• **Government of Nunavut**

Design Brief
Sewage Lagoon Upgrade
Repulse Bay, Nunavut

Type of Document
First Submission

Project Name
Repulse Bay Sewage Lagoon Upgrade

Project Number
OTT-00207086-A0

Prepared By:
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Date Submitted
October, 2013

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Date Submitted:
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1 Introduction

Exp Services Inc. (**exp**) was retained by the Department of Community and Government Services (CGS), Government of Nunavut (GN), to review the existing sewage disposal facility and complete the detail planning and design for the Sewage Lagoon Upgrade, for the Hamlet of Repulse Bay (Hamlet), Nunavut.

As per the Terms of Reference (TOR) of this project, to keep pace with the growth of the community, there is a need to provide proper disposal of sewage to wetland with a proper retention cell complete with liner. Nunavut Water Board has identified conditions to be addressed in Hamlet of Repulse Bay licence number NWB3REP0409.

1.1 Background

The Hamlet utilizes a sewage disposal facility located approximately 400 metres from the northeast edge of the community as shown on Figure 1.1 - Location Plan. The sewage disposal facility, which is located at the old solid waste disposal site, consists of a simple truck offload discharge area. Wastewater is directed to a natural wetland area. The wastewater proceeds downstream through the wetland along a 1,400m flow path, passing through a series of wetlands and surface water bodies, prior to entering Hudson Bay. This facility was referenced as the licenced sewage discharge location in NWB Water Licence No. NWB3REP0409, dated June 11, 2004. The licence has since expired. This licence stipulated maximum effluent parameters, which included BOD_5 of 80 mg/L and suspended solids of 100 mg/L.

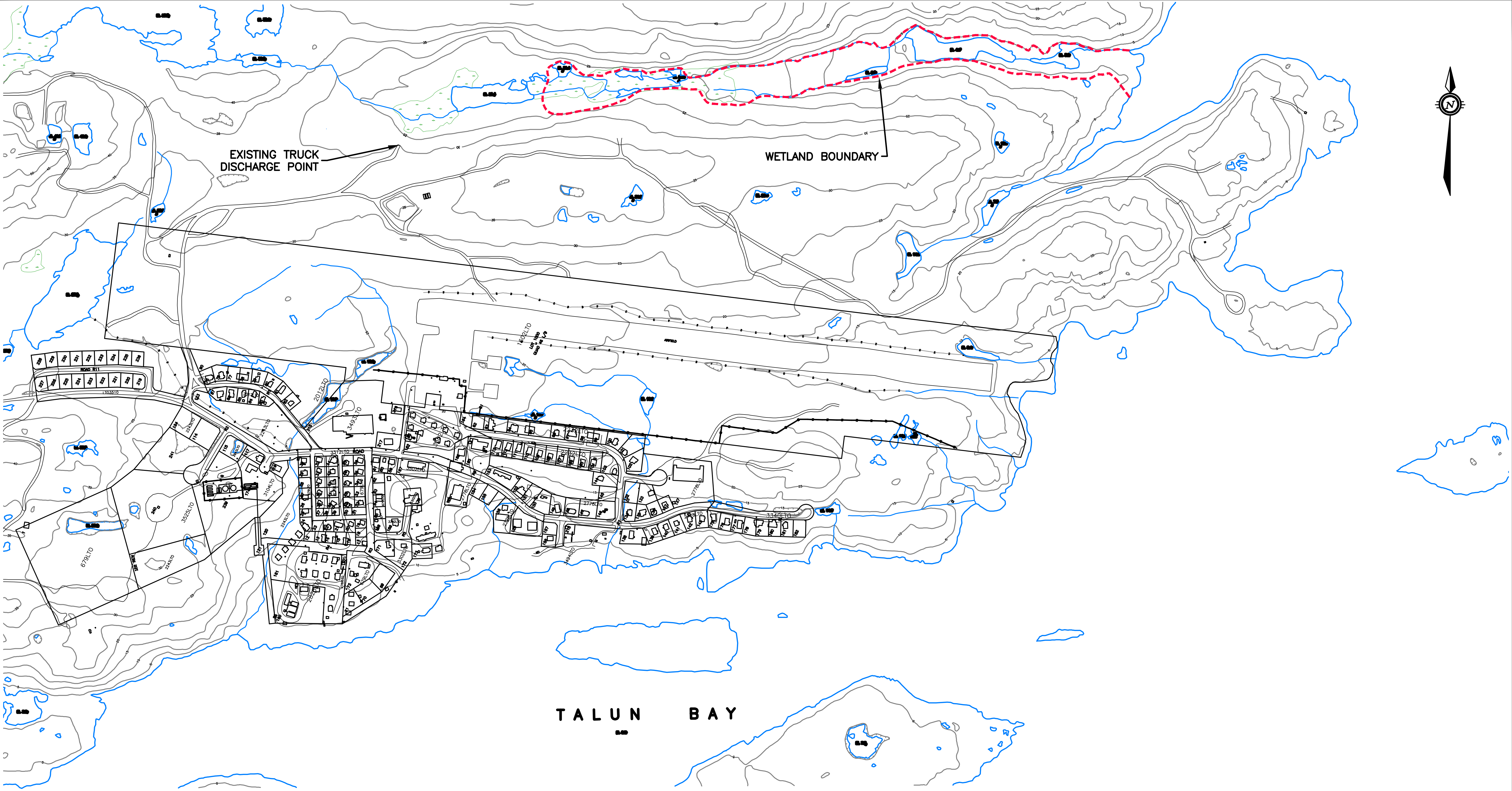
The Repulse Bay sewage management system was the subject of a report prepared by Ferguson, Simek and Clark (FSC) in March 2002. This study reports that references are made to this sewage discharge point in various reports prepared by Dillon, DPW (GNWT) and UMA over the period 1984 to 1994. The study examined the treatment performance of this system and, based upon sampling by Dillon in 1998, reported the following performance.

Parameter	Removal
BOD_5	88%
Suspended Solids	87%
Ammonia	95%
Total Phosphorus	94%
Faecal Coliform	100%

FSC conducted a review of wetland performance based upon hydraulic and organic loadings and concluded that the hydraulic loading fell within the recommended range. It was noted that organic load may exceed recommended values during the spring, but that NWB effluent requirements should be met for a further 20 years. It was recommended that the wetland be monitored for indications of erosion, channeling or anaerobic conditions.

1.2 Regulatory Issues

The sewage treatment facility is subject to existing Water Licence Number NWB3REP04093 dated June 11, 2005. Under this licence, the NWB has identified conditions to be addressed in the Hamlet of Repulse Bay include:



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scale: 1:7,500	PROJECT:	REPULSE BAY	project no.: OTT-00207086A
date: 04/10/13	TITLE:	LOCATION PLAN	FIGURE 1.1
drawn by: S.BUTLER			

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References: REPULSE-2-3-4-TOPO.dwg

- Part D 2 stipulates effluent performance parameters for the facility.
- The effluent parameters are to be measured at monitoring site REP-4, which is defined as the final discharge point of the sewage system. A precise location for this station is not provided.
- A freeboard of at least 1.0 metre, or as recommended by a qualified geotechnical engineer and as approved by the Board in writing, for all dams, dykes or other structures intended to contain, withhold, divert or retain water or wastes.
- The Sewage Disposal Facility is to be maintained and operated, to the satisfaction of an Inspector in such a manner as to prevent structural failure.

The INAC Water Use Inspection Report for 2010 provides specific comments regarding the sewage treatment system in Repulse Bay. It is noted that discharge quality and seepages are considered to be unacceptable. In terms of non-compliance the comment, “Sewage is released directly into the environment and runs to the ocean through a valley in a melt water flow channel.” It is also noted that there is no lagoon in the community.

1.3 Scope of Services

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

1. Travel to Repulse Bay to gather information on the existing site known from the conditions imposed by Nunavut Water Board Water Licence, INAC and DFO Inspection Reports.
2. Design a Sewage Holding Cell and indicate the source of material.
3. The existing Wetland Sewage treatment area shall also be assessed to insure compliance.
4. The report/design shall be prepared to meet the requirements of NWB, INAC, DE (NU) & DFO.
5. Assessment Study should be conducted with any alternate to produce the gravel by crushing and mixing to produce proper gravel for different applications.
6. The design shall address any environmental and wild life impacts.
7. The design shall indicate the quantity based on the specifications for different applications (embankment, Sub-base, Base, Surface and Concrete Aggregate).
8. The Study shall also indicate the materials available in existing pits and other potential sources.
9. The design shall address concerns of NWB Licence.
10. Any other issues indicated in Water Licence.
11. Drawings & O&M manuals to meet NWB requirements.

2 System Requirements

2.1 General

The proposed sewage treatment facility must meet the long term needs of the Hamlet, as well as the regulatory requirements of the Hamlet's water licence. The 'Water and Sewage's Facility Capital Program Standards and Criteria" as provided by the CGS, indicates the design horizon for sewage lagoons is to be between 15 - 20 years. As per the direction of the CGS, the design horizon for the Sewage Lagoon shall be 20 years, ending in 2033.

2.2 Population

The population projections for this project was taken from the "Nunavut: Community Population Projections" as published by the Nunavut Bureau of Statistics, June 24, 2010. The Nunavut Bureau of Statistics provides projected populations of the Nunavut communities to the year 2036. Table 2.1, below, summarizes the population projections to the year 2033.

2.3 Sewage Generation

The sewage generation rate for the community must be determined. Sewage generation rates are generally assumed to be equal to the water consumption rates for a community. For communities that make use of trucked water and sewage services, the base water consumption rate is assumed to be 90 litres per capita day (l/c/d). In addition an allowance must be made for non-residential water uses such as commercial, institutional and industrial demands. The total community water use per capital is estimated using the following formula.

PCC = RWU (1.0+0.00023 x Population)

Where:

PCC is per capita consumption, and

RWU is the residential water consumption (90 l/c/d)

Table 2.1 - Anticipated Sewage Generation over the Project Planning Horizon

Year	Population	PCC (L/cap/day)	Daily Generation (L/day)	Annual Generation (m^3)
2013	907	108.8	98,682	36,020
2018	993	110.6	109,826	40,090
2023	1079	112.3	121,172	44,230
2028	1168	114.2	133,386	48,690
2033	1270	116.3	147,817	53,950

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 water licence # NWB3REP0409 Issued June 11, 2004 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 2.2.

Table 2.2 - Effluent Quality Standards

Parameters	Maximum Average Concentration
BOD5	80 mg/L
Total suspended solids (TSS)	100 mg/L
Faecal coliforms	1 x 104 CFU/100 mL
Oil and grease	No visible sheen
pH	Between 6 and 9

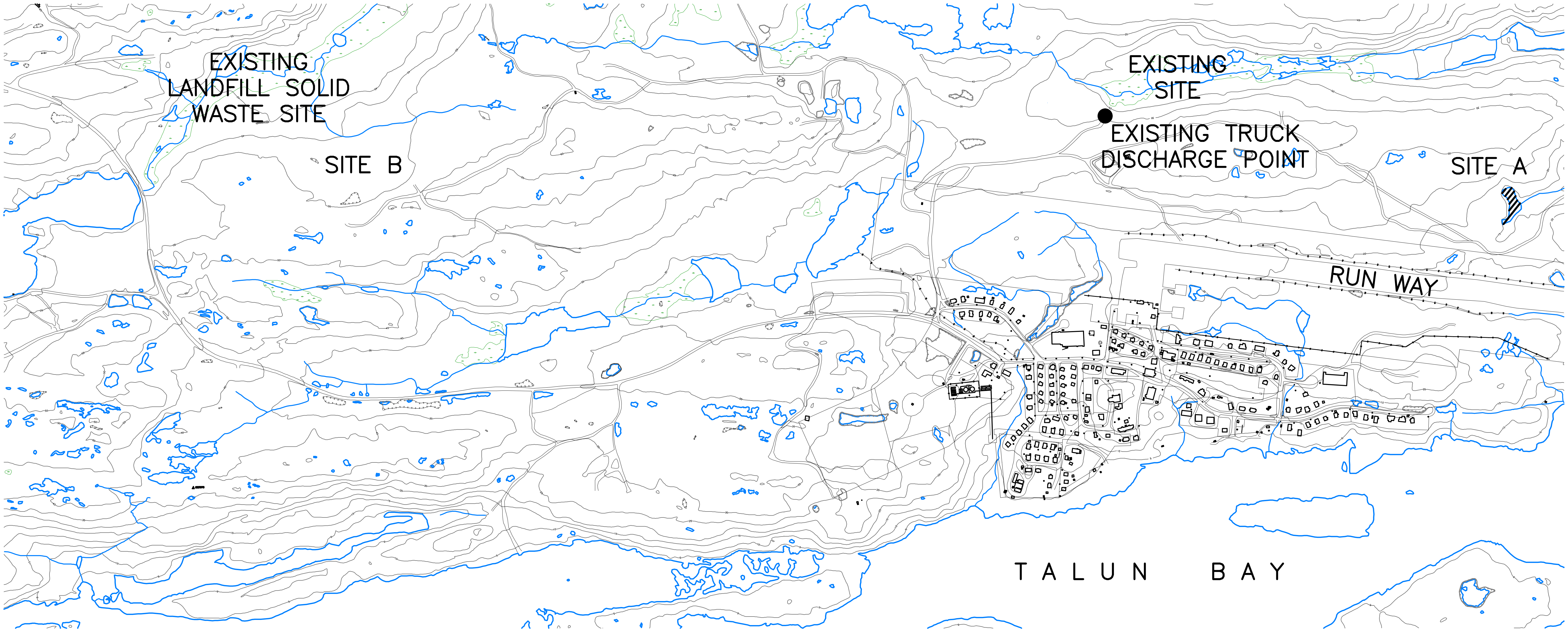
3 Alternative Sites

3.1 Alternative Sites

As part of the overall site visit during October 2012, a meeting was held with the SAO. Comments were sought regarding any alternative sites for the location of a sewage treatment facility. Two sites, referred to as Sites A and B were identified. These sites are depicted on Figure 3.1. Site A, which is located on the north side of the existing runway close to the ocean was visited and it was determined that it was too close to the runway and not large enough area to construct a new lagoon. Site B was visited. This site, which is near the new solid waste disposal site, was chosen based upon a review of topographical maps. This site had potential but it was ruled out because at the bottom of a wetland where the Hamlet is building a facility for the elders.

3.2 Site Evaluation

Based on the meeting with Council and the Town Foreman, as well as the review of the local area for alternate sites, it is recommended that an emphasis be placed on the potential for rehabilitation and remediation of the existing facility to meet the concerns and conditions of the Water Board and provide the long term sewage disposal requirements of the Hamlet.



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scale 1:10,000	PROJECT: REPULSE BAY	project no. OTT–00207086A
date 04/10/13		
drawn by S.BUTLER	TITLE: ALTERNATE SITE	FIGURE 3.1

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References:

4 Site Investigation

The following investigations were conducted to gather information necessary for the development of a design. Detailed site investigation(s) was undertaken, including the following:

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

4.1 Site Inspection

This inspection noted the following:

- The existing sewage disposal facility consists of a simple truck offload discharge area, which is directed to a natural wetland area.
- There is no lagoon present at the truck discharge point.
- The truck discharge area is intended to drain through the natural wetlands, which is approximately 1,400 m long.
- The wetlands is very lush and it appears to be very successful at treating the sewage released to it.
- Sampling program was undertaken. Samples were sent to the Laboratory for anaylsis.
- Alternative sites for the location of the sewage treatment facility were examined Site A was too close to the runway and Site B east of the Hamlet,
- Gravel is a scarce commodity within the Hamlet and any major construction will require a quarrying and crushing program.

4.2 Topographic Survey

A topographic survey of the existing facility and wetlands area was undertaken. This survey confirmed that the information provided in the background report with regards to the location and size of the various components of the facility. The existing facility is shown on Figure 4-1. The survey crew, in conjunction with the wetlands specialist, mapped out the limits of the existing wetlands treatment.

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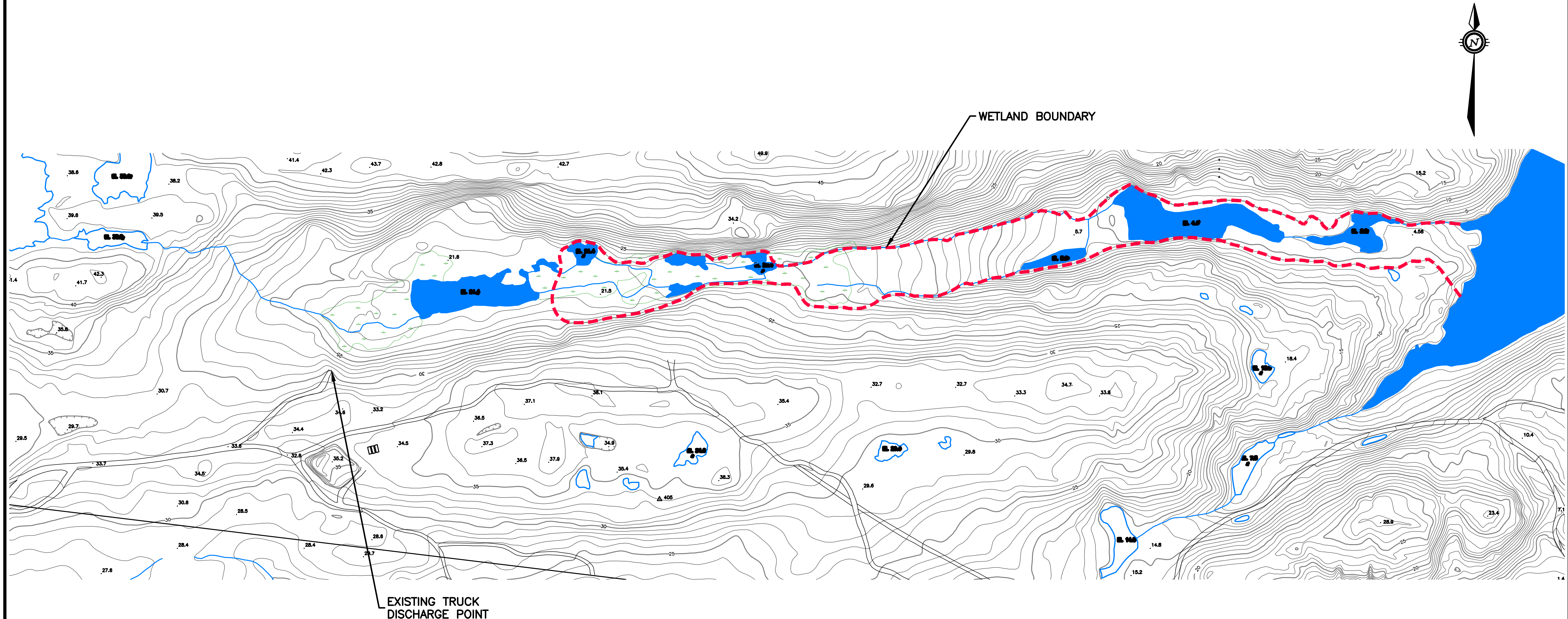

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date 04/10/13		
drawn by S.BUTLER	TITLE: EXISTING FACILITY	FIGURE 4.1

4.3 Geotechnical Investigation

The field work for the geotechnical investigation was performed in early October, 2012. The scope of this field program included the drilling of 7 boreholes to depths of 1.2 to 6 metres, and the installation of thermistors in 2 boreholes. At 6 of the 7 boreholes silt, sand and gravel where found at depths of 1.2 to 4.4 metres. Two of the boreholes terminated in this stratum. Granite bedrock was cored at 5 of the 7 boreholes. Based on the observed conditions at the boreholes it has been concluded that the proposed lagoon site is largely underlain by permeable soils. This also indicates that the materials that are available for berm construction will be permeable. Thus, some method that avoids seepage through the berms must be identified. The following alternatives were considered.

- Synthetic liner in the berms, and keyed into the permafrost.
- Maintaining a frozen core within the berms.
- Fully lining the lagoon with a synthetic liner.

Successful design of the alternative of a synthetic liner in the berms requires definition of the long term extent of thaw below the lagoon and within the berms. This indicates the need for a geothermal analysis. The alternative of maintenance of a frozen core within the berms requires a geothermal assessment to confirm the viability and implications of this alternative. A fully lined lagoon will provide an effective barrier against seepage, but the risk of uplift due to hydrostatic pressure must be recognized. Measures that should be considered, if a full liner is selected, include an under-drain system.

Slope stability for the lagoon berms has been evaluated. The recommended berm slopes are as follows:

- For the upstream face (lagoon internal face) 3H:1V
- For the downstream face (external face of berm) 4H:1V

The geotechnical investigation indicated the potential for thaw settlement. The potential for this settlement must be incorporated into the design of any synthetic liners, as there is a risk of tear for the liner if appropriate measures are not incorporated. Thaw settlement may have ongoing operating implications, in that occasional reshaping may be required over the lagoon service life.

In summary, an assessment of local soils indicated that the matter of seepage through the permeable native materials must be considered, and measures must be designed to manage this seepage potential. The need for a geothermal analysis is indicated.

4.4 Geothermal Assessment

A geothermal assessment was conducted by Naviq Consulting Inc. The following is excerpted from the recommendations of that study.

- Berms that incorporate a frozen core approach may not be feasible. An impermeable barrier system is recommended.
- The liner or barrier should ideally be located on the upstream face of the berm. The liner should be installed to un-weathered bedrock, which is located at depths of 3 to 5 metres.
- As an alternative to installation of the liner to sound bedrock, thermosyphons can be used. These thermosyphons would be placed horizontally at a depth of 2 metres below existing grade.
- Advice is provided regarding the extent of the thermosyphon system required along the north perimeter of the lagoon to avoid leakage along the interface between the berm and the existing slopes.

- There is the potential for the placement of the liner in the downstream face of the berms. The downstream toe of the liner should be placed at a depth of 3 to 2.5 metres in undisturbed soil. Issues, such as seepage pressure must be considered, should this concept be selected.
- The selection of liners materials requires careful consideration.
- The geothermal analysis has not considered the impact of structures such as culverts and access manholes. Careful attention should be directed towards such structures, should they be incorporated into the design.

In summary, the geotechnical investigation has identified the issue of permeable soils that must be considered during the design of the lagoon berms. The geothermal assessment provides advice regarding liners, as a method of avoiding seepage of the lagoon contents, and guidance regarding actions required to render the liner resistant against leakage of the lagoon contents.

4.5 Wetlands Assessment

An assessment of the condition and performance of the existing wetland has been conducted. The assessment report also provides information gathered from a literature review and comments regarding potential performance. The assessment reported that phytoremediation is occurring in the wetland, but it is also reported that indications of overload of organic material were noted during the September 2012 site visits. The literature review indicates the potential for removal of up to 90% of suspended solids and BOD is achievable with a wetland.

In summary, the existing wetland appears to be removing contaminants despite overload of organic materials. Provision of a sewage lagoon upstream of the wetland is recommended as a method to reduce contaminants and pathogens released to the wetland. The literature review has provided some guidance regarding the level of performance that can be realized within a wetland.

4.6 Environmental Assessment

A Screening Level Environmental Assessment (SLEA) was conducted, as required under the terms of the Canadian Environmental Assessment Act. This assessment was conducted to identify and document the environmental effects of the proposed project, and to determine the need to mitigate the impacts of this proposal. In general, it was concluded that the extent of existing disturbance at the proposed site was considered moderate and that upgrade to the sewage system is not expected to significantly alter the existing environment. The SLEA determined that the project will have net positive effects for the community. No significant long term effects are anticipated. Most effects are associated with construction, and these can be managed using appropriate mitigation techniques.

5 Sewage Treatment System

5.1 General

The proposed Repulse Bay Sewage Treatment Facility will be comprised of a storage lagoon followed by a wetland. It is intended that the wetlands remain the primary treatment method with the sewage lagoon providing a level of pretreatment as well as retention. The purpose of the sewage lagoon is to retain the sewage until the appropriate time for release to the wetland and to remove the majority of the solids from the effluent prior to its release to the wetlands. It is desirable that discharge to the wetlands occur during that part of the year when warmer weather prevails to maximize the opportunity for treatment.

5.2 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'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 5.1 presents the Influent Concentration data as excerpted from the Cold Climate Utilities Manual.

Table 5.1 - Characteristics of Influent Wastewater

Parameter	Influent Concentration **(mg/L)**	Per Capita Loading **(g/day)**
BOD_5	460	50.6
Suspended Solids	490	53.9

The above values are comparable to those assumed in previous assessments, including FSC 2002.

5.3 Lagoon

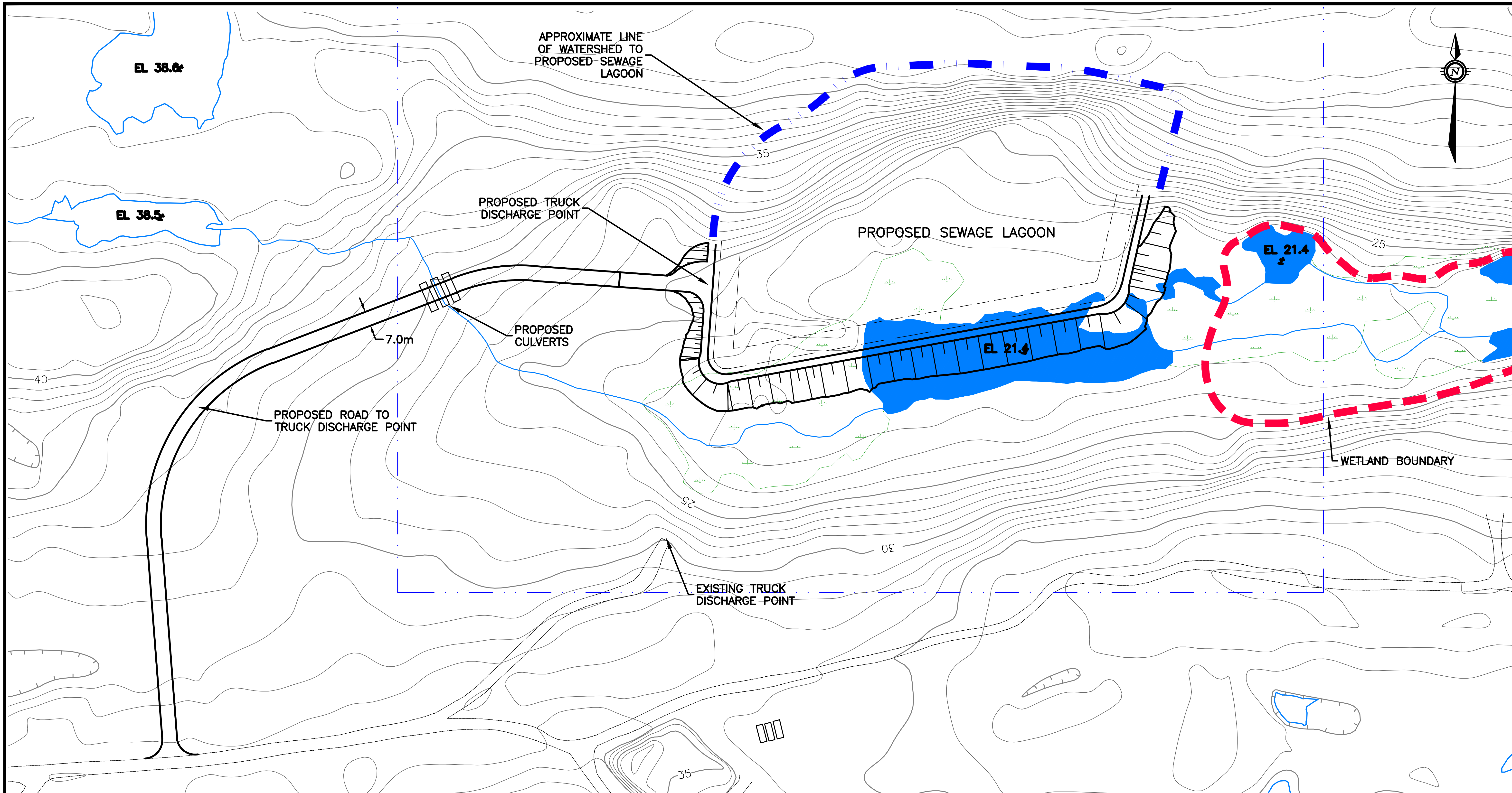
5.3.1 Function

The site for the proposed lagoon is tightly constrained by rising topography and the exiting solid waste site to the south, as well as the downstream wetland. Encroachment of the lagoon into the wetland is not desirable due to the disruption of this area. Challenging geotechnical conditions are anticipated within the wetland area. The site extent that is available for construction of the proposed lagoon is depicted in L. The proposed sewage lagoon must meet the following requirements:

- Provide sufficient capacity to meet the sewage storage requirements
- Provide for accumulated sludge storage, and
- Maintain a 1 metre freeboard

The wetland assessment of September 2012 observed that wetlands were being overloaded due to the direct discharge of sewage. It was also observed that the wetland was not providing the required removal of grease and oil. Thus, the primary role of the lagoon will be the reduction of the loading upon the wetland. The proposed lagoon will provide the following functions:

- Over-winter storage of sewage
- Suspended solids reduction, prior to discharge to the wetland
- Reduction of organic loading into the wetland



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scale 1:2000	PROJECT: REPULSE BAY	project no. OTT-00207086A
date 04/10/13	TITLE: LAGOON WATERSHED	FIGURE 5.1
drawn by S.BUTLER		

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References: REPULSE-2-3-4-TOPO.dwg

- Grease and oil reduction, prior to discharge to the wetland
- Storage of accumulated sludge

In addition to the sewage related functions, it must be recognized that there is a small watershed area that drains towards the proposed lagoon. Allowance must be provided for runoff arising from this area.

5.3.2 Mode of Operation

Typically, northern sewage lagoons are designed to retain all generated sewage, and that the treated contents be discharged once annually by some decanting process. The facility proposed for Repulse Bay is somewhat unusual due to the constrained site, limited potential lagoon volume and presence of a substantial wetland. The following mode of operation is proposed for the lagoon.

- The lagoon refills over the winter season.
- Decanting is initiated via a spillway when the elevation of the lagoon contents rise to the spillway crest. The outflow rate to the wetland would equal the influent rate during this portion of the decanting process.
- The decanting process would be completed through active emptying of the lagoon contents over a 30 day period initiated on August 15. This would complete the annual cycle and prepare the lagoon for the pending winter.
- The lagoon is fully decanted over a 30 day period ending on September 15.

5.3.3 Sewage Generation

The estimate of the rate of sewage generation is presented above, in section 2.3 of this report, and is summarized as follows.

Table 5.2 – Estimate of the Rate of Sewage Generation

Year	Population	Daily Generation (L/day)	Annual Generation (m^3)
2013	907	98,682	36,020
2018	993	109,826	40,090
2023	1079	121,172	44,230
2028	1168	133,386	48,690
2033	1270	147,817	53,950

5.3.4 Runoff Estimate

Repulse Bay sewage treatment area is located in a valley draining down gradient to the ocean. The lagoon watershed area, as shown in Figure 5.1, was calculated, using the Topographic Survey data, to be 14,000 m^2.

The volume generated from the watershed area was calculated using historic precipitation data for Rankin Inlet. This is the nearest station, for which climatic data is available. This information is presented in Table 5.3.

Table 5.3 - Rankin Inlet Climate Normals

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (^{o}C)													
Daily Average	-31.9	-30.1	-25	-16.3	-5.9	4.2	10.4	9.5	3.4	-5.3	-17.8	-26.7	-11
Daily Maximum	-28.3	-26.2	-21	-11.7	-2.4	7.9	14.9	13	5.8	-2.4	-13.9	-22.9	-7.3
Daily Minimum													
Precipitation (mm)													
Rainfall	0	0.1	0	1	7.4	25	39.5	57.3	39.2	11.9	0.1	0	181.5
Snowfall	67	93	129	136	115	49	0	3	46	231	209	119	1197
Precipitation	6.6	8.9	12.6	14.3	18.4	29.8	39.5	57.6	43.8	34.6	19.8	11.3	297.1

The proposed operating mode for the lagoon incorporates overflow into the wetlands after June 15 of each year. Thus there is no requirement to incorporate an allowance for storage of runoff that arises between June 15 and the end of lagoon decanting. Allowance must be made for the storage of runoff arising from 163.3 mm of precipitation which occurs between September 15 and June 15. Based on the watershed area of 14,000 m^2, the volume of runoff the sewage lagoon must be able to accommodate watershed is 2,286 m^3.

A portion of the total precipitation will be lost to evapotranspiration, the sum of the evaporation and plant transpiration from the land. Given the short summer season, and limited vegetation, it has been assumed that evapotranspiration will not be considered in the sizing this facility.

5.3.5 Working Volume Utilization

It is intended that the lagoon provide over-winter storage of sewage, and that overflow into the wetlands be delayed until the wetland becomes active after June 15. Active decanting of the lagoon contents will take place between August 15 and September 15 of each year, in preparation for the pending winter. The required storage of 42,608 m^3, to meet this requirement for the design horizon of 2033 is determined as follows:

1. Sewage storage from the end of decanting, September 15, to the start of release, June 15, requires 273 days of storage. The projected population for the year 2033 (as per table 2.3) is 1270 persons. The estimated per capita sewage generation rate for this population is 116.3 l/cap/per. This equals a required storage for sewage of 40,322 m^3.
2. Storage for runoff must account for the precipitation that falls between the end of decanting September 15, to the start of release, June 15. The table 5.3 above the precipitation over this period can be expected to be 163.3 mm. Given the drainage area of 14,000m^2, the required storage capacity of 2,286 m^3 must be provided for storage of runoff.

5.3.6 Sewage Sludge Accumulation

The sewage lagoon must provide storage for solids (sludge) which accumulate in the sewage lagoon. There is very limited data regarding the operational behaviour of lagoons in arctic environments. Due to this lack of data, various assumptions, which are summarized as follows, were used to develop an estimate of sludge accumulation rates.

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 the 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.

The preceding assumptions lead to an annual per capita rate of sludge accumulation of 32.85 kg/capita, and this represents a per capita volume of $0.329m^3$.

The following table summarizes the rate of sludge accumulation anticipated in Repulse Bay.

Table 5.2 - Sludge Accumulation Anticipated in Repulse Bay

Year	Population	Sludge Generated	Sludge Accumulated
2013	907	298	298
2014	924	304	602
2015	942	310	912
2016	960	316	1228
2017	976	321	1549
2018	993	327	1876
2019	1,011	333	2209
2020	1,028	338	2547
2021	1,045	344	2891
2022	1,062	349	3240
2023	1,079	355	3595

Year	Population	Sludge Generated	Sludge Accumulated
2024	1,096	361	3956
2025	1,114	367	4323
2026	1,131	372	4695
2027	1,149	378	5073
2028	1,168	384	5457
2029	1,187	391	5848
2030	1,207	397	6245
2031	1,228	404	6649
2032	1,249	411	7060
2033	1,270	418	7478

The sludge that is anticipated to accumulate over the 20 year design period can be accommodated within the allocated sludge storage zone located in the lowest 1.0 metres of the proposed lagoon.

5.3.7 Estimated Lagoon Performance

There are several removal mechanisms within a sewage lagoon, including sedimentation and biochemical oxidation. Sedimentation involves removal of BOD_5 and suspended solids through settling as sludge to the bottom of the lagoon. 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 A). Following sedimentation BOD_5 and suspended solids concentrations are estimated as 300 mg/L and 160 mg/L, respectively.

5.3.8 General Design Characteristics

Lagoons have been constructed in the Arctic using both permeable and non-permeable berms. The use of permeable berms at this location is not considered appropriate as a controlled decanting of sewage into the wetlands, both in terms of dates and location, is required to optimize performance. Thus, a method of providing non-permeable berms must be selected. The geotechnical investigation has determined that the local soils are permeable and not suitable as a water containing barrier. The geothermal assessment has discounted the use of a frozen core within the berms as a method of containing the sewage. The geothermal assessment recommends that a liner be placed on the internal face of the berms, and that this liner be keyed into un-weathered bedrock. The bedrock is found at a depth of 2 to 5 metres. As an alternative to keying into the bedrock, thermosyphons can be placed horizontally to achieve a cut-off for seepage below the berm liner.

A design that is based upon the above assumptions, including the use of thermosyphons, has been developed. Figure 5.2 illustrates this proposed lagoon layout. Figure 5.2 presents typical sections through the proposed lagoon cell. These sections depict the proposed liner arrangement. It is intended that 1 metre of freeboard be incorporated into the berm cross sections.

5.3.9 Decanting Methods

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

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

5.3.10 Seepage Cell Design

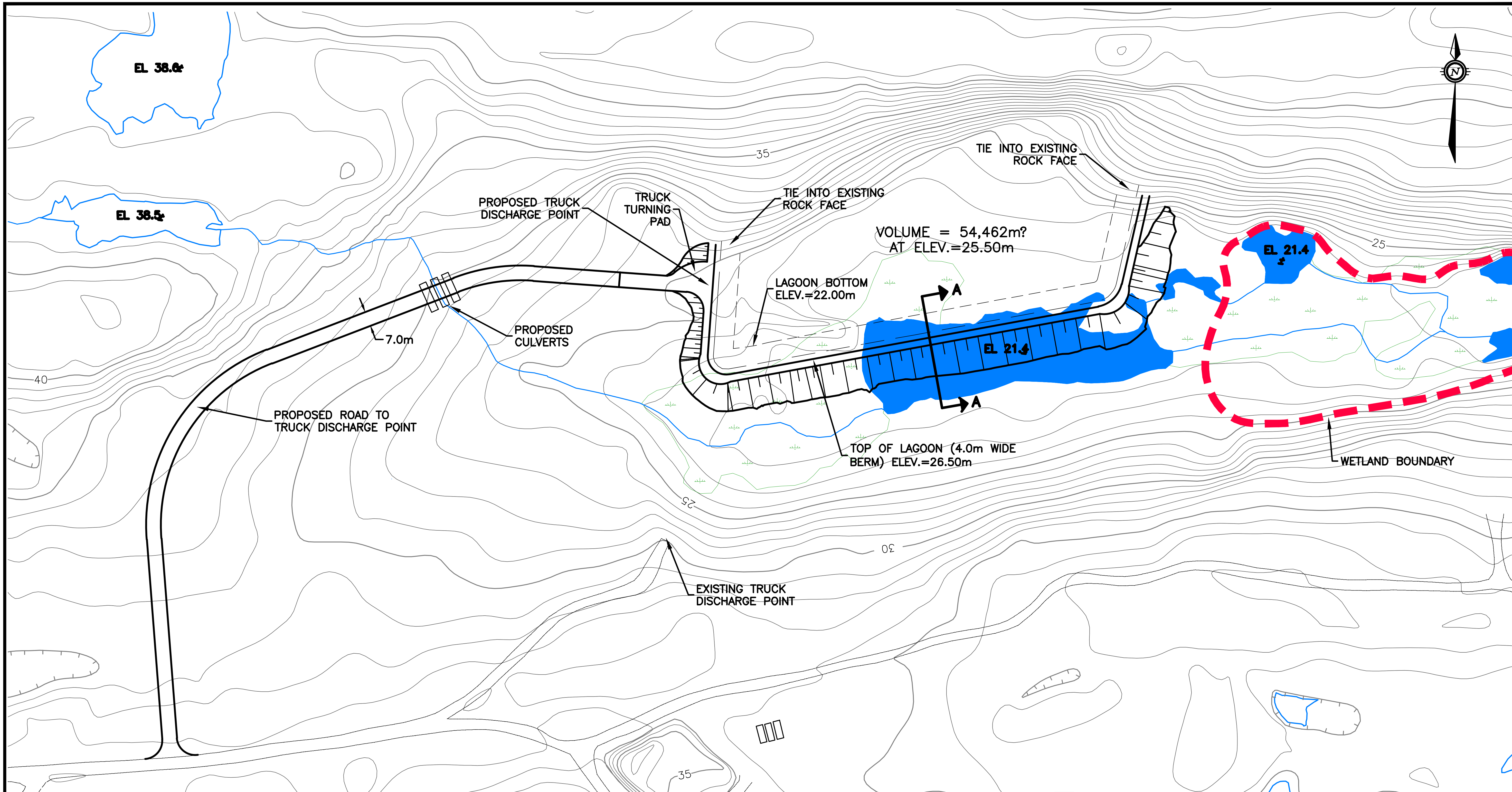
Many lagoons in the north depend on the permeability of their berms to allow the sewage to seep or leak out during the summer. This method does not allow for the control of the timing or rate of decanting. This method does not insure that the lagoon will be fully decanted prior to the onset of the following winter. The use of a seepage cell has not been incorporated into the proposed design.

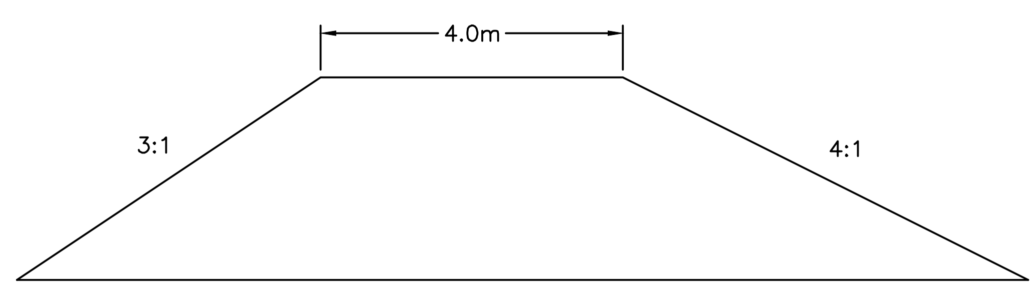
5.3.11 Discharge Pipe

For lagoons that are designed to be impermeable, a positive decanting method must be provided. The installation of a discharge pipe and valve through the berm is common in southern locations. In storage lagoons in northern locations, the discharge pipe is only used seasonally. This results in an arrangement where a portion of the pipe and valve arrangement are situated within a frozen berm. Frequently the pipe and valve must be thawed prior to their use, which has caused operational concerns, and in some instances has proven impossible.

As a further issue, the geothermal assessment has raised concerns relating to structure, such as control manholes, that penetrate the lagoon berms. More specifically, these penetrations provide an opportunity for additional thaw, which may result in unintended seepage in the vicinity of the control structure.

It has been determined that the use of a discharge pipe that penetrates the berm is not appropriate for this installation. This decanting mechanism has not been incorporated into the design.





SECTION A–A

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scale 1:2000	PROJECT: REPULSE BAY	project no. OTT–00207086A
date 04/10/13	TITLE: PROPOSED LAGOON LAYOUT	FIGURE 5.2
drawn by S.BUTLER		

Filename: p:\projects\civil engineering services\207000\ott-00207086-a0 - sewage lagoon upgrades, repulse bay, nu - gn\d - drawings\seawagelagoon - copy.dwg
Last Plotted: 10/4/2013 2:55:09 PM Plotted by: agostinoe
References: REPULSE-2-3-4-TOPO.dwg

5.3.12 Pumping

Pumping the effluent from the lagoon is the most operator demanding alternative. It is also the most dependable. This method requires that the pumps be installed and removed each year. During operation the pumps 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. Pumps also provide a very good method for controlling the time and rate of discharge which is important for lagoons which use a wetlands as a secondary or additional treatment.

Pumping has been selected as the preferred method of decanting the lagoon in Repulse Bay.

5.3.12.1 Summary

It is recommended that pumping be the method used for the decanting of the Repulse Bay lagoon. The Repulse Bay system includes a wetlands treatment system with the lagoons providing retention and treatment and the wetlands providing additional treatment or polishing. The performance of the lagoon is dependent on retention time and the wetlands performance is dependent on the time and rate of discharge. 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. Although pumping is the most operator dependent, it provides the best control over the release time and release rate, and is easiest to repair or replace as the system is accessible.

5.3.13 Sludge Management

Effluent quality will guide when a sludge management program is implemented. Monitoring of the effluent from the lagoon will indicate deterioration in outflow quality due to re-suspension of accumulated sludge from the bottom of the lagoon. Prior to disposal, the sludge must be tested to ensure the disposal method chosen is safe and environmentally responsible. Sludge removed from the lagoons can be disposed of in a separate cell constructed at the landfill site. The sludge should be covered with granular material and allowed to freeze.

5.4 Wetlands Treatment

5.4.1 General

The natural wetland downstream of the proposed lagoon site will be incorporated into the sewage system design. In order to remove contaminants effectively, treatment wetlands have to be an appropriate size. Design of constructed treatment wetlands takes contaminant loading, desired effluent concentrations and background concentrations into consideration.

The Guidelines for the Approval and Design of Natural and Constructed Treatment Wetlands for Water Quality Improvements by Alberta Environment use the following equation to calculate the required area for treatment (AE, 2000):

$$A = \frac{(0.0365 \times Q)}{K} \times \ln\frac{(C_i - C^*)}{C_e - C^*}$$

Q = Design Flow, m^3/d
C_i = Influent Concentration
Ce = Target Effluent Concentration
C* = Wetland background limit (mg/L)
for TSS, C* = 8
for BOD, C* = 5
k = Areal rate constant @ 20 ^oc (m/yr)
for TSS, k = 35
for BOD, k = 34
A = Required wetland area (ha)

The highest loading rate for the wetlands is during the 30 day decanting period. Discharge over this 30 day period of all of the sewage and runoff stored in the sewage lagoon, 42,608 m^3, would give rise to a daily hydraulic loading to the wetland of 1,420 m^3/day. The sewage, which represents 40,322 m^3 of this volume, is that part of the decanted liquid responsible for the contaminant loading into the wetland. The daily volume responsible for the contaminant loading is 1,344 m^3.

The assumed BOD concentration in the influent into the wetland area from the lagoon is 300 mg/L. This influent concentration is based upon the conservative assumption that BOD reduction in the lagoon, which is limited to sedimentation, will represent 35% removal. For the purposes of these calculations an effluent BOD concentration of 40 mg/L, which is 50% of the effluent criteria has been assumed. A wetland background concentration of 5 mg/L has also been assumed. The required size of a treatment wetland for BOD removal is 3.1 ha.

Similar calculations have been conducted to develop an estimate of the area required to manage the suspended solids load. The assumed TSS concentration in the outflow from the lagoon, following 65% removal through sedimentation, is 160 mg/L and the target concentration for TSS was set at 50 mg/L. The background concentration in the wetland was assumed to be 8 mg/L. The required size for a treatment wetland for TSS removal is 1.8 ha.

It should be noted that the above calculations are generally used for constructed treatment wetlands such as open water surface wetlands. The existing natural wetland area does not completely represent a purpose constructed wetland. However, the area of the existing natural wetland is 6.4 ha in size, which indicates that there should be ample area for treatment prior to discharge to Hudson Bay.

5.4.2 Estimated System Performance

The effluent criteria assumed in this analysis are substantially more demanding that those that are typically applied to sewage treatment system in Nunavut. Typical effluent criteria imposed in water licences are 100 mg/L and 80 mg/L for suspended solids and BOB_5 respectively. Previous investigations included "Vegetated Filter Strip Wetland Assessment, Arctic Bay." (Trow 2008), indicate that 80% removal of contaminants, including suspended solids and BOB5 through wetland polishing. Table 5.4 summarizes the estimated performance of the sewage treatment system.

Table 5.4 - Effluent Quality from the Wetlands

Parameter	Units	Influent from Lagoon	Removal	Effluent from Wetlands
BOD_5	mg/L	300	80%	60
TSS	mg/L	160	80%	32

The natural wetland, which will be receiving pre-treated sewage from the newly constructed sewage lagoon, is expected to successfully remove BOD_5 TSS, pathogens, nitrogen compounds, phosphate, grease and oil before the wastewater enters the ocean. Existing native vegetation and microorganisms will be the main contributors to the reduction in contaminants and nutrients.

5.5 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 5.5 summarizes the levels of treatment predicted from the sewage treatment system in comparison to the water licence criteria.

Table 5.5 - Summary of Treatment Levels

Parameter	Units	Criteria	Influent	Effluent from Lagoon	Effluent from Wetland+
BOD_5	mg/L	100	460	300	60
TSS	mg/L	120	490	160	32
FC	#/100ml	1×10^6	1×10^7	1×10^6	<100,000

6 Monitoring and Compliance Points

6.1 Effluent Monitoring and Compliance

Table 6.1 - Sampling Points Coordinates

SNP#	Description	Latitude	Longitude	Comment
1	Truck Discharge	66° 31' 38.29"	86° 13' 38.28"	
2	Lagoon Pump Discharge	66° 31' 31.97"	86° 13' 02.55"	
3	End of Wetlands	66° 30' 55.97"	86° 12' 13.54"	Compliance Point

Table 6.2 - Sampling Frequency

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

7 Cost Estimate

The works included in the cost estimate include the following:

- Construction a new lagoon facility
- Improvements to road access to the new lagoon facility
- Construction a new truck discharge area
- Development of a decanting system

The estimated cost for the improvements to the sewage disposal system in Repulse Bay is $5,211,300. A breakdown of the estimated cost is shown in table 7.1 and a detailed estimate is provided in Appendix B.

Table 7.1 – Breakdown of Cost Estimate

Description	**Estimated Cost**
Mobilization	$ 900,000.00
Site development	$ 447,800.00
Berm construction	$2,187,300.00
Liner	$ 442,000.00
Inlet structure	$ 38,000.00
Outlet structure & Decanting Equipment	$ 272,750.00
Signage and monitoring	$ 54,900.00
Sub total	**$4,342,750.00**
Contingencies (20%)	$ 868,550.00
Total	**$5,211,300.00**

8 Conclusions and Recommendations

The following summarizes the conclusions and recommendations put forth in this report for the preliminary design for the Hamlet's wastewater treatment facility.

1. Sewage is currently discharged at a point near the Hamlet solid waste site. This sewage flows into a natural wetland.
2. The existing sewage disposal facilities do not meet the long term needs of the community. Reporting by INAC in 2010 presented the opinion that the discharge quality was not acceptable.
3. A design horizon for the improvements to the sewage treatment facility has been set as 20 years. At the end of the design period the population is estimated as 1,270 and the daily sewage generation rate is projected to be 147.8 m^3.
4. The following effluent requirements have been set for this project.
    a. BOD_5 - 80 mg/L
    b. Total suspended solids - 100 mg/L
    c. Faecal coliforms – 1 $X10^4$/100mL
    d. Oil and grease – no visible sheen
    e. pH – between 6 and 9
5. In consultation with the community a review of alternative sites for sewage treatment facilities was conducted. The current sewage discharge site was selected as the most appropriate location for the new works.
6. Site investigations, which included a site inspection, topographic survey, geotechnical investigation, wetlands assessment, geothermal assessment and environmental assessments have been conducted. The findings of these various investigations have been integrated into the proposed design.
7. The geotechnical investigation has recommended that an impermeable liner be used, based upon local soils characteristics. Installation of this liner on the inner face of the lagoon berms has been selected.
8. The geothermal assessment has determined that a frozen core within the berms is not a feasible approach for the containment of lagoon seepage. The alternatives of keying into sound rock or installation of thermosyphons are suggested. Thermosyphons, located at a depth of 2 metres below existing grade, have been selected as the preferred technique for the containment of seepage.
9. The wetlands assessment has determined that phytoremediation is taking place, however there are currently indications of overloading. This assessment recommends that a lagoon be provided to reduce contaminant loads to the wetlands. Guidance is provided regarding the potential treatment that can be achieved by the wetlands.
10. A sewage treatment system that includes a lagoon and the natural wetlands is proposed. The lagoon will provide the following functions.
    a. Over-winter storage of sewage
    b. Reduction of solids, organic, grease and oil loadings to the wetland
    c. Storage of accumulated sludge

11. The following mode of operation is proposed for the lagoon.
    a. Over-winter storage of sewage, with delay of overflow from the lagoon until the wetlands become active
    b. Active decanting of the lagoon between August 15 and September 15 of each year
12. A small area of 1.4 ha is tributary to the lagoon. Drainage from this area cannot be redirected. The lagoon must include an allowance of 4,460 m^3 for runoff from this area.
13. It is estimated that a total of 7,478 m^3 of sludge will accumulate over the 20 year planning period of this project. Lagoon effluent quality should be monitored, over the project life, as this will provide guidance regarding the need for lagoon de-sludging.
14. A total lagoon working volume of 42,608 m^3 is required.
15. The following summarizes the general arrangement of the lagoon.
    a. The lowest 1 metre of lagoon volume is reserved for sludge storage
    b. Provide 40,322 m^3 of storage for sewage generated during the over-winter period
    c. Provide 2,286 m^3 of storage for runoff
    d. A further 1 metre of freeboard is to be provided above the required working volume
16. It is recommended that the annual decanting of the lagoon be performed by pumping.
17. An estimate of the required area for a constructed wetlands that would be required to manage the sewage generated in Repulse Bay has been prepared. The existing natural wetland is substantially larger than these estimates.
18. It is anticipated that the proposed sewage treatment system made up of a lagoon combined with the natural wetland will provide an effluent that exceeds the discharge criteria.
19. Recommended sampling locations and frequency of sampling is provided in this report.
20. The estimated cost for a sewage lagoon and the associated works is $5,211,300.

Appendix A – Excerpt from Ontario MOE Guidelines for the Design of Sewage Treatment Works, July 1984

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 B – Cost Estimate

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
1	**Mobilization / Demobilization Phase 1**	L.S.	1	$900,000.00	$900,000.00
2	**a)** Supply and deliver silt fence including wood stake	m	550	$4.00	$2,200.00
	b) Installation of silt fence including wood stake and trenching	m	550	$4.00	$2,200.00
3	Supply,deliver and place granular material to construct new berms	cu.m	38000	$45.00	$1,710,000.00
4	Supply,deliver and place extra material for wet area c/w geogrid for construct new berms	cu. m	6000	$60.00	$360,000.00
5	**a)** Supply,deliver gabion mats for erosion protection at toe of berm	m.sq	510	$100.00	$51,000.00
	b) Installation gabion mats for erosion protection at toe of berm	m.sq	510	$130.00	$66,300.00
6	**a)** Supply and deliver liner for proposed berm	m.sq.	5500	$14.00	$77,000.00
	b) Installation of liner for proposed lagoon including sand bedding, sand cover, and anchor trench	m.sq.	5500	$30.00	$165,000.00
7	**a)** Supply and deliver Thermosyphon system	L.S	1	$110,000.00	$110,000.00
	b) Installation of Thermosyphon system	L.S.	1	$90,000.00	$90,000.00
8	**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
9	Supply, deliver and place granular material to construct new access road	m.sq.	4200	$38.00	$159,600.00
10	Supply, deliver and place granular material to construct truck turning pads	cu. m	1600	$45.00	$72,000.00
11	Supply, deliver and place 150mm of granular A material to top road and turn for truck discharge point	m.sq.	7000	$30.00	$210,000.00
12	**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
13	**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
14	**a)** Supply and deliver piping for outlet structure including 300 dia. HDPE series 100 pipe c/w concrete block	m	65	$180.00	$11,700.00
	b) Installation of piping for outlet structure	m	65	$90.00	$5,850.00
15	**a)** Supply and deliver 600mm dia. nestable pipe including pressure treated wood post and lag bolt	m	50	$250.00	$12,500.00
	b) Installation of 600mm dia. nestable pipe including pressure treated wood post and lag bolt	m	50	$110.00	$5,500.00

Sewage Treatment Facility
Repulse Bay
OTT-00207086-A0

Class "C" Cost Estimate
October 2013

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
16	**a)** Supply and deliver truck discharge structures, including erosion protection and	ea	1	$70,000.00	$70,000.00
	b) Installation of truck discharge structures, including erosion protection and bollards	ea	1	$25,000.00	$25,000.00
17	Supply, deliver and install boulder barriers	ea	36	$50.00	$1,800.00
18	**a)** Supply and deliver CMP	m	72	$350.00	$25,200.00
	b) Installation of CMP	m	72	$500.00	$36,000.00
19	**a)** Supply and deliver thermistor casing c/w data logger	ea	4	$7,000.00	$28,000.00
	b) Installation of thermistor c/w data logger	ea	4	$2,500.00	$10,000.00
20	**a)** Supply and deliver seepage monitoring tubes	ea	4	$500.00	$2,000.00
	b) Installation of seepage monitoring tubes	ea	4	$1,500.00	$6,000.00
21	**a)** Supply and deliver signage	ea	8	$350.00	$2,800.00
	b) Installation of signage	ea	8	$200.00	$1,600.00
22	**a)** Supply and deliver pump including engine, wheel kit 150mm dia. hose, pressure gauge, ball valve, flange and coupling	ea	1	$80,000.00	$80,000.00
	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
23	**a)** Supply and deliver 1.2m x 2.4m Project Information Sign	ea	1	$2,500.00	$2,500.00
	b) Installation and Maintain 1.2m x 2.4m Project Information Sign	ea	1	$750.00	$750.00
24	**a)** Supply and deliver sampling well	ea	1	$500.00	$500.00
	b) Installation of sampling well	ea	1	$750.00	$750.00

SUBTOTAL	**$4,342,750.00**
20% CONTINGENCY	**$868,550.00**
TOTAL	**$5,211,300.00**