The estimated capital cost for the rehabilitation and expansion of the Igloolik Sewage Treatment Facility is $7,397,838.

## 8.1 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 approximately $74,000 as detailed in Appendix B.

## 8.2 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 an interest rate of 8%, "General Terms of Reference for a Community Water and Sanitation Service Study, Appendix A" MACA 1986, is summarized in Table 8.1.

**Table 8.1: Life Cycle Cost Summary**

| | |
|---|---|
| Capital Cost | $7,397,838 |
| Present Value of O&M Costs over 20 Years | $726,543 |
| Life Cycle Costs | $8,124,380 |

# 9 Conclusions and Recommendations

The following summarizes the conclusions and recommendations for the preliminary design for the Hamlet's sewage lagoon upgrades.

- The existing sewage lagoon in Igloolik does not meet the long term needs of the Hamlet, nor does it meet the treatment requirements as per the Hamlet's water licence.
- The existing sewage lagoon has numerous maintenance issues that must be addressed as part of the expansion of the sewage treatment facility, including slope stability, localized berm failures and upgrades to the sewage infleunt points.
- The project population for the year 2036 for the Hamlet is 2431 persons.
- Based on the projected population, the project sewage generation rate is 137 lpcd.
- Soils beneath the existing sewage lagoon, and lands adjacent to the lagoon are not ice rich, therefore it is recommended that the new lagoon cells be fully lined lagoons as part of the expanded sewage lagoon system.
- It is recommended that the lagoons be decanted yearly through a pumping process as this will provide the best control of time and rate of discharge. The ability to control the time and rate of discharge allows the operators to optimize the level of treatment from the sewage lagoon system and wetlands.
- Of the 3 alternatives analyzed for the expansion of the Igloolik sewage lagoon system, it is recommended Alternative 3, which incorporates a new lagoon to the northwest of the existing lagoon and the use of the rehabilitated existing lagoon as a storage cells, be adopted for the design of the proposed expansion.
- It is recommended that the new sewage treatment facility utilize the wetlands between the proposed facility and Foxe Basin to provide additional treatment of the effluent before it is released into the environment.
- The 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.
- The assessment of the Hamlet's current granular supplies was not conclusive. Granular deposits have been identified along the costal line but crushing and screening will be required.
- It is estimated that the capital cost for the construction of a new sewage lagoon and rehabilitation of the existing lagoons will be approximately $7,397,838.
- The estimated annual operating and maintenance costs for the new facility, including the cost of decanting will be approximately $74,000 per annum (at present day worth).
- The overall lifecycle cost over the 20 year design horizon of the facility is approximately $8,124,380.
- The estimated final quality of the effluent will meet or exceed the requirements of the water licence. The proposed new sewage lagoon system will be in compliance of the new water licence.

# 10 References

Friedmann, 1994, Rivkina et al., 2000, Junge et al., 2004

Doku and Heinke, 1993, Nunez et al., 1995, Kadlec and Knight, 1996, Franti, 1997, Cameron et al., 2003, US EPA, 2006, Woerner and Lorimor, 2008

Canadian Dam Safety Guidelines

Trow Associates Inc, 2008, *Environmental Assessment Screening New Sewage Lagoon and Rehabilitation of Existing Lagoon for the Hamlet of Clyde River*

Dillon Consulting Limited, 2003, *Igloolik Sewage Management – Planning Study Draft Report*

G.W. Heinke, D.W. Smith and G.R. Finch, 1988, *Guidelines for the Planning, Design, Operation and Maintenance of Wastewater Lagoon Systems*, November 1988

Trow Associates Inc., 2010, *Geotechnical Investigation Liquid and Solid Waste Management, Hamlet of Igloolik, Nunavut,* March 16, 2010

Trow Associates Inc., *Vegetated Wetland Filter Strip Assessment, Hamlet of Clyde River, Nunavut*, February 2008

Naviq Consulting Inc., *Geothermal Analysis of Proposed Sewage Lagoon, Igloolik, NU*, January 2008

Canadian Society for Civil Engineering, 1986, *Cold Climate Utilities Manual*

*Water and Sewage Facilities Capital Program: Standards and Criteria*, July 14, 1993

Minister of the Environment, Government of Ontario, *Guidelines for the Design of Water and Sewage Works*

Metcalfe and Eddy, *Wastewater Engineering Treatment, Disposal and Reuse, Third Edition 1991,* McGraw-Hill

Environment Canada, *Canadian Climate Normals 1971-2000*

Viessman et al., 1972, *Introduction to Hydrology, Fifth Edition,* Intext Educational Publishers

Nunavut Bureau of Statistic, Government of Nunavut, Nunavut: *Community Population Projections 2009 - 2036*

# Appendix A – Capital Cost Estimates

**Phase 1 - New Cell Construction**

| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| 1 | **Mobilization / Demobilization Phase 1** | L.S. | 1 | $600,000.00 | $600,000.00 |
| 2 | **a)** Supply and deliver silt fence including wood stake | m | 775 | $4.00 | $3,100.00 |
| | **b)** Installation of silt fence including wood stake and trenching | m | 775 | $4.00 | $3,100.00 |
| 3 | Supply,deliver and place granular material to construct new berms | cu.m | 51700 | $33.00 | $1,706,100.00 |
| 4 | Excavatation, grading and disposal on site as Berm materials | cu.m | 15000 | $13.00 | $195,000.00 |
| 5 | **a)** Supply and deliver liner for proposed lagoon | m.sq. | 55000 | $14.00 | $770,000.00 |
| | **b)** Installation of liner for proposed lagoon including sand bedding, sand cover, and anchor trench | m.sq. | 55000 | $20.00 | $1,100,000.00 |
| 6 | **a)** Supply and deliver materials for spillway structure | ea | 2 | $4,500.00 | $9,000.00 |
| | **b)** Installation of spillway structure | ea. | 2 | $10,000.00 | $20,000.00 |
| 7 | Supply**,** deliver and place granular material to construct truck turning pad | cu. m | 1000 | $33.00 | $33,000.00 |
| 8 | Supply, deliver and place 150mm of granular A material to top road and turn for truck discharge point | sq.m. | 2000 | $65.00 | $130,000.00 |
| 9 | **a)** Supply and deliver piping for inlet structure including 200 dia. HDPE series 100 pipe, concrete block and pipe support | ea. | 2 | $8,000.00 | $16,000.00 |
| | **b)** Installation of piping for inlet structure | ea. | 2 | $5,000.00 | $10,000.00 |
| 10 | **a)** Supply and deliver piping for outlet structure including 150 dia. HDPE series 100 pipe and wood support | ea. | 2 | $4,000.00 | $8,000.00 |
| | **b)** Installation of piping for outlet structure | ea. | 2 | $3,000.00 | $6,000.00 |
| 11 | **a)** Supply and deliver piping for outlet structure including 300 dia. HDPE series 100 pipe c/w concrete block | m | 100 | $160.00 | $16,000.00 |
| | **b)** Installation of piping for outlet structure | m | 100 | $80.00 | $8,000.00 |
| 12 | **a)** Supply and deliver 600mm dia. nestable pipe including pressure treated wood post and lag bolt | m | 460 | $220.00 | $101,200.00 |
| | **b)** Installation of 600mm dia. nestable pipe including pressure treated wood post and lag bolt | m | 460 | $110.00 | $50,600.00 |
| 13 | **a)** Supply and deliver truck discharge structures, including erosion protection and bollards | ea. | 2 | $40,000.00 | $80,000.00 |
| | **b)** Installation of truck discharge structures, including erosion protection and bollards | ea. | 2 | $25,000.00 | $50,000.00 |
| 14 | Supply, deliver and install boulder barriers | ea. | 11 | $50.00 | $550.00 |
| 15 | **a)** Supply and deliver signage | ea. | 8 | $350.00 | $2,800.00 |
| | **b)** Installation of signage | ea. | 8 | $200.00 | $1,600.00 |

**Phase 1 - New Cell Construction**

| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| 16 | **a)** Supply and deliver pump including engine, wheel kit 150mm dia. Hose, pressure gauge, ball valve, flange and coupling | ea. | 1 | $75,000.00 | $75,000.00 |
| | **b)** Installation of pump including engine, wheel kit, 150mm dia. Hose, pressure gauge, ball valve, flange and coupling | ea. | 1 | $4,500.00 | $4,500.00 |
| 17 | **a)** Supply and deliver 1.2m x 2.4m Project Information Sign | ea. | 1 | $2,000.00 | $2,000.00 |
| | **b)** Installation and Maintain 1.2m x 2.4m Project Information Sign | ea. | 1 | $750.00 | $750.00 |
| 18 | **a)** Supply and deliver new chain link feces | m | 650 | $100.00 | $65,000.00 |
| | **b)** Installation of new chain link fences | m | 650 | $150.00 | $97,500.00 |
| | **SUBTOTAL** | | | | **$5,164,800.00** |
| | **20% CONTINGENCY** | | | | **$1,032,960.00** |
| | **GST** | | | | **$258,240.00** |
| | **TOTAL** | | | | **$6,456,000.00** |

**Phase 2 - Decommissioning of Existing**

| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| 1 | **a)** Supply and deliver silt fence including wood stake | m | 675 | $4.00 | $2,700.00 |
| | **b)** Installation of silt fence including wood stake and trenching | m | 675 | $4.00 | $2,700.00 |
| 2 | Re-use existing berm material to backfill lagoon | cu.m | 15250 | $15.00 | $228,750.00 |
| 3 | Supply,deliver and place granular material to backfill lagoon | cu.m | 24900 | $33.00 | $821,700.00 |
| 4 | Remove and dispose off existing Chain Link Fence | L.S. | 1 | $5,000.00 | $5,000.00 |

| | |
|---|---|
| **SUBTOTAL** | **$1,060,850.00** |
| **20% CONTINGENCY** | **$212,170.00** |
| **GST** | **$53,042.50** |
| **TOTAL** | **$1,326,062.50** |

## Phase I - Construction of New Cell

| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| 1 | **Mobilization / Demobilization Phase 1** | L.S. | 1 | $600,000.00 | $600,000.00 |
| 2 | **a)** Supply and deliver silt fence including wood stake | m | 581 | $4.00 | $2,325.00 |
| | **b)** Installation of silt fence including wood stake and trenching | m | 581 | $4.00 | $2,325.00 |
| 3 | Supply,deliver and place granular material to construct new berms | cu.m | 33000 | $33.00 | $1,089,000.00 |
| 4 | Excavatation, grading and disposal on site as Berm materials | cu.m | 11250 | $13.00 | $146,250.00 |
| 5 | **a)** Supply and deliver liner for proposed lagoon | m.sq. | 41250 | $14.00 | $577,500.00 |
| | **b)** Installation of liner for proposed lagoon including sand bedding, sand cover, and anchor trench | m.sq. | 41250 | $20.00 | $825,000.00 |
| 6 | **a)** Supply and deliver materials for spillway structure | ea. | 1 | $4,500.00 | $4,500.00 |
| | **b)** Installation of spillway structure | ea. | 1 | $10,000.00 | $10,000.00 |
| 7 | Supply**,** deliver and place granular material to construct truck turning pad | cu. m | 500 | $33.00 | $16,500.00 |
| 8 | Supply, deliver and place 150mm of granular A material to top road and turn for truck discharge point | sq.m. | 2000 | $65.00 | $130,000.00 |
| 9 | **a)** Supply and deliver piping for inlet structure including 200 dia. HDPE series 100 pipe, concrete block and pipe support | ea. | 1 | $8,000.00 | $8,000.00 |
| | **b)** Installation of piping for inlet structure | ea. | 1 | $5,000.00 | $5,000.00 |
| 10 | **a)** Supply and deliver piping for outlet structure including 150 dia. HDPE series 100 pipe and wood support | ea. | 1 | $4,000.00 | $4,000.00 |
| | **b)** Installation of piping for outlet structure | ea. | 1 | $3,000.00 | $3,000.00 |
| 11 | **a)** Supply and deliver piping for outlet structure including 300 dia. HDPE series 100 pipe c/w concrete block | m | 75 | $160.00 | $12,000.00 |
| | **b)** Installation of piping for outlet structure | m | 75 | $80.00 | $6,000.00 |
| 12 | **a)** Supply and deliver 600mm dia. nestable pipe including pressure treated wood post and lag bolt | m | 300 | $220.00 | $66,000.00 |
| | **b)** Installation of 600mm dia. nestable pipe including pressure treated wood post and lag bolt | m | 300 | $110.00 | $33,000.00 |
| 13 | **a)** Supply and deliver truck discharge structures, including erosion protection and bollards | ea. | 1 | $40,000.00 | $40,000.00 |
| | **b)** Installation of truck discharge structures, including erosion protection and bollards | ea. | 1 | $25,000.00 | $25,000.00 |
| 14 | Supply, deliver and install boulder barriers | ea. | 11 | $50.00 | $550.00 |
| 15 | **a)** Supply and deliver signage | ea. | 8 | $350.00 | $2,800.00 |
| | **b)** Installation of signage | ea. | 8 | $200.00 | $1,600.00 |

**Phase I - Construction of New Cell**

| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| 16 | **a)** Supply and deliver pump including engine, wheel kit 150mm dia. Hose, pressure gauge, ball valve, flange and coupling | ea. | 1 | $75,000.00 | $75,000.00 |
| | **b)** Installation of pump including engine, wheel kit, 150mm dia. Hose, pressure gauge, ball valve, flange and coupling | ea. | 1 | $4,500.00 | $4,500.00 |
| 17 | **a)** Supply and deliver 1.2m x 2.4m Project Information Sign | ea. | 1 | $2,000.00 | $2,000.00 |
| | **b)** Installation and Maintain 1.2m x 2.4m Project Information Sign | ea. | 1 | $750.00 | $750.00 |
| 18 | **a)** Supply and deliver new chain link fences | m | 488 | $100.00 | $48,750.00 |
| | **b)** Installation of new chain link fences | m | 488 | $150.00 | $73,125.00 |

| | |
|---|---|
| **SUBTOTAL** | **$3,814,475.00** |
| **20% CONTINGENCY** | **$762,895.00** |
| **GST** | **$190,723.75** |
| **TOTAL** | **$4,768,093.75** |

**Sewage Treatment Facility**
**Alternative 2**
**Phase 2 - Rehabilitation of Existing Cells**



| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| 1 | **Mobilization / Demobilization Phase 2** | L.S. | 1 | $0.00 | $0.00 |
| 2 | **a)** Supply and deliver silt fence including wood stake | m | 675 | $4.00 | $2,700.00 |
| | **b)** Installation of silt fence including wood stake and trenching | m | 675 | $4.00 | $2,700.00 |
| 3 | New ditch construction and disposal of excavated material off site | m | 200 | $35.00 | $7,000.00 |
| 4 | Desludging of Existing Lagoon Cells | cu.m | 7305 | $10.00 | $73,050.00 |
| 5 | Remove existing cmp and replace with new 300mm dia.cmp | L.S | 1 | $1,000.00 | $1,000.00 |
| 6 | Supply,deliver and place granular material to construct new berms | cu.m | 14700 | $33.00 | $485,100.00 |
| 7 | **a)** Supply and deliver liner for proposed lagoon | m.sq. | 26250 | $14.00 | $367,500.00 |
| | **b)** Installation of liner for proposed lagoon including sand bedding, sand cover, and anchor trench | m.sq. | 26250 | $20.00 | $525,000.00 |
| 8 | **a)** Supply and deliver materials for spillway structure | ea. | 2 | $4,500.00 | $9,000.00 |
| | **b)** Installation of spillway structure | ea. | 2 | $10,000.00 | $20,000.00 |
| 9 | Supply, deliver and place granular material to construct truck turning pad | cu. m | 500 | $33.00 | $16,500.00 |
| 10 | **a)** Supply and deliver gabion mats for erosion protection at toe of berm | sq.m | 440 | $90.00 | $39,600.00 |
| | **b)** Installation of gabion mats for erosion protectin at toe of berm c/w woven geotextile | sq.m | 440 | $130.00 | $57,200.00 |
| 11 | Supply, deliver and place 150mm of granular A material to top road and turn for truck discharge point | sq.m. | 1640 | $65.00 | $106,600.00 |
| 12 | **a)** Supply and deliver piping for inlet structure including 200 dia. HDPE series 100 pipe, concrete block and pipe support | ea. | 2 | $8,000.00 | $16,000.00 |
| | **b)** Installation of piping for inlet structure | ea. | 2 | $5,000.00 | $10,000.00 |
| 13 | **a)** Supply and deliver piping for outlet structure including 150 dia. HDPE series 100 pipe and wood support | ea. | 2 | $4,000.00 | $8,000.00 |
| | **b)** Installation of piping for outlet structure | ea. | 2 | $3,000.00 | $6,000.00 |
| 14 | **a)** Supply and deliver piping for outlet structure including 300 dia. HDPE series 100 pipe c/w concrete block | m | 10 | $120.00 | $1,200.00 |
| | **b)** Installation of piping for outlet structure | m | 10 | $80.00 | $800.00 |
| 15 | **a)** Supply and deliver 600mm dia. nestable pipe including pressure treated wood post and lag bolt | m | 360 | $220.00 | $79,200.00 |
| | **b)** Installation of 600mm dia. nestable pipe including pressure treated wood post and lag bolt | m | 360 | $110.00 | $39,600.00 |
| 16 | **a)** Supply and deliver truck discharge structures, including erosion protection and bollards | ea. | 2 | $40,000.00 | $80,000.00 |

## Phase 2 - Rehabilitation of Existing Cells

| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| | **b)** Installation of truck discharge structures, including erosion protection and bollards | ea. | 2 | $25,000.00 | $50,000.00 |
| 17 | Supply, deliver and install boulder barriers | ea. | 28 | $50.00 | $1,400.00 |
| 18 | **a)** Supply and deliver signage | ea. | 8 | $350.00 | $2,800.00 |
| | **b)** Installation of signage | ea. | 8 | $200.00 | $1,600.00 |
| 19 | **a)** Supply and deliver 1.2m x 2.4m Project Information Sign | ea. | 1 | $2,000.00 | $2,000.00 |
| | **b)** Installation and Maintain 1.2m x 2.4m Project Information Sign | ea. | 1 | $750.00 | $750.00 |
| 20 | **a)**Supply and deliver new chain link feces | m | 375 | $100.00 | $37,500.00 |
| | **b)** Installation of new chain link fences | m | 375 | $150.00 | $56,250.00 |

| | |
|---|---|
| **SUBTOTAL** | **$2,106,050.00** |
| **20% CONTINGENCY** | **$421,210.00** |
| **GST** | **$105,302.50** |
| **TOTAL** | **$2,632,562.50** |

**Phase 1 - Construction of New Cell**

| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| 1 | **Mobilization / Demobilization Phase 1** | L.S. | 1 | $600,000.00 | $600,000.00 |
| 2 | **a)** Supply and deliver silt fence including wood stake | m | 440 | $4.00 | $1,760.00 |
| | **b)** Installation of silt fence including wood stake and trenching | m | 440 | $4.00 | $1,760.00 |
| 3 | Supply,deliver and place granular material to construct new berms | cu.m | 31800 | $33.00 | $1,049,400.00 |
| 4 | Excavatation, grading and disposal on site as Berm materials | cu.m | 10700 | $13.00 | $139,100.00 |
| 5 | **a)** Supply and deliver liner for proposed lagoon | m.sq. | 27000 | $14.00 | $378,000.00 |
| | **b)** Installation of liner for proposed lagoon including sand bedding, sand cover, and anchor trench | m.sq. | 27000 | $20.00 | $540,000.00 |
| 6 | **a)** Supply and deliver materials for spillway structure | ea. | 1 | $4,500.00 | $4,500.00 |
| | **b)** Installation of spillway structure | ea. | 1 | $10,000.00 | $10,000.00 |
| 7 | Supply, deliver and place granular material to construct truck turning pad | cu. m | 500 | $33.00 | $16,500.00 |
| 8 | Supply, deliver and place 150mm of granular A material to top road and turn for truck discharge point | sq.m. | 2000 | $65.00 | $130,000.00 |
| 9 | **a)** Supply and deliver piping for inlet structure including 200 dia. HDPE series 100 pipe, concrete block and pipe support | ea. | 1 | $8,000.00 | $8,000.00 |
| | **b)** Installation of piping for inlet structure | ea. | 1 | $5,000.00 | $5,000.00 |
| 10 | **a)** Supply and deliver piping for outlet structure including 150 dia. HDPE series 100 pipe and wood support | ea. | 1 | $4,000.00 | $4,000.00 |
| | **b)** Installation of piping for outlet structure | ea. | 1 | $3,000.00 | $3,000.00 |
| 11 | **a)** Supply and deliver piping for outlet structure including 300 dia. HDPE series 100 pipe c/w concrete block | m | 100 | $160.00 | $16,000.00 |
| | **b)** Installation of piping for outlet structure | m | 100 | $80.00 | $8,000.00 |
| 12 | **a)** Supply and deliver 600mm dia. nestable pipe including pressure treated wood post and lag bolt | m | 155 | $220.00 | $34,100.00 |
| | **b)** Installation of 600mm dia. nestable pipe including pressure treated wood post and lag bolt | m | 155 | $110.00 | $17,050.00 |
| 13 | **a)** Supply and deliver truck discharge structures, including erosion protection and bollards | ea. | 1 | $40,000.00 | $40,000.00 |
| | **b)** Installation of truck discharge structures, including erosion protection and bollards | ea. | 1 | $25,000.00 | $25,000.00 |
| 14 | Supply, deliver and install boulder barriers | ea. | 11 | $50.00 | $550.00 |
| 15 | **a)** Supply and deliver signage | ea. | 8 | $350.00 | $2,800.00 |
| | **b)** Installation of signage | ea. | 8 | $200.00 | $1,600.00 |

**Igloolik** **Sewage Treatment Facility** **Class "C" Cost Estimate**

**OTT-00019838-A0** **Alternative 3**

**Phase 1 - Construction of New Cell**

| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| 16 | **a)** Supply and deliver pump including engine, wheel kit 150mm dia. Hose, pressure gauge, ball valve, flange and coupling | ea. | 1 | $75,000.00 | $75,000.00 |
| | **b)** Installation of pump including engine, wheel kit, 150mm dia. Hose, pressure gauge, ball valve, flange and coupling | ea. | 1 | $4,500.00 | $4,500.00 |
| 17 | **a)** Supply and deliver 1.2m x 2.4m Project Information Sign | ea. | 1 | $2,000.00 | $2,000.00 |
| | **b)** Installation and Maintain 1.2m x 2.4m Project Information Sign | ea. | 1 | $750.00 | $750.00 |
| 18 | **a)**Supply and deliver new chain link fences | m | 350 | $100.00 | $35,000.00 |
| | **b)** Installation of new chain link fences | m | 350 | $150.00 | $52,500.00 |

| | |
|---|---|
| **SUBTOTAL** | **$3,205,870.00** |
| **20% CONTINGENCY** | **$641,174.00** |
| **GST** | **$160,293.50** |
| **TOTAL** | **$4,007,337.50** |

**Phase 2 - Reconstruction of Existing Cells**

| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| 1 | **Mobilization / Demobilization Phase 2** | L.S. | 1 | $0.00 | $0.00 |
| 2 | **a)** Supply and deliver silt fence including wood stake | m | 725 | $4.00 | $2,900.00 |
| | **b)** Installation of silt fence including wood stake and trenching | m | 725 | $4.00 | $2,900.00 |
| 3 | New ditch construction and disposal of excavated material off site | m | 200 | $35.00 | $7,000.00 |
| 4 | Desludging of Existing Lagoon Cells | cu.m. | 7305 | $10.00 | $73,050.00 |
| 5 | Remove existing cmp and replace with new 300mm dia. cmp | L.S | 1 | $1,000.00 | $1,000.00 |
| 6 | Re-use existing berm material to construct new berms | cu.m | 37000 | $13.00 | $481,000.00 |
| 7 | Supply,deliver and place granular material to construct new berms | cu.m | 8500 | $33.00 | $280,500.00 |
| 8 | **a)** Supply and deliver liner for proposed lagoon | m.sq. | 35000 | $14.00 | $490,000.00 |
| | **b)** Installation of liner for proposed lagoon including sand bedding, sand cover, and anchor trench | m.sq. | 35000 | $20.00 | $700,000.00 |
| 9 | **a)** Supply and deliver materials for spillway structure | ea. | 2 | $4,500.00 | $9,000.00 |
| | **b)** Installation of spillway structure | ea. | 2 | $10,000.00 | $20,000.00 |
| 10 | Supply**,** deliver and place granular material to construct truck turning pad | cu. m | 500 | $33.00 | $16,500.00 |
| 11 | **a)** Supply and deliver gabion mats for erosion protection at toe of berm | sq.m | 440 | $90.00 | $39,600.00 |
| | **b)** Installation of gabion mats for erosion protectin at toe of berm c/w woven geotextile | sq.m | 440 | $130.00 | $57,200.00 |
| 12 | Supply, deliver and place 150mm of granular A material to top road and turn for truck discharge point | sq.m. | 1640 | $65.00 | $106,600.00 |
| 13 | **a)** Supply and deliver piping for inlet structure including 200 dia. HDPE series 100 pipe, concrete block and pipe support | ea. | 2 | $8,000.00 | $16,000.00 |
| | **b)** Installation of piping for inlet structure | ea. | 2 | $5,000.00 | $10,000.00 |
| 14 | **a)** Supply and deliver piping for outlet structure including 150 dia. HDPE series 100 pipe and wood support | ea. | 2 | $4,000.00 | $8,000.00 |
| | **b)** Installation of piping for outlet structure | ea. | 2 | $3,000.00 | $6,000.00 |
| 15 | **a)** Supply and deliver piping for outlet structure including 300 dia. HDPE series 100 pipe c/w concrete block | m | 10 | $120.00 | $1,200.00 |
| | **b)** Installation of piping for outlet structure | m | 10 | $80.00 | $800.00 |
| 16 | **a)** Supply and deliver 600mm dia. nestable pipe including pressure treated wood post and lag bolt | m | 360 | $220.00 | $79,200.00 |
| | **b)** Installation of 600mm dia. nestable pipe including pressure treated wood post and lag bolt | m | 360 | $110.00 | $39,600.00 |

## Phase 2 - Reconstruction of Existing Cells

| ITEM | DESCRIPTION | UNIT | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|---|
| 17 | **a)** Supply and deliver truck discharge structures, including erosion protection and bollards | ea. | 2 | $40,000.00 | $80,000.00 |
| | **b)** Installation of truck discharge structures, including erosion protection and bollards | ea. | 2 | $25,000.00 | $50,000.00 |
| 18 | Supply, deliver and install boulder barriers | ea. | 28 | $50.00 | $1,400.00 |
| 19 | **a)** Supply and deliver signage | ea. | 8 | $350.00 | $2,800.00 |
| | **b)** Installation of signage | ea. | 8 | $300.00 | $2,400.00 |
| 20 | **a)** Supply and deliver 1.2m x 2.4m Project Information Sign | ea. | 1 | $2,000.00 | $2,000.00 |
| | **b)** Installation and Maintain 1.2m x 2.4m Project Information Sign | ea. | 1 | $750.00 | $750.00 |
| 21 | **a)** Supply and deliver new chain link feces | m | 500 | $100.00 | $50,000.00 |
| | **b)** Installation of new chain link fences | m | 500 | $150.00 | $75,000.00 |

| | |
|---|---|
| **SUBTOTAL** | **$2,712,400.00** |
| **20% CONTINGENCY** | **$542,480.00** |
| **GST** | **$135,620.00** |
| **TOTAL** | **$3,390,500.00** |

# Appendix B – Operation & Maintenance and Lifecycle Costs

**<u>Alternative 1</u>**

**Yearly General O&M**

1% of Capital Costs

$7,796,700 x 1% = $78,000

**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 | $78,000 |
| Decanting Cost | $6,000 |
| **Total O&M Costs** | **$84,000** |

**Life Cycle Cost of O&M Costs**

@ 8% Discount Rate

| Year | Year Cost | Present Value |
|---|---|---|
| 1 | $78,000 | $72,222 |
| 2 | $78,000 | $66,872 |
| 3 | $78,000 | $61,919 |
| 4 | $78,000 | $57,332 |
| 5 | $78,000 | $53,086 |
| 6 | $78,000 | $49,153 |
| 7 | $78,000 | $45,512 |
| 8 | $78,000 | $42,141 |
| 9 | $78,000 | $39,019 |
| 10 | $78,000 | $36,129 |
| 11 | $78,000 | $33,453 |
| 12 | $78,000 | $30,975 |
| 13 | $78,000 | $28,680 |
| 14 | $78,000 | $26,556 |
| 15 | $78,000 | $24,589 |
| 16 | $78,000 | $22,768 |
| 17 | $78,000 | $21,081 |
| 18 | $78,000 | $19,519 |
| 19 | $78,000 | $18,074 |
| 20 | $78,000 | $16,735 |
| **Total** | | **$765,815** |

**<u>Alternative 2</u>**

**Yearly General O&M**

1% of Capital Costs

$7,428,900 x 1% = $74,000

**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 | $74,000 |
| Decanting Cost | $6,000 |
| **Total O&M Costs** | **$80,000** |

**Life Cycle Cost of O&M Costs**

@ 8% Discount Rate

| Year | Year Cost | Present Value |
|---|---|---|
| 1 | $74,000 | $68,519 |
| 2 | $74,000 | $63,443 |
| 3 | $74,000 | $58,744 |
| 4 | $74,000 | $54,392 |
| 5 | $74,000 | $50,363 |
| 6 | $74,000 | $46,633 |
| 7 | $74,000 | $43,178 |
| 8 | $74,000 | $39,980 |
| 9 | $74,000 | $37,018 |
| 10 | $74,000 | $34,276 |
| 11 | $74,000 | $31,737 |
| 12 | $74,000 | $29,386 |
| 13 | $74,000 | $27,210 |
| 14 | $74,000 | $25,194 |
| 15 | $74,000 | $23,328 |
| 16 | $74,000 | $21,600 |
| 17 | $74,000 | $20,000 |
| 18 | $74,000 | $18,518 |
| 19 | $74,000 | $17,147 |
| 20 | $74,000 | $15,877 |
| **Total** | | **$726,543** |

**Alternative 3**

**Yearly General O&M**

1% of Capital Costs

$7,462,700 x 1% = $74,000

**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 | $74,000 |
| Decanting Cost | $6,000 |
| **Total O&M Costs** | **$80,000** |

**Life Cycle Cost of O&M Costs**

@ 8% Discount Rate

| Year | Year Cost | Present Value |
|---|---|---|
| 1 | $74,000 | $68,519 |
| 2 | $74,000 | $63,443 |
| 3 | $74,000 | $58,744 |
| 4 | $74,000 | $54,392 |
| 5 | $74,000 | $50,363 |
| 6 | $74,000 | $46,633 |
| 7 | $74,000 | $43,178 |
| 8 | $74,000 | $39,980 |
| 9 | $74,000 | $37,018 |
| 10 | $74,000 | $34,276 |
| 11 | $74,000 | $31,737 |
| 12 | $74,000 | $29,386 |
| 13 | $74,000 | $27,210 |
| 14 | $74,000 | $25,194 |
| 15 | $74,000 | $23,328 |
| 16 | $74,000 | $21,600 |
| 17 | $74,000 | $20,000 |
| 18 | $74,000 | $18,518 |
| 19 | $74,000 | $17,147 |
| 20 | $74,000 | $15,877 |
| **Total** | | **$726,543** |

# Appendix C – MOE Guidelines

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 – Canadian Climate Normals

▼ Temperature

1981 to 2010 Canadian Climate Normals station data

| Temperature | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year | Code |
| **Daily Average (°C)** | -30.8 | -31.2 | -27.8 | -19.2 | -8.2 | 2.0 | 7.6 | 5.2 | -0.0 | -8.1 | -19.0 | -25.7 | -12.9 | D |
| **Standard Deviation** | 2.5 | 2.8 | 2.5 | 2.6 | 2.2 | 1.5 | 1.2 | 1.1 | 1.5 | 2.5 | 3.1 | 3.7 | 1.6 | D |
| **Daily Maximum (°C)** | -27.4 | -27.9 | -24.1 | -15.0 | -4.6 | 4.7 | 11.3 | 8.0 | 1.8 | -5.8 | -15.6 | -22.3 | -9.7 | D |
| **Daily Minimum (°C)** | -34.3 | -34.7 | -31.6 | -23.2 | -11.7 | -0.7 | 3.8 | 2.2 | -1.9 | -10.3 | -22.3 | -29.2 | -16.2 | D |
| **Extreme Maximum (°C)** | -1.5 | -9.0 | -1.5 | 7.5 | 7.0 | 17.0 | **24.0** | 21.5 | 15.0 | 3.5 | 0.0 | -1.5 | | |
| **Date (yyyy/dd)** | 1979/ 23 | 1986/ 17 | 1980/ 23 | 1984/ 30 | 1993/ 30 | 1991/ 18 | **2001/ 28** | 1991/ 05 | 1988/ 02 | 1988/ 05 | 1995/ 13 | 1998/ 03 | | |
| **Extreme Minimum (°C)** | -47.5 | **-53.0** | -45.5 | -39.0 | -26.5 | -14.0 | -2.0 | -5.0 | -14.5 | -32.0 | -36.5 | -44.0 | | |
| **Date (yyyy/dd)** | 1987/ 05 | **1979/ 12** | 1986/ 09 | 1985/ 09 | 1999/ 01 | 1980/ 11 | 1979/ 21 | 1981/ 29 | 1979/ 29 | 1978/ 30 | 1986/ 23 | 1983/ 29 | | |

▼ Precipitation

1981 to 2010 Canadian Climate Normals station data

| Precipitation | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year | Code |
| **Rainfall (mm)** | 0.0 | 0.0 | 0.0 | 0.1 | 1.1 | 12.8 | 27.6 | 41.1 | 17.9 | 0.8 | 0.0 | 0.0 | 101.3 | C |
| **Snowfall (cm)** | 13 | 10 | 15 | 16 | 19 | 6 | 0 | 2 | 13 | 31 | 31 | 17 | 173 | C |
| **Precipitation (mm)** | 12.8 | 9.7 | 14.7 | 16.3 | 20.5 | 19.2 | 27.9 | 43.0 | 31.0 | 32.1 | 31.1 | 16.7 | 274.8 | C |
| **Average Snow Depth (cm)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **Median Snow Depth (cm)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **Extreme Daily Rainfall (mm)** | 0.0 | 0.0 | 0.0 | 0.6 | 19.6 | 13.6 | 26.4 | **26.8** | 24.0 | 5.0 | 0.0 | 0.0 | | |
| **Date (yyyy/dd)** | 1978/ 01 | 1978/ 01 | 1978/ 01 | 1995/ 28 | 2001/ 22 | 1998/ 21 | 1990/ 29 | **2000/ 26** | 1994/ 11 | 1998/ 06 | 1977/ 01 | 1977/ 01 | | |
| **Extreme Daily Snowfall (cm)** | 21 | 9 | 12 | 19 | 26 | 13 | 4 | 32 | 13 | 23 | **53** | 11 | | |
| **Date (yyyy/dd)** | 1992/ 06 | 1983/ 27 | 1991/ 07 | 2001/ 30 | 1978/ 17 | 1990/ 08 | 2002/ 07 | 1979/ 26 | 1979/ 16 | 1978/ 12 | **1982/ 19** | 1985/ 26 | | |
| **Extreme Daily Precipitation (mm)** | 24.0 | 8.5 | 11.6 | 19.4 | 26.3 | 13.6 | 26.4 | 32.0 | 24.0 | 23.2 | **53.3** | 11.4 | | |
| **Date (yyyy/dd)** | 1992/ 06 | 1983/ 27 | 1991/ 07 | 2001/ 30 | 1978/ 17 | 1998/ 21 | 1990/ 29 | 1979/ 26 | 1994/ 11 | 1978/ 12 | **1982/ 19** | 1985/ 26 | | |
| **Extreme Snow Depth (cm)** | 23 | 24 | 27 | **38** | 23 | 16 | 2 | 2 | 10 | 15 | 17 | 30 | | |
| **Date (yyyy/dd)** | 1993/ 01 | 1989/ 28 | 1992/ 31 | **1998/ 30** | 1994/ 01 | 1995/ 01 | 2002/ 08 | 1985/ 27 | 1991/ 30 | 1994/ 31 | 1991/ 30 | 1991/ 31 | | |

*Canadian Climate Normals 1981-2010 Hamlet of Igloolik, Nunavut. Canadian Climate Normals station Data, Retrieved November 19, 2014