Trow

Design Brief
New Sewage Lagoon and Rehabilitation of Existing Sewage Lagoon for the Hamlet of Clyde River

Prepared for:
Department of Community Government and Services
Government of Nunavut

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Executive Summary

Trow Associates Inc. were retained by the Department of Community and Government Services, Government of Nunavut to review the existing sewage lagoon and complete the detail planning and design for the construction of a new sewage treatment facility for the Hamlet of Clyde River, Nunavut. The project was based on the scope of works as presented in the "Clyde River Sewage Management – Planning Study" – completed by Dillon Consulting Limited.

The existing Clyde River sewage lagoon is located 1.2 kms to the west of the community and is located approximately 800 m north of Patricia Bay. The existing facility currently does not meet the storage requirements of the Hamlet nor does it meet the treatment requirements of the Hamlet's water licence. The new sewage facility shall be required to meet both the 20 year needs of the Hamlet and provide sewage treatment to meet the requirements of the Hamlet's water licence as issued by the Nunavut Water Board. The projected population for the Hamlet in the year 2028 is 1456. It is estimated that the annual sewage generated by this population will be approximately 64,000 m^3.

To meet these requirements it is recommended that the existing sewage lagoon cell be rehabilitated and utilized as a storage cell and that a new sewage lagoon cell be constructed to the south and west of the existing lagoon to supplement the existing lagoon storage capacity to meet the needs of the Hamlet. It is also recommended that the land between the proposed facility and Patricia Bay remain as undisturbed tundra and be included in the sewage treatment facility as a filterstrip wetlands.

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

As the recommended design requires in excess of 40,000 m^3 of granular material, it is recommended that a new quarry site be developed for this project. The Hamlet's current quarry sites are being utilized for municipal needs and do not have sufficient material to complete this project.

The estimated capital cost of the proposed facility is $4,385,000.00 with a yearly operation and maintenance cost of $50,000.00.

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1.0 Introduction

Trow Associates Inc. (Trow) were retained by the Department of Community & Government Services (CGS), Government of Nunavut (GN) to complete the detail planning and design for the construction of a new sewage lagoon for the Hamlet of Clyde River (Hamlet), Nunavut. The scope of works for the project is based on the "Clyde River Sewage Management - Planning Study" completed by Dillon Consulting Limited in 2003.

The existing Clyde River sewage lagoon is located approximately 1.2 km to the west of the community, as shown on Figure 1. It is bordered to the north by the Hamlet's bulky metals waste site, to the east by the Hamlet's solid waste site and to the west by a drainage course. Effluent from the existing facility flows to the south towards Patricia Bay, approximately 800 metres from the existing sewage lagoon. The land between the existing sewage lagoon and Patricia Bay is undeveloped tundra.

The existing sewage lagoon does not meet the storage requirements of the Hamlet, and effluent samples taken in August 2006 did not meet the regulatory requirements of the Hamlet's water licence. The intention of this project is to upgrade the sewage treatment facility to meet the needs of the Hamlet for 20 years, and the requirements of their water licence.

1.1. Background

The background information provided for this project included the "Clyde River Sewage Management - Planning Study" completed by Dillon Consulting in 2003 and the "Clyde River Sewage Lagoon Geotechnical Investigation", dated 1991 completed by Thurber Engineering Limited. The planning study completed by Dillon is to be the basis for this project.

1.1.1. Clyde River Sewage Management - Planning Study

The scope of work undertaken for the "Clyde River Sewage Management Planning Study" as listed in the report includes:

1. *Interview with community officials regarding the operational history and the effectiveness of the existing sewage lagoon.*
2. *Obtain copies of regulatory inspection reports and recommendations that the community has on file.*
3. *Visit the community and conduct a detailed inspection of the existing sewage lagoon and document with photos.*
4. *Determine the feasibility of upgrading the existing sewage lagoon to accommodate the projected 20 year sewage volume.*
5. *Gather topographic and photographic mapping of the community and identify possible alternate lagoon sites.*
6. *Determine the feasibility of constructing the new lagoon at alternate sites versus expanding the existing site.*

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GOVERNMENT OF NUNAVUT

LOCATION PLAN - CLYDE RIVER SEWAGE LAGOON

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FIG 1

7. *Prepare a summary report including the following:*
   - *analyze the problems with the existing lagoon and propose repairs so that it will operate in accordance with regulatory guidelines and requirements.*
   - *design sketches of proposed modifications and Class B Cost Estimates.*
   - *for alternative lagoon sites, provide sketches showing lagoon configurations, capacity, berm heights, access road and Class B Cost Estimates.*
   - *a recommendation for the most cost effective long term solution for the sewage treatment for the community.*

The planning study referenced the original design drawings which showed the lagoon was to be constructed to an overall depth of 4 m with a capacity of 19,500 m^3. The lagoons were to have a top width on the dykes of 10 m so that a permanent ice dam would be created within the dyke and liners would not be required. The lagoon was to be decanted by a culvert located in the western berm. The site investigation completed as part of the planning study noted the following discrepancies between the design drawings and the as-built conditions.

1. *The dimensions of the existing lagoon were measured as 59 m x 109 m to the inside top of the berms. The same dimensions on the design drawings were to be 75 m x 138 m, therefore it was concluded that the lagoon was constructed smaller than the original design drawings.*
2. *The top of the dyke is approximately 4 m as opposed to the 10 m in the original design drawings.*
3. *The slope on the outside of the dykes is measured at approximately 1.5H:1V as opposed to the 3H:1V in the design drawings.*
4. *The lagoon drainage culvert was not constructed as per the original design.*
5. *There exists a truck dump pad on the north side as well as a truck dump pad on the southern dyke as opposed to the three concrete truck dump pads proposed for the north side.*

The Planning Study summarized the following concerns at the existing facility:

1. *The lagoon drain is inoperative and is no longer in use.*
2. *Berm settlement has occurred and temporary repairs have been required.*
3. *Minor seepage of sewage effluent was observed on the outside toe of the dyke at the south west corner.*
4. *There is little erosion protection visible on the inside slope of the dykes. The inside slope is slumping in many places and remedial work is required.*
5. *There is an abandoned culvert barrel and other minor debris in the lagoon.*
6. *The site is not fenced and there is no signage identifying the purpose of the facility.*

The Planning Study summarized the investigation into sewage treatment alternatives as follows:

"The preferred method of sewage management that was determined for Clyde River is a facultative lagoon at the existing site for the following reasons:

1. *Adequate land availability for lagoon expansion.*
2. *Meets effluent criteria set by the regulators.*
3. *Easy to operate and maintain.*
4. *Proven effectiveness in northern climates.*
5. *Site already approved for lagoon operations*."

The study also noted that the existing site was selected as there was no community opposition, no known constraints and the site is already used for sewage treatment.

1.1.2. Clyde River Sewage Lagoon Geotechnical Investigation

The "Clyde River Sewage Lagoon Geotechnical Investigation" put forth the recommended design of the original lagoon. The recommendations included:

Table 1.1 – Geotechnical Recommendations – Background Report

Criteria	Recommendation
Freeboard	2 metres
Dyke Crest Width	10 metres
Interior Slope	4H : 1V
Exterior Slope	3H : 1V
Erosion Protection	200 mm of riprap on all slopes

As noted in the planning study, the lagoon was not constructed to meet these criteria.

1.2. Scope of Services

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

1. A community visit and site investigation.
2. Review of available resources within the Hamlet.
3. Completion of a topographic survey.
4. Completion of a geotechnical investigation and report.
5. Investigate the opportunity to include the wetlands 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 of the existing lagoon.

2.0 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's Facility Capital Program Standards and Criteria" as provided by the CGS, indicates the design horizon for sewage lagoons is to be between 15 -20. As per the direction of the CGS, the design horizon for this project shall be 20 years, until the year 2028.

2.2. Population

The population projections for this project will be based on "Nunavut: Community Population Projections" as published by the Nunavut Bureau of Statistics. The Nunavut Bureau of Statistics population projections provide projected populations of the Nunavut communities to the year 2020. As the planning horizon for this project is past the population projections available from the Nunavut Bureau of Statistics, the population projections from 2020 to 2028 are estimated using the average growth rate for the Hamlet between the year 2000 and 2020 of 2.3%. The table below summarizes the population projections to the year 2028.

Table 2.1 - Population Projections

Planning Year	Year	Population	Planning Year	Year	Population
	2000	771	7	2015	1095
	2001	789	8	2016	1121
	2002	812	9	2017	1144
	2003	830	10	2018	1167
	2004	848	11	2019	1190
	2005	867	12	2020	1214
	2006	890	13	2021	1242
	2007	913	14	2022	1270
0	2008	937	15	2023	1300
1	2009	959	16	2024	1330
2	2010	982	17	2025	1360
3	2011	1007	18	2026	1391
4	2012	1028	19	2027	1423
5	2013	1050	20	2028	1456
6	2014	1072			

2.3. Sewage Generation

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

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

Table 2.2 - Residential Water Usage

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

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

The non-residential water usage by a community tends to increase with increases in the population. To determine the Total Community Water Usage the Residential Water Usage is adjusted based on population to provide a Total Water Usage per Capita. The Total Water Usage per Capita, 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 – 2000	RWU x (1.0 + 0.00023 x Population)
2000 – 10,000	RWU x [-1.0 + {0.323 x Ln(Population)}]
Over 10,000	RWU x 2.0

The daily water consumption, and therefore the sewage generated by the community, is equal to the population multiplied by the Total Water Usage per Capita. Based on the design population of 1456 for the year 2028, and a total water usage per capita rate of 120 lpcd, the daily sewage generation rate is equal to 174,720 lpd. This is equal to a yearly sewage generation rate of 63,773 m^3.

2.4. Regulatory Requirements

The proposed sewage treatment facility will have to meet the effluent quality standards as set out in the Hamlet's water licence. The Hamlet is operating under a valid water licence, licence #NWB3CLY0308 issued on September 15, 2003 by the Nunavut Water Board, as required under the Nunavut Lands Claim Agreement and the Nunavut Waters Act. The effluent quality standards set out in the water licence are summarized in the Table 2.4.

Table 2.4 – Effluent Quality Standards

Parameters	Maximum Average Concentration
BOD_5	120 mg/l
Total suspended solids (TSS)	180 mg/l
Faecal coliforms	1 x 106 CFU/dl
Oil and grease	No visible sheen
pH	6 and 9

3.0 Site Investigation

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

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

3.1. Site Inspection

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

1. The existing sewage lagoon has two truck discharge locations which are used depending on wind directions. The main truck discharge is located on the northern side of the lagoon, with a secondary truck discharge located on the southern side of the lagoon which is used when the winds are from the south, normally in storm events.
2. The existing discharge locations are in a poor state of repair and do not have a sewage discharge chute, requiring the operator to be in a precarious location to operate the discharge valve on the back of the truck.
3. There is erosion at the outlet of the overflow pipe.
4. Indications of slope instability are evident along the top of the berm.
5. There are localized areas of partial failure of the existing dyke system.
6. There is seepage from the lagoon along the southern berm.
7. There is a potential wetlands area hydraulically downstream of the lagoon, between the existing lagoon and Patricia Bay.
8. The area to the east is occupied by the Hamlet's solid waste site, there is no opportunity to expand the sewage lagoon in this direction.
9. The area to the north is occupied by the Hamlet's bulky metals waste site, there is no opportunity to expand the sewage lagoon in this direction.
10. The area to the northwest is very wet as several small drainage courses converge in this area. For hydrological, geotechnical and ecological reasons this area is not suitable for expansion of the sewage lagoon.

3.2. Topographic Survey

A topographic survey was undertaken of the existing lagoon, as well as the land between the existing lagoon and Patricia Bay.

The survey of the existing lagoon site reaffirmed the conclusions put forth in the Planning Study with regards to dimensions and side slopes of the existing lagoon. Minor discrepancies in dimensions between the survey and those reported in the planning study are primarily due to locations where measurements were taken. The characteristics of the existing lagoon, based on the topographic survey, are shown in the Table 3.1 and the survey of the lagoon is shown in Figure 2.

Table 3.1 – Existing Lagoon Characteristics

	Original Design	Existing Lagoon (Planning Study)	Existing Lagoon (Survey)
Dimensions	75m x 138m	59m x 119m	65m x 123m
Side Slopes	3 H : 1 V	1.5 H : 1 V	1.5 H : 1 V
Top of Dyke Width	10 metres	4 metres	4.5 to 5 metres

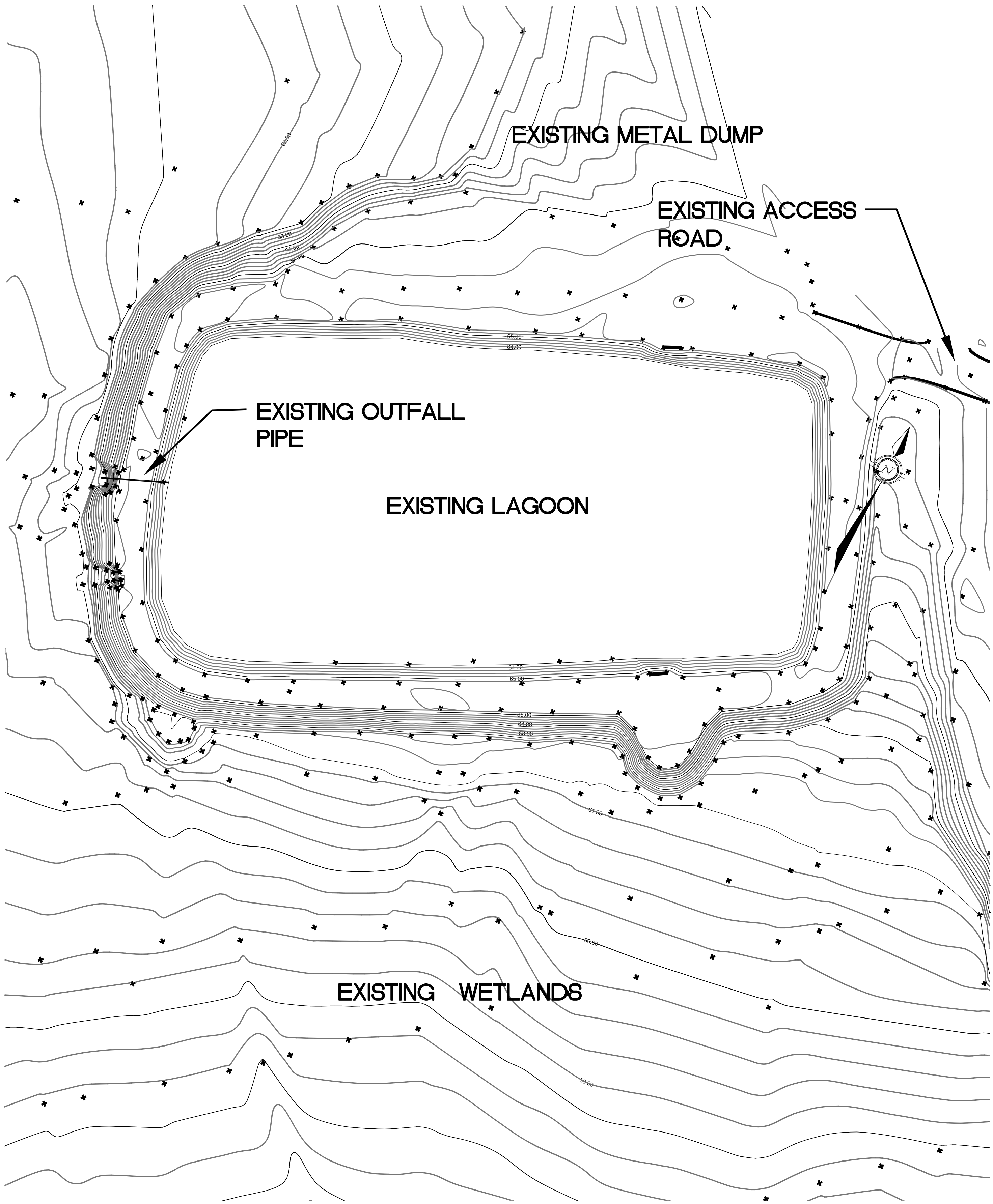
The topographic survey of the area for the proposed expansion of the sewage treatment facility indicates a slope across the site of approximately 4%, generally in a southern direction from the existing lagoon through to Patricia Bay. The survey also located the small watercourse on the western boundary of the lagoon. This watercourse will be considered as the western boundary of any potential wetlands.

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 7 hectares of tundra is being utilized for wetlands treatment while there is potential to expand this area to approximately 23.5 hectares.

3.3. Geotechnical Investigation

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

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



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SCALE 1:1000	CLIENT: GOVERNMENT OF NUNAVUT		JOB NO. OTCD19055A
DATE: 17/01/08	TITLE: TOPOGRAPHIC SURVEY - LAGOON		FIG. 2
DRAWN: MMR			

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

The investigation has revealed that the problems currently being experienced with the existing lagoon relate to its construction on ice rich soils. Construction of the lagoon has resulted in degradation of the permafrost and thawing of the underlying ice rich soils, thereby resulting in large settlements of the berms. The geotechnical investigation has also indicated that the berms have been constructed with permeable soils and as a result are prone to seepage. The slopes of the existing lagoons are too steep and slough in an attempt to stabilize themselves. The remedial measures would essentially consist of arresting the settlements of the berms, preventing seepage out of the berms and flattening the slopes to a stable inclination. In order to prevent additional settlements of the berms, it is essential to restore the permafrost under the existing berms.

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

3.4. Wetlands Assessment

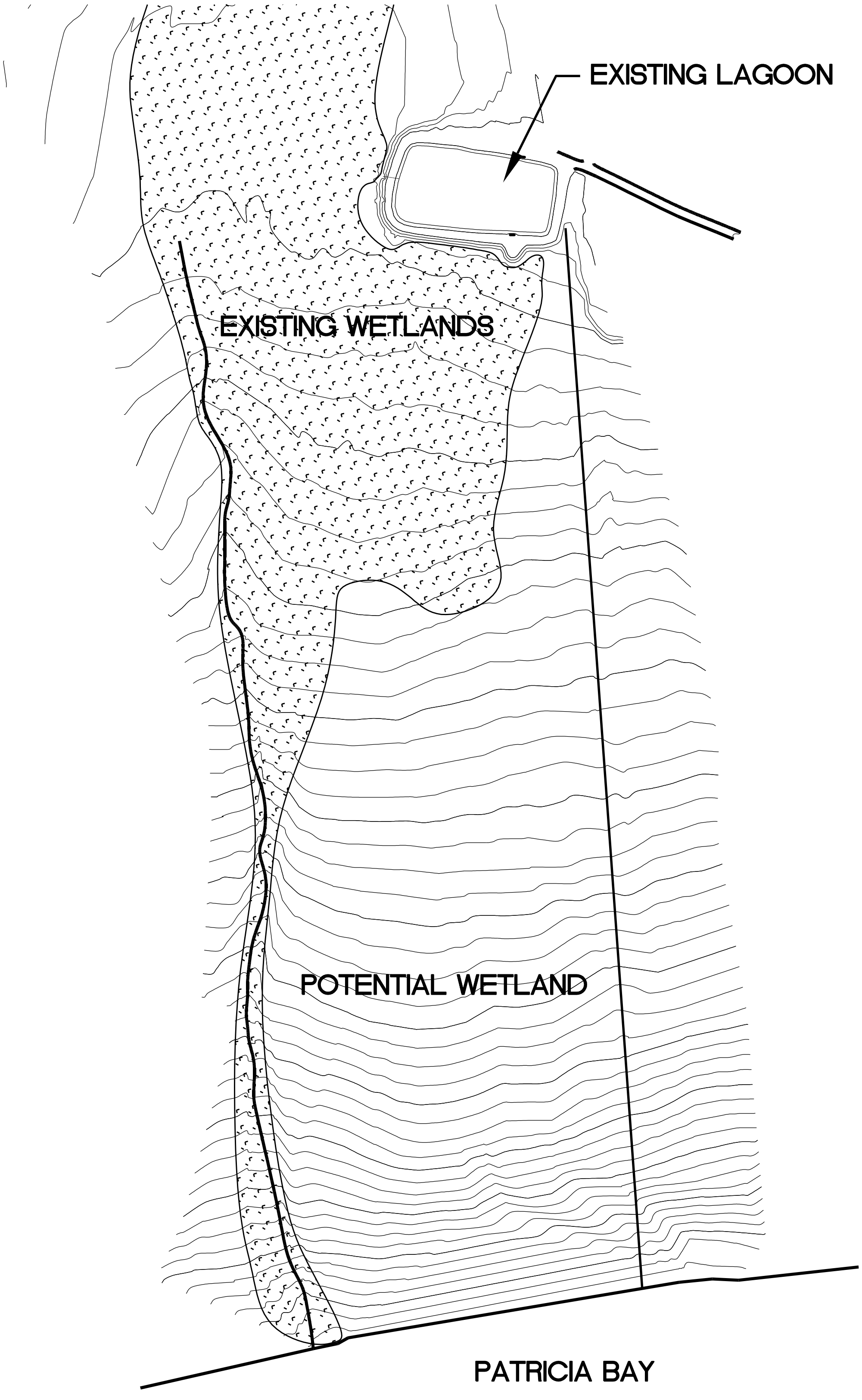
Treatment of raw sewage in a new sewage lagoon in Clyde River will be combined with the utilization of a wetlands treatment as a final polishing. The area to be used as wetlands for the Clyde River treatment facility is a vegetated filterstrip wetland as described below.

The proposed sewage lagoon will be constructed next to the existing lagoon and the area between the lagoon and the ocean will be incorporated into the sewage treatment process as shown in Figure 3. The wetlands area is 23.5 hectare in size (approximately 720 m long and 325 m wide) with an average slope of 6 to 7%. The soils are comprised of silty sand with permafrost at 1 m in the summer months, as noted in the geotechnical investigation. The well established native vegetation community will be used and alterations or modifications to the plant community composition are not necessary to increase removal of contaminants. The plant species present, which include willows, grasses, sedges and mosses, are suitable for the phytofiltration processes that will reduce BOD and TSS.

3.5. Environmental Assessment

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

The Government of Nunavut 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



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SCALE	1:5000	CLIENT: GOVERNMENT OF NUNAVUT	JOB NO. OTCD19055A
DATE:	17/01/08	TITLE: LIMITS OF WETLANDS	FIG. 3
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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 Government of Nunavut is the Responsible Authority (RA).

The existing sewage lagoon is located approximately 1.2 km west of the Clyde River community on the west shore of Patricia Bay.

Construction of a new sewage lagoon is necessary because the existing lagoon is too small for the Hamlet and the berms are failing. Trow is designing a new sewage treatment lagoon with a larger capacity which takes growth of the population of Clyde River over the next 20 years into consideration. It incorporates a vegetated filterstrip wetland as an additional polishing step using existing native vegetation. A number of components of the proposed project will interact with Valued Ecosystem Components (VECs) during the construction phase, operating phase and decommissioning of the existing sewage lagoon. A number of interactions may have a negative effect, however, all of the negative effects can be mitigated through mitigation measures, maintenance programs or implementation of health and safety plans. These interactions are short term, localized and do not result in residual negative effects on the environment. The overall and long term effect of the project is positive.

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

4.0 Detail Design

4.1. Lagoon Size

The proposed sewage lagoon system for Clyde River is to be a storage cell system. Storage cell lagoon systems must store the sewage generated from the end of one decanting cycle to the start of the next. It is proposed that the decanting of the Clyde River 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 335 days period (approximately 11 months). Based on the projected population of 1456 and the sewage generation rate of 120 lcpd, the total required storage is 58,500 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 on 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 Clyde River 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

A slope stability analysis was performed to determine the steepest slopes of the berms that would be stable under prevailing conditions and provide a factor of safety of 1.5 for static loading conditions, and a factor of safety of 1.1 for seismic loading conditions. It is noted that although the central core of the berms and the underlying natural soils would be maintained in a constantly frozen state, the outside and inside slopes of the berms would be subject to seasonal freezing and thawing. The inside slopes of the berms were therefore analysed for completely submerged case whereas the outside slopes of the berms were analysed for steady state seepage conditions. Static as well as seismic loading 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 3.5H:1V and 2.75H:1V respectively. It is noted that the computed slopes would be stable provided that the berms are not overtopped, are not subjected to ‘rapid drawdown’ condition and that the underlying ice rich soils are permanently maintained in a frozen state.

4.2.1.2. Rehabilitation of Existing Lagoon Berms

The remedial measures would essentially consist of arresting the settlements of the berms, preventing seepage out of the berms and flattening the slopes to a stable inclination. In order to prevent additional settlements of the berms, it is essential to restore the permafrost under the existing berms. The permeability of the berms may also be reduced by maintaining the berms in a constantly frozen state. It has been established that the inside slopes of 3.5H:1V and outside slopes of 2.75H:1V would be stable with an adequate factor of safety.

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 Clyde River which would utilize an ice dam design for the berms.

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

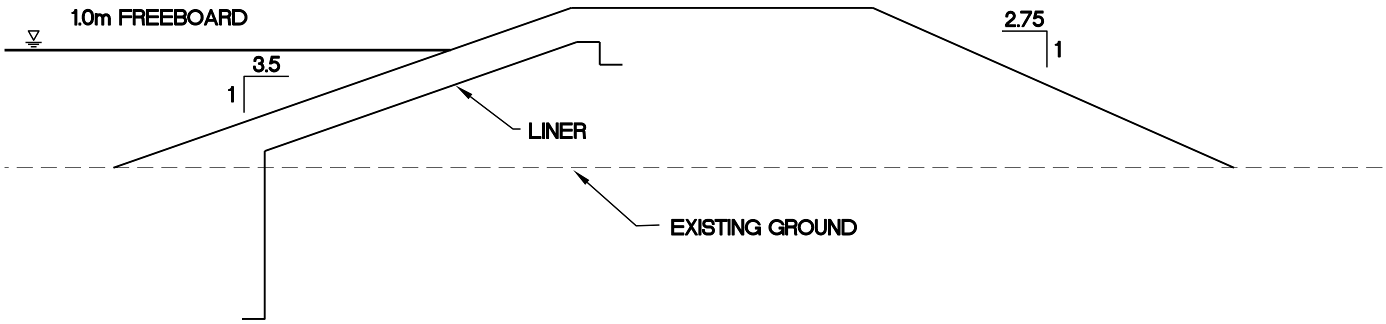
The application of an ice dam concept as a primary containment method was not recommended based on the analysis. As an alternative the geothermal model proposed that a liner, or other barrier, be incorporated into the upstream face of the berm and keyed into the permafrost at the toe of the berm. The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

No secondary cooling of the berm was currently recommended, however, a monitoring system for ground temperatures and seepage throughout the berm structures was recommended to be implemented. Sealed PVC casings should be installed through the berm structure and into the subgrade soils into which thermistor cables may be installed to monitor ground temperatures. Selected casings should be "battered" to the upstream side so to provide the opportunity to monitor berm and subgrade temperatures on the upstream side. To monitor seepage, vertical slotted standpipes should be installed along the crest of the berm. These standpipes should be of a diameter to permit the recovery of liquid within the standpipe for environmental/biological testing.

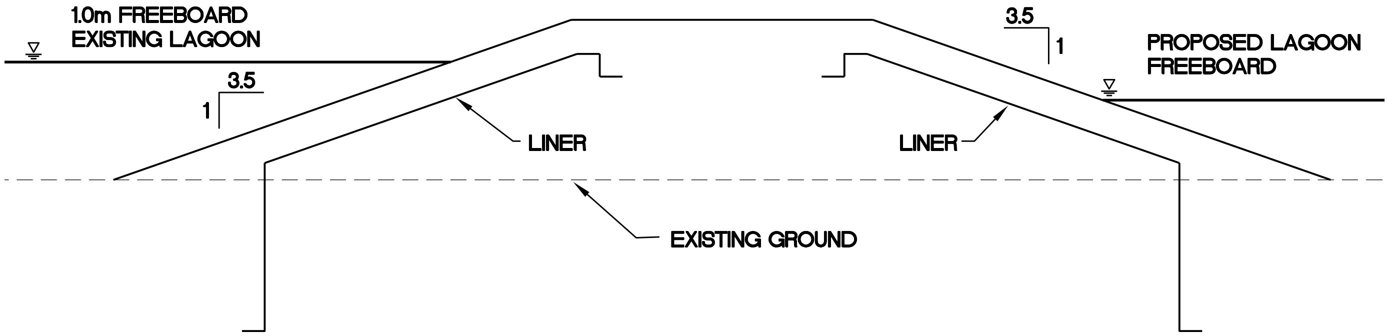
Based on monitoring of the core temperatures of the berm and further potential of seepage, secondary cooling by way of thermosyphons may be required in the future.

4.2.3. Recommended Berm Design

As per the geotechnical recommendations, the proposed berm design is to have a 3.5H:1V slope on the upstream side of the berm with a 2.75H:1V slope on the downside of the berm. The berm crest width will be 4 m, except where the top of the berm is utilized for access, either for the decanting process or discharging of the sewer trucks where it will be 5 m wide to better accommodate vehicles. As per the recommendations of the geotechnical report and geothermal analysis, the berms will be constructed with a liner on the upstream slope to provide an impermeable boundary, with an ice dam providing secondary containment and ensuring the liner is keyed into an impermeable surface, i.e. the permafrost. The typical berm sections are shown in Figure 4.



EXTERIOR BERM



INTERIOR BERM

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SCALE 1:100	CLIENT: GOVERNMENT OF NUNAVUT		JOB NO. OTCD19055A
DATE: 17/01/08	TITLE: TYPICAL BERM SECTION		FIG. 4
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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 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 and valve through the berm is common in southern locations with continuous discharge. In storage lagoons in northern locations, the discharge pipe is only used seasonally, and pipe and valve arrangements are installed through a frozen berm. This tends to require that the pipe and valve have to be thawed prior to their use. This has caused operational concerns, and in some instances has proven impossible.

4.3.3. Pumping

Pumping the effluent from the lagoon is the most operator demanding alternative, however is also the must dependable. This requires the pumps to be installed and removed each year, and during operation must be checked on a regular basis. It also has the added operational cost for fuel. The operation of a pump is a relatively dependable operation, and in the case of failure, a relatively easy system to repair or replace. 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 Clyde River system includes a wetlands treatment system with the lagoons providing retention and treatment and the wetlands additional treatment or polishing. The performance of the wetlands performance is dependent on the time and rate of discharge.

Due to the presence of ice rich soil, the geotechnical investigation concluded that the use of seepage cells was not appropriate at this site. In addition, seepage cell construction does not allow for sufficient control over the time and rate of discharge, and therefore is not suitable for this application.

The installation of piped discharges poses operational challenges, primarily thawing of the pipe at the time of discharge. They are also more prone to freeze and may not be recoverable which would result in a costly repair or abandonment of the system.

Pumping 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 therefore is recommended as the preferred method of decanting.

4.4. Sludge Management

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

Prior to disposal, the sludge must be tested to ensure 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 landfill site. The sludge will be covered with granular material and allowed to freeze.

5.0 Lagoon Alternatives

The storage requirements for the Clyde River sewage lagoon system will be required to provide eleven months of storage or the equivalent of approximately 58,500 m^3 of storage as per Section 4.1.

The expansion of the existing facility is restricted to the north and east by the presence of the bulky metal waste site and domestic waste site. The area to the northwest was determined not to be suitable during the site investigation due to hydrological, geotechnical and ecological reasons. There is insufficient space to the west to accommodate the entire expansion due to the presence of the drainage course approximately 150 m to the west of the existing lagoon. Therefore, the two alternatives for expansion of the existing sewage treatment facility are the construction of a new lagoon to the south or a new lagoon to the south and west of the existing site.

Sewage lagoons in the arctic are generally operated as storage lagoons with annual releases of sewage generally in late summer or early fall. However, the presence of the existing lagoon presents the opportunity to incorporate it into the new system as either a primary cell or as a storage cell.

Sewage lagoon systems in the south have shown that incorporating primary cells improve treatment. One of the disadvantages of the use of primary cells in the arctic is they require continuous discharge and therefore will not operate on a trucked sewage collection system during the winter.

To meet the requirements of the new facility, the two layouts and two operating methods (primary or storage cell) were combined to create four alternatives.

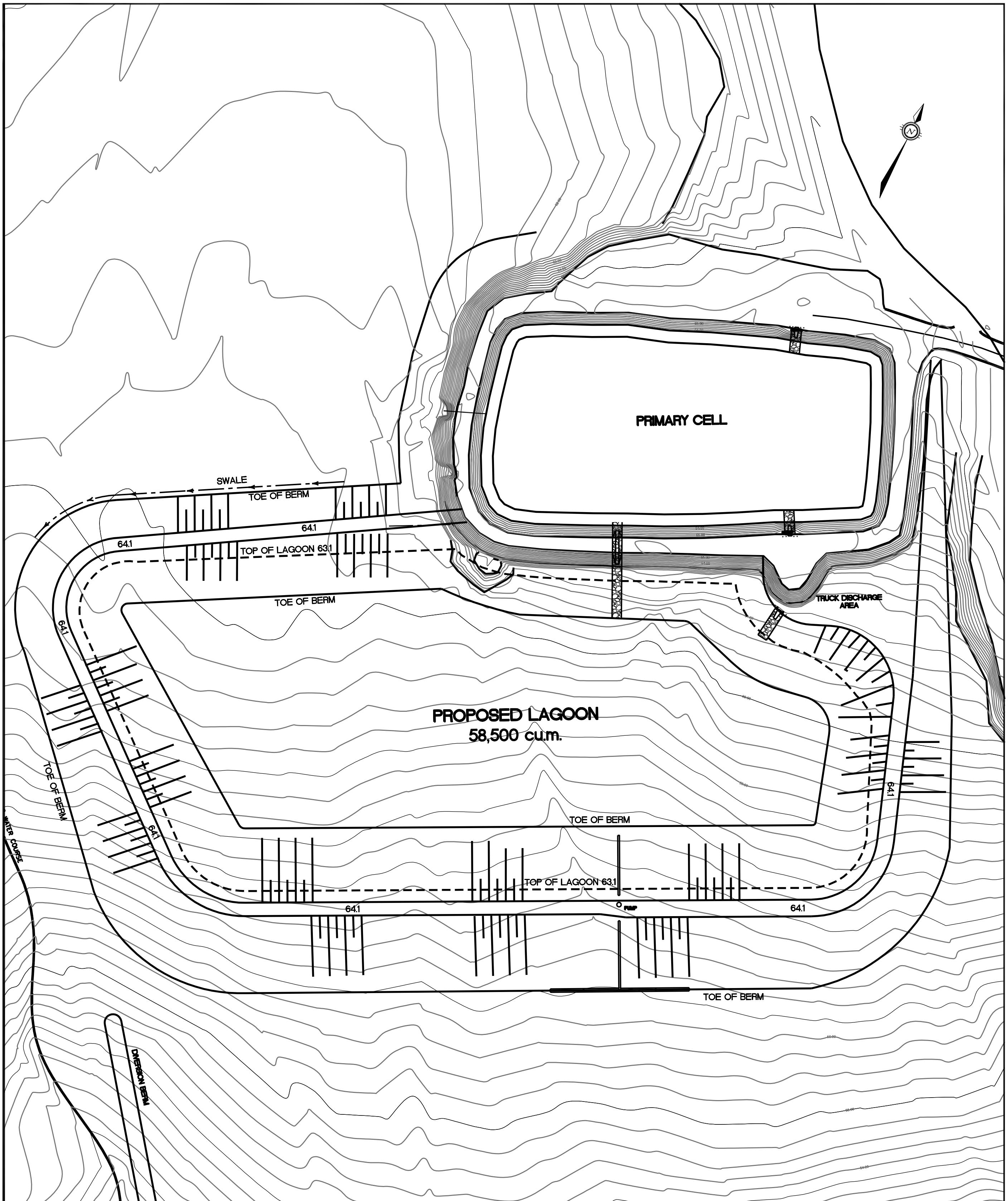
Alternative 1

The first alternative is to operate the existing lagoon as a primary lagoon and the construction of a new cell to the south of the existing site to provide the storage requirements of the system as shown on Figure 5. The eastern boundary of the new cell would correspond to the eastern boundary of the existing cell with the western boundary extending to approximately 20 m from the existing drainage course. The southern boundary would be determined by meeting the required storage capacity for the lagoon.

Alternative 1 will operate using the existing sewage lagoon to be used as a primary cell for the summer months. The new lagoon will be required to meet the complete storage requirements of the sewage treatment system, 58,500 m^3.

Alternative 2

The second alternative is to use the existing cell to provide storage and construct a new cell to the south of the existing sewage lagoon to provide the additional storage required as shown on Figure 6. The eastern boundary of the new cell would correspond to the eastern boundary of the existing cell with the western boundary extending to approximately 20 m from the existing



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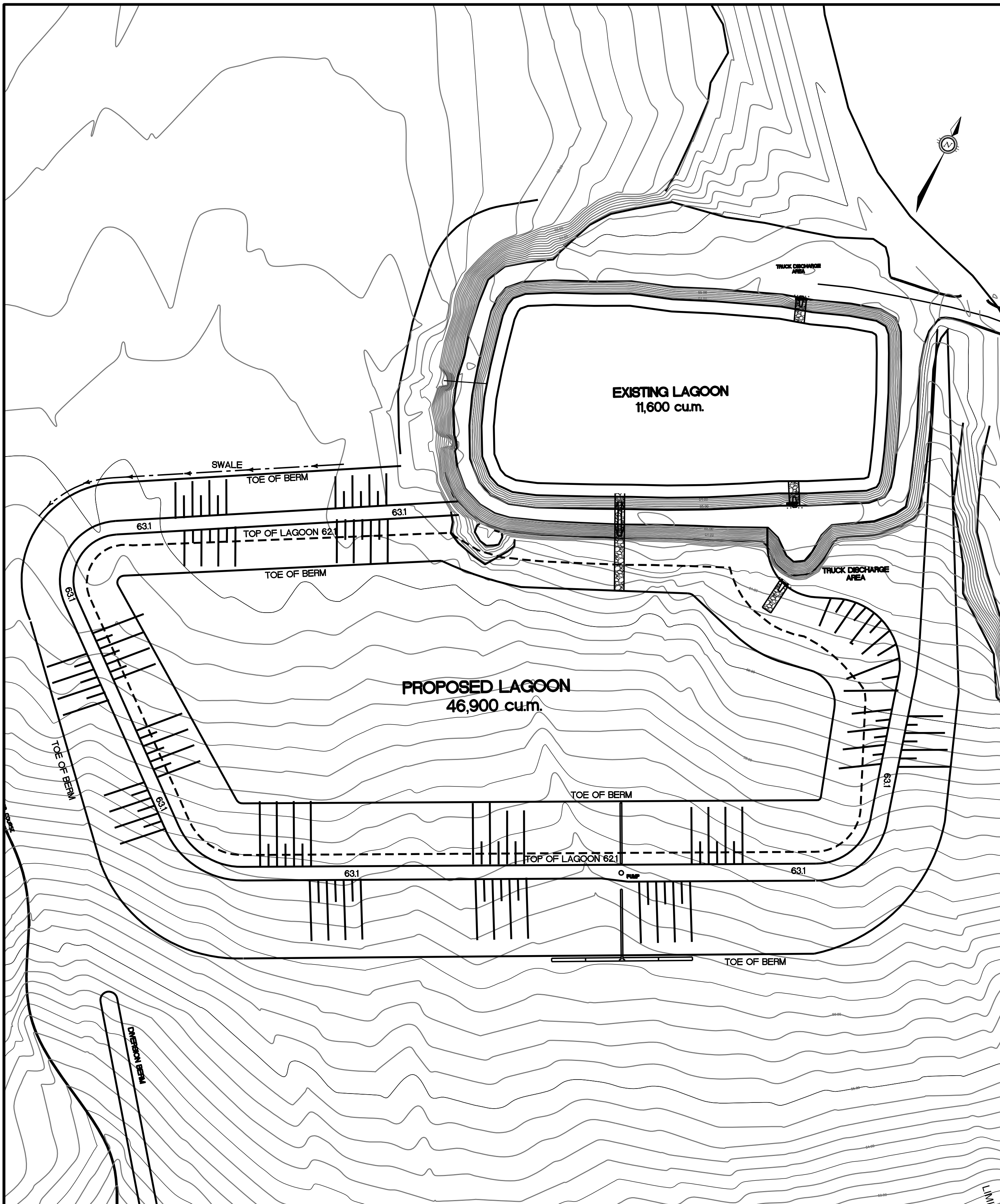
SCALE: N.T.S.	CLIENT: GOVERNMENT OF NUNAVUT	JOB NO. OTCD19055A
DATE: 17/01/08	TITLE: CLYDE RIVER - ALTERNATIVE 1	FIG.5
DRAWN: MMR		



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SCALE 1:1500	CLIENT: GOVERNMENT OF NUNAVUT		JOB NO. OTCD19055A
DATE: 17/01/08	TITLE: CLYDE RIVER - ALTERNATIVE 2		FIG.6
DRAWN: MMR			

drainage course. The southern boundary would be determined by meeting the required storage capacity for the lagoon.

Alternative 2 will utilize the capacity of the existing lagoon (reported as 11,600 m^3) and the new cell to provide the additional required storage for the sewage treatment facility 46,900 m^3.

Alternative 3

The third alternative is to operate the existing lagoon as a primary lagoon and the construction of a new cell to the south and west of the existing lagoon to provide the storage requirements of the system as shown on Figure 7. The eastern boundary of the new cell would correspond to the eastern boundary of the existing cell and the cell's western boundary would again be approximately 20 m from the existing drainage course. The cell would be located to the south as well as the west of the existing sewage lagoon.

Alternative 3 will operate using the existing sewage lagoon to be used as a primary cell for the summer months. The new lagoon will be required to meet the complete storage requirements of the sewage treatment system, 58,500 m^3.

Alternative 4

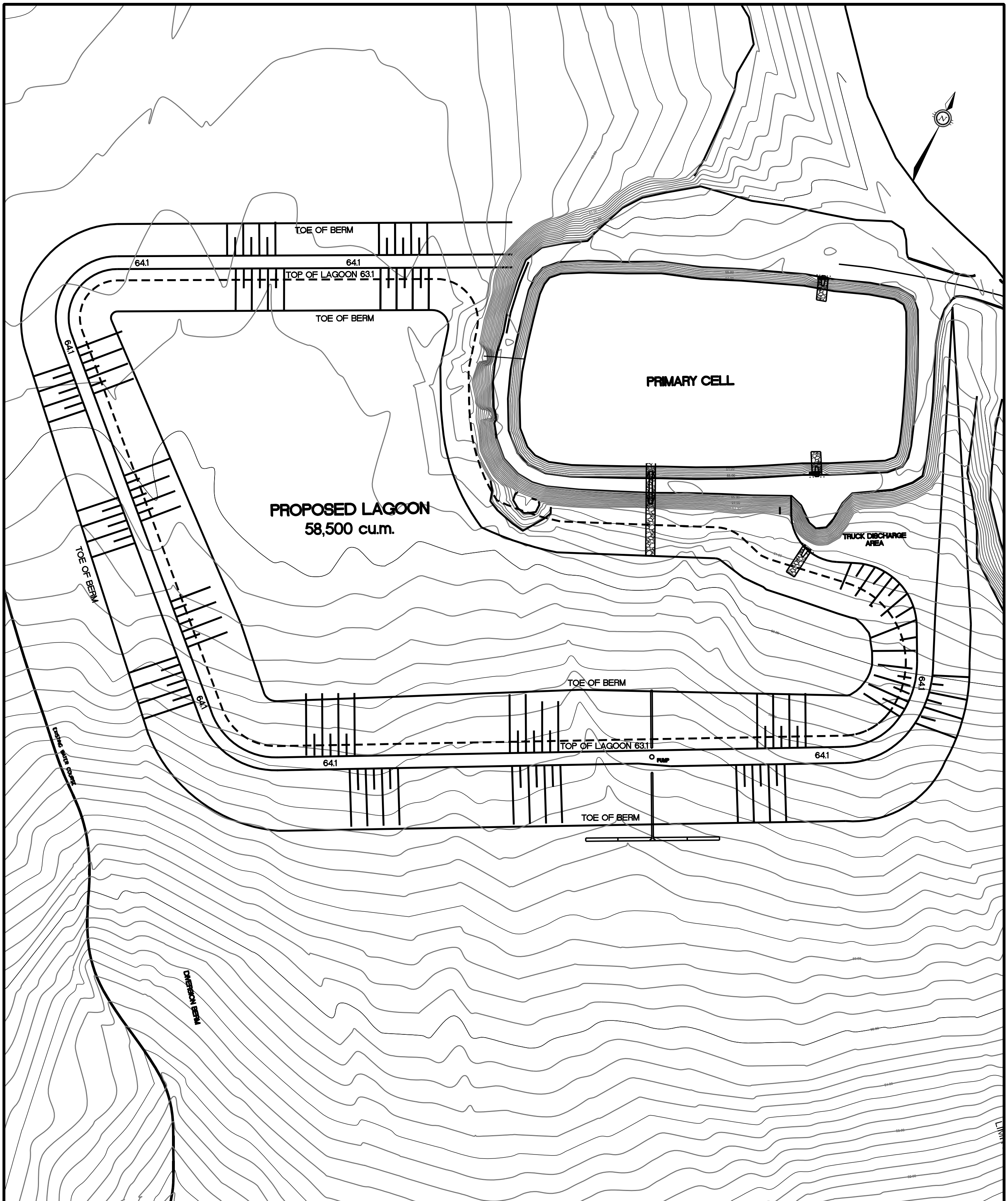
The fourth alternative is to use the existing cell to provide storage and construct a new cell to the south and west of the existing sewage lagoon to provide the additional storage required as shown on Figure 8. The eastern boundary of the new cell would correspond to the eastern boundary of the existing cell and the cell's western boundary would again be approximately 20 m from the existing drainage course. The cell would be located to the south as well as the west of the existing sewage lagoon.

Alternative 4 will utilize the capacity of the existing lagoon (report as 11,600 m^3) and the new cell to provide the additional required storage for the sewage treatment facility 46,900 m^3.

5.1. Evaluation Process

The evaluation of the four 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 prescreen 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 criteria. The



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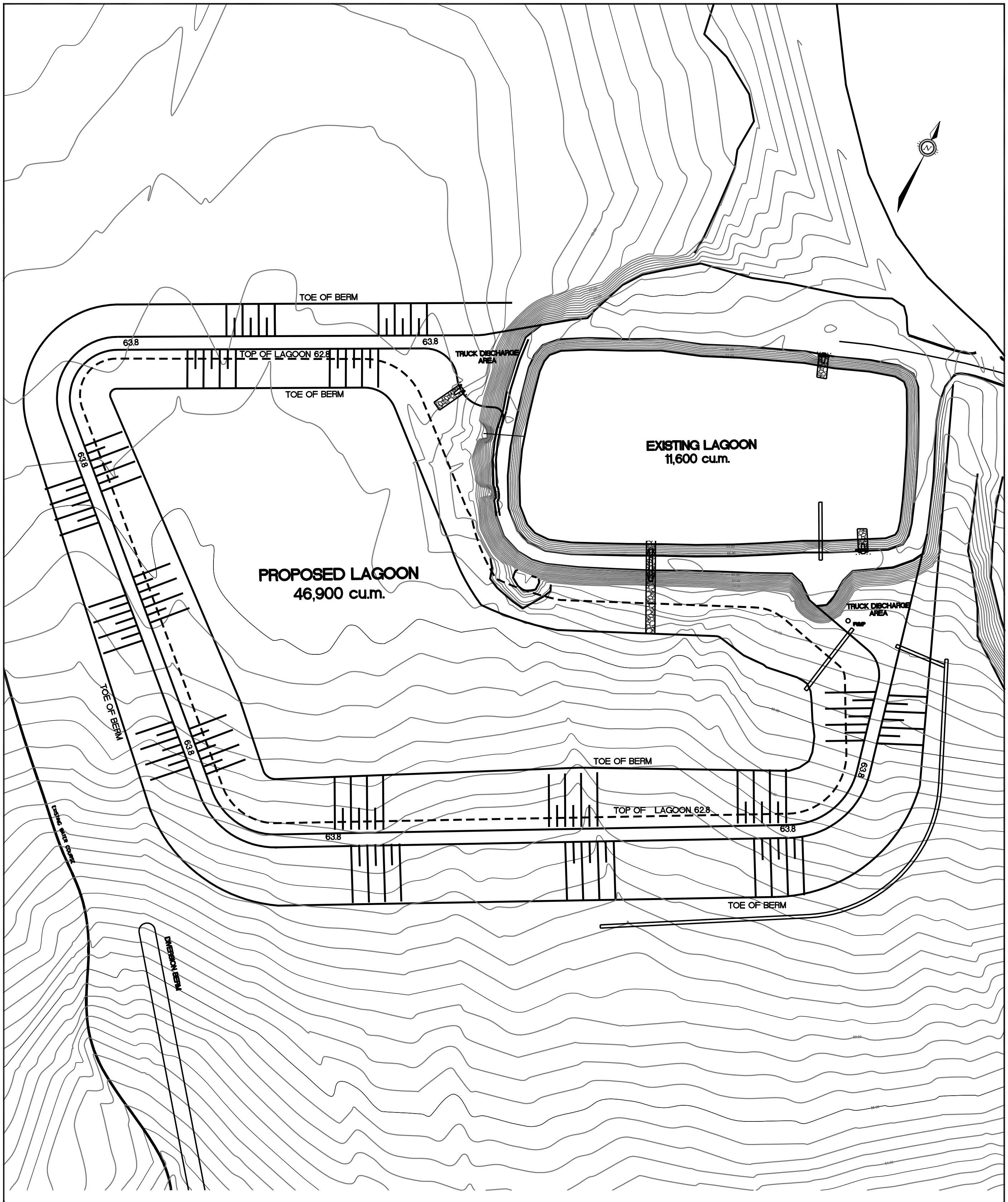
SCALE 1:1500	CLIENT: GOVERNMENT OF NUNAVUT		JOB NO. OTCD19055A
DATE: 17/01/08	TITLE: CLYDE RIVER - ALTERNATIVE 3		FIG.7
DRAWN: MMR			



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SCALE: 1:1500	CLIENT: GOVERNMENT OF NUNAVUT	JOB NO. OTCD19055A
DATE: 17/01/08	TITLE: CLYDE RIVER - ALTERNATIVE 4	FIG.8
DRAWN: MMR		

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 Clyde River sewage lagoon system the "must" criteria are listed below:

1. Ability to meet the Hamlet requirements: the facility must be required to meet the long term storage requirements of the Hamlet as set forth in Section 4.1.
2. Regulatory requirements: 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 Clyde River sewage lagoon system is based on the following "want" criteria and weighting:

1. Capital Cost: an objective of the project is to minimize capital cost (criterion weight – 10)
2. 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)
3. 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)
4. Truck Discharge Operations: the system should incorporate an easy safe truck discharge location (criterion weight – 5)
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)
6. 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)

5.2. Evaluation of Alternatives

5.2.1. "Must" Criteria

The two criteria that the Clyde River 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 2028 and meet the regulatory requirements of the Hamlet's water licence as set out by the Nunavut Water Board.

The four alternatives can all be designed to meet the required storage for the projected population for the year 2028 and therefore meet the requirements of the Hamlet. In addition, all four alternatives presented would provide a storage lagoon system providing one-year storage, followed by treatment in the existing wetlands between the lagoon site and Patricia Bay. It is therefore anticipated that all four options shall be able to provide sufficient treatment to meet the requirements of the Hamlet's water licence.

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

5.2.2. Assessment of Alternatives

The four alternatives for the expansion of the Clyde River 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 four alternatives and are presented in detail in Appendix A. The capital cost, as well as score for each alternative and the weighted score are summarized in Table 5.1.

Table 5.1 – Capital Costs

Alternative	Capital Cost	Score
Alternative 1	$5,236,000	7
Alternative 2	$4,078,000	10
Alternative 3	$4,723,000	8
Alternative 4	$4,385,000	9

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 four alternatives is included in Appendix B. The life cycle costs and score for each alternative are summarized below in Table 5.2.

Table 5.2 – Life Cycle Costs

Alternative	Life Cycle Cost	Score
Alternative 1	$5,805,000	6
Alternative 2	$4,549,000	10
Alternative 3	$5,245,000	8
Alternative 4	$4,876,000	9

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 existing sewage lagoon cell as a primary lagoon with an overflow to a new storage lagoon cell. Only the storage 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 9 for Decanting Operations.

Alternative 2 incorporates the existing sewage lagoon cell as storage cell. This reduces the required size of the new lagoon, however, it requires that both the existing cell and the new cell be decanted in the fall. The truck discharge arrangement requires that decanting be either through two pumping locations or pumping of the existing cell into the new cell. Either arrangement is more complicated than a single pumping operation possible with a primary cell or common area for pumping as in alternative 4. This alternative scores 5 for Decanting Operations.

As with Alternative 1, Alternative 3 incorporates the existing sewage lagoon cell as a primary lagoon with an overflow to a new storage lagoon cell. Only the storage lagoon requires decanting in the fall and therefore the decanting process, will include a one-time set up, monitoring and disassembly of the pumping system. This alternative is easiest to operate and therefore scores 9 for Decanting Operations.

Alternative 4 incorporates the existing sewage lagoon cell as storage cell. This reduces the required size of the new lagoon, however, it requires that both the existing cell and the new cell be decanted in the fall. In this alternative it is possible to locate both pumping setups in a common area which will allow for some of the infrastructure to be common to both systems and an easier operation of the two systems. This alternative scores 7 for Decanting Operations.

5.2.2.4. Truck Discharge (Weight 5)

Alternative 1 and 2 utilizes the existing truck discharge location for the existing cell, and a new truck discharge located in the northeast corner of the new lagoon. Access to the new truck discharge will be achieved along the existing berm. The new discharge location will be used during the winter months and will be more difficult to use and maintain than the existing site which is located off an existing road. As there is a requirement to maintain 2 truck discharge points, and one is difficult to maintain, these alternatives will score 6 for Truck Discharge Operations.

Alternative 3 and 4 utilizes the existing truck discharge location for the existing cell, and a new truck discharge located on the north side of the new lagoon. Access to the new truck discharge will be by extending the existing road. Both truck discharges will be accessible from the road and therefore will be easy to operate and maintain. As both truck discharge points are easily accessible and maintained, these alternatives will score 8 for Truck Discharge Operations.

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 four alternatives, as well as their score are presented in Table 5.3.

Table 5.3 – Granular Requirements

Alternative	Granular Requirements	Rating
Alternative 1	71,500 m^3	5
Alternative 2	50,100 m^3	10
Alternative 3	60,400 m^3	7
Alternative 4	54,100 m^3	9

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.

Alternatives 1 and 3 utilize the existing sewage lagoon as a primary cell for the summer months. Sewage lagoon systems in the south, which include primary cells generally provide improved levels of treatment over those that do not incorporate a primary cell into the system. Therefore, it can be expected that alternatives 1 and 3 will provide improved sewage treatment over alternatives 2 and 4 which provide only storage. However, as the primary cell can only be used during summer months, when continuous discharge from the primary cell to the storage cell is feasible, the improved level of treatment will only occur for approximately one quarter or one third of the sewage generated. As all alternatives incorporate a long term storage call and wetlands, it is anticipated that the final quality of the effluent will exceed the requirements of the water licence and the relative improvements by the primary cell will be minor.

Alternative 1 and 3 are expected to provide marginally better treatment and therefore will score 10 and Alternatives 2 and 4 will score 8 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 5.4. Table 5.4 also summarizes the weighting of the criteria and generates a weighted score for each alternative.

Table 5.4 – Evaluation of Alternatives

Criteria	Weight	Alternative 1		Alternative 2		Alternative 3		Alternative 4	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Capital Cost	10	7	70	10	100	8	80	9	90
Life cycle cost	9	6	54	10	90	8	72	9	81
Decanting Operations	7	9	63	5	35	9	63	7	49
Truck Discharge	5	6	30	6	30	8	40	8	40
Granular Material	3	5	15	10	30	7	21	9	27
Treatment	3	10	30	8	24	10	30	8	24
Total Score			262		309		306		311
Ranking			**4**		**2**		**3**		**1**

5.3. Analysis Summary

As shown on Table 5.4, Alternative 4 was rated #1 and therefore is the recommended alternative for the expansion of the Clyde River sewage lagoon. This alternative provides the second lowest capital cost, life cycle costing and demand on aggregate material, while being an easier system to operate than Alternative 2. It is recommended that the preliminary design be based on Alternative 4 as the preferred alternative.

6.0 Sewage Treatment

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

6.1. Influent Characteristics

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

Table 6.1 – Characteristics of Waste Water

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

6.2. Sewage Lagoon

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

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

Where:

C_e = Effluent concentration (mg/L)

C_1 =Influent concentration (mg/L)

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

t = Residence time in lagoon (days)

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

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

Where:

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

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

Θ = Temperature activity coefficient

T = Temperature (˚C)

The temperature activity coefficient (Θ) for various sewage treatment processes falls in the range of 1.00 to 1.10, with higher values indicating greater sensitivity to changing 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 results in the removal of a portion of the BOD_5. The remaining contaminants are in soluble and colloidal forms. The colloidal materials represent the remaining suspended solids. Subsequent to initial sedimentation, removal is achieved by bio-chemical oxidation. The colloidal fraction is converted into various 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 quality of the effluent released from the sewage lagoon is summarized in Table 6.3.

Table 6.3 – Effluent Quality from the Lagoon

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

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

6.3. Wetlands Treatment

Treatment of raw sewage in new sewage lagoon in Clyde River will be combined with the utilization of a vegetated filterstrip wetland as a final polishing step. The filterstrip wetland area is 23.5 hectare in size (approximately 720 m long and 325 m wide) with a slope of 6 to 7%.

The geotechnical investigations carried out in August 2007 found that the soil in the filterstrip wetland area is comprised of silty sand with permafrost at 1 m in the summer months. This type of soil is suitable for infiltration processes and will facilitate the two main processes of contaminant removal from pre-treated sewage: uptake of contaminants and nutrients by plant roots and degradation by microorganisms in the rhizosphere.

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

The microorganisms found in extreme cold environments such as the arctic are extremophiles, such as obligate cryophilic/psychrophilic bacteria and archaea which grow and reproduce in temperatures between -20^{o}C and 20^{o}C. These bacteria and archaea are known to grow and reproduce in arctic ice and permafrost. The microbial processes that are involved in the degradation of organic materials are generally carried out by heterotrophic bacteria which use organic compounds as 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 a microbial biomass which in turn increases the degradation of organic material.

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

Table 6.4: Estimated Reduction in BOD and TSS

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

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

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

6.4. Sewage System Treatment Summary

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

Table 6.5 – Summary of Treatment Levels

Parameter	Units	Criteria	Influent	Effluent from Lagoon	Effluent from Wetland†
BOD_5	mg/L	120	460	97	18
TSS	mg/L	180	490	172* 116**	33* 22**
FC	#/100ml	1×10^6	1×10^7	1×10^6	<100,000

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

7.0 Monitoring and Compliance Points

7.1. Effluent Monitoring and Compliance

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

Table 7.1 – Sampling Point Coordinates

STP#	Description	Northing	Easting	Comment
1	Existing Truck Discharge	70° 28’ 12.01”	68° 37’ 51.19”	
2	Proposed Truck Discharge	70° 28’ 10.63”	68° 38’ 01.16”	
3	Lagoon Decanting Point	70° 28’ 07.98”	68° 37’ 41.85”	
4	End of Wetlands	70° 27’ 46.66”	68° 37’ 23.82”	Compliance Point

Table 7.2 – Sampling Frequency

STP#	Description	Frequency
1	Existing Truck Discharge	Yearly
2	Proposed Truck Discharge	Yearly
3	Lagoon Decanting Point	Twice Yearly – start and end decanting
4	End of Wetlands	Twice Yearly – start and end decanting

7.2. Ground Temperature and Seepage Monitoring

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

It is recommended that the ground temperatures be monitored every three months for the first two years after construction, and twice yearly, early spring and mid to late fall, after the second year. The standpipes should be monitored yearly, early to mid fall, for the presence of seepage.

8.0 Granular Supply

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

These included:

- a granular source located just north of the community behind the arena which is currently an active gravel deposit,
- a granular source on the road to the water lake, which is an active granular deposit,
- a granular source located near the airport, and
- a quarry where a recent drill and blast operation had occurred.

The existing granular sources, although able to meet the annual granular needs of the Hamlet, were not felt to be sufficient to meet the requirements of this project.

Subsequently, Trow reviewed two reports regarding the granular material, including "Evaluation of Granular Material Deposits near Clyde River, N.W.T." prepared by Terrain Analysis and Mapping Services Limited in the early 1980's as well as the "*Granular Resource Management – 12 Communities, Baffin Region, Nunavut*" prepared by Trow Associates in 2004.

The "Evaluation of Granular Deposits near Clyde River, N.W.T." report identified a total of twenty potential deposits. Of these, four deposits were deemed to be unsatisfactory, eight deposits were very limited quantities of material – 10,000 m^3 or less, five deposits had between 25 – 65,000 m^3 and three deposits had over 70,000 m^3. It is estimated that 40,000 m^3 of material will be required to complete the proposed works. Of these three deposits, Deposit 4 is behind the existing arena and believed to be part of the deposit currently being used by the Hamlet, therefore, it has been depleted from its original capacity and would no longer be able to provide the required material. In addition, it is felt that the deposit should be left to meet the Hamlet's annual granular needs. Deposit 15 is reported to have between 75 and 150,000 m^3 of material. It is located to the north of the road to the airport and may be a potential source of aggregate supply for this project. Deposit 10 is the most promising deposit from this report as it has a reported 300,000 m^3 of available material. Deposit 10 is located to the east of the runway but the exact boundaries of the deposit were not identified in the report therefore it is not known if it lies within the existing airport boundary or if the material would be available.

The Granular Resource Management Report prepared by Trow was a desktop study. The information in the report is limited to the examination of geological maps and aerial photography. The report identified three areas of till located close to the Hamlet which corresponds to the deposits behind the arena and six alluvium areas. Four of the alluvium areas were located along the existing river to the east of the airport, while the other two are located on the south bank of Clyde River, close to the discharge into Patricia Bay. None of the alluvium deposits appear to be current areas of extraction or are easily accessible.

The construction of a new sewage lagoon and rehabilitation of the existing sewage for the Hamlet will require substantial granular material. It is estimated that in excess of 70,000 m^3 of material will be required. From the site visit and review of available reports it does not appear that the Hamlet currently has an aggregate support supply that can meet this demand. Potential sources were identified in the existing reports which will require further investigation to determine their suitability and accessibility for this project.

9.0 Cost Estimate

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

1. Construction of a new storage lagoon;
2. Rehabilitation of the existing sewage lagoon to be utilized as a primary cell during the summer months;
3. Construction of a diversionary berm adjacent to the existing drainage course on the west side of the wetlands area;
4. Upgrades to the existing truck discharge locations

A detailed breakdown of the cost estimate is included in Appendix A and includes a 10% contingency allowance. The estimated capital cost for the rehabilitation and expansion of the Clyde River Sewage Treatment Facility is $4,385,000.00.

9.1. 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 $50,000 as detailed in Appendix B.

9.2. Life Cycle Costing

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

Table 9.1 – Life Cycle Cost Summary

Capital Cost	$4,385,000
Present Value of O&M Costs over 20 Years	$491,000
Life Cycle Costs	$4,876,000

10.0 Conclusions and Recommendations

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

1. The existing sewage lagoon in Clyde River does not meet the long term needs of the Hamlet, nor does it meet the treatment requirements as per the Hamlet's water licence.
2. The 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 truck discharge points.
3. The project population for the year 2028 for the Hamlet is 1456 persons.
4. Based on the projected population, the project sewage generation rate is 120 lpcd.
5. The line between the existing sewage lagoon and Patricia Bay is undisturbed tundra and has potential to be utilized as a wetlands treatment to provide additional or polishing to the effluent from the sewage lagoon prior to discharge to the environment.
6. Soils beneath the existing sewage lagoon, and lands adjacent to the lagoon are ice rich, therefore it is not recommended that either seepage cells or fully lined lagoons be utilized as part of the expanded sewage lagoon system.
7. Based on the geothermal analysis, it is recommended that a lined berm keyed into the permafrost utilizing an ice core dam within the berm as secondary containment be used for the design of the berms for the creation of the sewage lagoon.
8. It is recommended that the berms 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.
9. Of the four alternatives analyzed for the expansion of the Clyde River sewage lagoon system, it is recommended Alternative 4, which incorporates a new lagoon to the south and west of the existing lagoon and the use of the existing lagoon as a storage cell be adopted for the design of the proposed expansion.
10. It is recommended that the new sewage treatment facility utilize the wetlands between the proposed facility and Patricia Bay to provide additional treatment of the effluent before it is released into the environment.
11. The environmental assessment undertaken concluded that although there are potentially negative impacts to the projects, 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.
12. It is recommended that effluent monitoring be undertaken at both the sewage lagoon and the end of the wetlands which shall be the compliance point for the new sewage treatment facility.

13. As the earth berms are water retaining structures, they fall within the dam safety guidelines and therefore should incorporate a monitoring program.
14. It is recommended thermistors and standpipes be installed within the berm to monitor ground temperatures and seepage to the cell through the berm.
15. As the Hamlet's current granular supplies are limited and are being utilized for ongoing maintenance of infrastructure, it is recommended that a new gravel supply be developed for this project.
16. It is estimated that the capital cost for the construction of a new sewage lagoon and rehabilitation of the existing lagoon will be $4,349,000.00.
17. The estimated annual operating and maintenance costs for the new facility, including the cost of monitoring and sampling, testing and decanting will be $49,000.00 per annum.
18. The overall lifecycle cost over the 20 year design horizon of the facility is $4,830,000.00.
19. The estimated final quality of the effluent at the compliance point, i.e. the end of the wetlands is BOD 18 mg/L and TSS of 22 mg/L and faecal coliforms of less than 100,000 which meets or exceeds the requirements of the Hamlet's water licence.

Trow Associates Inc.

REGISTERED PROFESSIONAL ENGINEER
S. L. BURDEN
22/02/08
LICENSEE
N.W.T.

Steven Burden, P.Eng.
Senior Project Manager
Infrastructure Division

Stephen Douglas
Senior Designer
Infrastructure Division

PERMIT TO PRACTICE
TROW ASSOCIATES INC.
Signature [signature]
Date Feb 22, 2008
PERMIT NUMBER: P 184
The Association of Professional Engineers, Geologists and Geophysicists of the NWT / NU

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Appendix A:
Capital Cost Estimates

ALTERNATIVE 1

Item	Description	Unit	Quantity	Unit Price	Amount
1	Mobilization & Demobilization	L.S.	1	$ 400,000.00	$ 400,000.00
	Existing Lagoon				
2	Supply , deliver and place granular material to stabilize the existing berm	m^3	2400	$ 45.00	$ 108,000.00
3	Supply deliver and install Truck Discharge Structures, including erosion protection	L.S.	1	$ 30,000.00	$ 30,000.00
4	Supply deliver and install liner in exist. Lagoon	m2	2800	$ 55.00	$ 154,000.00
5	Supply Deliver and Install a spillway structure	Ea.	1	$ 25,000.00	$ 25,000.00
	Proposed Lagoon				
6	Supply Deliver and Install Truck Discharge Structures, including erosion protection	Ea.	2	$ 30,000.00	$ 60,000.00
7	Supply deliver and install liner in proposed lagoon	m2	12800	$ 55.00	$ 704,000.00
8	Construct access road and turn around for truck discharge point.	m^3	300	$ 40.00	$ 12,000.00
9	Supply , deliver and place granular material to construct new berm	m^3	69100	$ 45.00	$ 3,109,500.00
10	Supply Deliver and Install silt fence	m	1250	$ 20.00	$ 25,000.00
11	Supply Deliver and Install piping for Outlet Structure	Ea.	1	$ 60,000.00	$ 60,000.00
12	Supply Deliver and Install boulder barriers	Ea.	68	$ 250.00	$ 17,000.00
13	Supply Deliver and Install thermistor casing	Ea.	20	$ 500.00	$ 10,000.00
14	Supply Deliver monitoring thermistors	Ea.	2	$ 1,500.00	$ 3,000.00
15	Supply Deliver and Install seepage monitoring tubes	Ea.	20	$ 500.00	$ 10,000.00
16	Construct diversionary berm	m	700	$ 45.00	$ 31,500.00
17	Install Signage	LS	1	$ 1,000.00	$ 1,000.00
				Subtotal	**$ 4,760,000.00**
				10% Contingency	**$ 476,000.00**
				Total	**$ 5,236,000.00**

ALTERNATIVE 2

Item	Description	Unit	Quantity	Unit Price	Amount
1	Mobilization & Demobilization	L.S.	1	$ 400,000.00	$ 400,000.00
	Existing Lagoon				
2	Supply , deliver and place granular material to stabilize the existing berm	m^3	2400	$ 45.00	$ 108,000.00
3	Supply deliver and install Truck Discharge Structures, including erosion protection	L.S.	1	$ 30,000.00	$ 30,000.00
4	Supply deliver and install liner in exist. Lagoon	m2	2800	$ 55.00	$ 154,000.00
5	Supply Deliver and Install a spillway structure	Ea.	1	$ 25,000.00	$ 25,000.00
6	Supply Deliver and Install piping for Outlet Structure	Ea	1	$ 20,000.00	$ 20,000.00
	Proposed Lagoon				
7	Supply Deliver and Install Truck Discharge Structures, including erosion protection	Ea.	2	$ 30,000.00	$ 60,000.00
8	Supply deliver and install liner in proposed lagoon	m2	10800	$ 55.00	$ 594,000.00
9	Construct access road and turn around for truck discharge point.	m^3	300	$ 40.00	$ 12,000.00
10	Supply , deliver and place granular material to construct new berm	m^3	47700	$ 45.00	$ 2,146,500.00
11	Supply Deliver and Install silt fence	m	1250	$ 20.00	$ 25,000.00
12	Supply Deliver and Install piping for Outlet Structure	Ea.	1	$ 60,000.00	$ 60,000.00
13	Supply Deliver and Install boulder barriers	Ea.	68	$ 250.00	$ 17,000.00
14	Supply Deliver and Install thermistor casing	Ea.	20	$ 500.00	$ 10,000.00
15	Supply Deliver monitoring thermistors	Ea.	2	$ 1,500.00	$ 3,000.00
16	Supply Deliver and Install seepage monitoring tubes	Ea.	20	$ 500.00	$ 10,000.00
17	Construct diversionary berm	m	700	$ 45.00	$ 31,500.00
18	Install Signage	LS	1	$ 1,000.00	$ 1,000.00
				Subtotal	**$ 3,707,000.00**
				10% Contingency	**$ 370,700.00**
				Total	**$ 4,077,700.00**

Trow Associates Inc.
Clyde River Sewage Treatment Facility
OTCD00019055A

ALTERNATIVE 3

Class 'C' Cost Estimate

Item	Description	Unit	Quantity	Unit Price	Amount
1	Mobilization & Demobilization	L.S.	1	$ 400,000.00	$ 400,000.00
	Existing Lagoon				
2	Supply , deliver and place granular material to stabilize the existing berm	m^3	2400	$ 45.00	$ 108,000.00
3	Supply deliver and install Truck Discharge Structures, including erosion protection	L.S.	1	$ 30,000.00	$ 30,000.00
4	Supply deliver and install liner in exist. Lagoon	m^2	2800	$ 55.00	$ 154,000.00
5	Supply Deliver and Install a spillway structure	Ea.	1	$ 25,000.00	$ 25,000.00
	Proposed Lagoon				
6	Supply Deliver and Install Truck Discharge Structures, including erosion protection	Ea.	2	$ 30,000.00	$ 60,000.00
7	Supply deliver and install liner in proposed lagoon	m2	13400	$ 55.00	$ 737,000.00
8	Construct access road and turn around for truck discharge point.	m^3	300	$ 40.00	$ 12,000.00
9	Supply , deliver and place granular material to construct new berm	m^3	58000	$ 45.00	$ 2,610,000.00
10	Supply Deliver and Install silt fence	m	1250	$ 20.00	$ 25,000.00
11	Supply Deliver and Install pump ,inlet and outlet piping for Outlet Structure	Ea.	1	$ 60,000.00	$ 60,000.00
12	Supply Deliver and Install boulder barriers	Ea.	68	$ 250.00	$ 17,000.00
13	Supply Deliver and Install thermistor casing	Ea.	20	$ 500.00	$ 10,000.00
14	Supply Deliver monitoring thermistors	Ea.	2	$ 1,500.00	$ 3,000.00
15	Supply Deliver and Install seepage monitoring tubes	Ea.	20	$ 500.00	$ 10,000.00
16	Construct diversionary berm	m	700	$ 45.00	$ 31,500.00
17	Install Signage	LS	1	$ 1,000.00	$ 1,000.00
				Subtotal	**$ 4,293,500.00**
				10% Contingency	**$ 429,350.00**
				Total	**$ 4,722,850.00**

ALTERNATIVE 4

Class 'C' Cost Estimate

Item	Description	Unit	Quantity	Unit Price	Amount
1	Mobilization & Demobilization	L.S.	1	$ 400,000.00	$ 400,000.00
	Existing Lagoon				
2	Supply , deliver and place granular material to stabilize the existing berm	m^3	2400	$ 45.00	$ 108,000.00
3	Supply deliver and install Truck Discharge Structures, including erosion protection	L.S.	1	$ 30,000.00	$ 30,000.00
4	Supply deliver and install liner in exist. Lagoon	m2	2800	$ 55.00	$ 154,000.00
5	Supply Deliver and Install a spillway structure	Ea.	1	$ 25,000.00	$ 25,000.00
6	Supply Deliver and Install piping for Outlet Structure	Ea	1	$ 20,000.00	$ 20,000.00
	Proposed Lagoon				
7	Supply Deliver and Install Truck Discharge Structures, including erosion protection	Ea.	2	$ 30,000.00	$ 60,000.00
8	Supply deliver and install liner in proposed lagoon	m2	12600	$ 55.00	$ 693,000.00
9	Construct access road and turn around for truck discharge point.	m^3	300	$ 40.00	$ 12,000.00
10	Supply , deliver and place granular material to construct new berm	m^3	51700	$ 45.00	$ 2,326,500.00
11	Supply Deliver and Install silt fence	m	1250	$ 20.00	$ 25,000.00
12	Supply Deliver and Install piping for Outlet Structure	Ea.	1	$ 60,000.00	$ 60,000.00
13	Supply Deliver and Install boulder barriers	Ea.	68	$ 250.00	$ 17,000.00
14	Supply Deliver and Install thermistor casing	Ea.	20	$ 500.00	$ 10,000.00
15	Supply Deliver monitoring thermistors	Ea.	2	$ 1,500.00	$ 3,000.00
15	Supply Deliver and Install seepage monitoring tubes	Ea.	20	$ 500.00	$ 10,000.00
16	Construct diversionary berm	m	700	$ 45.00	$ 31,500.00
17	Install Signage	LS	1	$ 1,000.00	$ 1,000.00
				Subtotal	**$ 3,986,000.00**
				10% Contingency	**$ 398,600.00**
				Total	**$ 4,384,600.00**

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

Alternative 1

Yearly General O&M

1% of Capital Costs

$5,236,000 x 1% = $52,000

Decanting Costs

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

Annual O&M Costs

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

Life Cycle Cost of O&M Costs

@ 8% Discount Rate

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

Alternative 2

Yearly General O&M

1% of Capital Costs

$4,077,700 x 1% = $41,000

Decanting Costs

Existing Cell

Fuel	80 litres at $1.25	$100
Operator	1 hours per day @ $75/hr	$75
Miscellaneous		$25
Total		$200
Pumping 5 days	5 x $125	$1,000
New Cell		
Fuel	80 litres at $1.25	$100
Operator	2 hours per day @ 75	$150
Miscellaneous		$50
Total		$300
Pumping 20 days	20 x $300	$6,000
Total	$1,000 + $6,000	$7,000

Annual O&M Costs

General O&M Costs	$41,000
Decanting Cost	$7,000
Total O&M Costs	**$48,000**

Life Cycle Cost of O&M Costs

@ 8% Discount Rate

Year	Year Cost	Present Value
1	$48,000	$44,444
2	$48,000	$41,152
3	$48,000	$38,104
4	$48,000	$35,281
5	$48,000	$32,668
6	$48,000	$30,248
7	$48,000	$28,008
8	$47,000	$25,933
9	$48,000	$24,012
10	$48,000	$22,233
11	$48,000	$20,586
12	$48,000	$19,061
13	$48,000	$17,650
14	$48,000	$16,342
15	$48,000	$15,132
16	$48,000	$14,011
17	$48,000	$12,973
18	$48,000	$12,012
19	$48,000	$11,122
20	$48,000	$10,298
Total		**$471,270**

Alternative 3

Yearly General O&M

1% of Capital Costs

$4,722,850 x 1% = $47,000

Decanting Costs

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

Annual O&M Costs

General O&M Costs	$47,000
Decanting Cost	$6,000
Total O&M Costs	**$53,000**

Life Cycle Cost of O&M Costs

@ 8% Discount Rate

Year	Year Cost	Present Value
1	$53,000	$49,074
2	$53,000	$45,439
3	$53,000	$42,073
4	$53,000	$38,957
5	$53,000	$36,071
6	$53,000	$33,399
7	$53,000	$30,925
8	$53,000	$28,634
9	$53,000	$26,513
10	$53,000	$24,549
11	$53,000	$22,731
12	$53,000	$21,047
13	$53,000	$19,488
14	$53,000	$18,044
15	$53,000	$16,708
16	$53,000	$15,470
17	$53,000	$14,324
18	$53,000	$13,263
19	$53,000	$12,281
20	$53,000	$12,658
Total		**$521,648**

Alternative 4

Yearly General O&M

1% of Capital Costs

$4,384,600 x 1% = $44,000

Decanting Costs

Existing Cell

Fuel	80 litres at $1.25	$100
Operator	2 hours per day @ $75/hr	$150
Miscellaneous		$50
Total		$300
Pumping 5 days	5 x $300	$1,500

New Cell

Fuel	80 litres at $1.25	$100
Operator	2 hours per day @ 75	$150
Miscellaneous		$50
Total		$300
Pumping 20 days	15 x $300	$4,500
Total	$1,000 + $6,000	$6,000

Annual O&M Costs

General O&M Costs	$44,000
Decanting Cost	$6,000
Total O&M Costs	**$50,000**

Life Cycle Cost of O&M Costs

@ 8% Discount Rate

Year	Year Cost	Present Value
1	$50,000	$46,296
2	$50,000	$42,867
3	$50,000	$39,692
4	$50,000	$36,751
5	$50,000	$34,029
6	$50,000	$31,508
7	$50,000	$29,175
8	$50,000	$27,013
9	$50,000	$25,012
10	$50,000	$23,160
11	$50,000	$21,444
12	$50,000	$19,856
13	$50,000	$18,385
14	$50,000	$17,023
15	$50,000	$15,762
16	$50,000	$14,595
17	$50,000	$13,513
18	$50,000	$12,512
19	$50,000	$11,586
20	$50,000	$10,727
Total		**$490,906**

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

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

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

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

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

TABLE 6.1

SEWAGE TREATMENT PROCESSES AND TYPICAL EFFLUENT QUALITY

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

NOTE :

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