Cape Dorset Sewage Lagoon Feasibility Study

Final Report

Prepared for:
Government of Nunavut
Community and Government Services

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Sign-off Sheet

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Table of Contents

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LIST OF TABLES

LIST OF FIGURES

Note: Figures are located following the section in which they are referenced.

LIST OF APPENDICES

Executive Summary

Cape Dorset is located on Dorset Island off the southern tip of Baffin Island in Nunavut (64° 13′ 54″ N 76° 32′ 25″ W) and has a population of approximately 1,400 people. The community employs trucked water and sewer; sewage is collected from individual holding tanks and transported to the sewage treatment facility.

Cape Dorset currently has two sewage treatment facilities; one facility is in use, the other facility was completed in 2007 and has never been used. The facility currently in use is a 3 cell "stepped" primary treatment lagoon system that has been in use for more than 30 years. This facility is located approximately 1 km west of the hamlet and discharges into Telik Inlet. The lagoon system has historically had stability issues associated with the steep terrain where it was constructed and the steep slopes on the lagoon berms. These conditions have resulted in berm failures, which have in turn caused significant untreated sewage discharges. An adjacent smaller "emergency" sewage pond has been used when the existing lagoon system has failed.

Several studies have been completed on sewage options including mechanical treatment, to replace the 3-cell lagoon. After consideration of all the options, the Government of Nunavut advanced the construction of a new sewage lagoon southwest of the Hamlet near P-Lake in 2007.

The P-Lake sewage treatment lagoon was designed for a 20 year design life, providing a capacity of 96,000 cubic metres for year round storage, and configured for an annual discharge. A five metre high berm is the main earth structure, which incorporates freeze back and a bentonite liner to provide an impermeable containment system. The lagoon is discharged through an outlet structure that penetrates through the berm.

Access to the P-Lake lagoon is a 920 metre long access road with one switchback that ultimately climbs 50 metres up the steep terrain to the sewage lagoon site.

The P-Lake lagoon system (access road and sewage lagoon) has encountered several significant problems, and as a result has not been utilized by the community since the construction was completed in 2007.

Problems with the P-Lake Lagoon system include:

- A steep and narrow access road with safety issues associated with steep grade, the hairpin turn on the alignment, and the visibility along the alignment
- Erosion of the road surface during spring melt
- Extensive snow drifting on the road during the winter
- Uncontrolled seepage from the lagoon through the west berm
- Suspected seepage from the lagoon through the east side of the lagoon

- Freezing of the lagoon discharge piping and control valve
- Surface runoff into the lagoon from storm runoff and spring snowmelt
- Wind related issues around the sewage discharge point causing air dispersion of sewage during truck discharges

The scope of this project was to complete a feasibility study to assess options for upgrading the P-Lake sewage lagoon facility to address the aforementioned problems. Conceptual designs for the proposed upgrades have been developed and opinions of probable cost (Class D cost estimates) for the feasible solutions have been provided. The upgrade options selected must allow the lagoon to meet the standards approved by the Nunavut Water Board (NWB), and must meet the applicable environmental and health and safety regulations and practices.

A site visit and inspection of the P-Lake Lagoon facility was completed and meetings were conducted with Cape Dorset Council and Hamlet Staff. The meetings were intended to gain first-hand accounts of the problems, and collect input on potential solutions.

The findings of this study support many of the Hamlet's concerns, and the regulatory issues. Firstly, the access road is considered unsafe due to the road configuration. Secondly, seepage was observed out of the west berm during the field visit. Finally, a hydrologic analysis conducted found that the lagoon capacity may be reduced by over 20% due to surface runoff entering the lagoon. The combination of a leaking berm and surface runoff suggests that the retention capacity of the lagoon may be compromised. The study also concluded that seepage of sewage-contaminated water towards the water supply T-Lake will **not** occur because of topography and the 20 metres elevation difference between the lagoon and T-Lake; T-Lake is approximately 20 m higher and 1 km away from the P-Lake Lagoon.

Options were developed and presented in this report to address both the problems with the P-Lake Lagoon itself, and the conveyance of sewage to the lagoon. Cost, community acceptance, regulatory acceptance, constructability, operation and maintenance requirements, and safety have been considered when evaluating the options.

The recommended improvements for P-Lake Lagoon include:

- Attempt to plug the leak in the west berm using bentonite (opinion of probable cost $25,000 including materials and time for monitoring effectiveness of this method). Bentonite should be added to lagoon in spring. Additional bentonite additions may be required once the lagoon is operational and the lagoon is at higher operating depths.
- Abandon the existing decant pipe through the west berm in place by grouting it closed. The Hamlet should acquire a portable fuel powered pump (opinion of probable cost $135,000) that may be used to decant the lagoon once per year.

- Improve the ditch drainage system around the service road to reduce the volume of runoff and snowmelt entering the lagoon. Regrading of flat or negatively sloped sections and cleaning of the ditches is recommended. Other local upgrades to improve drainage could also be implemented if needed (opinion of probably cost $100,000).

Sealing the leaking berm with bentonite has been recommended because it is low cost and easy to implement. However, there is a significant probability that this solution may not adequately plug the leak. If this method proves ineffective, then it is recommended that a new treatment cell be constructed using material from the existing berm, along with additional granular material from the community. Construction of a new cell may also be an attractive option if lagoon capacity is reached sooner than expected or if the Hamlet wishes to improve the quality of the effluent from the system.

The estimated annual operation and maintenance cost of the lagoon ranges from $25,000 for the existing lagoon to $36,000 should a secondary cell be constructed.

The recommendations for conveyance of sewage to the lagoon include:

- Discontinue using the access road for hauling sewage and instead construct a lift station and forcemain. The access road would be used as a service road requiring less maintenance. The capital cost ($6.1 Million) and annual operation and maintenance cost ($406,000) of this option are likely similar to access road upgrades; however, the lift station and forcemain option will alleviate safety issues and operational issues associated with hauling sewage on the access road (even with access road improvements).

- Consultation with the Hamlet to confirm whether it is preferable to pursue the installation of a lift station and forcemain in order to avoid using the access road for hauling sewage, as opposed to improving the access road.

If the decision were made to improve the Access Road instead of installing a lift station and forcemain, the recommendation would be to improve the roadway near the hairpin turn (Option B3). The proposed work improves the issues associated with the sharp curve and the steep grade; however, completely eliminating these issues is not possible with the available road alignment and the steep terrain.

Snow drift management using snow fencing and/or snow sheds could be investigated further if a decision is made to continue to use the access road to haul sewage. The issue concerning the orientation of the truck discharge station and windblown sewage may be addressed using a quick-connect hose system at the truck discharge chute or by developing an alternate discharge chute with an orientation perpendicular to the prevailing wind direction.

1.0 INTRODUCTION

1.1 PROJECT LOCATION

Cape Dorset is located on Dorset Island off the southern tip of Baffin Island in Nunavut; the geographic coordinates are 64° 13′ 54″ N latitude, and 76° 32′ 25″ W). The only all season access to Cape Dorset is by air, and sealift provides seasonal access during the limited open water season. **Figure 1.1** shows the project location.

1.2 PROJECT BACKGROUND

Cape Dorset has approximately 1,400 people. The community is served by local roads and power is supplied by diesel generators. All other municipal services are provided locally by the Hamlet with support from the Government of Nunavut (GN). Sewage collection in Cape Dorset is accomplished using eduction trucks that transport sewage from holding tanks to the sewage treatment facility. Water delivery is also conducted using trucks.

Cape Dorset currently has two sewage treatment facilities. The facility currently being used was initially constructed decades ago, and incrementally improved upon throughout the years. This facility is comprised of a 3-cell lagoon located approximately 1 km west of the hamlet, which discharges to Telik Inlet (Arctic Ocean). The three cells have an estimated volume of 30,000 m^3 and are located along a 370 m long valley that slopes towards Telik inlet with an average grade of more than 20%. The three cells are constructed in a terraced formation with sewage flowing from one cell to the next. Although designed to ex-filtrate, culverts were installed in each berm to accommodate overflow conditions and reduce the risk of berm breaches, which result in erosion and potential failure. The purpose of this facility is to detain the sewage for a period adequate to provide preliminary treatment prior to the discharge into Telik Inlet. However, the facility has experienced a number of problems from its inception due to the steep grade and the fact that the facility is located in a natural runoff channel, resulting in inundation by runoff from adjacent land (for which the lagoon cells are not adequately sized). As a result, berm failures, winter overflows and berm breaches in spring have been a recurring problem, and therefore detention times are likely inadequate to provide acceptable sewage treatment. At times, the Hamlet has been forced to use the “emergency” system that is an older and smaller single cell lagoon located approximately 600 m west of Cape Dorset, but that facility is faced with similar problems.

A planning study was initiated in 2001 to address issues related to the 3-cell lagoon and investigate options for a long-term wastewater treatment system. The options considered in the 2001 study included the expansion of the existing 3-cell lagoon, a new lagoon at a different site, primary physical treatment with deep water or shoreline discharge, and a pre-engineered secondary treatment plant. The most cost effective option was determined to be construction of a new sewage lagoon in an area east of the community, referred to as Site R. The second most preferable solution was construction of a primary level treatment plant (macerator) with deep water discharge. Two other options were rejected during the 2001 study including new lagoons at Sites P and Q. Site P is a small lake located southwest of the Hamlet and at the top of a steep and rocky hill and had been ruled out because it was thought to be too costly to build. Site Q is a small lake located just southeast of Cape Dorset and was ruled out initially because it was needed as an emergency potable water supply. Expansion of the 3-cell lagoon was also ruled out, presumably due to space and the limitation of the steep terrain.

Cape Dorset also submitted an application for an amended water license from the Nunavut Water Board (NWB) in 2001. In March of 2002, Environment Canada (EC) issued an Inspector's Directive under the Fisheries Act that stated the release of untreated sewage into Telik Inlet is "a serious and imminent danger" to waters frequented by fish. The GN responded to the directive in August 2002 and advised EC that repairs to the lagoons were being undertaken, but the issues with the limited capacity of the 3-cell lagoon would remain. As a result, the GN decided at that time to develop a mechanical treatment plant. The water license was subsequently granted in September 2002.

A short time after the 2001 study, the GN reconsidered and ruled out both preferable solutions from the 2001 study. A new lagoon at Site R would be too close to the airport and could introduce a bird strike hazard and therefore may not meet regulatory approval requirements. The primary level treatment plant was also ruled out due to the recent problems encountered by a similar facility in Rankin Inlet, Nunavut.

In July 2002, the GN and community agreed that a pre-engineered secondary level treatment facility should replace the existing 3-cell lagoon facility. The GN committed that the facility would be operational by 2004. However, after preliminary engineering design for this solution was started, the pre-engineered treatment plant was reconsidered because of concerns about escalating operation and maintenance costs, requirements for operator training and limited acceptance by the community for a new technology. Instead, the GN wanted to reconsider Site P as a potential location for a new sewage lagoon. A direct cost comparison between a mechanical plant (sequencing batch reactor) and the P-Lake lagoon option, including capital cost as well as operations and maintenance costs, was first conducted in May of 2003.

Dillon Consulting Ltd. (Dillon) completed a study in August of 2003 that compared the mechanical plant to the P-Lake Lagoon Option on the basis of several criteria, including:

- Capital cost
- Capital cost uncertainty
- Operation and maintenance cost
- Operation and maintenance cost uncertainty
- Regulatory requirements
- Process uncertainty
- Community acceptance

A weight-of-evidence approach was used to compare both options. Operation and maintenance cost was determined to have the greatest impact on the overall comparison. Dillon determined that the P-Lake Lagoon was the preferable solution in the 2003 report.

Dillon completed the final design report for the P-Lake Lagoon in January of 2006. The report included sewage generation calculations, lagoon design including the berm, access road and other details, fisheries investigation, treatment quality estimations, development of a sampling program and regulatory approvals. The P-Lake sewage treatment lagoon was designed for a 20 year life span (i.e. until 2026) based on population projections available at the time. The facility was designed to provide annual retention for 96,100 m^3 of sewage, which was the predicted annual generation in 2026. The designed lagoon consists of a roughly five metres high berm containing a bentonite liner required to provide the desired retention plus 1 m of freeboard and 0.5 m of sludge depth. A thermal analysis was conducted and it was determined that the berm would freeze and the lagoon base would remain impermeable due to permafrost and the bentonite liner. A culvert outfitted with a control valve was installed through the base of the berm to permit controlled drawdown of the lagoon at the end of each summer.

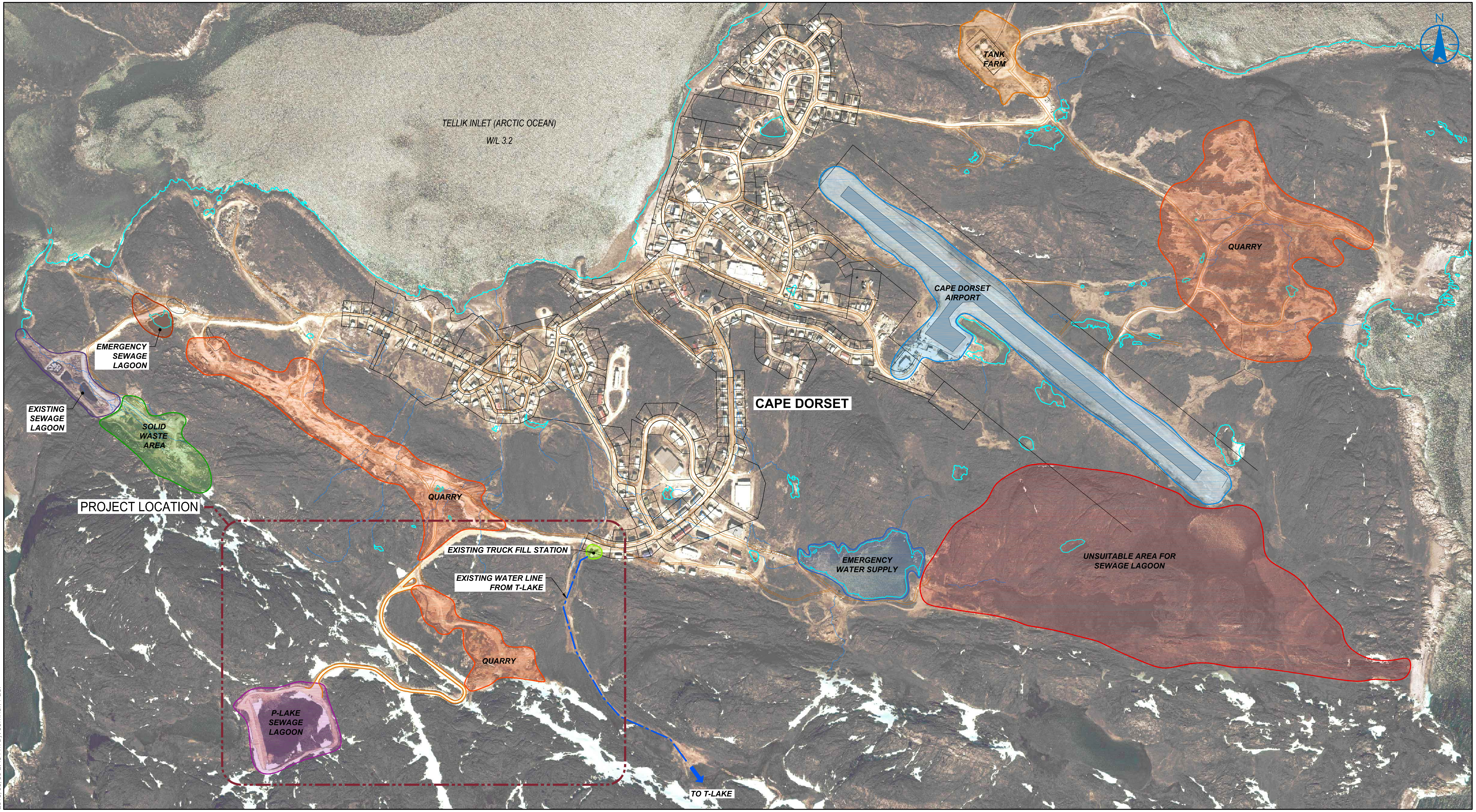
The 2006 Dillon report also contained a design for a 1 km long access road up the steep hill to the lagoon with a maximum grade of 8.3% and a tight radius (25 – 30 m) hairpin curve. A truck turning pad, gravity truck discharge flume for sewage to be dumped into the lagoon and ditches and culverts to direct runoff around the lagoon were also designed. The total cost of the project was estimated at just over $3.2 Million.

The P-Lake Lagoon was constructed in 2007 but has been plagued by several problems as described in several reports paraphrased in **Section 2.4** and summarized in **Section 3**. Nonetheless, the NWB approved the amended water license application in March 2008 despite outlining concerns about the lagoon's construction and the difficult access road. However, due to the problems with the P-Lake Lagoon and access road, the Hamlet has not used the P-Lake Lagoon and instead continues to use the 3-cell lagoon system. Several geotechnical and thermal investigations on the lagoon have been conducted but the problems have not been rectified to date.

1.3 PROJECT OBJECTIVES

The scope of this project includes a feasibility study to assess options for upgrading the P-Lake sewage lagoon facility to render it operational. The study will assess the system and its components, and present options for resolving the safety and design issues that are presented in **Section 3**. Preliminary designs for the proposed upgrades will be developed and Class D cost estimates for feasible solutions will be prepared.

The upgrade options selected must allow the lagoon to meet the standards approved by the Nunavut Water Board (NWB) and must meet the applicable environmental and health and safety regulations.



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Client/Project

THE GOVERNMENT OF NUNAVUT
COMMUNITY AND GOVERNMENT SERVICES
CAPE DORSET SEWAGE LAGOON FEASIBILITY STUDY

Figure No.

1.1

Title

Cape Dorset
Project Location Plan

2.0 DATA COLLECTION AND REVIEW

2.1 TOPOGRAPHY

Terrain has always played a significant role in wastewater treatment in the north and Cape Dorset is no exception. Cape Dorset is located at approximately 48 m above sea level and is surrounded by rocky hills that are several hundred metres high. As such, locating a flat surface suitable for a sewage lagoon is challenging. The 3-cell lagoon system was integrated into a natural drainage route sloping towards the north and Telik Inlet by constructing a stepped series of berms along the valley. The newer P-Lake sewage lagoon was constructed near the site of an existing lake and is contained in a valley with a berm joining the sides of the valley.

2.2 CLIMATE

According to Environment Canada (data collected between 1981 and 2010), Cape Dorset receives an average of 158 mm of rainfall per year (May to October) and 291 cm of snow per year (primarily between September and May). The 291 cm of snow is equivalent to approximately 261 mm of water. This amounts to an average of 419 mm (water equivalent) of annual precipitation.

Average temperatures in January and February are close to -25°C while the average temperature in July is 8°C. Average daily high temperatures range between 12°C in July to -22°C in February. The average temperature is above freezing for only four months of the year, between June and September. As such, the time available for biological treatment of wastewater in the lagoons is quite limited and typical of northern communities.

2.3 POPULATION PROJECTIONS

Population projections for Cape Dorset for the next 20 years (until 2034) were obtained from the Government of Nunavut Bureau of Statistics and summarized in **Table 2.1**.

Table 2.1 Cape Dorset Population Projections

Year	Projected Population	Year	Projected Population
2014	1,473	2025	1,726
2015	1,496	2026	1,747
2016	1,520	2027	1,768
2017	1,545	2028	1,788
2018	1,569	2029	1,808
2019	1,592	2030	1,829
2020	1,615	2031	1,852
2021	1,638	2032	1,874
2022	1,660	2033	1,896
2023	1,683	2034	1,919
2024	1,705		
Data from Government of Nunavut Bureau of Statistics: http://www.stats.gov.nu.ca/en/Population.aspx. Population projections were prepared by Nunavut Bureau of Statistics on August 16, 2010 (note July, 2014 data does not provide a projection).			

2.4 PREVIOUS REPORTS AND STUDIES

The following subsections provide a summary of the previous reports and studies that were reviewed to provide adequate background information for the current assignment.

2.4.1 Sewage Treatment Alternatives for the Hamlet of Cape Dorset, Nunavut (Dillon Consulting Ltd., August 2003)

The purpose of this study was to summarize the extensive work conducted to date regarding sewage treatment in Cape Dorset and to assess the options for long-term sewage treatment. The options assessed included a mechanical treatment plant (sequencing batch reactor) and the P-Lake Sewage Lagoon. A weight-of-evidence approach was used to assess both options. Criteria included operation and maintenance cost (25%), operation and maintenance cost uncertainty (15%), capital cost (20%), capital cost uncertainty (10%), regulatory environment (10%), process uncertainty (10%) and community acceptance (10%). The weight-of-evidence analysis resulted in the P-Lake Lagoon being considered the favorable option, mostly due to the lower operation and maintenance cost and less uncertainty in the operation and maintenance cost.

2.4.2 P Lake Area Sewage Lagoon System Final Design Report (Dillon Consulting Ltd., January 2006)

The purpose of this study was to calculate the required sewage lagoon size based on 20 year sewage generation projections and develop conceptual layout for the lagoon, site access road, lagoon outfall and overall site layout, and to assess the expected lagoon treatment. Cost analyses, a fish assessment in P-Lake and a geotechnical investigation were conducted as well.

The lagoon was sized to contain 96,100 m^3 of sewage, which was the forecasted annual sewage generation in Cape Dorset in 2026. To accomplish this, a 5 m berm was designed to include a 3.5 m operating depth, 0.5 m sludge depth and 1 m freeboard. The berm was designed to have 2.5:1 slopes, a 4 m wide flat top and low permeability bentonite/geotextile (Bentomat®) line placed vertically and keyed 2 m into the sub-base to prevent seepage through the berm. A truck turn-around pad and sewage discharge flume were designed for trucks to empty the sewage into the lagoon. A gravity discharge culvert through the berm with a valve was designed to allow for seasonal discharge of the treated sewage to the downstream terrain leading to Telik Inlet.

A geotechnical investigation was completed by AMEC as part of this study. The geotechnical investigation included a description of the assumed subsurface conditions based on field reconnaissance, geothermal modeling of the berm, assessment of available material borrow sites and recommendations for the liner positioning within the berm. No field drilling, slope stability analysis or seepage analysis was conducted for the design report. Instead, it was assumed that no seepage would occur through the incorporation of a geomembrane within a frozen core berm.

An access road was designed between the Hamlet and P Lake Sewage Lagoon for trucks to convey the sewage to the lagoon. The road was designed to suit and accommodate the terrain.

The entire system (road and lagoon) was estimated to cost approximately $3.2 Million including 10% for engineering, 20% for contingency and GST. The 20 year life cycle cost, including lagoon capital cost and sewage hauling, was estimated to be approximately $17.9 Million.

The lagoon was designed to meet the following effluent quality criteria:

- 45 mg/L BOD_5
- 45 mg/L suspended solids
- 10^4 Fecal Coliform / 100 mL

2.4.3 Cape Dorset Sewage Lagoon Water License Amendment – Geotechnical Review (BGC Engineering Inc., June 2006) – Memorandum

The purpose of this memorandum was to conduct a geotechnical review of the documents filed for an amendment application for Cape Dorset's water license. The P-Lake Sewage Lagoon Final Design Report, tender documents, construction contract and geotechnical investigation report were reviewed. BGC concluded that the submission for the water license amendment to the Nunavut Water Board (NWB) should be rejected due to shortcomings in the geotechnical aspects of the design, which are described in detail in the memorandum.

2.4.4 Geotechnical Investigation – Sewage Lagoon, Cape Dorset, NU (Dillon Consulting Ltd., November, 2006) – Memorandum

On behalf of Dillon Consulting Ltd., AMEC Earth and Environmental carried out a geotechnical drilling program at the Cape Dorset Sewage Lagoon site. The drilling was completed to assess the soil and permafrost conditions along the proposed berm alignment and at the lagoon to confirm assumed subsurface conditions used for the geothermal modeling and berm design completed in October 2005. 22 shallow boreholes and 2 test pits were completed. Bedrock was encountered at an average depth of 2 m and the thickness of the active layer (above permafrost) was found to be between 1.8 m and 2 m. It was concluded that the soil and permafrost conditions are in close agreement to the assumed conditions used in the geothermal modeling and berm design, and as such, seepage under the berm was considered unlikely.

2.4.5 Additional Geotechnical Analyses for P-Lake Sewage Lagoon (AMEC Earth and Environmental, August 2007)

This report contains a review of the geothermal conditions of the berm based on as-built information and subsurface conditions observed during installation of the cut-off trench construction. Slope stability analyses were conducted for the berm and road sections.

The geothermal analysis found that the berm core will freeze over the first few years and will remain frozen, even if climate warming continues as expected. However, it was recommended that a thermal monitoring program be initiated to confirm the findings of the geothermal analysis. It was concluded that seepage under the lagoon is very unlikely if the liner is installed in accordance with the design specifications. Because of the predicted freezing of the berm, a seepage analysis was not found to be necessary. No concerns regarding slope instabilities of the berms and road sections were found.

2.4.6 Additional Stability and Seepage Analysis for P-Lake Sewage Lagoon (AMEC Earth and Environmental, November 2007)

In preparation for a NWB public hearing, the stability of the upstream berm slope was assessed under rapid drawdown conditions and a seepage analysis was conducted assuming there are undetected holes in the liner.

The study concluded that the berm slopes are stable even if the frozen core is not developed and the liner was not installed. Seepage was estimated to be low (between 0.00033 m^3/s and 0.0000033 m^3/s) depending on the exact hydraulic conductivity of the berm material and the thickness of the active zone. Piping was not found to be an issue.

2.4.7 P Lake Area – Sewage Lagoon System Record Drawings (Dillon Consulting Ltd., November 2007)

Record drawings showing details of the lagoon and access road were reviewed as part of the current project.

2.4.8 Independent Geothermal Evaluation of Proposed Design (BCG Engineering, January 2008) – Memorandum

This report noted several shortcomings of the previous thermal analysis and conducted independent thermal modeling based on the as-built conditions. The analysis considered the effects of water seepage through the lagoon and long term climate warming. Despite results that show the berm core temperatures will be higher than those predicted by AMEC, the study concluded that the berm and lagoon sub-grade should remain sufficiently frozen to provide containment for a thirty year design life. The study also indicated that the integrity of the lagoon containment system would depend on the operation and management of the sewage (e.g. filling and emptying schedule).

2.4.9 CEAA Screening of the Cape Dorset Sewage Lagoon (Jacques Whitford AXYS Ltd., January 2008)

This report outlines the results of the environmental screening as required under the Canadian Environmental Assessment Act (CEAA). The report concluded that there were no significant negative impacts expected due of the P-Lake sewage lagoon and supporting infrastructure.

2.4.10 AMEC Geotechnical Engineer's Inspection Report to the New P-Lake Sewage Lagoon (AMEC Earth and Environmental, October, 2008)

Runoff entering the lagoon and subsequent observation that the lagoon berm was leaking (after the control discharge valve was closed) was the trigger for this investigation, which aimed at determining the cause of the leakage.

Two leakage concerns were noted: Firstly, runoff water was leaking through the road embankments and into the lagoon. At the time of inspection at the end of August, 2008, there was approximately 2 metres of water in the lagoon, after the control valve had been closed for since the end of July.

Secondly, leakage was observed at the toe of the main berm. It was believed that the water was penetrating under or through the unfrozen main berm. The report indicated that the accumulated runoff caused the berm core, assumed to be frozen from the thermal analysis, to prematurely thaw and this, in combination with the built up hydraulic head from the stored runoff water, caused the berm to leak. It was also hypothesized that the bentonite liner may be damaged or improperly sealed off in the cutoff trench.

The report concluded by stating that the berm would likely freeze after the second winter which would significantly reduce or eliminate the berm leakage. It was recommended to clear snow from the berm throughout the winter to promote the berm to freeze and to divert the runoff away from the lagoon. Installation of thermistors in monitoring wells was recommended to monitor berm core temperatures.

2.4.11 Temperature Data Review for Sewage Lagoon Dyke (AMEC Earth and Environmental, March 2010)

The purpose of this study was to review recorded temperature data inside the P-Lake lagoon berm and compare the data to the predicted temperatures developed during the design phase using geothermal analyses. The berm temperatures were monitored for approximately one year between November 2008 and December 2009. Three monitoring holes were installed in the main west berm and one in the smaller east berm. The study found that the active layer (i.e. susceptible to seasonal freeze-thaw cycles) was thicker than predicted by the geothermal models. The models predicted that the active layer would be approximately 2.7 metre thick while the measured temperatures indicated it was 3.85 metre thick one year after construction. This discrepancy was attributed to a warmer-than-average summer in 2009. Below 4.2 metre, the measured temperatures were generally cooler than the model predicted. Overall, the study concluded that the predicted and actual temperatures are in general agreement. The berm was in a frozen state in December 2009.

2.4.12 Cape Dorset Tracer Study Technical Report (Arktis Piusitippaa Inc., October 2011)

A dye tracer study was carried out to investigate the leakage through the lagoon berm. Leakage was visible at three locations along the main west berm. The Hamlet also indicated that leakage occurs through the east berm but the water level in the lagoon (from runoff water) at the time of inspection was too low to assess this leak. Significant leakage was identified through the main west berm. In addition, unknown inflow to the lagoon was noted. Although the source of the inflow is uncertain, it may be due to shallow groundwater inflow.

2.4.13 Cape Dorset Lagoon Thermistors (Naviq Consulting Inc., July 2013) – Memorandum

Thermistor data collected between 2008 and 2012 was reviewed from at least four locations at the P-Lake Lagoon, each to 18.8 m depth. Several issues related to data quality were discussed and it was noted that the questionable data quality renders the analyses suspect. At one location, deep seasonal thawing is expected to occur 9 metre below ground, while seasonal thawing to 4 metre was found at two locations. The depth of thawing was considered atypical for the Cape Dorset area and could be a sign of long-term permafrost degradation or may be occurring naturally due to the dry granular nature of the soils. The report noted that the deep seasonal thawing observed may indicate seepage through the containment structure.

2.4.14 Dam Safety Review (EXP Services Inc., August 2013) - Draft

This study suggested that the liner in the lagoon may have been damaged or is not installed properly (i.e. not sealed into the bedrock properly). As a result, seepage is occurring which renders the berm unstable given the 2.5:1 side slopes that are not adequate for a seepage berm. The report notes that the downstream side of the berm is susceptible to failure and recommends that the bentonite liner be removed and replaced with a proper installation.

The report also recommends the following related to the P-Lake Lagoon:

- Consider pumping as an alternative means of decanting the lagoon, instead of relying on the gravity discharge pipe that freezes.
- Remove backfill in the berm spillway; a steel plate could be used to facilitate vehicle travel instead of the backfill.
- Construct a second truck discharge pad and discharge chute.
- Replace malfunctioning thermistors or install new thermistors to 25 metre depth.
- Widen and lower the road around the lagoon to reduce safety concerns.
- Widen the access road at the hairpin turn and provide passing lanes at strategic locations.
- Provide lighting to the access road.

Overall, the study recommends that the P-Lake Lagoon not be used for wastewater storage and treatment until the identified safety issues are resolved.

2.5 FIELD VISIT

Stantec conducted a field visit to Cape Dorset on August 26 to 28, 2014. Ken Johnson (Stantec Project Manager) and Jim Oswell (Stantec Permafrost Engineer) attended the site visit along with Erin Mentink and Mattew Price from the GN.

The field visit included an inspection of the P-Lake Lagoon access road, service road and the lagoon itself. Issues such as the road alignment, grade, drainage and lagoon leakage were discussed. The lagoon discharge route west of the P-Lake Lagoon was also inspected including the lake, stream and wetland. Meetings with the Hamlet staff and Cape Dorset Council were also held.

More details about the community consultation conducted by Stantec are provided in **Section 4**. A detailed trip report, including photographs, is attached in **Appendix A**.

3.0 EXISTING CONDITIONS

3.1 TOWN SERVICING

Sewage collection in Cape Dorset is accomplished using eduction trucks that transport sewage from holding tanks to the sewage treatment facility. The community had intended on trucking the sewage to the P-Lake lagoon constructed in 2007 (see process description in **Section 3.2**). However, due to problems with the lagoon itself and the access to the lagoon (described in **Sections 3.3 and 3.4**), sewage is still being trucked to the 3-cell preliminary treatment system. As mentioned, the 3-cell system is a preliminary treatment facility, and subject to erosion issues due to the steep terrain and steep embankment construction.

Based on discussions with the Hamlet administration, approximately 10 truckloads of sewage are currently collected each day amounting to between 100 m^3 and 150 m^3 of sewage trucked per day. The Hamlet also reported that in 2003, 53 Million litres of water was used by the community which amounts to approximately 145 m^3 per day.

3.2 EXISTING P-LAKE LAGOON PROCESS

The existing uncommissioned sewage lagoon system operates as a single cell retention lagoon with a seasonal discharge; the anticipated effluent quality from the lagoon would be enhanced primary with a Biological Oxygen Demand (BOD5) / Total Suspended Solids (TSS) concentrations of less than 100 milligrams/litre (mg/L). The performance of the system would ultimately be influenced by the weather in any given summer season.

The seasonal discharge is generally scheduled for late summer or early fall to take advantage of the treatment available with sunlight, and warmer temperatures during the summer months. Treatment would be limited to sedimentation during the fall, winter and spring.

The seasonal discharge from the lagoon was designed to occur through a valve controlled gravity pipeline through the retention berm structure. The discharge would travel through two lakes (larger of the two referred to a P Lake); the lakes are separated by a minor "wetland" area. The effluent would discharge from the second lake into a small stream that flows into a rock fall area that falls steeply at a 2 to 1 slope (on average) for approximately 60 metres vertically to an area with a slope of 4 to 1 (on average) in the final 130 metres (horizontal distance) before ultimately discharging into the ocean. The effluent becomes a subsurface flow at the top of the rockfall area and appears to resurfaces near the ocean.

For the purposes of the "regulation" of the wastewater treatment process, the discharge from the retention of lagoon is considered the point of effluent monitoring. The additional supplementary processes associated with retention in P Lake and the second lake, the minor wetland area, and the subsurface flow are not considered to be part of the treatment processes.

The earth structures constructed as part of the retention lagoon were intended to provide a low permeable earth structure. The low permeability structure was created with a seepage barrier consisting of a geosynthetic clay liner, embedded 2 metres into native materials in a cut-off trench.

3.3 P-LAKE LAGOON ISSUES

Several problems have occurred with the P-Lake lagoon since its construction in 2007 as summarized on **Figure 3.1**. As a result, the Hamlet has not used the lagoon and continues to use the 3-cell terraced lagoon system. The Hamlet has reported the following problems with the P-Lake lagoon, many of which are documented in other reports summarized in **Section 2.4**:

- Prior to commissioning a minor concentrated flow at the toe of retention berm was observed; a dye tracer study confirmed that the seepage was originating from the retention pond.
- Community has express concerns about potential seepage out of the east side of the lagoon (i.e. towards the town).
- Seasonal thawing of the berm occurs which may contribute to the seepage observed.
- Lagoon drawdown pipe and control valve are susceptible to freezing.
- Inundation by storm runoff and spring snowmelt reduces lagoon and treatment capacity.
- Water in the active layer may also inundate the lagoon and reduce available storage.
- Wind dispersion of sewage may occur at the sewage discharge chute and truck turn-around area due to the orientation of the discharge chute relative to the dominant wind direction.

The regulators have also expressed concern about a number of non-compliance issues associated with the retention lagoon. The specific concerns include the minor concentrated flow at the toe of the retention berm, and the performance of the freeze back of the retention berm. The regulators have noted that the compliance planning for these and other issues associated with the retention lagoon is incomplete.

In addition, the Hamlet has expressed concerns about suspected seepage from the P-Lake Sewage Lagoon towards the T-Lake potable water supply located approximately 1 km southeast of the P-Lake lagoon. However, T-Lake is approximately 20 m above the P-Lake lagoon so it can be concluded from a hydraulic perspective that sewage in P-Lake will not flow toward T-Lake.

3.4 ACCESS ISSUES TO P-LAKE LAGOON

Separate from the performance issues related to the P-Lake Lagoon, there are major concerns associated with the access road to the lagoon. The gravel access road constructed in 2007 is aligned to include one switchback to navigate the 50 metre difference in elevation between the lagoon site and the previous end of the existing roadway closest to the lagoon. With approximately 10 truckloads of sewage being hauled each day, the issues identified have resulted in operational and safety concerns for the truck drivers. The Hamlet has reported the following problems with the access road:

- Road is too steep and narrow and has an unsafe hairpin turn; trucks are likely to slide while driving up or down the incline.
- Erosion of the road is occurring during spring melt.
- Extensive snow accumulation and drifting occurs over the road in winter.
- Visibility along the road is poor at times after dark.

In addition to the access road, the safety of the service road around the lagoon has been questioned due to steep slopes at the southeast section and erosion caused by spring runoff.

Many of the aforementioned road issues are noted on **Figure 3.1**.

3.5 HYDROLOGIC ANALYSIS

A basic hydrologic analysis was completed to estimate the amount of precipitation that may enter the P-Lake lagoon because of rainfall runoff and snowmelt. Based on the topography of the two hillsides on each side of the lagoon, there is approximate 4.8 ha around the lagoon that contributes runoff and snow melt towards the lagoon (see **Figure 3.2**; not including the 3.3 ha area of the lagoon itself as estimated by the area inside the perimeter service road). Due to the steep and rocky terrain around the lagoon, it is assumed that little runoff and snowmelt will infiltrate and that most will flow towards the lagoon. For this reason, a runoff coefficient of 80% was selected. Based on observations during the site visit and discussions with the Hamlet, the drainage ditches surrounding access road around the lake are somewhat ineffective; hence, it is assumed that 50% of the flow towards the lagoon enters the lagoon while the remaining 50% is diverted away from the lagoon by the ditch system.

Based on these assumptions, the average annual volume of precipitation (from snowmelt and rainfall runoff) entering the P-Lake lagoon can be estimated:

Inundation = (48,000 m^2 contributing area) x (0.419 m annual precip.) x (0.8 runoff coefficient) x (0.5 fraction entering lagoon) = **8,049 m^3**

Furthermore, it is assumed that all precipitation falling on the lagoon itself (inside of the perimeter service road) will enter the lagoon:

Inundation = (33,000 m^2 contributing area) x (0.419 m annual precip.) = **13,827 m^3**

Total Annual Precipitation Entering Lagoon = 8,049 m^3 + 13,827 m^3 = **21,876 m^3**

Approximately 22,000 m^3 of snowmelt and rainfall runoff may enter the P-Lake lagoon each year that represents approximately 23% of the total lagoon design volume of 96,100 m^3. This should be accounted for when considering the capacity of the lagoon to accommodate future sewage demands.

Additional inflows, potentially from shallow groundwater, have been noted, particularly in the 2011 Tracer Study conducted by Arktis Piusitippaa Inc. in September of 2011. Any groundwater inflows would be in addition to the surface runoff and would further reduce the capacity of the lagoon for wastewater.

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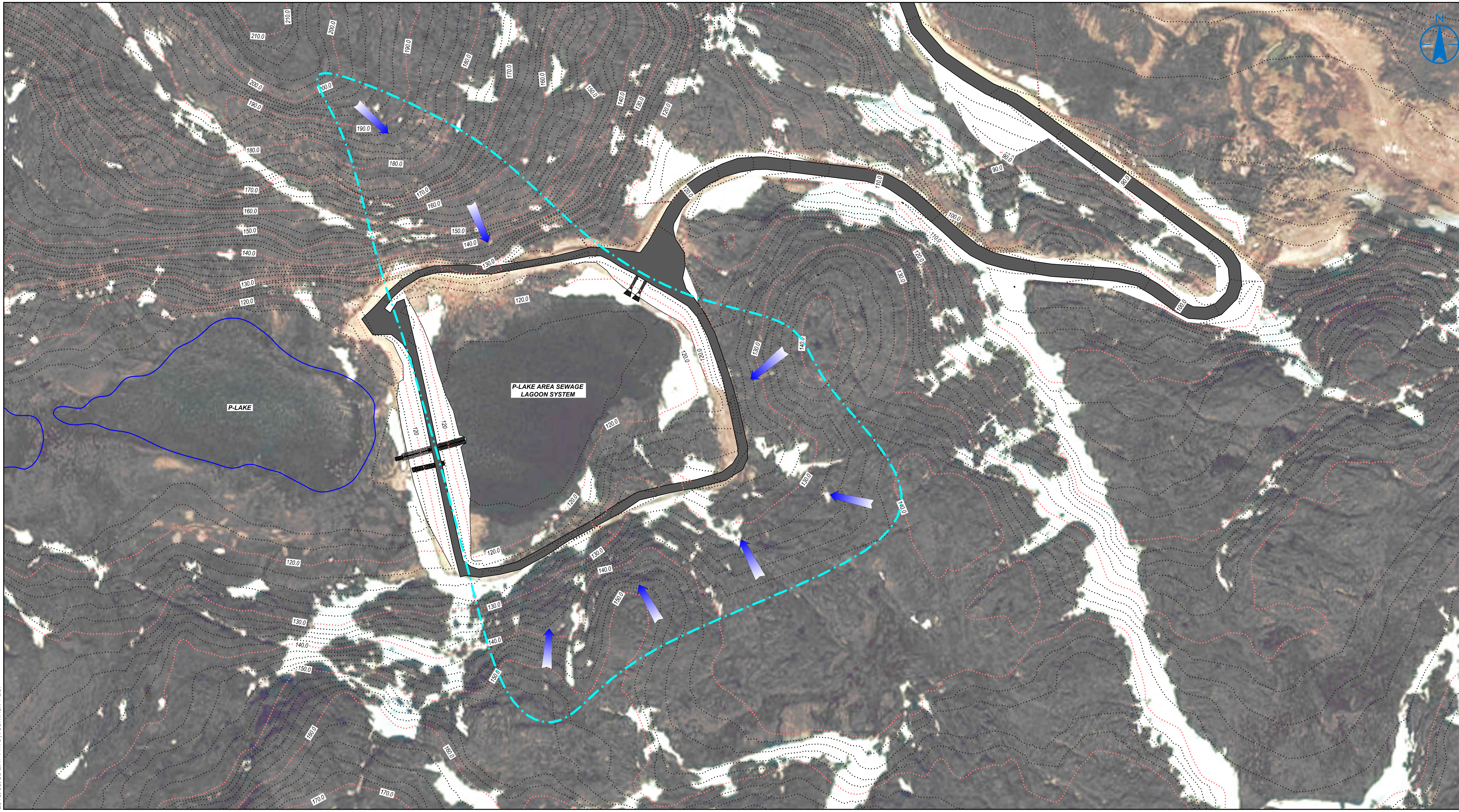
CAPE DORSET SEWAGE LAGOON FEASIBILITY STUDY

Figure No.
3.1

Title
P-Lake Sewage Lagoon
Site Plan



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Legend

Contributing Area Boundary (8.06 ha) to P-Lake Sewage Lagoon

Surface Runoff Flow Direction

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Figure No.

3.2

Title

P-Lake Sewage Lagoon
Contributing Surface Runoff Area

4.0 COMMUNITY CONSULTATION

During the field visit to Cape Dorset, discussions were completed with Hamlet Staff and with Hamlet Council. Documentation of those discussions is found in **Appendix A** with the field visit reports. A summary of those discussions is provided below.

Community consultation for this project is an important aspect to understanding the problems faced by the Hamlet in utilizing the P-Lake Lagoon and the opinions of Hamlet staff that have to deal with these problems on a regular basis. Where possible, input from the community has been addressed or implemented into the solutions proposed to improve the P-Lake sewage lagoon and access road.

4.1 HAMLET STAFF DISCUSSION

Based on discussions with Cape Dorset's Foreman and Senior Administrative Officer, the following feedback and information was noted:

- There is a concern that sewage trucks might slide backwards going up the lagoon access road in the winter. The steep grade is a concern.
- The road leading to the lagoon is providing easier access to the water supply at Tee Lake.
- Staff provided several alternative road alignments for Stantec to consider in the review.
- The waterline from Tee Lake is freezing two to three times per year in spite of heat tracing (not related to P-Lake lagoon).
- The ditch along the south side of the access road has insufficient capacity for spring snowmelt.
- The lagoon is leaking from both the east and west berms.
- The discharge manhole fills up with water.
- Approximately 10 truckloads of sewage are collected per day, amounting to between 100,000 and 150,000 litres of sewage per day. In 2003, 53 Million litres of water was used by Cape Dorset.

4.2 HAMLET COUNCIL DISCUSSION

Based on discussions with Cape Dorset's Hamlet Council, the following feedback and information was noted:

- More studies on the lagoon are needed, especially to address concerns that seepage may occur between the lagoon and the water supply lake.
- Water monitoring may be required near the community to assess suspected seepage towards the east through the berm near the truck discharge point (there are sampling wells near the landfill).
- It was suggested that a mechanical treatment system could be purchased for between $500,000 and $600,000.

- There is a suspected leak in the geomembrane liner at the west berm.
- The discharge pipe freezes easily; it was noted that pumping is used to discharge most lagoons in Nunavut.
- It was noted that there are sampling well sites at the lagoon.
- Council suggested that a new lagoon could be constructed near the existing sewage lagoon system or near the airport (subsequently it was noted that this site would be too close to the emergency water supply lake).
- Council feels that the access road to the lagoon is "an accident waiting to happen".
- Snow drifting is an issue along the access road (wind monitoring data is available at Tee Lake).
- A sewage lift station could be an alternative to trucking sewage to the lagoon.

5.0 DESIGN CRITERIA

5.1 DESIGN HORIZON

The project design horizon will be 20 years (2014 until 2034).

5.2 DESIGN CRITERIA

Criteria used to develop, compare and evaluate upgrade options include:

- Cost
- Community acceptance
- Regulatory acceptance
- Constructability
- Operation and maintenance requirements
- Existing guidelines and standards
- Safety

5.3 SEWAGE GENERATION RATES

Current sewage generation can be measured based on the daily truck dumping. Based on discussions with the Hamlet, maximum daily discharge is 10 trucks (each 3,500 U.S gallon or 15,000 litres), totaling 150,000 litres (150 m^3) per day. The Hamlet has also indicated that 53 million litres of water used in 2003 by the community that amounts to approximately 145 m^3 per day.

Considering 150 m^3/day and the current population of 1,473, the sewage generation per capita would be approximately 102 L/c/day.

Government of Nunavut Bureau of Statistics population projections have been used to forecast sewage generation rates for the next 20 years, until 2034. **Table 5.1** summarizes the forecasted sewage generation rates. The formula used to estimate daily sewage generation per capita results in higher sewage generation rates compared to the current sewage generation rate (102 L/c/day) but will result in a conservative estimate for the lifespan of the sewage lagoon.

Table 5.1 Cape Dorset Sewage Generation Rates

Year	Projected Population[A]	Daily Sewage Generation (L)	Annual Sewage Generation (m^3)[B]
2014	1,473	177,500	64,800
2015	1,496	181,000	66,100
2016	1,520	184,600	67,400
2017	1,545	188,500	68,800
2018	1,569	192,200	70,200
2019	1,592	195,700	71,400
2020	1,615	199,300	72,700
2021	1,638	203,000	74,100
2022	1,660	206,400	75,300
2023	1,683	210,100	76,700
2024	1,705	213,600	78,000
2025	1,726	217,000	79,200
2026	1,747	220,400	80,400
2027	1,768	223,800	81,700
2028	1,788	227,100	82,900
2029	1,808	230,400	84,100
2030	1,829	233,900	85,400
2031	1,852	237,700	86,800
2032	1,874	241,400	88,100
2033	1,896	245,100	89,500
2034	1,919	248,900	90,800

Notes:
A – Population forecast from Government of Nunavut Bureau of Statistics:
http://www.stats.gov.nu.ca/en/Population.aspx
B – Sewage generation estimated using the formula:
Water Consumption (L/d/capita) = 90 x (1 + 0.00023 x population) – Reference: Department of Municipal and Community Affairs, Government of the Northwest Territories.

5.4 ASSESSMENT OF LAGOON CAPACITY

The design capacity of the P-Lake sewage Lagoon is 96,100 m^3. Based on as-built topography data available, the lagoon volume is approximately 88,000 m^3 including 1 m of freeboard (volume to the top of berm is approximately 115,000 m^3). These volumes are estimates only and would need to be confirmed with a detailed field survey. For this analysis, it will be assumed that 96,100 m^3 of storage is available in the lagoon.

Based on **Table 5.1** and the assumed lagoon capacity of 96,100 m^3, the lagoon will have capacity until beyond 2034 assuming that most of the lagoon storage is available for wastewater.

However, inundation by runoff and snowmelt will reduce the available capacity. Currently, it is estimated that approximately 22,000 m^3 of snowmelt and rainfall runoff may enter the P-Lake Lagoon each year (refer to **Section 3.5** for assumptions and calculations). Therefore, without improvement to the drainage surrounding the lagoon, only 74,100 m^3 of storage may be available annually. In this case, the lagoon capacity will be exceeded by 2022 (however, lagoon lifespan will be somewhat longer if per capita sewage generation is less than forecast, which is possible given the estimated current per capita generation rate of 102 L/d/capita). The significant reduction in lagoon capacity from runoff and snowmelt entering the lagoon by seeping through the service road embankments is justification for the need to reduce this inundation.

The amount of inundation from groundwater, if any, is uncertain. The tracer study conducted in 2011 noted inflow from an unknown source (presumable during dry weather). This could have been from groundwater or it could have been from water percolating through the subsurface as a direct result of recent precipitation (in which case it would be accounted for the hydrologic analysis summarized above).

6.0 SEWAGE TREATMENT LAGOON IMPROVEMENTS

As noted in **Sections 3.3 and 3.4**, the P-Lake Lagoon has not been used for wastewater storage and treatment for two main reasons: Firstly, the lagoon itself has issues associate with seepage through the berms and inundation by runoff and snowmelt (and perhaps groundwater). Secondly, access to the lagoon using the road constructed in 2007 is not considered safe, especially in winter when the hairpin turn and severe snow drifting render the road nearly impassible by sewage trucks.

Therefore, two primary problems need to be rectified:

1. The lagoon must be improved so that it meets functional requirements in terms of available storage, retention and treatment.
2. Wastewater must be able to be conveyed to the lagoon in a safe and efficient manner.

As such, the proposed improvements have been categorized into Sewage Treatment Lagoon Improvements (this section) and Sewage Transfer Improvements (**Section 7.0**).

There are several options to improve treatment in the P-Lake Sewage Lagoon:

1. Repair leak in the berm (primarily the west berm where seepage is visible). There are several alternatives to attempt to stop the seepage.
2. Construct secondary cell downstream of the existing P-Lake lagoon (i.e. construct a two cell system; this option may also increase the total capacity of the lagoon system).

In addition to these primary options, the Hamlet may also consider improvements to reduce the volume of runoff and snowmelt that enter the lagoon, thus increasing the existing lagoon capacity for sewage treatment. Problems with the existing decanting structure should also be addressed.

6.1 BERM LEAK REPAIR

6.1.1 Existing Berm

The sewage lagoon is contained by a man-made containment berm along the west and northeast sides of the lagoon area. Natural topography provides containment on the other sides. The west berm characteristics and design features are understood to be as follows:

- Crest Length: 170 metres (approximately)
- Crest width: 3 to 4 metres (estimated)
- Base width: 18 metres (approximately)
- Berm height: 5 metres
- Berm construction: Type II granular (sand and gravel) fill

- Berm slopes: 2:5H:1V upstream and downstream
- Seepage barrier: Geosynthetic clay liner, embedded 2 metres into native materials in a cut-off trench
- Lagoon discharge: Via a 300 mm pipe through the base of the berm with a control valve (and access vault) through the downstream berm section

Several multi-bead thermistor cables are installed within the berm structures to provide ground temperature data.

It is understood that the containment berms were construction in 2007, but the lagoon has never been commissioned or filled due to performance issues with the west containment berm. Seepage was visible from the west berm during the site visit completed in August 2014. The seepage appeared to be at the interface between the berm structure and the native ground. However, Government of Nunavut personnel have reported (refer to Dam Safety Review by EXP Services Inc., 2013) that seepage was also observed from the containment structure during the spring snowmelt when the water depth is greater in the pond on the upstream side of the berm. Part of the geosynthetic clay liner that is supposed to provide sewage containment was observed on the crest of the berm during the August 2014 site visit.

6.1.2 Existing Berm Integrity

At this time, it is not possible to determine if, and to what extent, the continuous leak compromises the integrity of the existing berm because the lagoon has never been filled with sewage. Berm integrity may not be compromised if the leakage is limited to the toe of the berm (i.e. between the berm and native ground interface). However, if there is seepage higher up on the berm, there will be higher water pressure within the berm and this can compromise the slope stability of the downstream side of the berm.

6.1.3 Thermistor Data Analysis

Ground temperature data measured using four thermistors over the period of October 2013 to August 2014 was reviewed. The thermistor data is found in **Appendix B**. The following comments pertain to these data:

- The trumpet curves for the period October 2013 to August 2014 appear to be “well behaved” and consistent.
- From all four installations, the inferred mean annual ground temperature (MAGT) is about -3 °C.
- The majority of the ground profile is frozen throughout the year at each of these thermistor installations.
- The active layer is about 3 metres. This value is considered high for this latitude, but considering the nature of the soil (relatively dry granular soils within the lagoon containment structure), this may well be reasonable.

The active layer, estimated to be approximately 3 metres depth using the 2013-2014 thermistor data, is relatively consistent with the findings of AMEC in their March 2010 memorandum (see **Section 2.4.11**). Based on thermistor data between November 2008 and December 2009, they found the active layer was about 3.85 metres. This is greater than expected (models indicated an active layer of 2.7 metres depth), but was attributed to a warmer-than-usual summer in 2009. Thus, the 3 metre estimate based on the 2013-2014 data appears to be reasonable.

6.1.4 Berm Leakage Repair Options

The following conceptual strategies have been developed to address the leakage of the west berm (could also be applied to the northeast berm if leakage is confirmed at that location):

- Sealing leak by placement of bentonite powder in seepage path.
- Installation of vertical curtain wall to impermeable layer at depth.
- Reconstruct entire berm.
- Natural sealing of seepage by effluent

Sealing Leaks using Bentonite

In this option, a quantity of bentonite powder is released into the upstream pond in the vicinity where the seepage is believed to be originating. The concept would be that the bentonite would migrate into the containment structure, carried by the hydraulic head of the seeping water. Once inside the containment structure the bentonite would hydrate, expand and plug the seepage pathways.

The primary advantages of this option is that it is relatively inexpensive to implement and requires little or no specialized equipment or trained personnel (bentonite is understood to be a low level health hazard, addressed with minimal personal protective equipment).

The primary unknowns for this option are whether the bentonite would hydrate before being carried into the seepage channels within the containment berm (if hydration did not occur upstream or within the seepage channels then a seal may not be provided) and the uncertain effects of the hydraulic gradient on the bentonite-sealed seepage pathways. That is, if the seepage pathways were sealed under conditions of a low hydraulic gradient, would they remain sealed if the water level on the upstream side of the containment structure were raised to operational levels?

In addition, if as reported there are additional seepage pathways within the containment structure then an incremental program of adding bentonite powder may be needed as the lagoon fills and lower elevation seepage pathways are sealed. It is recommended that bentonite be added in increments and assess whether leakage is slowing down or stopping; measures should be taken to prevent the scenario where the leakage is stopped and the lagoon is filled with a water/bentonite mixture (bentonite is not likely to settle before seasonal discharge).

The cost of 2000 kg of bentonite powder is in the order of $250, FOB supplier. Therefore, the cost of this option will be nominal and the option could be implemented in the open water season of 2015. A budget allocation of $25,000 may be appropriate for this method to include the bentonite and the time to apply the bentonite and monitor the results.

There is no assurance that this scheme will achieve the desired results. If the leak is not sealed, there remains a risk of berm failure if the lagoon is filled and seepage occurs through the berm because the berm was not been designed as a seepage berm (see **Section 6.1.2**). There may also be regulatory issues associated with discharging the bentonite-water mixture at the end of the summer.

Installation of Vertical Curtain

This option covers a number of similar schemes to provide a vertical barrier to water seepage. Potential schemes include the following:

- Trenched liner or synthetic clay liner
- Slurry trench wall
- Jet/pressure grouting
- Sheet pile cut-off wall

The most important aspect of this option is the need to ensure that a good seal is provided at an impermeable layer at depth. As the current seepage is suspected as occurring along the interface between the containment structure and the native subgrade, excavation into the native subgrade to some depth to form a cut-off is considered critical. This may require physical excavation into the native subgrade to construct a cut-off trench.

For the trenched liner or slurry trench wall a relatively narrow trench is excavated through the containment structure and into the underlying bedrock or permafrost soils. The trench is then backfilled with a liner or bentonite slurry that would provide an impermeable barrier to water migration.

Jet/pressure grouting is a technique where an injection nozzle is inserted into the ground, either through driving or drilling and at the desired depth a bentonite and/or cementitious grout is injected under high pressure. The injection nozzle is slowly withdrawn upwards forming a vertical impermeable column. The injection nozzle is then re-inserted a short distance away and the procedure repeated until a continuous barrier wall is formed. Some methods include cutting and mixing tips so the grout is mixed with the native soils at depth.

A sheet pile wall may be a more practical alternative to the slurry or liner curtain. Only a minimal depth of excavation is needed to seal the sheet piles. Sheet piles may be either steel or synthetic materials. The potential issue with sheet piles is to ensure an adequate seal at the base of the wall within the native soils is achieved.

This option is of moderate to high expense, likely in the $1 to $5 million dollar order of magnitude cost. It may require specialized equipment and experienced personnel. Given the potential depth of the excavation (6 m or more), trench wall shoring will likely be required.

Containment Berm Reconstruction

The only assured option for providing a sealed containment structure is to reconstruct the entire containment structure. This option would require the following tasks:

- Excavation and stockpiling of the majority of the containment berm,
- Exposure of the native subgrade,
- Sealing of the subgrade. This may include pressure grouting, construction of a key trench or other means,
- Re-construction of the containment berm including a vertical seepage barrier.

The cost of this option (see **Table 6.1**) will exceed the cost of the original construction by a significant amount as the containment structure material will have to be handled several times during excavation and replacement. Construction in sections along the length of the structure may be feasible.

Table 6.1 Opinion of Probable Cost for Reconstruction of Containment Berm

Description	Units	Quantity	Unit Cost	Estimated Cost
Mobilization and Demobilization	Lump sum	1	$500,000	$500,000
Excavate and stockpile berm material	m^3	15,000	$75	$1,125,000
Rebuild berm (incl. vertical seepage barrier)	m^3	15,000	$125	$1,875,000
Spillway	Lump sum	1	$30,000	$30,000
Decant System	Lump sum	1	$135,000	$135,000
Contingency (40%)				$1,466,000
Total				**$5,131,000**

Natural Sealing of Leaks by Effluent

The final mitigation option is similar to the leak sealing using bentonite but that the suspended solids in the in the sewage would be eventually seal the berm leaks. The solids may be carried into the berm structure by the seeping water under hydraulic head and could conceivably plug small seepage pathways, eventually forming an impermeable structure.

The primary advantage of this option is the cost. There is no direct cost associated with this option as it involves gradual plugging of the berm leak over time by particles that are inherence to the effluent discharge from the lagoon. There are several potential indirect or consequential costs as discussed below, relative to disadvantages.

There are a number of disadvantages and challenges associated with this option. The first challenge may be the acceptability by regulatory agencies, as this option requires discharge of sewage into the lagoon with a leaking containment structure. The second challenge is the potential for a release of effluent through the berm (similar to the bentonite seal option, the effectiveness of this sealing option is impossible to predict). If the natural sealing and blockage of seepage paths does not occur, poorly treated effluent would migrate into the ponds downstream of the sewage lagoon. There is also risk of berm failure if the berm continues to leak when the lagoon is full; the berm was not designed as a seepage berm.

6.2 CONSTRUCTION OF SECONDARY TREATMENT CELL

A retention lagoon with a seasonal discharge at the end of the summer has the potential to treat wastewater in a northern community. However, various references recommend multiple detention/ retention cells for improved effluent quality. A recent presentation by a PhD student from Dalhousie University (Colin Ragush at the NTWWA Conference on November 15, 2014) stated that existing one cell Waste Stabilization Ponds (WSP) cannot solely be depended upon in the far north to meet the Wastewater Systems Effluent Regulations (WSER) established by the CCME waste harmonization project.

A multiple cell reconfiguration for the Cape Dorset sewage lagoon will improve the effluent quality from the system. A multiple cell configuration may produce an enhanced primary effluent quality in the range of 50 mg/L BOD5 / TSS. The performance of the system would ultimately be influenced by the weather in any given summer season.

A configuration for this system is presented on **Figure 6.1** and a process sketch is provided in **Appendix C**. The reconfiguration employs a new secondary lagoon constructed at the end of P Lake. The retention berm associated with this reconfiguration would be constructed from the berm structure on the existing lagoon, reducing the volume of the lagoon and developing a primary cell for the system. As excavation of the existing berm proceeds (i.e. to obtain material for the new berm), both the existing geosynthetic liner and access vault will be encountered. The access vault can be cut as excavation proceeds and the remaining vault filled in to the top of the reconfigured berm (the access vault will no longer be needed when the existing berm is reconfigured to be an overflow berm). The geosynthetic liner will be destroyed during excavation but this will not interfere with berm excavation as the liner does not have any "strength" associated with it, unlike other plastic-type geotechnical liners.

The capacity for the system would be provided from the volume of both cells. The construction of a secondary cell also provides an opportunity to increase the overall capacity of the lagoon system, addressing the capacity concerns that the Hamlet has (which are justified based on the amount of runoff and snowmelt that may enter the lagoon).

The new primary cell would operate as a continuous overflow system once the cell is filled. A seasonal pumped discharge would occur from the secondary cell, and this would coincident with a simultaneous pumped discharge from the primary cell to draw down the primary cell at the end of the discharge period.

This reconfiguration would be implemented to eliminate the need to repair the leak in the existing retention cell, because it would be operating as a continuous discharge cell. A review of the performance of the reconfigured berm under seepage conditions would be completed during the design of this reconfiguration to assure that the reconfigured berm would be stable. The slope of the reconfigured lagoon may require a slope adjustment to accommodate a stable condition for flow through the berm. It should be noted that the existing berm is not designed as a seepage berm.

Further effluent quality improvements may be achieved with the consideration of the compliance point for the facility operation. The secondary cell discharges into a minor overland flow system followed by infiltration flow area, and an infiltration / overland flow area. These elements will provide supplemental treatment to the effluent discharge. The inclusion of these treatment enhancements would require redefining of the compliance point in the water licence.

A class D opinion of the probable cost of the reconfiguration is $3.7 Million as shown in **Table 6.2**.

Table 6.2 Opinion of Probable Cost for Secondary Treatment Cell

Description	Units	Quantity	Unit Cost	Estimated Cost
Mobilization and Demobilization	Lump sum	1	$500,000	$500,000
New Access Road	m	300	$250	$75,000
Existing Access Improvement	m	350	$300	$105,000
Truck Turnaround	Lump sum	1	$20,000	$20,000
Retention Berm (Borrow from existing)	m^3	7,000	$125	$875,000
Retention Berm (Borrow from pit)	m^3	1,500	$150	$225,000
Detention Berm	m	40	$10,000	$400,000
Pond Spillway	Lump sum	2	$30,000	$60,000
Decant Systems	Lump sum	2	$135,000	$270,000
Overland Flow Development	Lump sum	1	$100,000	$100,000
Contingency (40%)				$1,052,000
Total				**$3,682,000**

6.3 RUNOFF/SNOWMELT INUNDATION

As discussed in **Section 3.4**, a significant volume (estimated to be 22,000 m^3) may enter the P-Lake Lagoon each year from rainfall runoff and snowmelt, including approximately 8,000 m^3 from the area outside of the perimeter service road. To maximize the available capacity of the lagoon for sewage retention and treatment, the measures should be taken to reduce the volume of runoff and snowmelt that enters the lagoon. A ditch has been constructed outside of the service road that surrounds the lagoon that is designed to collect the runoff and snowmelt and divert most of it around the lagoon. However, it has been reported that some runoff/snowmelt travels through the road embankment and into the lagoon, likely because of the somewhat porous granular material from which the road embankment is constructed. In addition, erosion of the service road around the lagoon has been reported.

Due to the natural topography around the lagoon, managing runoff and snowmelt is difficult and it is not possible to eliminate runoff and snowmelt from entering the lagoon. Options to reduce the amount of runoff and snowmelt entering the lagoon include:

- Minor ditch regrading and cleaning (where required)
- Lining the bottom of the ditch and outside road embankment with a low permeability material such as concrete or clay to reduce the amount of water seeping through the road embankment into the lagoon
- Installation of a half culvert above the roadway or within the ditch to collect and divert runoff/snowmelt
- Construction of a runoff diversion wall on the hillsides above the service road

6.3.1 Ditch Regrading and Cleaning

It is recommended that the ditch outside of the access road be inspected to ensure it is properly graded to promote the diversion of runoff and snowmelt around the lagoon. Flat or negatively sloped sections should be positively graded, where possible, and any large obstructions such as boulders should be removed from the ditch. Improving runoff/snowmelt diversion should also reduce erosion of the service road. The cost of this option depends on the existing condition of the ditch and how much grading is required, but should be relatively inexpensive. The opinion of probable cost is $100,000 for initial cleaning and grading and then a small amount (~$5,000) should be budgeted on an annual basis for ditch cleaning and minor repairs.

6.3.2 Ditch Lining

Lining the ditch and outside road embankment with clay may not be feasible as the clay would need to be imported, which will be expensive. Concrete or plastic (e.g. PVC) may be a better solution, and it could be used only along sections of the ditch/service road where seepage is occurring to keep the cost reasonable. In this case, the cost will depend on the amount of concrete or plastic required.

6.3.3 Half Culvert

A half culvert installed on the surface in the hillside just above the service road or within the ditch will collect runoff and snowmelt and divert it around the lagoon. The steel culvert would be virtually impermeable (assuming good joint connections) so this option would behave in a similar manner to ditch lining discussed above. This option may be relatively inexpensive to construct. However, there are several disadvantages including the possibility of granular material blocking the culvert and the likelihood that freeze-thaw cycles could damage the culvert and joints.

6.3.4 Diversion Wall

Construction of a runoff diversion wall along the hillsides above the service road is likely to be expensive, difficult to construct and maintain and may provide limited benefit unless an adequate seal between the wall and native (rocky and rough) subgrade is achieved.

6.4 DECANTING STRUCTURE IMPROVEMENTS

Freezing of the discharge pipe and control valve has been reported, which could cause problems during annual decanting of the lagoon. Options to rectify this problem include:

- Heat tracing the discharge pipe and control valve enclosure
- Using a pump to decant the lagoon

6.4.1 Heat Tracing

Heat tracing could be installed on the decanting pipe and valve chamber. Installing the heat traced pipe and chamber would require the existing pipe and access manhole to be excavated and new ones installed. A permanent power supply would also be required. Heat tracing has caused issues on the Tee Lake water supply pipe due to a lack of preventative maintenance. In general, heat tracing does require preventative maintenance and is susceptible to fail if not properly maintained. The cost of this option would be large if it is necessary to bring a power supply to the west end of the lagoon to continually power the heat trace.

Alternatively, the heat tracing could be permanently installed (for approximately $50,000) but only turned on before lagoon decanting, and therefore could be powered by a generator. In this case, it is uncertain whether the heat tracing will be able to thaw the frozen pipe sufficiently to allow the lagoon to discharge.

For these reasons, heat tracing is not recommended.

6.4.2 Pumping

The existing discharge pipe could be grouted closed and a pumping system used to decant the lagoon. Since the lagoon only needs to be decanted once per year, the pump could stored in the Hamlet and moved to the west berm only during decanting. A gas powered pump can be used or a generator can be used to run the pump during decanting. A pump capable of 80 L/s can drawdown the entire lagoon volume (96,100 m^3) in two weeks. A pump capable of 53 L/s can drawdown the lagoon in three weeks. Such a pump can be purchased for approximately $135,000. The opinion of probable cost for operating the pump system to drawdown the lagoon is $5,000 per year.

6.5 COMPARISON OF OPTIONS

The options for lagoon improvements have been compared based on several criteria as shown in **Tables 6.3 to 6.5**.

Table 6.3 Comparison of Lagoon Improvement Options (to address Berm Leakage and Treatment)

Criteria	Repair Berm				Construct Secondary Treatment Cell
	Seal Berm with Bentonite	**Install Vertical Curtain**	**Containment Berm Reconstruction**	**Natural Sealing of Leaks by Effluent**	
Capital Cost	$25,000 (Lowest Cost)	$1,000,000 to $5,000,000	$5,100,000 (Highest)	$0 (Lowest)	$3,700,000
Operation and Maintenance Cost (See **Appendix F** for details)	$25,000 for single cell lagoon O&M	$25,000 for single cell lagoon O&M	$25,000 for single cell lagoon O&M	$25,000 for single cell lagoon O&M	$36,000 for two cell lagoon O&M
Service Life	Lagoon will have capacity beyond 2034 if no runoff/snowmelt inundation. Lagoon capacity may be exceeded much sooner (estimated by 2022) given uncontrolled snowmelt/runoff inundation.	Lagoon will have capacity beyond 2034 if no runoff/snowmelt inundation. Lagoon capacity may be exceeded much sooner (estimated by 2022) given uncontrolled snowmelt/runoff inundation.	Lagoon will have capacity beyond 2034 if no runoff/snowmelt inundation. Lagoon capacity may be exceeded much sooner (estimated by 2022) given uncontrolled snowmelt/runoff inundation.	Lagoon will have capacity beyond 2034 if no runoff/snowmelt inundation. Lagoon capacity may be exceeded much sooner (estimated by 2022) given uncontrolled snowmelt/runoff inundation.	Size of secondary treatment cell can be designed for a service life of at least 20 years.
Regulatory Acceptance	Unknown if this will be acceptable (unproven technique)	Acceptable	Acceptable	Unknown if this will be acceptable (unproven technique)	Acceptable
Environmental Risk	Highest risk: risk that berm will continue to leak and could fail	Existing leak should be fixed but risk of future berm leakage	Existing leak should be fixed but risk of future berm leakage	Highest risk: risk that berm will continue to leak and could fail	Lowest risk: Additional berm provides redundancy and reduces risk of leak
Treatment Performance	Single cell – enhanced primary - BOD5 / TSS of less than 100 mg/L	Single cell –enhanced primary - BOD5 / TSS of less than 100 mg/L	Single cell – enhanced primary - BOD5 / TSS of less than 100 mg/L	Single cell – enhanced primary - BOD5 / TSS of less than 100 mg/L	Two cells – enhanced primary effluent quality in the range of 50 mg/L BOD5 / TSS.
Constructability	Easy	Most difficult to construct (deep excavation, specialized equipment and personnel)	More difficult construction: specialized techniques required	No work required	More difficult construction: specialized techniques required
Operations	Will require monitoring of potential leak	Routine inspection	Routine inspection	Will require monitoring of potential leak	Routine inspection (additional berm)
Community Acceptance	Unknown	Likely acceptable	Unknown	Unknown	Likely acceptable

Table 6.4 Comparison of Lagoon Improvement Options (to address Snowmelt and Runoff Inundation)

Criteria	Ditch Regrading and Cleaning	Ditch Lining	Half Culvert	Diversion Wall
Capital Cost	Unknown – depends on extent of cleaning/regrading. Suggested budget $100,000.	Unknown (depends on how much ditch is lined with concrete)	Relatively inexpensive (<$50,000)	Likely most expensive (cost depends on type of wall)
Operation and Maintenance Cost	$5,000 per year	$5,000 per year	$5,000 per year	More expensive: $10,000 per year
Performance	Should perform acceptably if ditch is maintained in good shape	Should perform acceptably if concrete lining is placed in suitable location(s)	Should perform acceptably if culvert is maintained in good shape	Risk that flow may leak under wall
Constructability	May be difficult to regrade	Straightforward	Potentially difficult to construct on steep and rocky hillside	Potentially difficult to construct on steep and rocky hillside
Operations	Straightforward – routine maintenance	Straightforward – routine maintenance	Culvert may damage easily or become blocked requiring more frequent maintenance	May be difficult to maintain and may require more frequent maintenance
Community Acceptance	Likely acceptable	Unknown	Unknown	Unknown

Table 6.5 Comparison of Lagoon Improvement Options (to address Lagoon Decanting)

Criteria	Heat Tracing	Pumping System
Capital Cost	$50,000 (generator powered heat tracing – only turn on heat tracing before/during decant). Cost will be much higher if permanent power supply is used.	$135,000
Operation and Maintenance Cost	$5,000 per year	$5,000 per year
Performance	Susceptible to failure if not properly maintained	Should perform as expected
Constructability	Retrofit existing decanting structure with heat tracing may be difficult	No permanent structure needed – pump is portable
Operations	Requires regular maintenance of heat tracing and power supply. Uncertain if heat tracing can melt frozen pipe.	Straightforward – maintain engine-driven pumps (stored in Hamlet)
Community Acceptance	Not likely acceptable (problems with Tee Lake water line heat tracing)	Likely acceptable

6.6 RECOMMENDED LAGOON IMPROVEMENTS

The following are the recommended lagoon improvements:

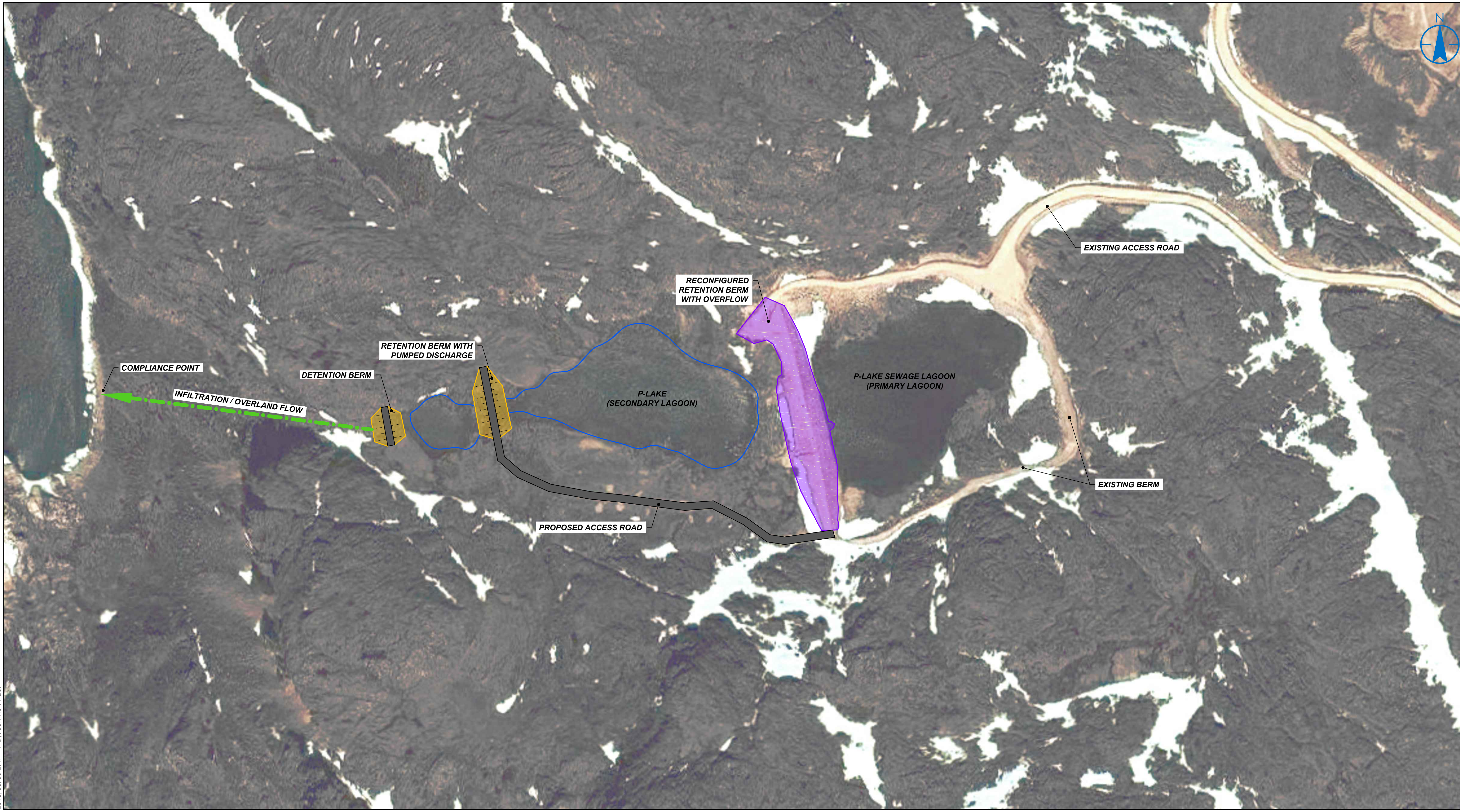
- The GN could consider attempting to plug the leak in the west berm using bentonite (total opinion of probable cost is $25,000). Bentonite should be added to the lagoon in spring. Additional bentonite additions may be required once the lagoon is operational and the lagoon is at higher operating depths. There is significant risk associated with this technique as described above, but the benefit is that the cost is relatively low and may be worth this "trial and error" type approach.

- The existing decant pipe through the west berm should be abandoned in place by grouting it closed. The Hamlet should acquire a gas powered pump (opinion of probable cost is $135,000) that can be used to decant the lagoon once per year. The pump does not need to be a permanent fixture, but rather only used when decanting.

- Improve the ditch drainage system around the service road to reduce the volume of runoff and snowmelt entering the lagoon. Regrading of flat or negatively slopes sections and cleaning of the ditches is recommended. Other local upgrades, as suggested in **Section 6.3**, could also be implemented if needed (cost ~$100,000).

Sealing the leaking berm with bentonite has been suggested because it is low cost and easy to implement. However, there is a good chance that this method may not adequately plug the leak. The Hamlet should monitor the berm leakage to determine if the leakage is stopped after bentonite addition(s). If this method proves ineffective, then it is recommended that a secondary treatment cell be constructed using a second berm as shown on **Figure 6.1**.

Construction of a secondary treatment cell may also be an attractive option if lagoon capacity is reached sooner than expected due to inundation by runoff and snowmelt.



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CAPE DORSET SEWAGE LAGOON FEASIBILITY STUDY

Nunavut

Figure No.

6.1

Title

P-Lake Lagoon Reconfiguration Option
Construct Secondary Treatment Cell

7.0 SEWAGE TRANSFER IMPROVEMENT OPTIONS

Sewage transfer improvements can be accomplished in two ways:

1. Using the access road, but improving the road by addressing operator safety concerns (**Section 7.1**).
2. Providing a sewage lift station with forcemain discharging to the lagoon (**Section 7.2**).

7.1 OPTIONS TO IMPROVE ACCESS ROAD

The existing road provides some operational challenges that are to be addressed if the road transport option in this comparative analysis is to be more viable. With the steep grades and the sharp 2:1 side slope drop off the road, there is a concern about driver and vehicle safety on this road. This concern is increased during inclement weather conditions or darkness.

In its current state, the roadway in many places is narrowed by water scour channels and has support at or near the guardrail giving way. In addition, the hairpin curve severely restricts the sightlines of the road ahead. The grade and slope of this roadway through the hairpin curve and on the sections above is considered steep.

The road on the straight sections in general appears to be in good condition, with a hard driving surface and overall good drainage cross-fall. However, in places, rain or snowmelt has scoured the surface and created deep longitudinal channels or ruts within the roadway. Those channels, with further rain or snowmelt become deeper and reduce the integrity of the roadway structure.

Water scour also resulted in several sections exhibiting base failure along the guardrail supports. Those portions of the road where support has failed and at sections where water has scoured channels into the road narrow the driving lanes and make it difficult for two trucks to pass in opposite directions.

With the road elevated above the surrounding ground and the steep sides of the embankment, the guardrail system in place is a good means of preventing vehicles going off road. The portion of missing guardrail close to the top end of the road should be replaced to prevent a vehicle going off road or surface water using this as an escape channel, further eroding the roadway.

For the discussion that follows, it is assumed that the users of this roadway are familiar with the roadway and the road conditions they may encounter.

There is significant road base failure at the straight section immediately above the hairpin curve and above the cut section through the rock outcropping, where the shoulder has failed and the guardrail supports and the guardrail are sliding into the ditch. If a vehicle were to drive into this failure zone, it would be difficult for the driver to recover the vehicle back onto the road.

The road is a relatively straight above the hairpin curve. However, the long drop down the embankment on the east side is disconcerting; the guardrail is an important and effective safety measure. Also on this section of the road, two trucks passing in opposite directions would have to do so slowly and carefully, as driving close to the failed or weakened shoulder could result in one or both trucks sliding into the guardrail or worse, down the embankment.

From the Community Consultation carried out as part of this project, truck operator safety is the primary concern. In this review, the focus was two-fold: 1) investigating roadway alignments that reduce the grade of the road and increase the radius of the hairpin curve, and 2) on the operational aspects of keeping roadway users and their vehicles safe.

7.1.1 Roadway Alignments, Grades and the Hairpin Curve

Alternative access road alignments with the aim of reducing the grade incline and improve on the hairpin curve for driver and vehicle safety were examined.

Key design considerations included:

- Applicability of existing guidelines and standards to the current access road and the options proposed
- Improved sightlines for drivers of the road ahead and of oncoming traffic
- Feasibility for construction
- Operational considerations such as grades, width of the roadway, maintenance, travel speed
- Cost and road safety

A review of the standards and guidelines used for roadways similar to the lagoon access road is summarized in **Table 7.1**.

Table 7.1 Summary of Access/Haul Road Guidelines

	Maximum Gradient/Slope on a Hairpin Curve (%)	Recommended Radius for a Hairpin Curve (m)	Operating speed (km/h)	Recommended Carriageway width and shoulder width (m)
Existing Road	6.0 – 8.3	20 - 30	Unknown	8.0
Indian Road Congress (IRC)	2.5	Not provided	20	11.5 + 1.5 shoulder
Transportation Association of Canada (TAC)	2.5	90	50	6.8 + 1.5 shoulder for one-way traffic 11.0 +1.5 shoulder for two-way traffic

The concern over the hairpin turn and the grade of the road made the analysis an exercise in optimization: using as much of the existing road as possible while flattening out the road without the need for significant blasting of the bedrock, re-grading a portion of the road on the embankment and widening the radius of the hairpin curve (given the space constraints).

A preliminary road safety evaluation report is attached in **Appendix D.** Although some of the interventions, such as signing, may not be directly applicable to the local circumstances, they are included for the sake of completeness. The drivers using this road are familiar with the road and the prevailing road conditions, so are assumed to be knowledgeable users.

Sightlines to the road ahead are a concern for drivers who have to negotiate a combination of a sharp curve and a steep incline.

Roadway grade and curve radius

Both the Indian Road Congress (IRC) and the Transportation Association of Canada (TAC) have specific guidelines recommending maximum grades in hairpin curves to be at 2.5%.

Over the length of the existing road, the grade ranges from approximately 8% to 15%. Within the hairpin curve, the grade ranges from 6% at the lower end to 8.3% at the upper end.

The TAC guidelines also recommend a minimum hairpin curve radius of 90 m, significantly more than the current 20 m to 30 m radius of the curve.

For this assignment, given the surrounding bedrock and space constraints, the targets for the design aim to increase the hairpin turn radius to a larger radius (55m to 60m), and limit the maximum grade at the hairpin turn and the climbing portion to a 4% to 5% grade. The intent of these changes is to improve driver and vehicle safety, improve sightlines of the road ahead and allow the driver to assess the condition of the road ahead.

Available topographical survey information was used in this conceptual design, as it provided the most readily available information for a conceptual level design to be developed. Google Maps also was used to confirm the location of landscape features in the area.

Travel speed

For the review, the design speed for this section of road was set at 30 km/h, which is consistent with similar access roads used elsewhere.

Roadway width

The width of the roadway currently is approximately 8 m throughout. This width is adequate provided the full 8 m are available to drivers and maintained in good driving condition. Washout sections and scour channels reduce the effective width. This is predominantly a maintenance issue, rather than a change in the design.

Given the absence of knowledge of truck traffic volumes or haul frequencies (other than the ten trips per day), a wider roadway is not being proposed. A 7.5 m to 8 m width is sufficient for two-way traffic given this low number of trips per day and driver familiarity with the road, the potential conditions they may encounter, and the low speed they travel at. However, less than this width may make it difficult for two vehicles to pass in opposite directions during periods of inclement weather.

7.1.2 Alternative Roadway Alignments

Along with the three alternative access road alignments that were originally provided during the community consultation process, two additional access road options were added that may provide lower cost alternatives, keeping in mind the space constraints for this roadway. Considerations for the different access road alignments were the overall length of road, the potential grades, the constructability and the cost.

The evaluation and design of the three Alternatives and the two new Options for road safety follows the independent road safety report "Access and Service Road Concerns," found in **Appendix D**. This report was used to develop the design criteria for the grade and the radius of the curve at the mid-level of the embankment.

The development of feasible Options for the roadway at this stage of the assignment is based primarily on geometric design considerations and not on the day-to-day operational requirements such as type of road surface, roadside marking and signing and snow and ice control.

Where possible, any proposed alignment is intended to maximize use of the existing terrain and reduce the need for excessive cut or fill sections.

A discussion of the grades and the issues surrounding the road alignment options is included in the review of each Alternative or Option below.

Review of Access Road Alignments

In each of the reviews, the need for blasting through significant portions of the terrain was minimized, as the cost of doing so significantly increases the cost of construction.

Common gravel road construction was assumed for the roadway improvements. This also results in the most cost effective means of long-term roadway maintenance and operation.

The cost estimates should be considered order-of-magnitude estimates only, as they were developed using limited information regarding availability of roadway construction materials and equipment, unreliable survey information (there were discrepancies between the survey files we were provided) and without information pertaining to recent construction costs in Cape Dorset. At best, the costs present an indication of the level effort required.

Appendix E contains plans and profiles and some typical details for Alternatives A, B and C as well as additional Options B1 and B3.

Alternative Road A

This Alternative results in the longest new road construction of the three Alternatives and, although insufficient topographical information was available for a more thorough evaluation, still includes sections of with grades of approximately 21%, 16%, 15%, 7.6% and 7.5%.

Given the terrain that this alignment passes through, these grades were the lowest that could be achieved given the existing topographical constraints. As this alignment far exceeds the recommended 4% to 5% "safe" grades for the type of truck used, this Alternative is not considered viable and no cost estimate was prepared.

Alternative Road B

For this Alternative, the design grades achieved over the existing terrain are 5.9%, 6.3%, 10%, and 21.4%, still greater than the target grade range. It also should be mentioned that this road, cut into the hillside, includes a steep side slope, making it potentially more dangerous for drivers without considerable roadside protection to prevent run off-road accidents.

As this Alternative also significantly exceeds the target range for grades, it is not considered feasible and no cost estimate was prepared.

Alternative Road C

This alternative essentially is a steep ramp up the hillside from the Hamlet to the sewage lagoon. Given the overall rise of the hillside, the grades on this road without significant infill of material are: 46%, 13.4% and 5.1%, making this road not only difficult to navigate longitudinally, but being a ramp, also incorporating steep side slopes that require roadside protection to prevent run-off-road accidents

Similar to Alternatives A and B, Alternative C is not feasible and no cost estimate is provided due to the considerable amount of fill that would be required to build the ramp.

Although the designs for Alternatives A, B and C attempted to meet the design criteria as much as possible, the grades presented for the Alternatives are the lowest that could be achieved given the terrain they pass through (and given the information available at this stage of the project).

Additional access road alignment Options

Two additional options have been developed, as described below. Both of these new options involve use of the existing road as much as possible, with realignments of the hairpin curve to improve road safety.

New Option B1

This Option is a realignment of the approach to the hairpin curve by approximately 425 m and an increase in the radius of the hairpin curve to 35 m. In this design, the hairpin curve itself is on a 4.1% grade with a grade of approximately 8.1% uphill from the curve.

It is assumed that, although the grade in and around the hairpin curve is reduced, the 8.1% grade section above the curve is steeper than the target range and closely matches the existing grade. For this reason, this Option is not considered a significant improvement. The only improvement of note is the radius of the hairpin curve and an increase in the potential operating speed to 35 km/h.

New Option B3

This Option results in a maximum grade of 5.8%, closer to the target range while taking into account the restrictions imposed by the steep terrain and the objective of keeping the cost reasonably low.

In this design, the hairpin curve itself is on a 5.3% grade, but the radius is now increased to 50 m, closer to the target range of 55 m - 60 m radius. This design incorporates an improvement throughout the length of the roadway, but of note are two curves with a short straight section at the mid-section, eliminating the need for such a tight radius hairpin curve. This design provides improved sightlines for the driver, higher operating speeds and safer navigation of the curves despite the grade being slightly above the 4% to 5% target range.

The roadway at the base of the hillside is modified to provide for an improved approach to the wider radius curve.

7.1.3 Opinion of Probable Cost

The opinions of probable cost (OPC) for the two Options are shown in **Table 7.2**.

Table 7.2 Opinion of Probable Cost for Access Road Improvements

Description	Units	Quantity	Unit Cost	Estimated Cost
New Access Road – Option B1 (Length of Road Improvement = 425 m)				
Mobilization and Demobilization	Lump sum	1	$500,000	$500,000
Bulk Rock Cut - Drill / Blast (in Quarry)	m^3	69,500	$35	$2,432,500
Bulk Rock Fill Load Haul Place	m^3	69,500	$25	$1,737,500
Road Surfacing	m^3	507	$100	$50,700
Optional Snow Sheds (16 m wide x 4.8 m clear) over deep cuts	Linear m	50	$4,800	$240,000
Contingency (40%)				$1,845,300
Total (Option B1)				**$6,458,500**

Description	Units	Quantity	Unit Cost	Estimated Cost
New Access Road – Option B3 (Length of Road Improvement = 1,460 m)				
Mobilization and Demobilization	Lump sum	1	$500,000	$500,000
Bulk Rock Cut - Drill / Blast (on new alignment)	m^3	53,900	$35	$1,886,500
Bulk Rock Fill Load Haul Place	m^3	63,500	$25	$1,587,500
Road Surfacing	m^3	1,741	$100	$174,100
Optional Snow Sheds (16 m wide x 4.8 m clear) over deep cuts	Linear m	250	$4,800	$1,200,000
Contingency (40%)				$2,139,240
Total (Option B3)				**$7,487,340**

Note that the snow sheds in each Option are discretionary and are aimed at reducing the volume of snow deposited onto the road. However, these structures add significant cost to the road improvements.

Recommended Roadway Alignment

The recommended roadway improvement from a design and road safety perspective is Option B3, which despite including partial reconstruction and new construction, is closest to meeting the design targets of IRC and TAC.

Option B3 extends the roadway length by approximately 500 m overall, but reduces the grade inclines in and above the hairpin curve, increases the hairpin curve radius and has an opinion of probable cost of $7.49 million, including the snow sheds. Without the snow sheds, the opinion of probable cost is reduced to $6.29 million.

7.1.4 Roadway Operations and Maintenance (O&M) Considerations

The following O&M cost estimates are based on a summary of costs for Northern roads. The equipment used for roads up to 2 km in length by Northern communities typically includes a grader, a front end loader, a bulldozer, a dump truck and a snow blower.

The Cape Dorset Integrated Community Infrastructure Sustainability Plan Vol 2 – March 8, 2011, was used for reference on the equipment that the hamlet has available. Details on the operation and maintenance costs are found in **Appendix F**.

Summer O&M

Given the gravel roadway surface, regular summer maintenance activity should consist of several passes by a grader on an as needed basis, but no less than three times per week, and repair of any dips in the road, potholes, ruts and scour channels created by surface water flow.

Repair of any weak or failed road sections, missing or badly damaged guardrail or guardrail supports is also a requirement to maintain the structural integrity of the roadway.

The annual Summer O&M cost (using an average of 75 "summer" days per year) is estimated to be in the order of $30,000 per year. This cost takes into consideration the relatively short distance and the high level of maintenance and repair required to keep the road base, the side slope and the usable driving width in good condition.

The estimate does not account for unusually wet summers, when the maintenance requirement would be higher.

Winter O&M

With snow removal, the O&M during this time of year is more involved. "Winter" conditions are assumed to exist for 290 days. The number of days used is an annual average only, and based on Government of Canada Climate/Monthly Data Reports (2001, 2003, 2004, 2005, 2006, 2012).

A grader may be used to remove the snow most of the time. The opinion of probable cost for winter grader service is $173,000 per year. Spreading gravel on icy sections is also included in this cost.

Grader operations also may be an effective means of reducing the need for larger equipment during a snowstorm or drifting snow event. If grader operations are initiated early in the event and continue throughout the snowstorm effective access to the lagoon may be maintained. Doing so also avoids a delay to hauling operations and interim storage capacity concerns. Continuous passes during the storm reduce the snow build up and, ultimately, the need for larger equipment. However, continuous operation of the grader during whiteout conditions may not always be possible or safe.

It is assumed that major snowstorms or events that result in greater accumulations of snow would require other types of equipment. The tandem axle truck may be equipped with either a snow blower or a bucket to remove the snow. For simplicity and only as an illustration, it was assumed that the need for this equipment on an annual basis would be for 12 such events (snowstorms or drifting events where graders would not be adequate to remove deeper snow deposits and drifts). If a loader with snow blower attachment were used in these 12 events, the estimated cost of snow removal is $35,000 annually. If a front-end loader were used to remove deeper snow, this cost increases to $56,000. These costs are assuming that attachments can be added to the existing equipment available to the Hamlet.

Annual Access Road O&M Cost

On an annual basis, and not including the cost of the major snowstorm or snowdrift events where a grader is ineffective, the basic level of service is estimated to cost $202,000. This cost will increase depending on the amount of snowstorms or snow drifting events that require larger equipment; for sake of illustration, 12 of these events would cost approximately $35,000 using a snowblower attachment and bring the total annual road O&M cost to $237,000.

Truck Hauling Cost

The operating cost of running trucks up and down the access road must be accounted for. The cost of operating trucks within the Hamlet (i.e. while collecting sewage for residences) and the time taken to unload the trucks is not accounted for because these are required no matter what option is used (i.e. is still required if the lift station/forcemain option, described later in this report, is selected). For the recommended Option (B3), the annual incremental opinion of probable cost of hauling sewage from the hamlet to the lagoon is $179,000 per year. This cost is based on hauling seven days per week and a 15 minute travel time on the lagoon access road (see **Appendix F** for details).

Road Markers

From some of the remarks and pictures of the access road under snow drifts, and in addition to the existing roadside posts with retroreflective tabs, tall (4 m) wooden posts with retroreflective sheeting material could be installed at regular intervals on the outside of the guardrail. These posts would provide longitudinal guidance for snow removal crews to delineate the edges of the roadway in deep snow (above the height of the current markers). A spacing of 50 m or as required to delineate the roadway alignment would provide additional (to the existing posts and tabs) longitudinal guidance for drivers and snow and ice control equipment operators.

Issues during Spring Melt

Melting snow and ice result in the road structure road becoming more fragile, and hence the observed erosion. Heavy surface water flows on the road are usually the main cause of the erosion, appearance of potholes and overall deterioration of the roadway surface.

"Washboarding" of the road is particularly prevalent during the spring melt, as trucks with heavy loads braking and accelerating at the hairpin curve vibrate and damage the road structure. Repeated action further deteriorates the roadway. The increased radius of the proposed redesign of the hairpin curve should alleviate much of this condition.

Climate resistant pavement would be the ultimate solution, but not considered economically feasible. Because alternative road alignments are being considered for the hairpin section of the access road, spring melt considerations can be incorporated into the design of the new road. Adequate ditches and culverts can be provided.

A weight limit policy could also be implemented during spring melt. Such policies are common in Canada. The weight limit policy can help preserve the condition of the road and avoid excessive damage to the surface. Use of smaller (and more frequent) loads could be investigated. A similar policy could be applied to the service road around the lagoon.

7.1.5 Snow Drifting Mitigation

The RDWI Consulting Engineers & Scientists (Dec 24, 2014, RDWI Ref No 1500864) Preliminary Snow Drift Assessment - Wastewater System Access Road Cape Dorset, NU (see **Appendix G**) was used as a guiding document in terms of identifying additional measures that could be used to reduce the amount of snow being deposited on the access road. These measures would increase the capital cost but could decrease the snow removal cost associated with removal of large drifts following snowstorms or other snow drifting events.

Regardless of the alignment of the access road, given the prevailing winds from the west, the generally east facing (lee) slope where the road is located acts as a snow drop zone. There are several options to reduce problematic snow drifting which has reportedly rendered the access road impassible during winter (refer to **Appendix G** for more details):

Snow Fence

Snow fences are typically several metres high, built of wood or prefabricated plastic, and are intended to capture snow that is transported by wind. A snow fence or series of snow fences could be constructed east of the lagoon, on the windward (west facing) side of the ridge. The snow fence would be intended to capture blowing snow on the windward side before it reaches the ridge crest, where it becomes deposited on the leeward side of the ridge (i.e. on the access road, particularly near the hair-pin turn). A number of smaller local snow fences could also be placed near problematic locations, ensuring that the catchment zone of the snow does not contain the road (which may be difficult because the access road is on the leeward side of the hill).

A snow fence could also be constructed at the western end of the Sewage Lagoon. In principle, this would shift some of the snow drop from the edge of the embankment to the Lagoon, also adding weight and insulation on top of the Lagoon (and slightly reducing the lagoon capacity for sewage when the accumulated snow melts in the summer). While not all of the snow would be deposited there, there may be a small reduction in the total volume being deposited on the Access Road.

In any case, the local topography along the access road will make it difficult to effectively improve the snow drifting problem. The possible snow fence locations discussed above may provide some improvement but may not be sufficient to mitigate all problem areas. Detailed modeling can be completed to assess likely improvements of the snow fences and to determine the best location for the snow fences.

Overhead Snow Protection

A roof covering the affected sections of the access road (snow shed) could be constructed (this was an option outlined for road alignment Options B1 and B3 discussed previously). Snow would be deposited on top and east of the roof covering the road, leaving the road relatively snow free. Similar but larger scale solutions have been used on some highways in British Columbia to protect roadways from avalanches.

A significant consideration in such an analysis is the density and weight of the snow, as blown snow is considerably more packed and heavier than fresh fallen snow. The depth of the snow cover to calculate the weight of the snow as well as the weight of the snow as it melts also are factors.

7.1.6 Truck Turn-Around Improvements

The Hamlet has concerns that the existing truck discharge location is oriented such that emptying the trucks into the lagoon (via the discharge chute) will be challenging in windy conditions. In the current configuration, trucks would be emptying sewage to the discharge chutes in a southwesterly direction, which is facing the prevailing winds from the west. Strong winds could cause spraying problems while the trucks are emptied.

There are two options for solving this problem:

- Install a quick-connect hose system wherein the trucks can connect a hose to a permanent fitting installed at the top of the discharge chute. This should reduce spray caused by the wind. The cost of this upgrade should be relatively inexpensive (~$5,000) and it should be installed in such a way that the fittings will not freeze up during the cold months.
- Reconfigure the truck turn -around area so that the trucks discharge sewage on the opposite side of the berm (not facing the prevailing wind). In this case, a culvert would need to be constructed through the berm to direct sewage to the lagoon. The culvert should be installed at a significant grade to minimize ice accumulation. This option will likely cost in the $50,000 range due to the need to excavate through the berm to install the culvert.

The quick-connect hose system is recommended as it will be less expensive to install and may result in less operational concerns provided that provisions are made to prevent the hose (attached to the truck) and fittings from icing up.

7.2 LIFT STATION AND FORCEMAIN OPTION

This option will rely on a new lift station to transfer sewage to the lagoon with a new forcemain to be installed along one side of the lagoon access road. In this case, the access road will not be required for trucking sewage to the lagoon, but instead can be used periodically to access the lagoon for maintenance. Road maintenance would be minimized and regular winter road maintenance may not be required.

7.2.1 Design Basis

The lift station (pumps and wetwell/storage tank) and forcemain are designed based on the need to convey one truckload of sewage to the lagoon at a time and thus the design is independent of future population growth (i.e. number of truckloads will increase as the Hamlet grows but the same lift station and forcemain can be used).

7.2.2 Forcemain

The proposed forcemain should be installed above ground (instead of buried pipe) because of the rocky terrain and permafrost soil conditions in the region. However, above ground installation will require extra measures to minimize heat loss and to protect the liquid within the pipe from freezing. Heat trace is not recommended for freeze protection as it would require a reliable power source and will add to the energy costs (heat tracing was also noted by the Hamlet to be ineffective on the potable water supply pipe). Since sewage will be pumped uphill to the lagoon, the forcemain will slope down towards the lift station, thus the need for heat tracing of the forcemain can be eliminated by draining the pipe back to lift station wetwell to prevent freezing. However, proper pipe insulation will be required for the long forcemain to minimize heat loss during winter.

In this option, access for routine inspection and maintenance of the forcemain and sewage treatment lagoon will be from the existing access road. The minimum width of clear working area for above ground pipes should be 4 m from centre of the pipe. Pipe supports and piling is required at certain intervals and should allow lateral movement of the pipe. Each pipe support at the piles should have a roller system to accommodate the horizontal movement. The forcemain should also be provided with thaw ports at 100 m intervals.

Appropriate pipe material selection is an important aspect for the forcemain design. Polyvinyl Chloride (PVC) pipes are prone to damage in freezing and thawing cycles or cleaning. Recent systems are typically being built with High Density Polyethylene (HDPE) pipes that can withstand freezing of fluid without damage. HDPE pipe has the lowest repair frequency compared with all other pressure pipe materials. HDPE pipe is flexible as well as easy to handle and install. Therefore, HDPE pipe is recommended for the proposed forcemain between the new lift station and sewage treatment lagoon.

7.2.3 Sewage Lift Station

The proposed sewage lift station will be comprised of the following components:

1. Truck discharge connection port
2. Sewage transfer pumps (1 duty/ 1 standby)
3. Screening/ sewage grinding
4. Flow metering
5. Sewage holding/ storage tank
6. Sewage discharge high lift pumps (1 duty/ 1 standby)

7. Pressure-coupling flexible connection to forcemain
8. Forcemain drain connection back to the sewage holding/ storage tank

The process flow diagram of the sewage lift station is shown on **Figure 7.1**.

All sewage lift station components except for the storage tank will be housed in a prefabricated building with heating / ventilation system, electrical controls and alarms. Prefabrication construction for the lift station is preferred as the onsite construction will be expensive due to short construction season and labour shortage.

The sewage holding/ storage tank will be provided beside the lift station to serve the dual purpose of wetwell and storage specially for draining the forcemain back after each pumping cycle. The sewage holding / storage tank is proposed to be above ground due to accommodate easier construction, thus requiring a small transfer pump to transfer the sewage from the truck to the holding tank. The sewage holding / storage tank will also be insulated to prevent freezing during winter or can be located inside a heated enclosure. As thawing and settling under the lift station structure and holding tank is anticipated, a geotechnical investigation field program will be required prior to detailed design in order to address structural design requirements.

Flexible coupling connections will be needed at the inlet and outlet of the lift station and storage tank to allow differential movement without causing break stress on the pipes.

The lift station will be equipped with a single truck hook up connection on the exterior of the lift station which will allow one sewage truck to discharge at a time. Pumps, piping and equipment are designed to receive and transfer the volume of one truck (15,000 L) in 10 minutes (25 L/s transfer rate).

Sewage from the trucks will be transferred to the above ground holding tank via the inline transfer pumps, one duty and one standby. The transfer pump will be operated by a local control panel switch mounted on the lift station wall. A screening/grinding system will be installed on the transfer line to the sewage holding/ storage tank to screen and shred large materials to prevent clogging of the downstream lift station components. In order to record incoming flow, a flow meter is proposed to be located upstream of the holding/storage tank.

The storage tank will need to be sized for the combined capacity of the truck discharge and the sewage drained back from the forcemain after each pumping cycle. There are two (2) sewage high lift pumps, one duty and one standby, that will operate based on the liquid level in the tank to pump the sewage through the forcemain to the lagoon. Forcemain connection to the sewage holding/storage tank will be isolated by a control valve that is normally open to allow complete draining of the pipe back to the tank. When the high lift pump is in operation, this valve will be closed to direct the flow to the lagoon.

The current design does not include a backup power generator, since the community has flexibility in truck haul frequency and also there is an accessible emergency discharge location to the lagoon. However, the design should provide provisions to hook up a backup power generator, if required.

7.2.4 Location of the Lift Station

The proposed lift station facility location has a significant influence on the overall capital and operating cost of the project. The main contributing factors are:

- Close proximity to the community will reduce truck hauling cost as well as utility service cost to the facility site.
- Farther away from the community along the lagoon access road will reduce forcemain length and pipe cost as well as storage tank size required to drain the forcemain after pumping. Odour issues in the Hamlet may also be reduced.

Based on the above considerations, two possible facility locations can be proposed as follows:

- Site "A" is close to the Hamlet (southeast of the community), beside the existing water Truck Fill Station. This option is proposed based on the proximity to the community. It will require a forcemain with a length of approximately 1,600 m and will require 30 m^3 of minimum storage for the pipe drain.
- Site "B" is located at the start of the lagoon access road (Station Zero).This option shortens the required length of the forcemain up to the point where the road safely allows truck hauling on year-round basis. This option will require a forcemain with a length of approximately 1,000 m and will require 19 m^3 of minimum storage for the pipe drain.

Figures 7.2 and 7.3 show the two proposed site options "A" and "B".

Design considerations for two site options are shown in **Table 7.3**.

Table 7.3 Design Considerations for Lift Station and Forcemain based on Site Options

Design Criteria	Unit	Site A	Site B
Elevation Difference from Lift Station to Lagoon	m	70	50
Truck Capacity	L	15,000	15,000
Truck Discharge Time	min	10	10
Truck Discharge Rate = Pump Transfer Rate	L/s	25	25
High Lift Pump Discharge Rate	L/s	25	25
High Lift Pump Discharge Head	m	91.6	65.2
Forcemain Length	m	1,600	1,000
Force Main Inside Diameter	mm	155	155
Minimum Storage Tank Volume	m^3	30	19

7.2.5 Evaluation of Site Options

Specific criteria have been developed for evaluating the two site options. **Table 7.4** summarizes the comparison of both proposed sites for each evaluation criterion.

Table 7.4 Comparison of Lift Station Sites "A" and "B"

Site Location	Site "A"	Site "B"
Accessibility	• Close to the community, thus shorter truck hauling and site servicing	• 600 m farther from Site "A" which requires longer truck hauling and site servicing
Length of Sewer Forcemain	• Requires longer forcemain (60% longer than Site "B"). • Requires more sewage storage for the long pipe drain, thus would have potential odour issues due to longer sewage detention time in the tank • Creates more pipe friction and requires higher static head, which would require pumps with higher discharge head	• Shorter forcemain • Requires less sewage storage for the pipe drain, thus sewage detention in the tank would be shorter and would have less potential for causing odour issues • Creates less pipe friction and requires less static head, which would require pumps with lower discharge head
Availability of Utilities	• Utility service is close-by	• Requires about 600 m extension of the power service line to the facility

7.2.6 Opinion of Probable Cost

Table 7.5 provides an opinion of capital cost summary for sewage lift station with forcemain, including installation and 40% contingency:

Table 7.5 Opinion of Probable Cost for Sewage Lift Station and Forcemain

Description	Capital Cost – Lump sums unless noted otherwise	
	Site Option "A"	Site Option "B"
Mobilization/Demobilization	$500,000	$500,000
Sewage Lift Station Building Package	$1,250,000	$1,250,000
Sewage Holding/Storage Tank	$80,000	$50,000
Forcemain ($2000/m)	$3,200,000 (1,600 m long)	$2,000,000 (1,000 m long)
Utility Power Service	$100,000	$250,000
Site Civil and Truck Access	$100,000	$200,000
Electrical, Control and Communication	$100,000	$100,000
Contingency (40%)	$2,132,000	$1,740,000
Total	**$7,462,000**	**$6,090,000**

7.2.7 Lift Station/Forcemain Operation and Maintenance Considerations

The primary operating cost for the lift station and forcemain is electricity to run the pumps. In addition, heating and ventilation at the lift station will be required. Annual maintenance on the lift station and forcemain are also required. The opinion of probable cost for the O&M of the lift station and forcemain option is summarized in **Table 7.6** with details provided in **Appendix F**.

The cost of operating trucks within the Hamlet (i.e. while collecting sewage for residences) is not accounted for because this is required no matter what option is used (i.e. is still required if the lift station/forcemain option is selected).

As the capital cost of "Site B" is lower than "Site A" and O&M costs of both locations will likely be similar, it is suggested that "Site B" is the preferable location for a lift station, should the lift station and forcemain option be preferred.

Table 7.6 Opinion of Probable Cost for O&M of Sewage Lift Station and Forcemain

Description	O&M Cost ($/year)	
	Site Option "A"	Site Option "B"
Lift Station Power	$120,000	$90,000
Lift Station Heating and Ventilation	$40,000	$40,000
Lift Station maintenance	$40,000	$40,000
Forcemain maintenance	$80,000	$50,000
Extra Hauling Distance to "Site B"	-	$70,000
40% Contingency	$112,000	$116,000
Total	**$392,000**	**$406,000**
Note: O&M costs in 2015 dollars and based on 10 sewage trucks per day (~150 m^3)		

It should be noted that access to the lagoon will still be required if the lift station and forcemain option is implemented. Lagoon access is required to facilitate drawdown and for routine inspections and maintenance. However, it is assumed that without regular use of the road by heavy sewage trucks, occasional access road maintenance requirements will not be intensive. In addition, regular winter road maintenance may not be required as truck access to the lagoons during winter is not anticipated on a regular basis.

7.3 OPTIONS COMPARISON

The options to improve the access road (“Option B3”) and to install a lift station and forcemain (“Site Option B”) to eliminate the need to use the access road to transport sewage to the lagoon were compared based on several criteria. **Table 7.7** summarizes this comparison.

Table 7.7 Comparison of Access Road Improvements and Lift Station/Forcemain Option

Criteria	Improve Access Road (“Option B3”)	Install Lift Station and Forcemain (Site “B”)
Capital Cost	$7.49 Million (incl. snow sheds)	$6.09 Million
Operation and Maintenance Cost (**App. F**)	$416,000 ($237,000 Road O&M and $179,000 additional truck hauling cost)	$406,000
Service Life	Access road should have long service life provided regular maintenance of road surface, ditches, culverts is completed.	Lift Station: ~20 year design life Forcemain: ~30 year design life
Environmental Risk	Risk of truck accident on road and subsequent spillage of sewage	Risk of forcemain breakage causing sewage to spill
Operations	• Despite improvements to hairpin curve, it is still a sharp turn on a steep grade • No specialized operator training required • No need for freezing protection measures	• Avoids regular use of challenging access road to transport sewage • Need to train operator(s) in operation and maintenance of pump and lift station facilities (e.g. heating, ventilation) • Need freezing protection measures (e.g. insulate forcemain)
Constructability	Cut and fill along hillside will make for challenging construction.	Construction of lift station will be straightforward but construction of above-ground forcemain over rough and steep terrain will pose some challenges.
Community Acceptance	Hamlet has expressed major safety concerns with use of the access road	Acceptance by hamlet is unknown; need to consult with Hamlet
Accessibility	Lagoon may not be accessible via the access road during blizzards conditions (alternative dumping spot would be needed).	Lift station should be generally accessible in most conditions. Note: Lagoon will still need to be accessible, but regular access to lagoon during winter may not be required.
Safety	Hairpin turn will still pose some safety risk and does not meet typical guideline requirements for grade and radius.	Generally considered safe

7.4 RECOMMENDED SEWAGE TRANSFER IMPROVEMENTS

The following are the recommended sewage transfer improvements:

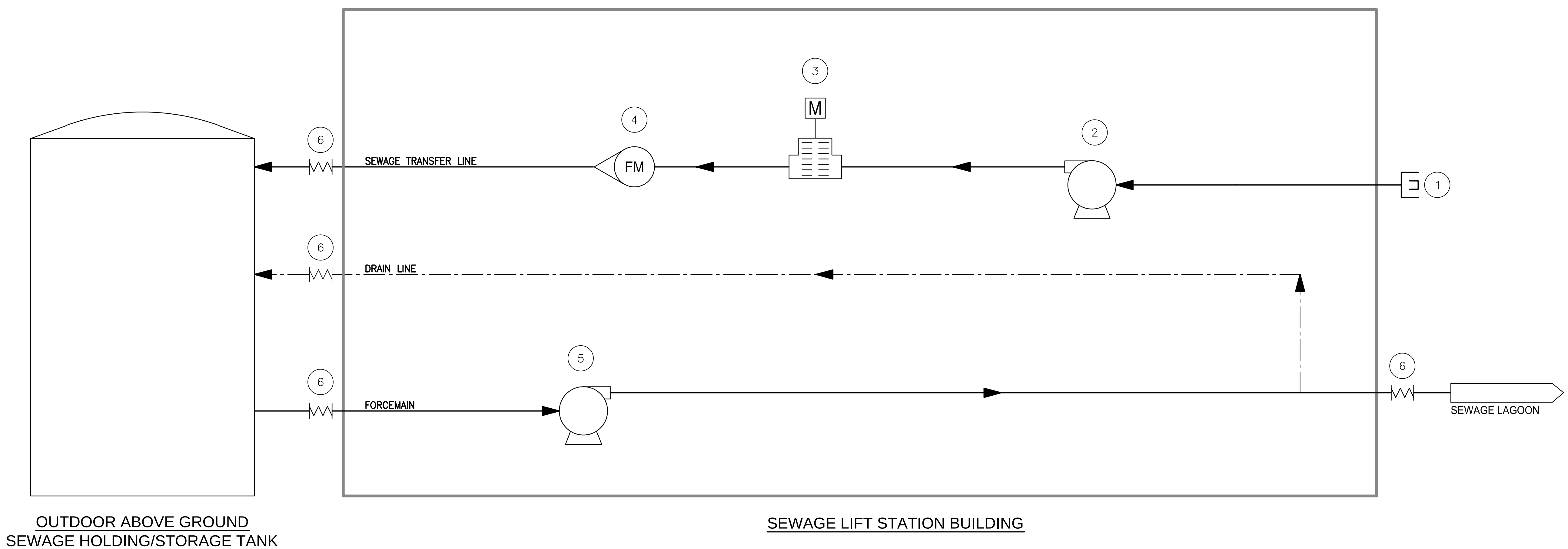
- Serious concerns exist regarding the safety and operability of the existing access road. It is our understanding that the Hamlet has similar concerns about the access road. Therefore, it is recommended that the access road not be used to haul sewage on a regular basis to the P-Lake Lagoon.

- A lift station and forcemain at Site "B" is the recommended alternative to pursue further in preliminary and detailed design in order to avoid using the access road for hauling sewage. The preliminary opinion of probable cost for this option ($6.1 Million) is comparable to the suggested hair-pin turn improvements (Option B3 - $7.5 Million with snow shed or $6.3 Million without snow shed) and the annual operation and maintenance cost of both options is also similar (just over $400,000). However, the lift station and forcemain option will alleviate safety issues and operational issues associated with hauling sewage on the access road (even with access road improvements).

- The Hamlet should be consulted to confirm whether it is preferable to pursue the installation of a lift station and forcemain in order to avoid using the access road for hauling sewage, as opposed to improving the access road. The ultimate decision on which option to pursue should involve input from the Hamlet.

- Option B3 is the recommended hairpin turn improvement option, in case the decision is made not to advance the lift station and forcemain option. The proposed hairpin turn improvements do not completely eliminate the sharp curve and steep grade that plagues the access road; doing so is not achievable given the topography. Devoted road maintenance will be required. Should the road become temporarily impassible during inclement weather, a contingency plan should be developed regarding where the sewage will be stored during such periods.

- Snow fences and/or snow shed options could be investigated if the Hamlet decides to continue to use the access road to haul sewage.



Key Notes

1. Truck Discharge Connection Port
2. Sewage Transfer Pump
3. Screening/Grinder
4. Flow Meter
5. Sewage Lift Pump
6. Flexible Coupling Connection

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CAPE DORSET SEWAGE LAGOON FEASIBILITY STUDY

Figure No.
7.1

Title
Sewage Lift Station
Process Flow Diagram

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2015/03/30 2:47 PM By: Sumner, Paul

Legend

- Existing Water Supply From T-Lake
- Existing Sewage Lagoon Access Road
- Proposed Sewage Forcemain
- Proposed Sewage Forcemain Crossing Road

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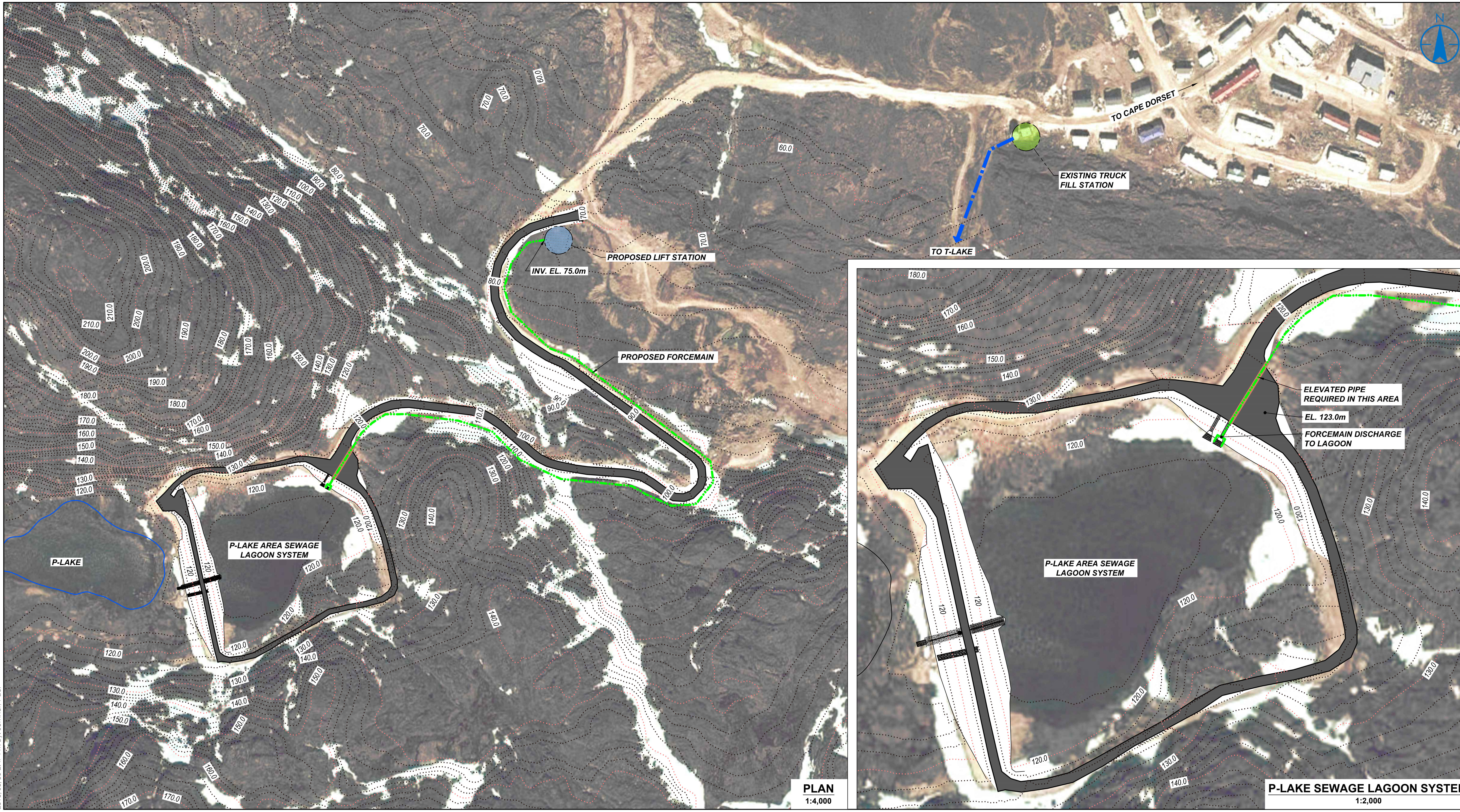
Figure No.

7.2

Title

Proposed Lift Station - Site-A
Location and Forcemain Route



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2015/03/30 2:47 PM By: Sumner, Paul

Legend

- Existing Water Supply From T-Lake
- Existing Sewage Lagoon Access Road
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Figure No.

7.3

Title

Proposed Lift Station - Site-B
Location and Forcemain Route

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The conclusions of this feasibility study are as follows:

- Based on observations made during the field visit, the west berm of the P-Lake lagoon is leaking, with the suspected leak occurring between the constructed berm and the native subgrade. It is difficult to determine to what extent berm integrity is being compromised by this leak.
- The access road to the lagoon is considered unsafe in its current alignment due to steep grades, the narrow roadway and the hairpin turn.
- Photos provided by the Hamlet have shown that snow drifting is a major problem along the access road in winter and therefore requires significant maintenance activity during winter.
- Snowdrifting along the access road is a major contributor to runoff related issues of erosion
- A significant volume of rainfall runoff and snowmelt (estimated to be as high as 22,000 m^3) may enter the P-Lake Lagoon each year. This results in a ~23% reduction in sewage retention capacity and may reduce the lifespan the facility and treatment effectiveness as more storage/retention is needed to accommodate future population growth in Cape Dorset.
- The elevation of the T-Lake water supply is approximately 20 m above the P-Lake Sewage Lagoon and approximately 1 km away. Therefore, seepage from the lagoon to the T-Lake will not occur.
- Supplemental sewage treatment would be provided beyond the discharge from the existing one cell system, therefore the compliance point for the system should be moved to consider this supplemental treatment

8.2 RECOMMENDATIONS

The recommendations are as follows:

Lagoon Berm Repairs

- The GN could consider attempting to plug the leak in the west berm using bentonite (total opinion of probable cost is $25,000). Bentonite should be added to the lagoon in spring. Additional bentonite additions may be required once the lagoon is operational and the lagoon is at higher operating depths. The potential success of this option is remote, and there is significant risk associated with this technique as described above, but the benefit is that the cost is relatively low and may be worth this "trial and error" type approach.

- The Hamlet should monitor the berm leakage to determine if the leakage is stopped after bentonite addition(s).

- If sealing the leaking berm with bentonite does not adequately plug the leak, then it is recommended that a secondary treatment cell be constructed using a second berm downstream of the P-Lake Lagoon. The secondary berm should be constructed such that it does not leak and can be discharged using a pump once per year. A modification to water license should be pursued such that the compliance point is further downstream where the effluent reaches Telik Inlet (i.e. after the wetland area and rockfall).

- The existing decant pipe through the west berm should be abandoned in place by grouting it closed. The Hamlet should acquire a gas powered pump (opinion of probable cost $135,000) that can be used to decant the lagoon once per year. The pump does not need to be a permanent fixture, but rather only used when decanting.

Diversion of Runoff and Snowmelt

- Improve the ditch drainage system around the service road to reduce the volume of runoff and snowmelt entering the lagoon. Regrading of flat or negatively slopes sections and cleaning of the ditches is recommended. Other local upgrades, as suggested in **Section 6.3**, could also be implemented if needed (cost ~$100,000).

Sewage Transfer to Lagoon

- Serious concerns exist regarding the safety and operability of the existing access road. It is our understanding that the Hamlet has similar concerns about the access road. Therefore, it is recommended that the access road not be used to haul sewage on a regular basis to the P-Lake Lagoon.

- A lift station and forcemain at Site "B" is the recommended alternative to pursue further in preliminary and detailed design in order to avoid using the access road for hauling sewage. The preliminary opinion of probable cost for this option ($6.1 Million) is comparable to the suggested hair-pin turn improvements (Option B3 - $7.5 Million with snow shed or $6.3 Million without snow shed) and the annual operation and maintenance cost of both options is also similar (just over $400,000). However, the lift station and forcemain option will alleviate safety issues and operational issues associated with hauling sewage on the access road (even with access road improvements).

- The Hamlet should be consulted to confirm whether it is preferable to pursue the installation of a lift station and forcemain in order to avoid using the access road for hauling sewage, as opposed to improving the access road.

- If the Hamlet prefers to improve the Access Road instead of installing a lift station and forcemain, Option B3 is the recommended hair-pin turn improvement option. The proposed hair-pin turn improvements do not completely eliminate the sharp curve and steep grade that plagues the access road; doing so is not achievable given the topography. Snow fences and/or snow shed options could be investigated if the Hamlet decides to continue to use the access road to haul sewage. Use of a quick-connect hose system at the truck discharge chute could reduce problems associated with the orientation of the chute towards the prevailing wind direction.

8.3 COST OF RECOMMENDED UPGRADES

The opinion of probable cost for the recommended upgrades is $6.4 Million. This includes bentonite addition to attempt to seal the west berm ($25,000), a new lift station and forcemain to transfer sewage from the Hamlet to the P-Lake Lagoon ($6.1 Million), service road ditch improvements to reduce inundation of the lagoon by runoff and snowmelt ($100,000) and a pumping decanting system for the lagoon ($135,000).

If a secondary treatment cell is required (either for capacity increase or in case sealing the berm is not effective), an additional $3.7 Million may be required.

The total annual operation and maintenance cost of the recommended options is approximately $431,000 including forcemain and lift station O&M ($406,000 for "Site B") and general maintenance of the lagoon ($25,000). These O&M costs do <u>not</u> include collection of sewage from individual holding tanks within the Hamlet as this is required no matter what option is pursued.

Appendix A TRIP REPORT

Cape Dorset sewage Lagoon Project

Trip Report Summary

Prepared by Ken Johnson, RPP, P.Eng.

August 26, and 27, 2014

Stantec project team: Ken Johnson (project manager / environmental engineer), Jim Oswell (permafrost engineer)

GN project team: Erin Mentink (GN Iqaluit); Matt Price (GN Cape Dorset)

Day 1

Evening inspection of access road and lagoon site for overview and orientation (video log 1) by Johnson and Oswell; general discussions of various issues concerning access road alignment, grade, and drainage, and lagoon leaking.

Day 2

Morning inspection of access road and lagoon for detailed site information on access road alignment, grade, and drainage (video log 2) by Johnson and Oswell; continuing discussion of various issues concerning access road alignment, grade, and drainage, and lagoon leaking.

Afternoon meeting with Hamlet staff by Johnson, Oswell and Mentink (see Attachments B and C).

Afternoon inspection of access road and lagoon with Mentink and Price, and discussions concerning access road alignment, grade, and drainage, and lagoon leaking.

Evening meeting with Council by Johnson, Oswell and Mentink (See Attachments B and D).

Day 3

Morning inspection of site for detailed information on discharge route from west berm to ocean by Johnson and Oswell; feartures include lake, stream, wetlands area and ultimate disappearance of stream into rockfall before discharge into ocean (video log 3).

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Afternoon inspection by Johnson of existing sewage lagoons for overview and orientation

Attachments

A. General site photos

- Lagoon panoramas from each corner (2 pages 2 panoramas on each page)

- Lagoon discharge area (lake, wetland, subsurface discharge)

B. Summary notes of meeting with Hamlet Staff and Hamlet Council

C. Satellite image with details and notes concerning road alignments based upon discussion with Hamlet staff

D. Satellite image with details and notes concerning various aspects of lagoon development based upon discussion with Hamlet Council.

E. Options for remedial work based upon Terms of Reference and site discussions

Video Logs available as a separate document (DVD)

END OF REPORT

View from Southwest Corner

View from Northwest Corner

Cape Dorset

Sewage Lagoon Assessment

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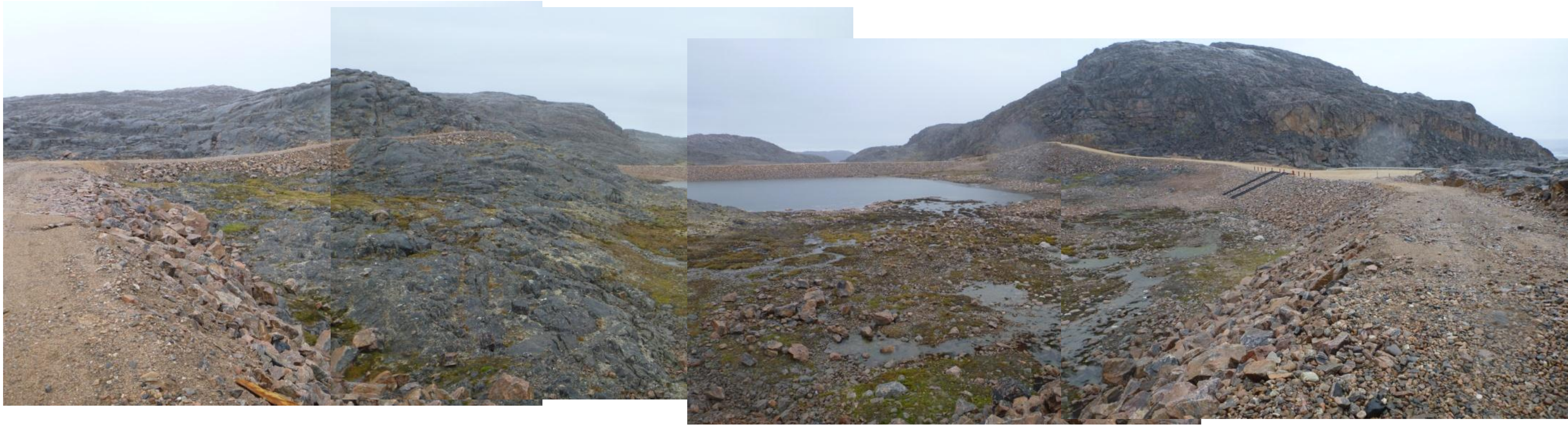
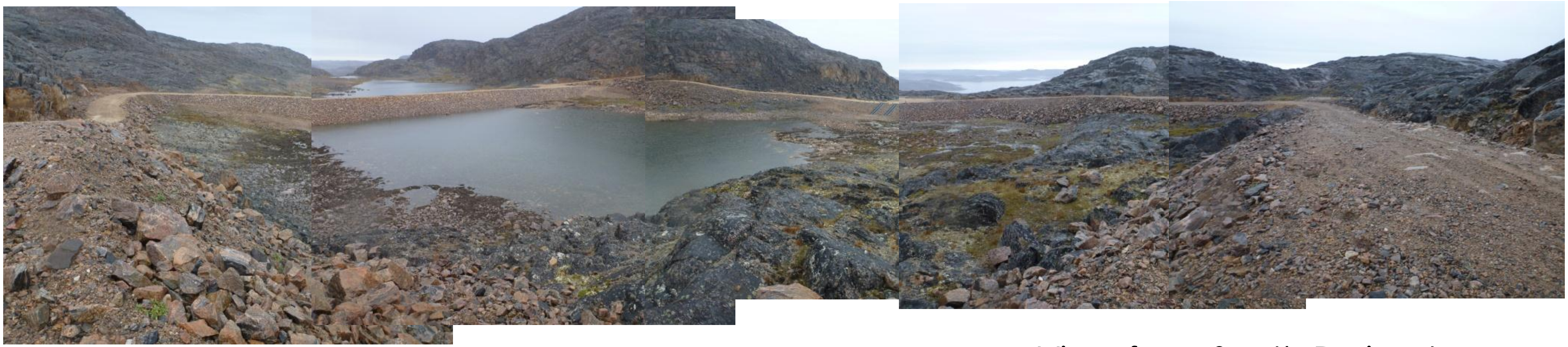
Panoramic Views

Compiled by Ken Johnson, RPP, P.Eng.
August 27 and 28, 2014



View from Southeast Corner



View from South Perimeter

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Sewage Lagoon Assessment

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Panoramic Views
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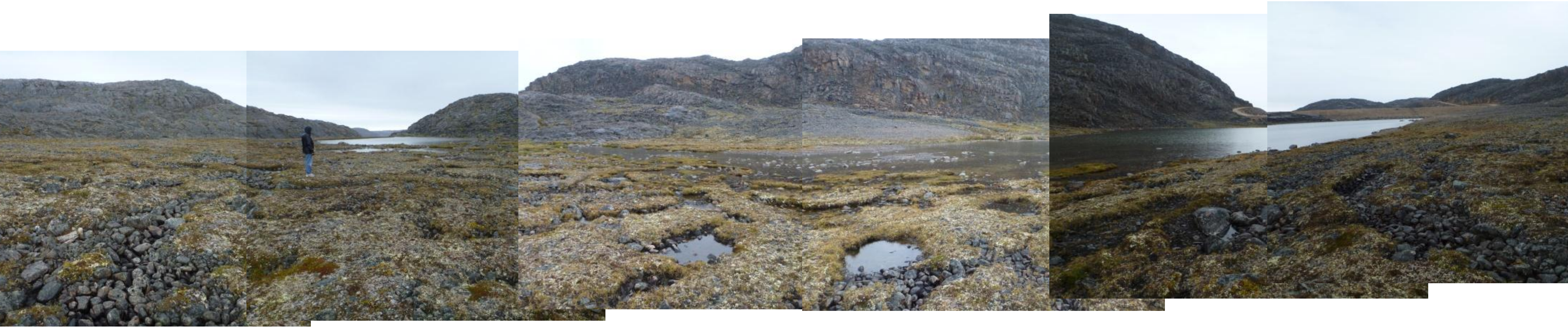
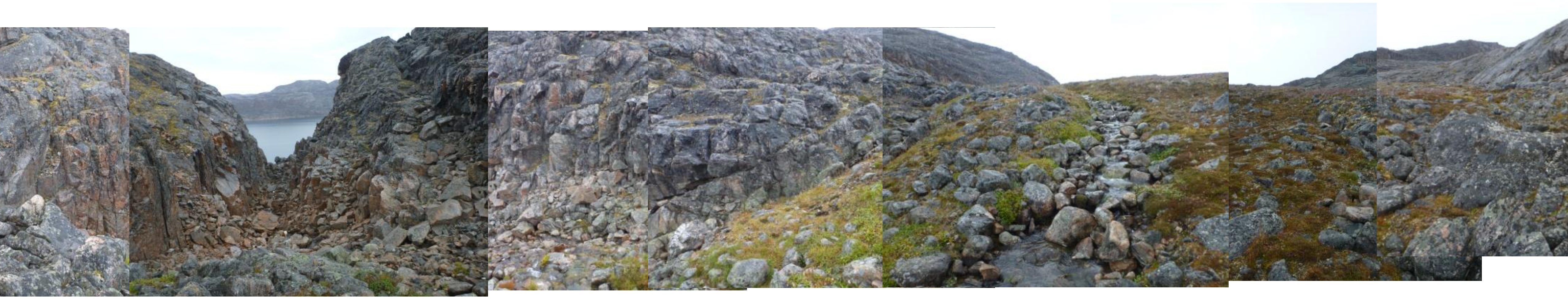


View at Pod and Wetland Area (west of lagoon)



View at Rockfall Near Ocean - Stream Flow Disappears

Cape Dorset

Sewage Lagoon Assessment

Stantec

Panoramic Views

Compiled by Ken Johnson, RPP, P.Eng.
August 27 and 28, 2014

Cape Dorset Lagoon Assessment

Notes from Meetings with Hamlet Administration and Hamlet Council

Prepared by Ken Johnson, RPP, P.Eng.

August 27 and 27, 2014

August 26, 2014

Meeting with the Hamlet Staff

Steve - Hamlet Foreman
Mary Jo - Senior Administrative Officer

- Comment that during winter the sewer trucks have frequently slid backward going up the road to the lagoon
- The road to the lagoon is providing access to water lake
- Three options for alternative access were discussed
- The waterline is freezing 2 to 3 times per year in spite of the use of heat tracing
- Ditch along the south side of road does not have enough capacity for the spring melt
- The lagoon is leaking from the east and the west
- The discharge manhole fills up water
- The grade along the access road is a concern
- Ten truckloads of sewage are usually collected per day; amounts to 100,000 to 150,000 litres per day
- In 2003, 53 million liters of water was used by the community

August 26, 2014

Meeting with the Hamlet council

- General comment about the road that it is a serviceable for access to the sewage lagoon
- General comment about the lagoon is currently free flowing
- Comment that some more studies are needed on the lagoon; specifically a concern that the level of the sewage lagoon is the same level as the water lake and seepage may occur
- Comment that water monitoring may be required near the community to assess seepage from the lagoon seepage to the east; there are sampling wells near the landfill
- Comment that a mechanical treatment system could be purchased for $500,000 to $600,000 dollars

- Comment that there is suspected leakage east through the berm at the truck dump
- Comment that there is a leak of the geomembrane liner system
- Comment that the piped discharge system from the lagoon is freezing
- Comment that pumping is now used for the discharge of most lagoons in Nunavut
- Comment that there are well sampling sites at the lagoon
- Suggestion that a new lagoon could be constructed near the existing sewage lagoon system; alternatively a new lagoon and could be constructed near the Airport (subsequently noted that proximity to emergency water supply would be an issue with this site)
- Comment that trucks traveling along the access road to the lagoon are an "accident waiting to happen"
- Comment that snow management is required for the snow drifting that occurs; there is wind monitoring at T lake by Nunavut Power which may be useful
- Comment that s sewage lift station is an option to replace truck travel on the road

END OF NOTES

NOTES
1. Alternate road alignments B and C proposed by Hamlet Administration during consultation session; alignment A proposed in consultation with Stantec.
2. Snow drifting identified by Hamlet Administration with depths well exceeding reach of front end loader.
3. Suspected leak from lagoon identified by Council based upon recollections of original ground drainage.
4. Tee Lake access trail constructed by Hamlet as alternate access to steep trail beside waterline.
5. Dominant winter wind direction taken from NavCanada wind rose for Cape Dorset.

Cape Dorset
Sewage Lagoon Assessment

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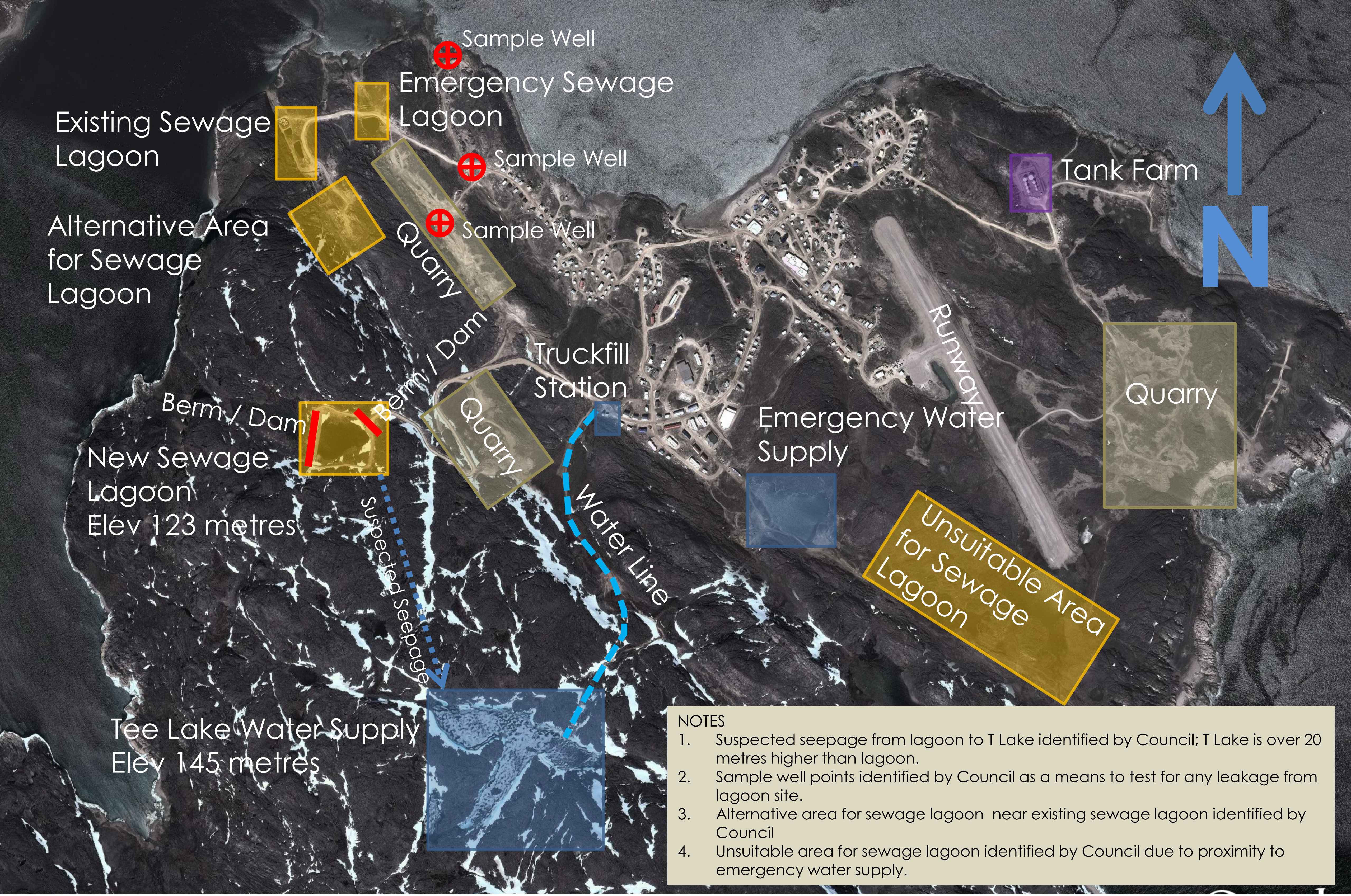
Trip Notes from Administration Discussion
Compiled by Ken Johnson, RPP, P.Eng.
August 27 and 28, 2014



NOTES

1. Suspected seepage from lagoon to T Lake identified by Council; T Lake is over 20 metres higher than lagoon.
2. Sample well points identified by Council as a means to test for any leakage from lagoon site.
3. Alternative area for sewage lagoon near existing sewage lagoon identified by Council
4. Unsuitable area for sewage lagoon identified by Council due to proximity to emergency water supply.

Cape Dorset
Sewage Lagoon

Stantec

Trip Notes from Council Discussion

Compiled by Ken Johnson, RPP, P.Eng.

August 27 and 28, 2014

Cape Dorset Lagoon Assessment

Options for Remedial Work and Process Enhancement

Prepared by Ken Johnson, RPP, P.Eng.

August 27 and 27, 2014

1. Road access - do nothing
2. Road access - Alignment A
3. Road access - Alignment B
4. Road access - Alignment C
5. Road drainage - no particular options identified at this time
6. Snow fencing for snow drifting control
7. Lift Station and Forcemain (access road to lagoon becomes service road)
8. Lagoon leak - do nothing - eventual plugging by biomass
9. Lagoon leak - grouting product added to flow to seal leak
10. Lagoon leak - grout curtain wall to seal wall
11. Lagoon leak - reconstruct entire berm
12. Downstream area - add to ww treatment process for retention / detention volume
13. Downstream area - add to ww treatment process for wetland area
14. Downstream area - add to ww treatment process for cascading area (subsurface flow)

Appendix B BERM THERMISTOR DATA

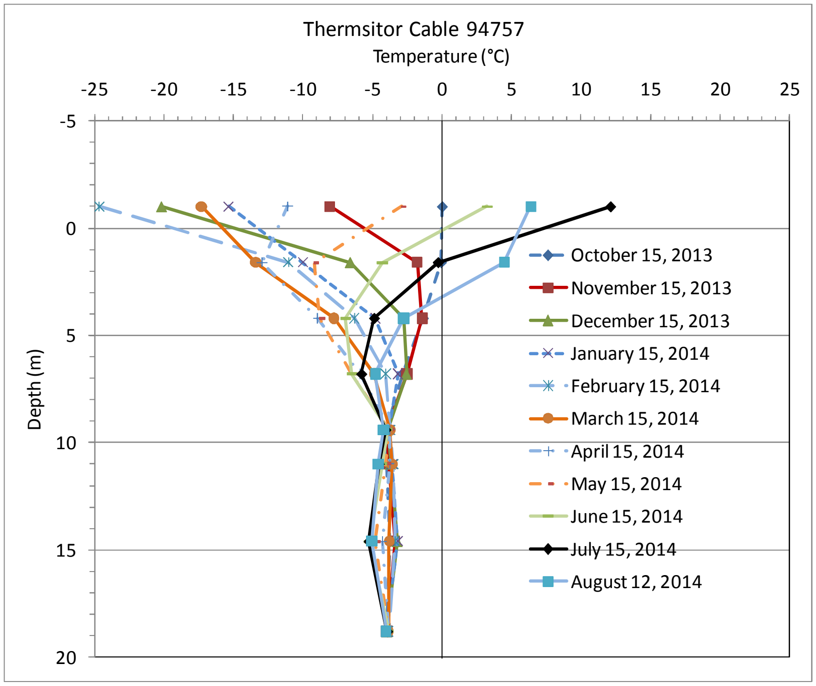


Figure B1: Ground temperature data from thermistor cable 94757

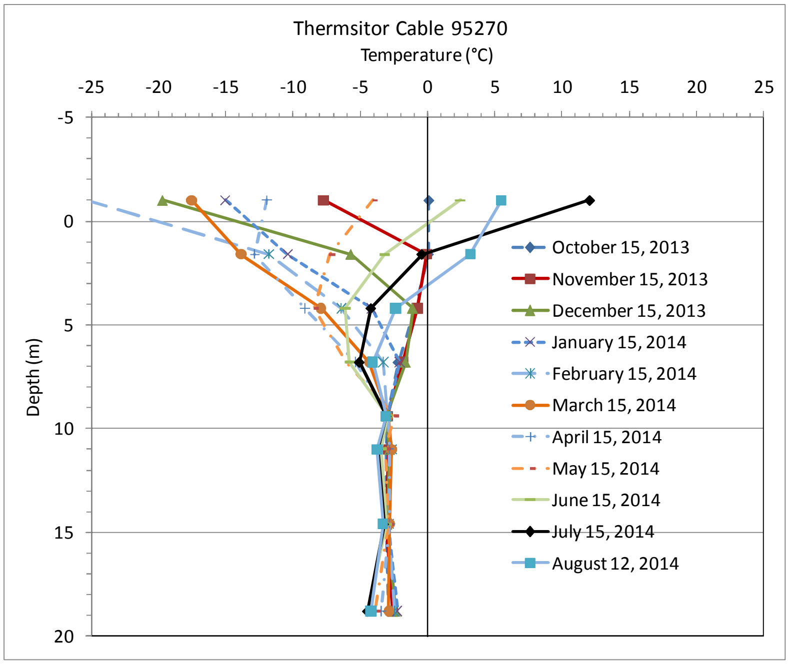


Figure B2: Ground temperature data from thermistor cable 95270

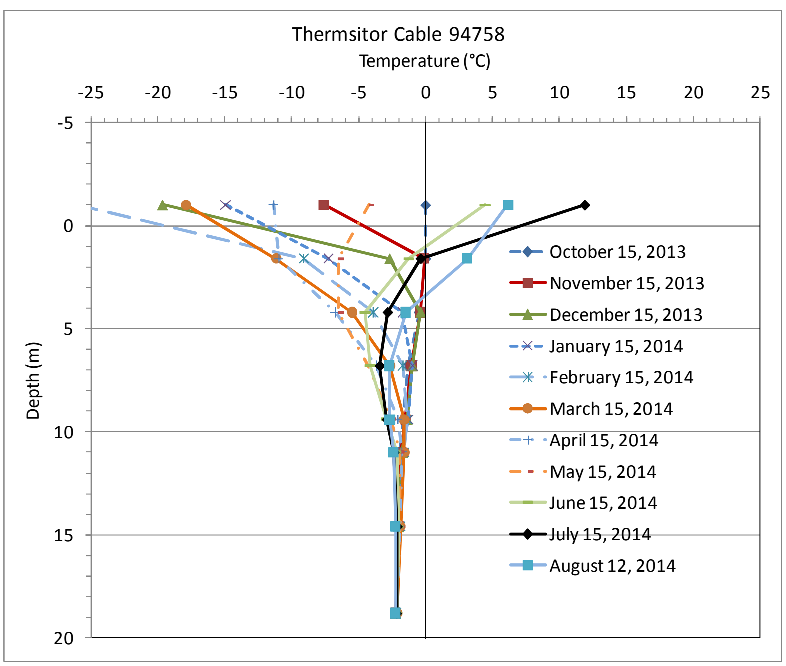


Figure B3: Ground temperature data from thermistor cable 94758

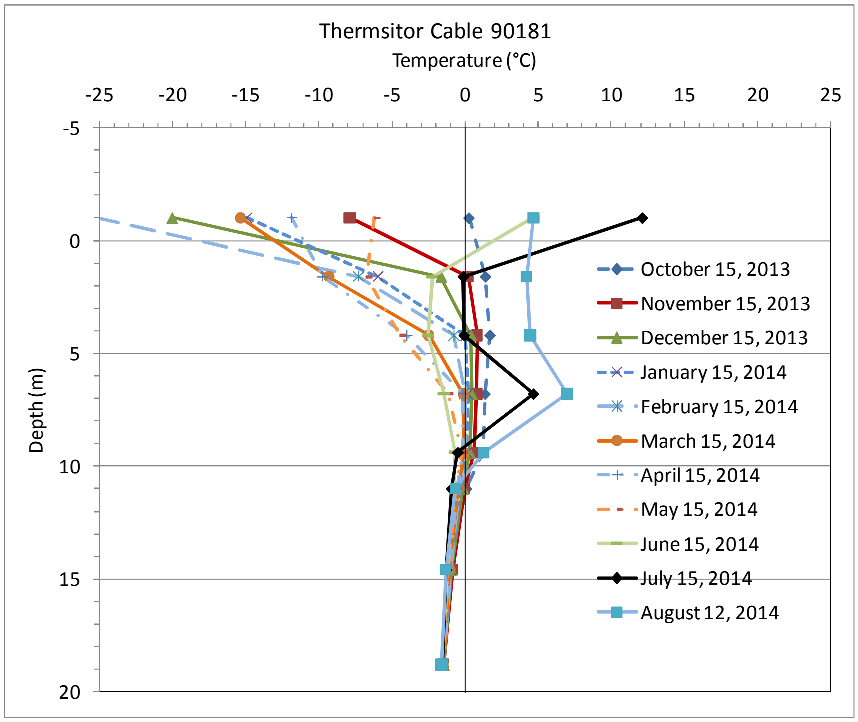


Figure B3: Ground temperature data from thermistor cable 90181

Appendix C WASTEWATER TREATMENT PROCESS REVIEW

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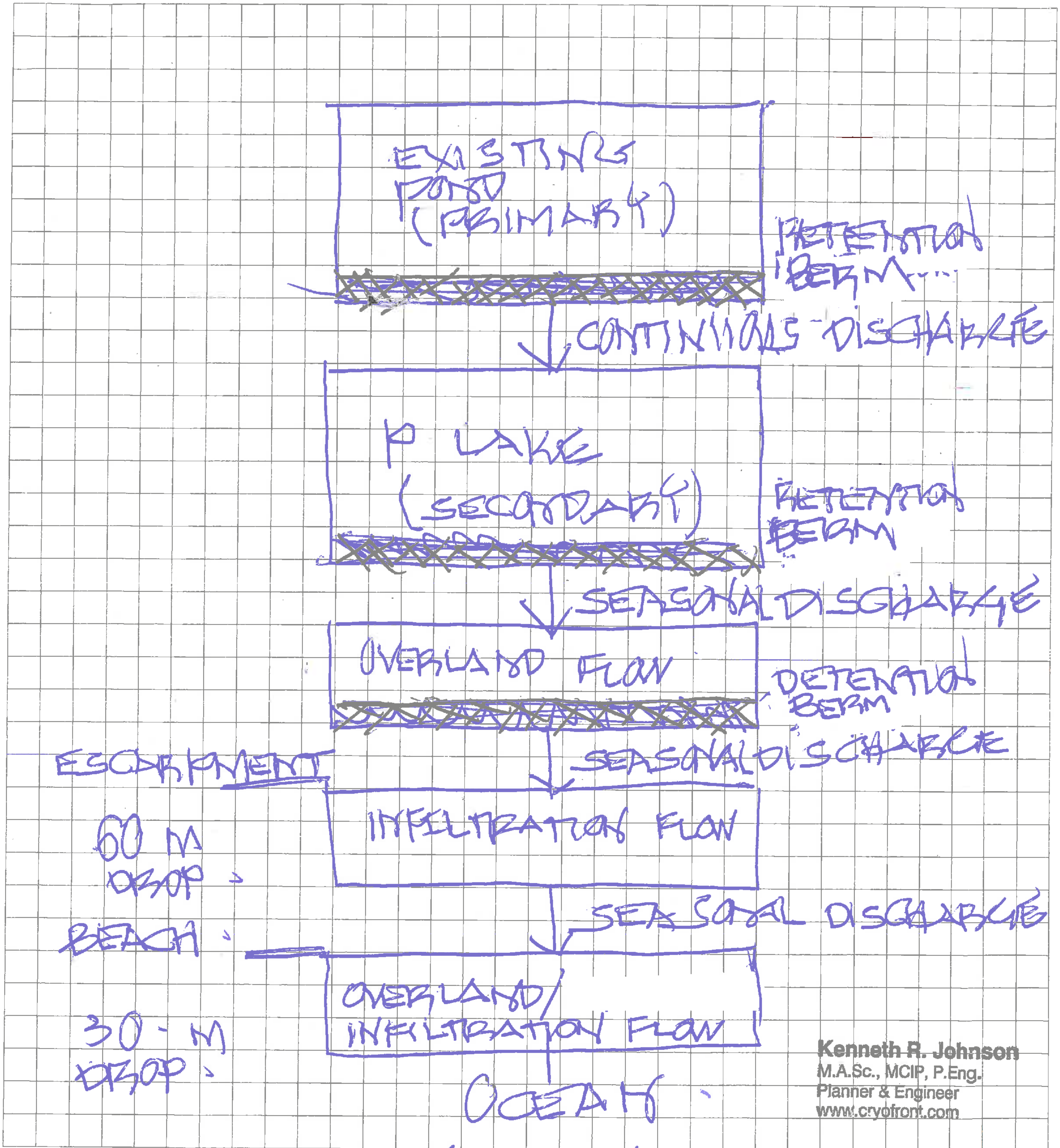

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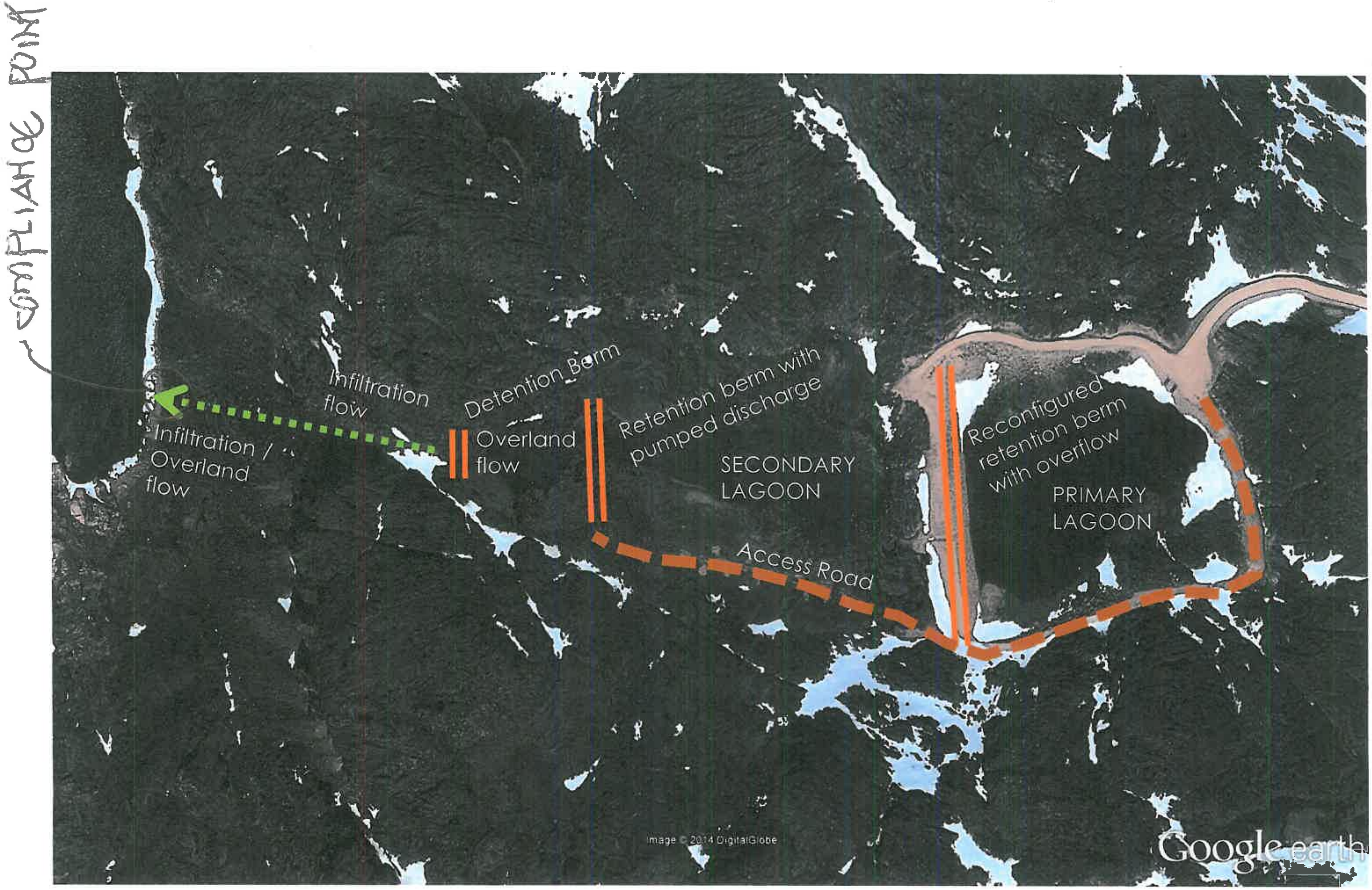

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Lagoon Reconfiguration

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Figure ??

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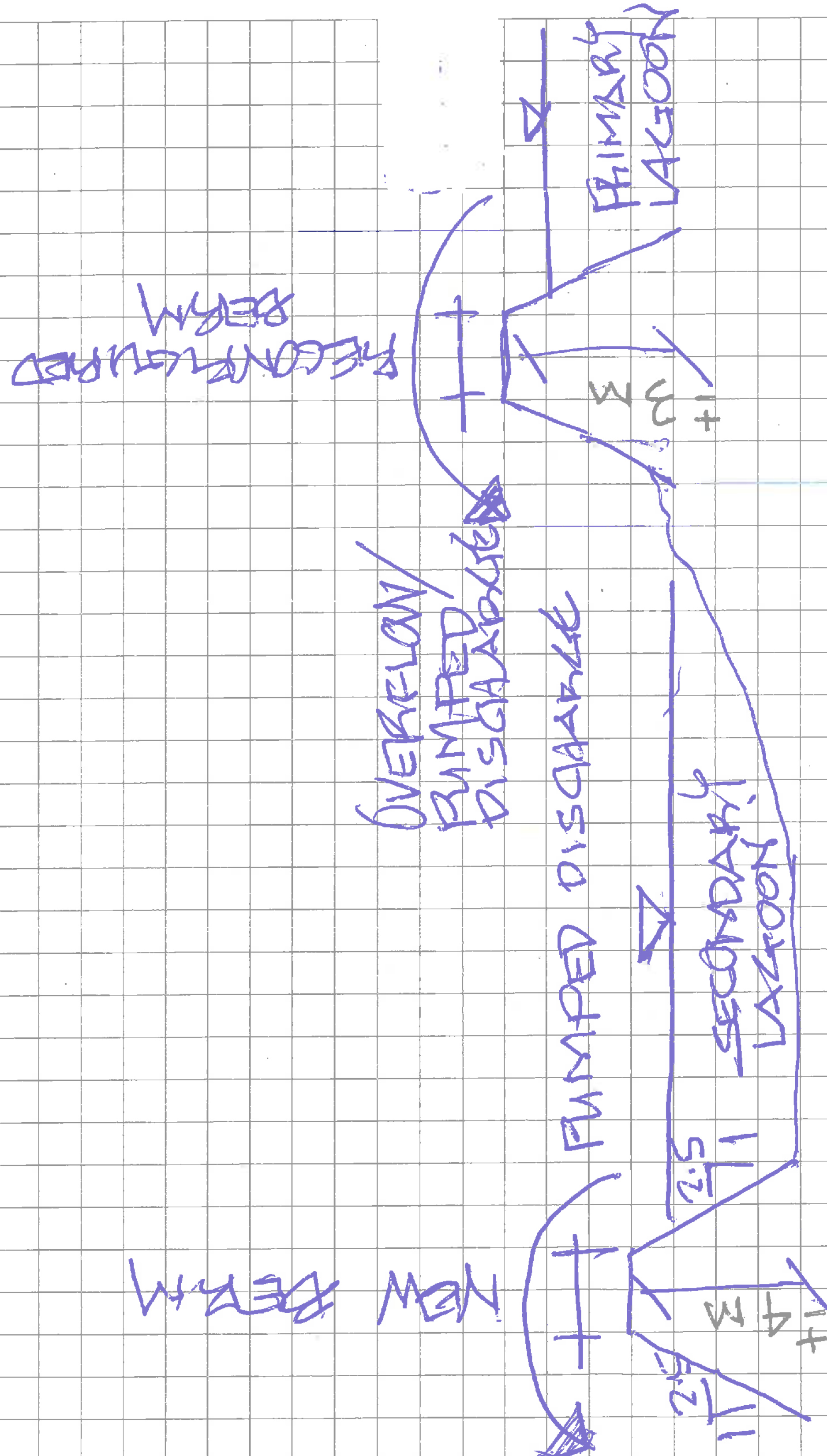

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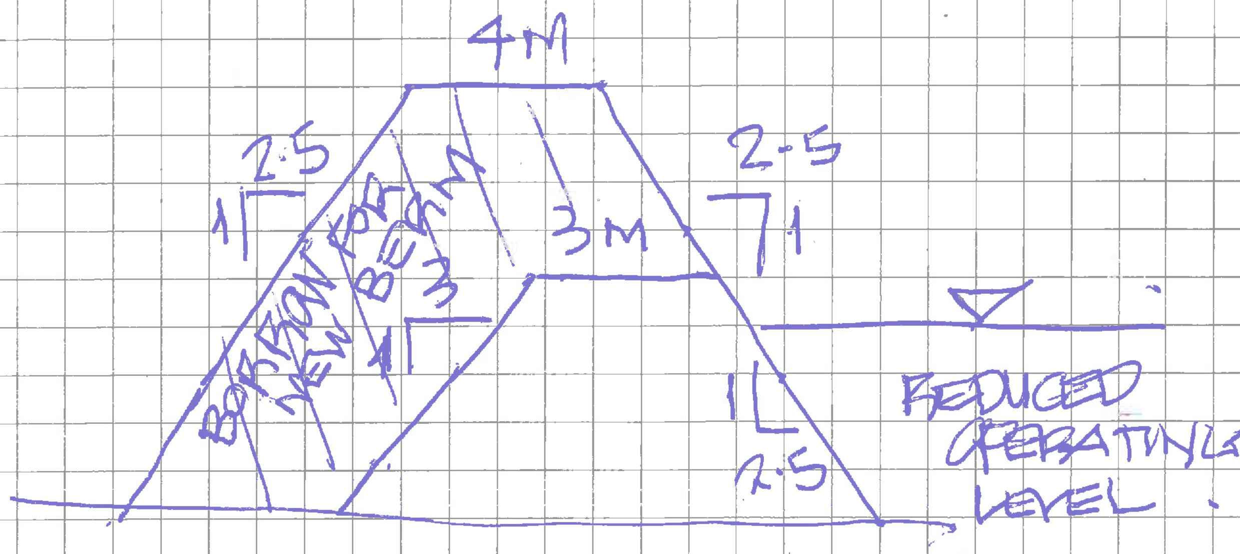
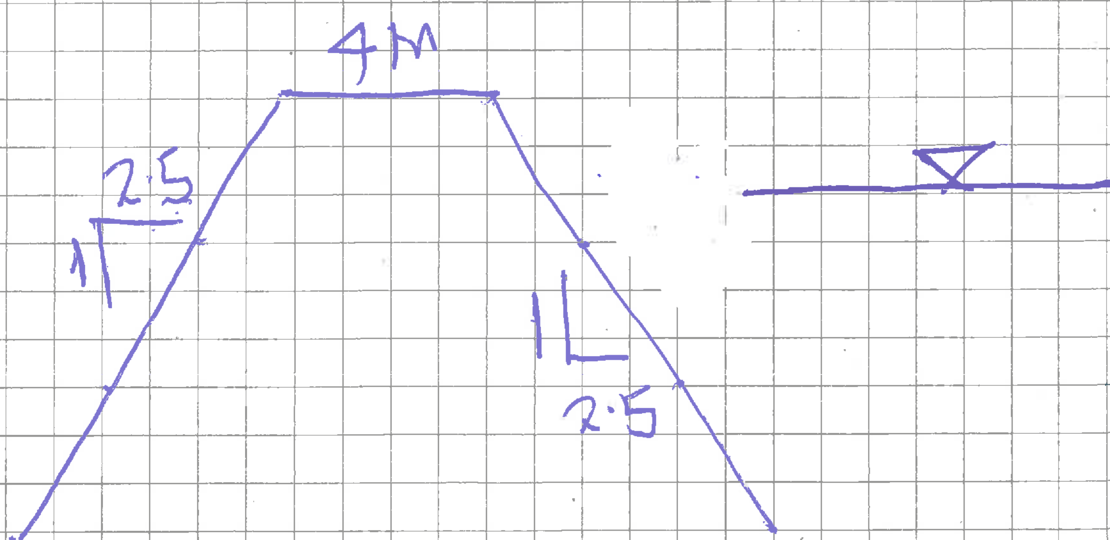


RECONFIGURED BERM



NEW BERM

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CAPE DORSET WW

JAN 0 6 2015

Designed by: KRJ

Checked by:

Appendix D ROAD SAFETY REVIEW

Access and Service Road Concerns

Figure 1 shows the access and service roads connecting the lagoon facility to the town in Cape Dorset. The next few paragraphs include a discussion of the road safety concerns on the Access Roads to the Lagoon and the Service Road around the facility; a brief assessment of each concern is conducted and potential solutions are recommended for each of the highlighted concerns.

Figure 1: Cape Doreset Access and Service Roads

- ***Safety of Hairpin Turn:***

✓ **Assessment**

The primary concern on the access road is the safety of the hairpin bend. The bend has an increasing grade and a number of horizontal curves. At the sharp U-turn a grade of 6.07% is observed between the beginning of the curve and its centre, moreover, the grade between the centre of the curve and its end is 8.3%. When considering typical design guidelines of hairpin curves it is noted that, the grades throughout the road exceed the allowable limits. As seen in table 1 from the IRC Hill Road Manual [1], the maximum allowable gradient on a hairpin curve is 2.5%. Furthermore, Transportation Association of Canada's (TACs) design guide for Canadian roads [2], recommends that a minimum radius of 90 metres for 180 degree turns on 50kph roads, this condition is clearly violated on the access road hairpin turn, where the radius is approximately 20-30m.

Table 1: Design Criteria For Hairpin Bends

Design Speed	20 Kmph
Minimum Carriageway Width	11.5 m for two lanes
Minimum Radius of Inner Curve	14.0 m
Minimum Length of Transition Curve	15.0 m
Maximum Gradient	2.50%
Minimum Gradient	0.50%
Superelevation	10%
Roadway Flaring	Concentric w.r.t. Center Line
Distance between two Hair Pin Bends	60m
Type of Full Roadway Width	Surfaced

✓ Suggestions

Re-design of the hairpin could be costly, therefore, considering alternatives, which could provide significant improvement to the situation, is recommended.

A number of low-cost remedies, such as chevron signs, sharp curve warning signs and lighting at the U-turn could all be considered to improve the safety at the curve. Further discussion of these measures in provided later in the report.

▪ *Road Widths:*

✓ Assessment

The southeastern service road is extremely narrow, with width ranging from (4.5 to 5.5 meters). There is no way this is enough to safely accommodate two vehicles, in fact, even for one-way service roads, Australian design guidelines [3] recommend that the minimum width of the lane should be 3.4m excluding the shoulder widths as evident in table 2. The narrow lanes or narrow roads in general raise safety concerns due to the increased likelihood of head-on, run off the road and sideswipe collisions. Figure 2,[4], shows the collision modification factors (CMFs) associated with the increase in the width of lanes on two-way rural roads. It is worth nothing here that 9ft (2.75m) lane widths increase the probability of collisions by 5% to 50% when compared to 12ft (3.67m) lanes, depending on the traffic volumes observed on the road.

Table 2: Minimum Service Road Lane Widths for Low Volume Traffic

	Minimum width per lane (m) for a service road that provides:	
Road Type	Residential access	Industrial access
One-way through traffic	3.4	3.4
Two-way through traffic	5.5	5.5

The minimum shoulder width required in the American Association of State Highway and Transportation Officials (AASHTOs) design guidelines is 0.61m [5], assuming that this shoulder is provided on the service road, this leaves us with 2.14m per lane which is well below acceptable limits. On the other hand, in case of the Access road, where road width ranges from (8~8.5m) as per the plans, similar calculations yield a lane width of 3.39m which is satisfactory unless other issues are observed on the road. It is also important to note that curved segments require increased road widths.

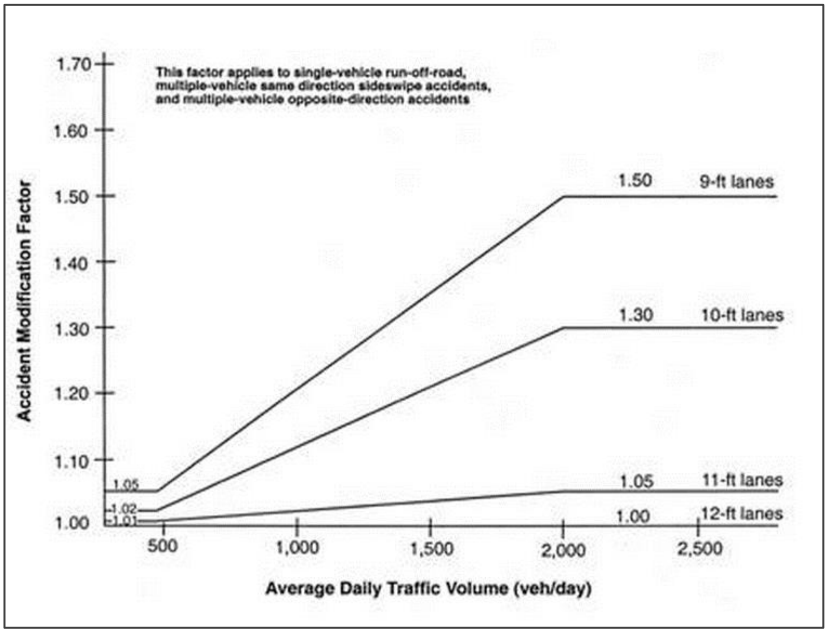


Figure 2: Collision Modification Factors For Different Lane Widths

✓ Suggestions

In order to resolve the situation of narrow lanes on the service roads there are two options 1) convert the road into a one-way road, however, this should only be considered as a temporary solution since the road width is still narrow for one-way traffic. 2) Increase the road width.

In a study by the US Federal Highway Administration (FHWA) evaluating safety of lane and shoulder width combinations on rural undivided two lane roads[6], a combination of wide lanes with narrow shoulders on rural roads are recommended. The study involves evaluating the effects of changing lane and shoulder widths on safety for roads of fixed pavement width. The combined effect of several collision modification factors for different alternatives was compared in the study and it was reached that roads of 3.66m lane widths produced optimal safety results. Adjusting lane and shoulder widths could be effective in addressing the discomforts experienced by drivers on the access road.

- ***Steep Grade:***

✓ **Assessment**

In addition to the steep grades experienced on the access road's hairpin turn, significantly steep curves are also found on the southeastern service road. TAC design guidelines recommend that the maximum grade on local industrial roads is 6% [2], this recommendation is clearly violated on both the access and service roads. Grades on the southeastern service road reach 15%. Whereas on the access road a grade of 7.6% is experienced between stations 0+800 and 0+900.

It is well accepted that sharp vertical grades have negative effects on safety. This is particularly true when grades are present before locations where vehicles are expected to slow down (e.g. intersections, driveways or horizontal curves) as in the case of the southeastern service road. Drivers approaching the curve "A", figure 1, come from a steep downward grade (6.5% from the crest of the vertical alignment to the beginning of the horizontal alignment). While drivers are expected to slow down before entering the horizontal curve, the sharp grade means that this is practically difficult to achieve.

In addition to the effects vertical curve have on speeds of vehicle, they also affect the sight distance available to drivers. Although the relationship between vertical curves and collisions count is not so clear, the TAC geometric design guide for Canadian roads still recommends the use of a collision modification factor (CMF) of 1.08 for every percent increase in vertical grade[2]. This indicates that for every percent increase in grades at a certain location increases the likelihood of collisions by 8 percent.

✓ **Suggestions**

Although the primary solution for steep grades is re-alignment of the grade, low cost measures do exist. The installation of grade warning signs could help remind drivers to adjust speeds. Another low-cost option that could be considered on the southeastern service road is transverse rumble strips. These strips are pavement markings that produce vibrations and audible warning when overpassed by a vehicle's types. The strips could be installed at the end of the vertical grade just before the beginning horizontal curve. One more measure, which could be considered on steep grades, is street lighting; this would increase sight distance on the grade and improve the visibility for drivers.

- ***Blind Spot:***

✓ **Assessment**

As mentioned earlier the combination of the steep grade and the sharp horizontal curve at point A on figure1 develop a highly demanding situation for drivers. Moreover, these risks are magnified in dark and icy conditions. Curves in general are associated with higher head-on and run off the road crashes due to poor visibility [7].

Assessment of the blind spot or a blind corner is possible by comparing the available sight distance (ASD) at the site to the minimum acceptable stopping sight distance (SSD). The SSD is known as the sum of two distances (1) the distance traveled during the perception reaction time (thinking time required before taking action) and (2) the breaking distance required to come to a complete stop in case an emergency is detected on the road. Table 4, 2.1.2.10 in the TAC design guidelines[2], compares the Stopping Sight Distance (SSD) required in normal conditions to the SSD on horizontal curves of different super-elevations; the calculations are based on the minimum allowable curve radius for different design speeds.

Table 3: Calculated Stop Sight Distance for Minimum Radius Curves

Design Speed (km/h)	Assumed Operating Speed (km/h)	Normal Stopping Sight Distance Table 1.2.5.3 (m)	Calculated Stopping Sign Distance on Minimum Radius Curves (m)		
			e = 0.04	e = 0.06	e = 0.08
40	40	45	46	46	46
50	47-50	60-65	60-66	60-66	60-66
60	55-60	75-85	77-90	77-90	77-90
70	63-70	95-110	98-120	97-120	97-120
80	70-80	115-140	117-152	116-152	116-151
90	77-90	130-170	135-180	134-180	134-181
100	85-100	160-210	161-219	160-218	160-219
110	91-110	180-250		181-259	181-259
120	98-120	200-290		205-302	204-301
130	105-130	230-330		229-338	229-338

✓ Suggestions

Addressing concerns at blind corners include posting warning signs about the limited sight distance encouraging drivers to slow down (figure 3). Reflective material should be used for the sign in order to increase its visibility in the dark. It is also recommended that chevron signs be installed throughout the curve location. Moreover, removal of objects obstructing the line of sight of drivers approaching the blind corner (eg: removal of trees, adjustments to embankment slopes) could also be an effective yet low cost measure, see figures (4 and 5). Another alternative would be to re-design the curve in accordance with accepted design guidelines, which, although a costly option, must be seriously considered if the location is highly accident-prone.

Figure 3: Blind Corner Warning Sign

Curve warning signs could reduce up to 18% of all crashes according to the FHWAs guide for reducing collisions on horizontal curves[7], while the reduction due to chevron signs ranges from 4 to 25% according to the same source.

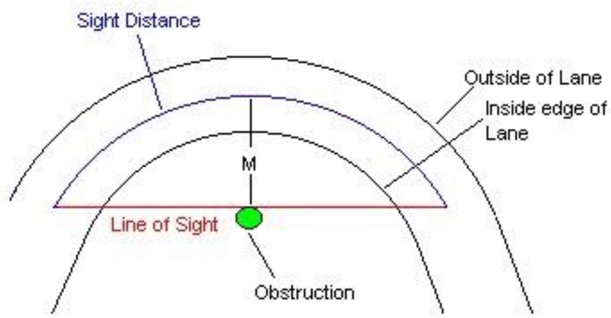


Figure 4: Stopping Sight Distance and Line of Sight

Figure 5: Trees Cut-off to Avoid Obstructing Driver's Line of Sight (Cape-Breton Trans Canada Highway)

- ***Poor Visibility In The Dark:***

✓ Assessment

Due to the presence of sharp vertical and horizontal alignments on the roads considered, visibility problems are expected. As discussed in case of the bind corner curve, horizontal and vertical curves both reduce the sight distance available to drives. Understandably, this problem is magnified during dark conditions. In fact, it is noted in the US FHWAs guide for reducing collisions on horizontal alignments [7] that 51% of 2002 fatal collisions on rural horizontal curve were nighttime crashes, a finding which was attributed to the reduced visibility.

✓ Suggestions

As a result, lighting should be considered particularly at locations of steep grades or sharp horizontal curves. As per AASHTOs guidelines, the need for lighting on rural highways is only warranted at critical locations[5], thus, providing lighting at locations circled in red on figure 1 is recommended.

- ***Spring Melt:***

✓ **Assessment**

The drop in temperatures during spring causes the snow and ice to melt, this results in roads becoming more fragile and hence the observed erosion. Heavy vehicles travelling on the road are usually the main cause of the erosion, the appearance of potholes and the overall deterioration of the road's surface.

✓ **Suggestions**

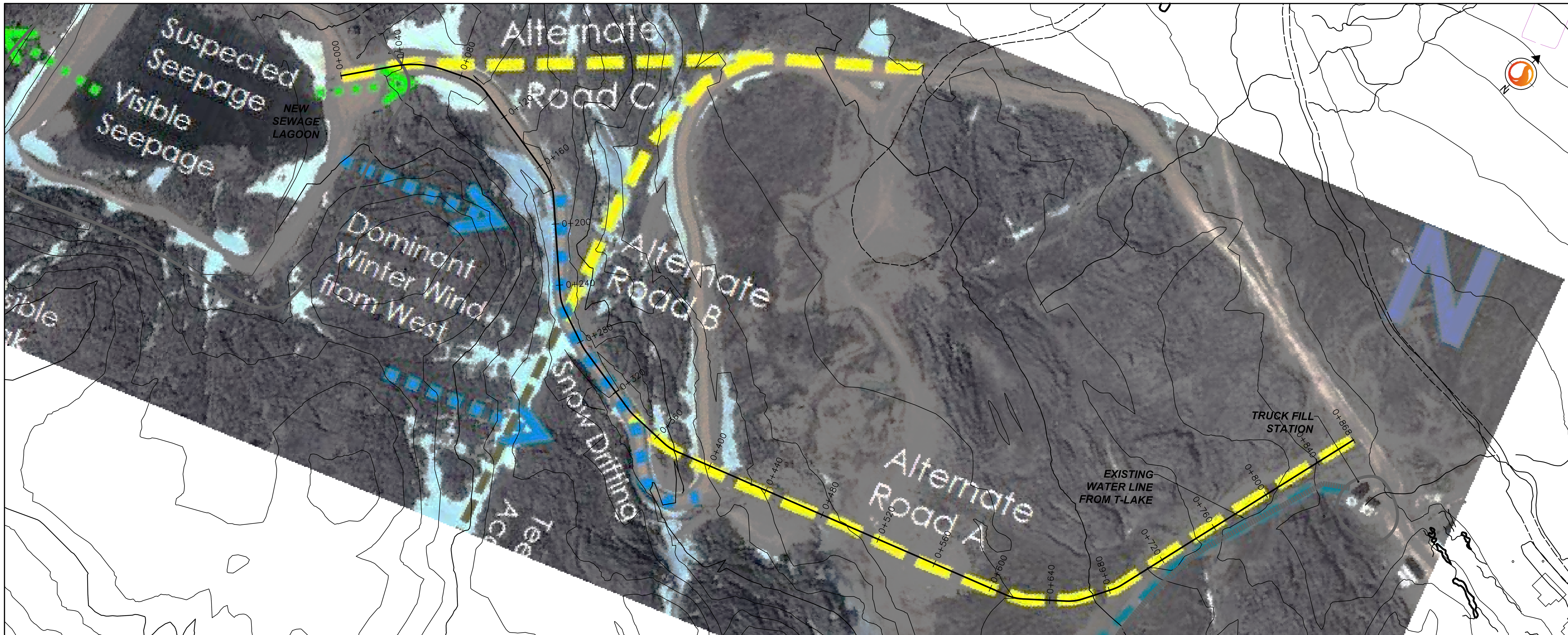
The root solution to such a problem would be to provide climate resistant pavement along the suspect locations. However, this can be economically infeasible especially for roads where the re-design and re-construction is not an option. Since alternative designs are being considered for the access road (hairpin), it is suggested that spring thaws are considered during the design stage of the new roads.

As for the service roads and other roads where alternatives are not considered, a policy, which is implemented in a number of areas across Canada, could come in handy. The policy involves imposing weight limits on trucks using the roads where spring thaw is expected, this helps preserve the condition of the road and avoid extensive damage to the pavement. Levinson et al. [8] found that 7-ton and 5-ton restriction could reduce annual facility costs on roads by 9% and 14% respectively. In addition, appropriate road signage including weight restrictions, the restricted times and spring melt warnings are all recommended at susceptible locations.

References

1. (IRC), I.R.C., *Hill Road Manual*, f.M. Ministry of Road Transport & Highways (MORTH, Editor. 1998.
2. (TAC), T.A.o.C., *Geometric design guide for Canadian roads.* 1999.
3. Roads, D.o.M., *Application of Design Principles and Guidelines*. 2005.
4. Harwood, D.W., et al., *Prediction of the expected safety performance of rural two-lane highways*. 2000.
5. Aashto, A., *Policy on Geometric Design of Highways and Streets.* American Association of State Highway and Transportation Officials, Washington, DC, 2001. **1**: p. 990.
6. Gross, F., et al., *Safety evaluation of lane and shoulder width combinations on rural, two-lane, undivided roads*. 2009.
7. Torbic, D., et al., *A Guide for Reducing Collisions on Horizontal Curves.* National Cooperative Highway Research Program, Guidance for Implementation of the AASHTO Strategic Highway Safety Plan. Report, 2004. **500**.
8. Levinson, D.M., et al., *Cost/Benefit Study of Spring Load Restrictions.* 2005.

Appendix E ACCESS ROAD IMPROVEMENT OPTIONS PRELIMINARY DRAWINGS



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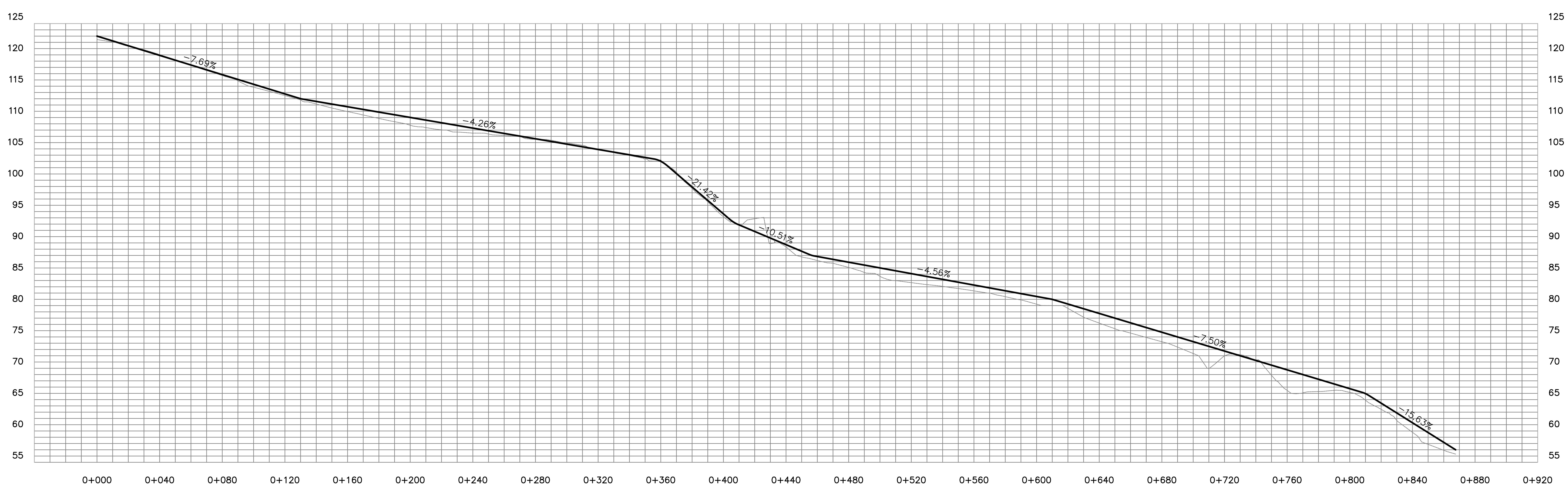

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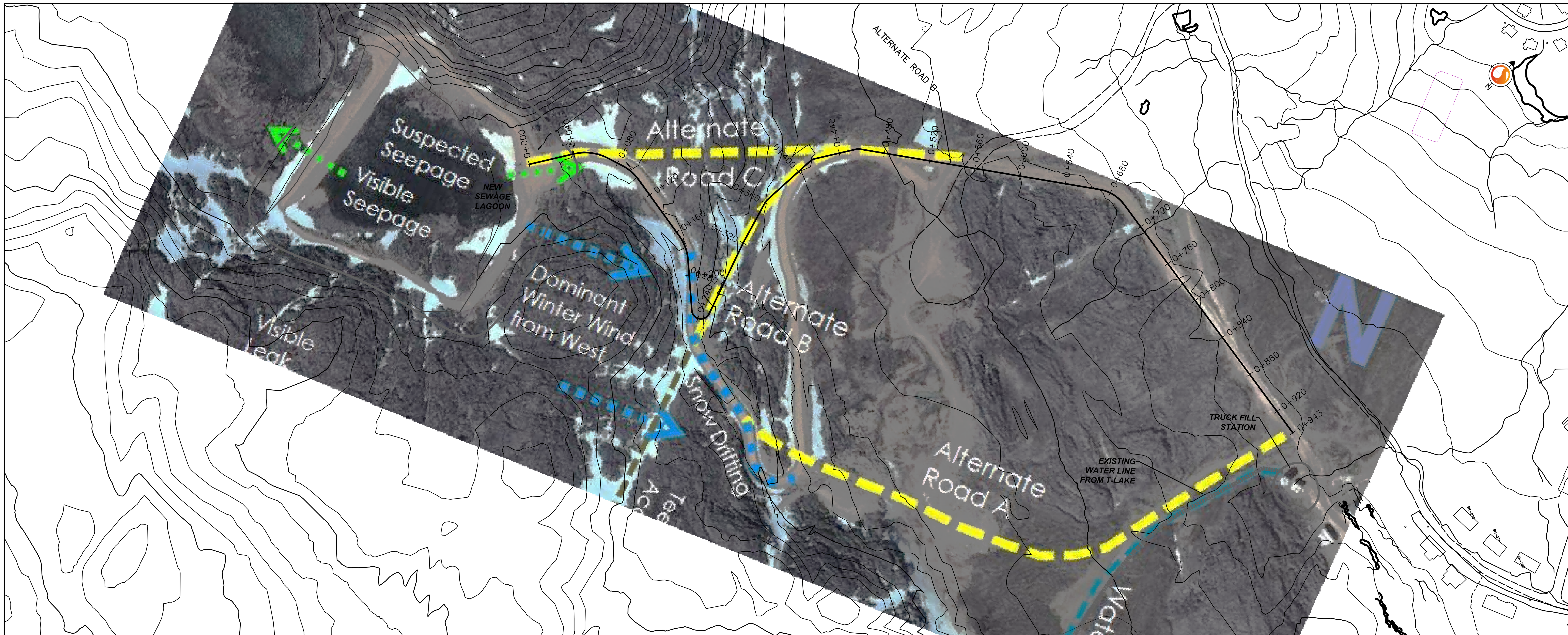

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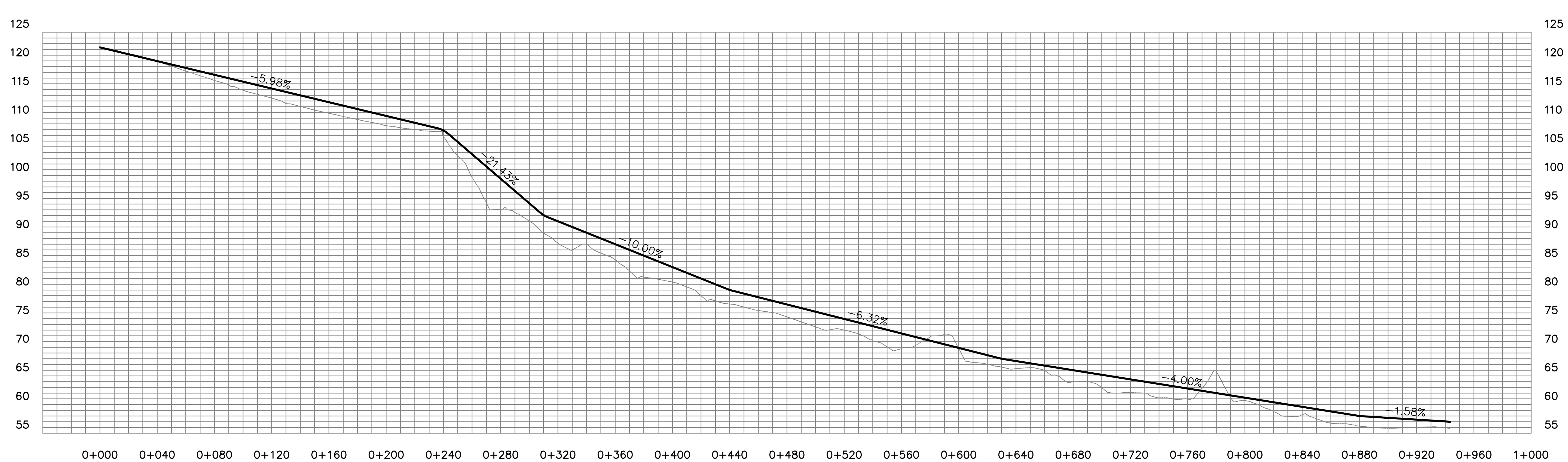

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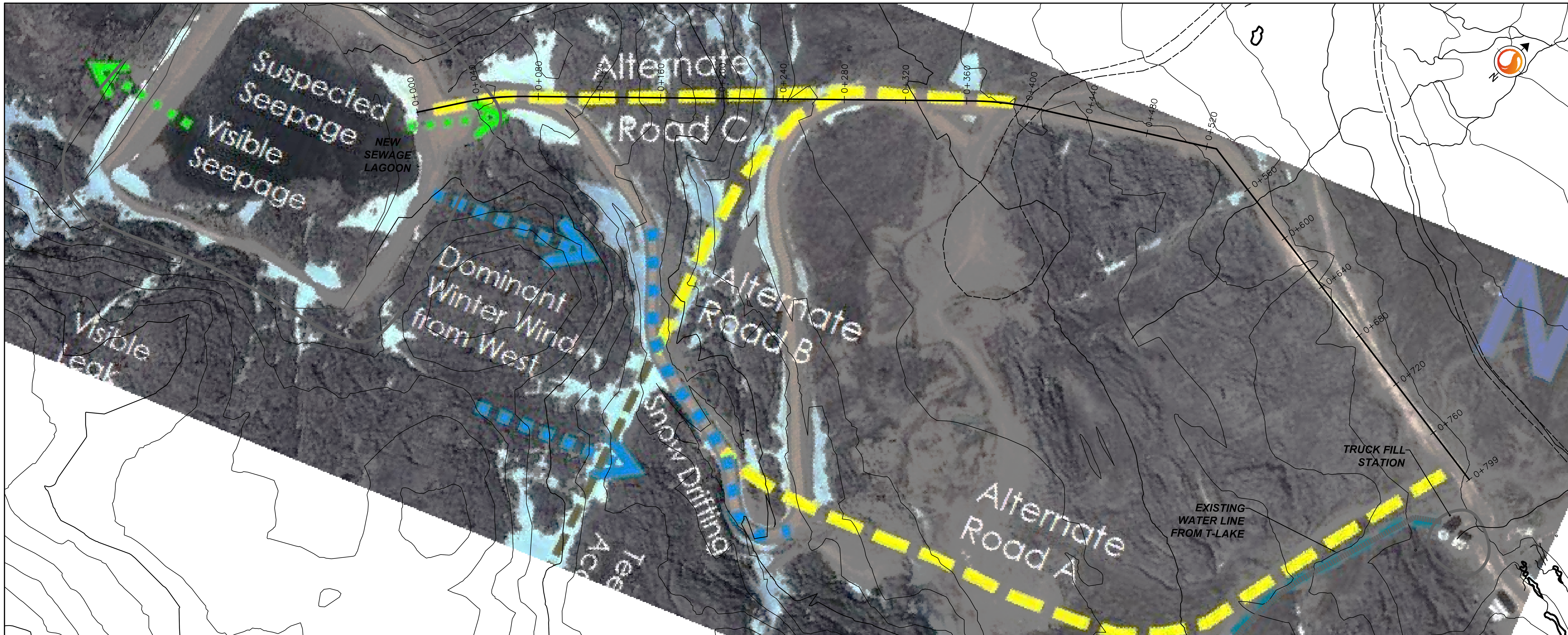

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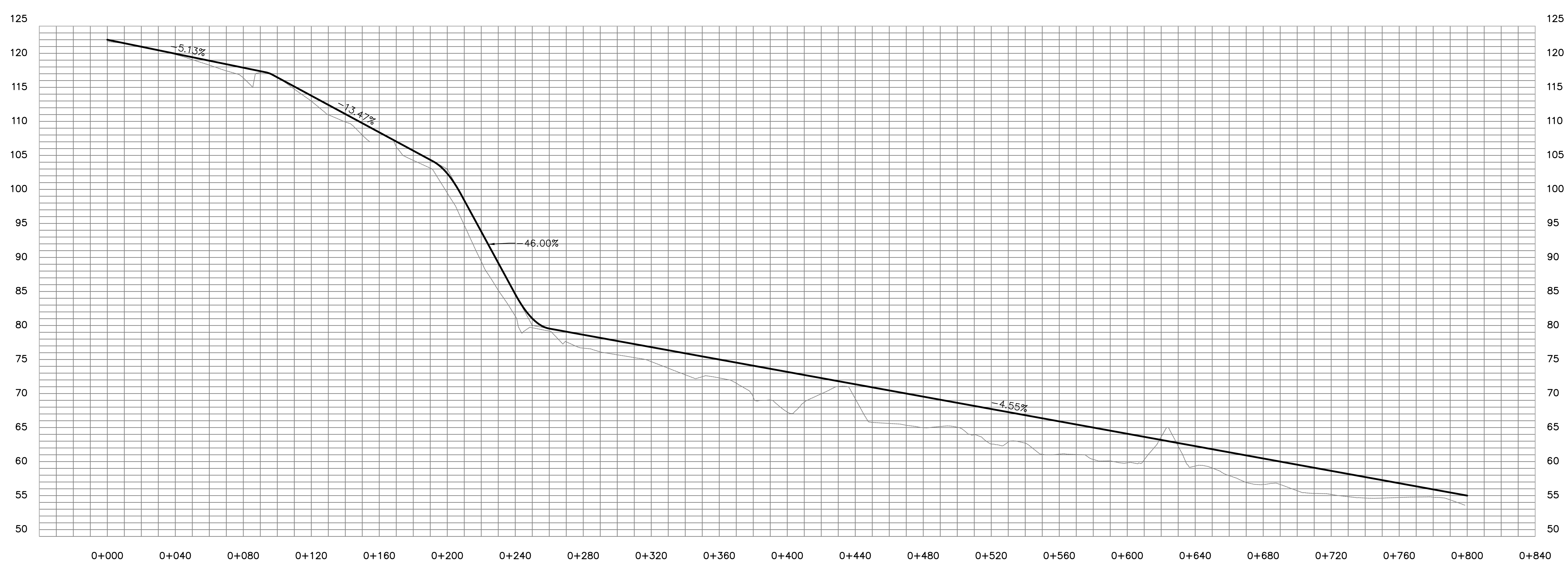

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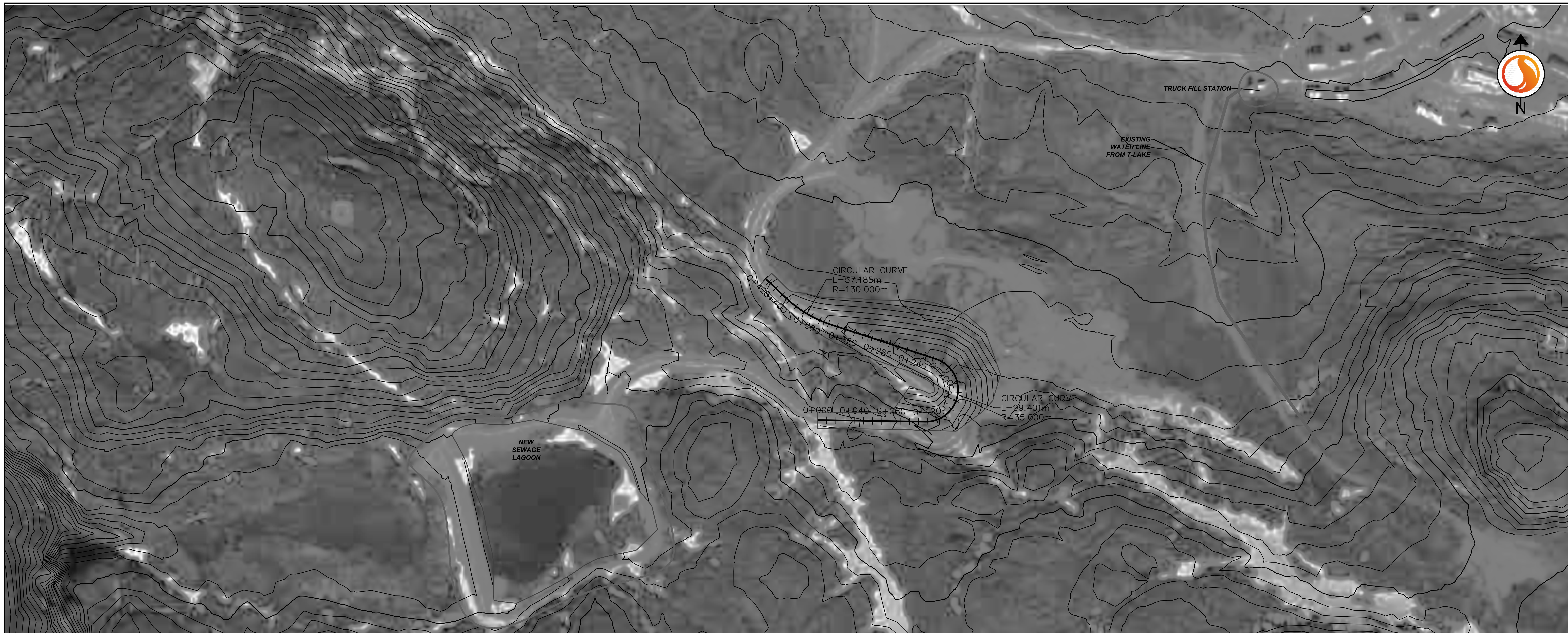

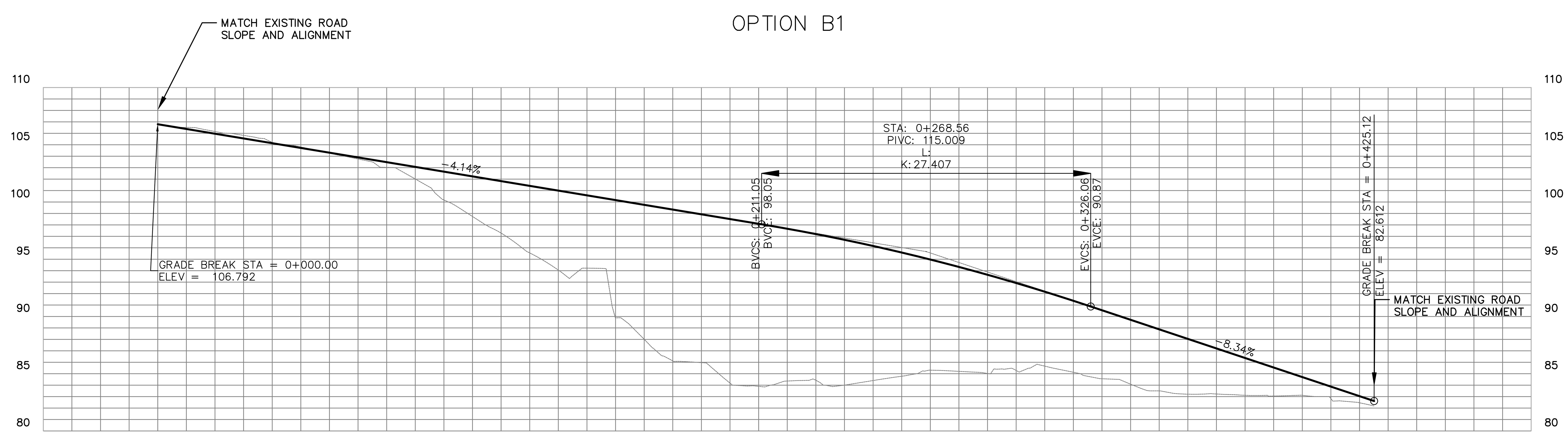

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CAPE DORSET LAGOON ASSESSMENT

CAPE DORSET, NU

Title

HAIRPIN MODIFICATION
OPTION B1

Project No.	Scale	
110126033		
Drawing No.	Sheet	Revision
	3 of 6	

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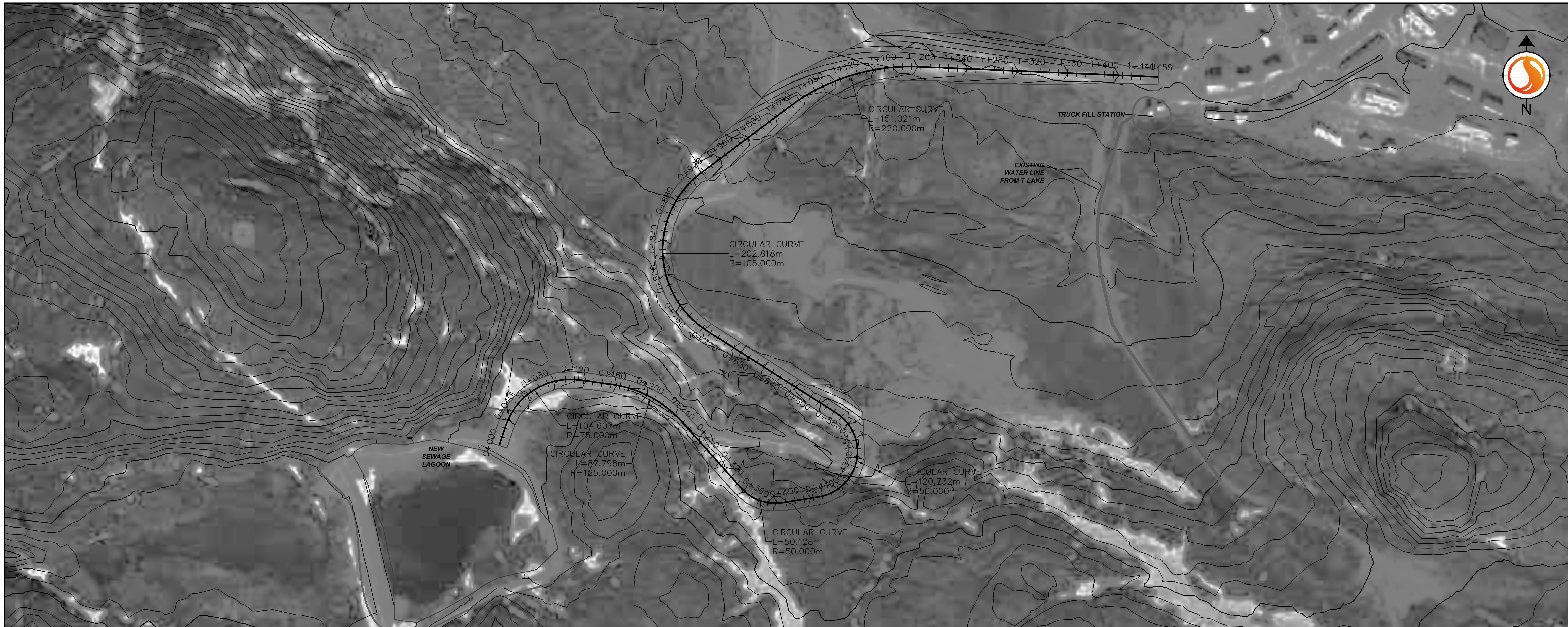

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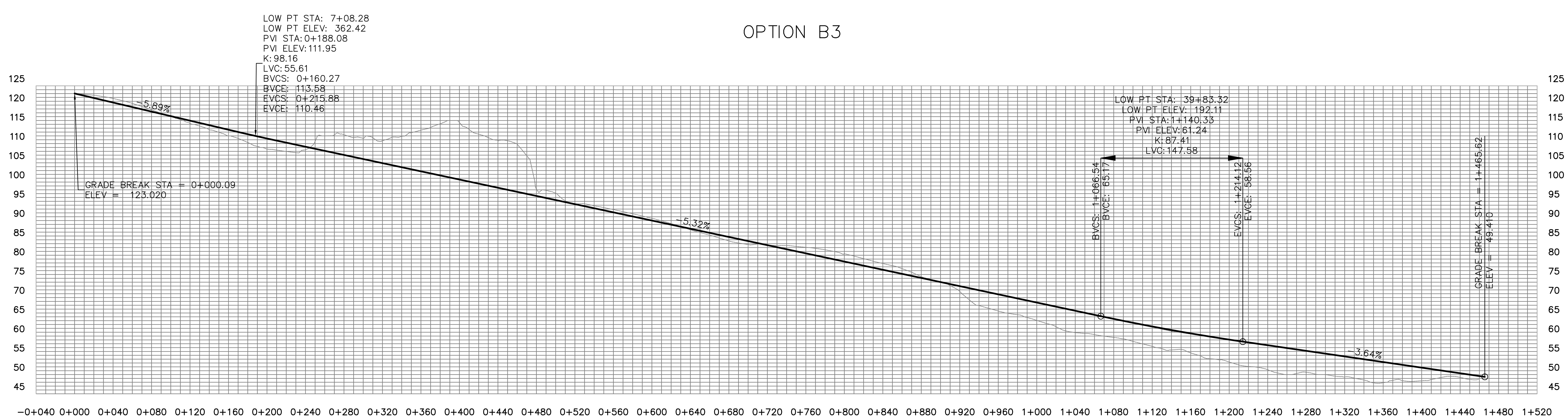

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HAIRPIN MODIFICATION
OPTION B3

Project No.	Scale	
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Drawing No.	Sheet	Revision
	4 of 6	

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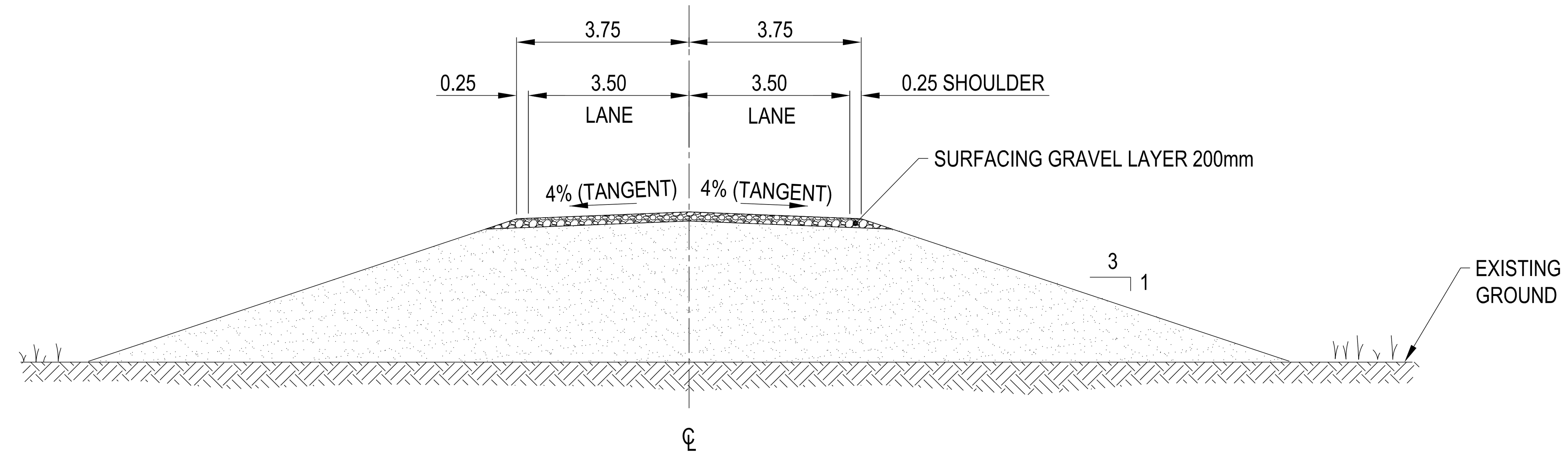

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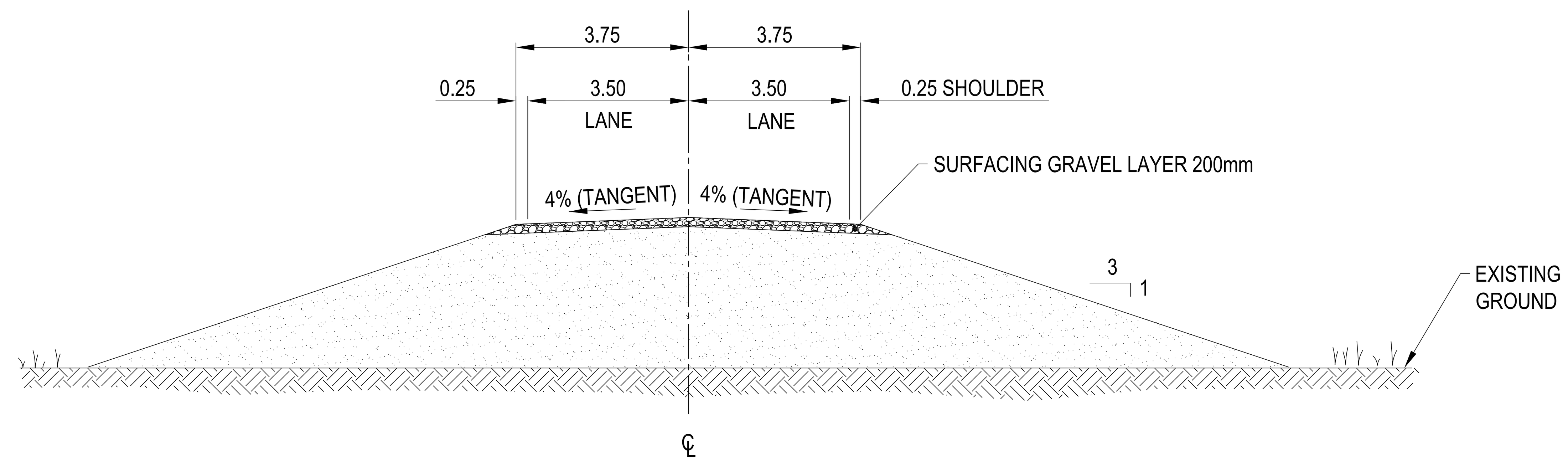

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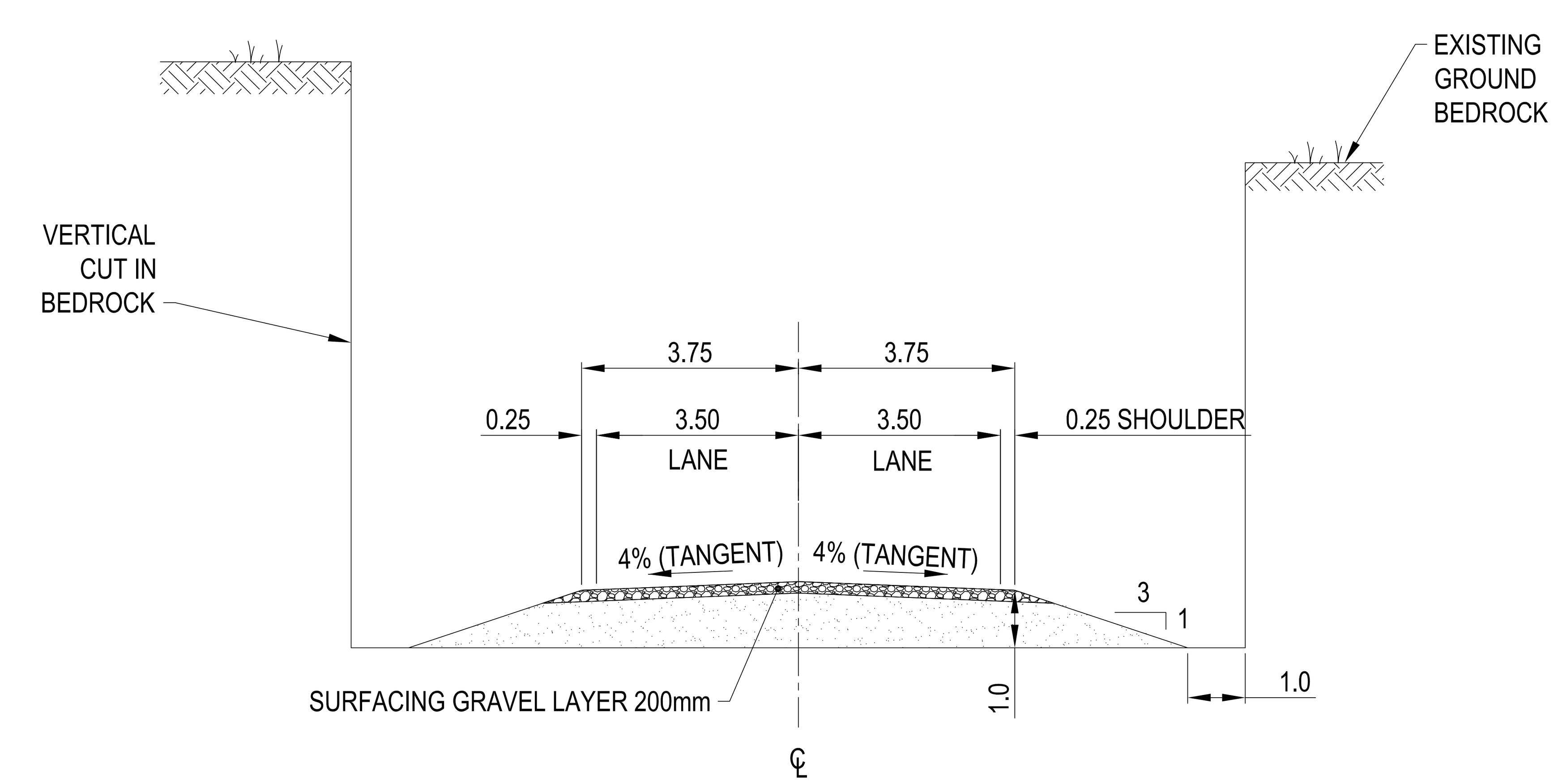

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CAPE DORSET LAGOON ASSESSMENT

CAPE DORSET, NU

Title

SECTIONS

Project No.	Scale	
110126033		
Drawing No.	Sheet	Revision
	6 of 6	

Appendix F OPERATION AND MAINTENANCE COSTS

Appendix F - Opinion of Probable Cost (Operation and Maintenance)

LAGOON OPERATION AND MAINTENANCE

All options (fixing berm leak or reconstructing berm):

Item	Units	Unit Rate	Quantity	Annual Cost	Assumptions / Notes
Inspection of lagoon	Hours	$100	36	$3,600	1 inspection per month, 3 hours each.
Maintenance of perimeter service road	km	$5,000	0.8	$4,000	Assume summer maintenance only (snowmobile in winter).
Annual cleaning/inspection of perimeter ditch	Hours	$100	50	$5,000	Ditch cleaned and inspected once per year and it takes one week.
Pump out lagoon	LS	$5,000	1	$5,000	Assuming secondary cell results in 1.5x total lagoon volume, and assuming decant structure is abandoned and instead lagoons are pumped out once per year at 80 L/s, 6 m of total head (~7kW pump)
			Subtotal	$17,600	
			40% contingency	$7,040	
			Annual O&M Cost	**$24,640**	

LAGOON OPERATION AND MAINTENANCE - IF SECONDARY TREATMENT CELL IS CONSTRUCTED

Item	Units	Unit Rate	Annual Quantity	Annual Cost	Assumptions / Notes
Inspection of lagoon	Hours	$100	48	$4,800	1 inspection per month, 4 hours each.
Maintenance of perimeter service road	km	$5,000	1.2	$6,000	Assume summer maintenance only (snowmobile in winter).
Annual cleaning/inspection of perimeter ditch	Hours	$100	75	$7,500	Ditch cleaned and inspected once per year and it takes 1.5 weeks.
Pump out lagoon	LS	$7,500	1	$7,500	Assuming secondary cell results in 1.5x total lagoon volume, and assuming decant structure is abandoned and instead lagoons are pumped out once per year at 80 L/s using ~10kW pump and a diesel generator.
			Subtotal	$25,800	
			40% contingency	$10,320	
			Annual O&M Cost	**$36,120**	

Appendix F - Opinion of Probable Cost (Operation and Maintenance)

SEWAGE TRANSPORTATION - USING IMPROVED ACCESS ROAD (ASSUMING OPTION B3 ROAD REALIGNMENT)

A) TRUCK HAULING

Access Road distance:	1.4	km
Hourly cost:	$ 140.00	for operator and truck
No. of trips per day:	10	
Assumed round-trip time:	15	minutes/trip
Time spent on access road:	2.5	hours per day
Cost per day:	$350	
Assuming hauls are 7 days per week:		
Annual subtotal:	$127,750	
40% Contingency:	$51,100	
Annual O&M Cost:	**$178,850**	

Note: Truck hauling cost includes time to drive up and down the access road only. It does not include time to collect sewage from individual holding tanks within the Hamlet or time to unload sewage, as these are required no matter which option is selected. As such, this cost was developed for comparison of O&M costs to other options.

B) ROUTINE SUMMER MAINTENANCE (SUMMER)

Grading:		
Access Road distance:	1.4	km
Hourly rental cost:	$ 190.00	for operator and grader
No. of passes:	4	per event
Assumed round-trip time:	0.4	hours/trip
Time spent on access road:	1.7	hours per event
Cost	$317	per event
Assuming regular grading occurs 3 times per week during 75 day summer:		
Total Number of Events:	32	
Grader Subtotal per Summer:	**$10,179**	
Guard Rail Repair:		
Guardrail, truck and 2 man crew:	$150	per hour
Assuming 2 hours per week during 75 day summer:		
Guard Rail Subtotal per Summer:	**$3,214**	
Pothole Repair:		
Gravel truck:	$120	per m^3
Assuming 6 m^3 per week during 75 day summer:		
Pothole Repair Subtotal:	**$7,714**	
Summer Maintenance Subtotal:	**$21,107**	(grading, guard rail maintenance, pothole repair)
40% Contingency:	**$8,443**	
Summer Routine O&M Cost:	**$29,550**	

C) ROUTINE WINTER MAINTENANCE

Grader Removing Snow:		
Access Road distance:	1.4	km
Hourly rental cost:	$ 190.00	for operator and grader
No. of passes:	4	per event
Assumed round-trip time:	0.75	hours/trip
Time spent on access road:	3	hours per event
Cost per snow removal event:	$570	per event
Assuming regular winter maintenance 5 times per week (i.e. to remove snow that falls or blows onto road):		
Number of events per 290 day winter:	207	
Grader Snow Removal Subtotal:	**$118,071**	
Gravel Truck Spreading Gravel on Icy Sections:		
Gravel truck:	$120	per m^3
Assuming 4 m^3 per week		
Gravel Spreading Subtotal:	**$5,143**	
Winter Maintenance Subtotal:	**$123,214**	
40% Contingency:	**$49,286**	
Winter Routine O&M Cost:	**$172,500**	

D) REMOVAL OF DEEP SNOW DURING SNOWSTORM / DRIFTING SNOW EVENTS IN WINTER
(i.e. When snow drifts are too deep for grader. Assume 12 such events per winter)

Option 1: Use Snowblower		
Access Road distance:	1.4	km
Estimated (uniform) volume of snow on the road:	33,600	m^3
Rental cost per hour (Loader with blower attachment	240	$/h
Assuming snow removal at a rate of:	3,840	m^3 per hr
Duration to clear the road:	9	h
Cost to clear road	2,100	$/event
Subtotal for 12 events per winter:	**$25,200**	
40% Contingency:	**$10,080**	
Total:	**$35,280**	

Option 2: Use Front End Loader		
Access Road distance:	1.4	km
Estimated (uniform) volume of snow on the road:	33,600	m^3
Rental cost per hour (Loader with blower attachment	240	$/h
Assuming snow removal at a rate of:	2,400	m^3 per hr
Duration to clear the road:	14	h
Cost to clear road	3,360	$/event
Subtotal for 12 events per winter:	**$40,320**	
40% Contingency:	**$16,128**	
Total:	**$56,448**	

TOTAL ANNUAL ACCESS ROAD O&M COST: $416,180

Appendix F - Opinion of Probable Cost (Operation and Maintenance)

SEWAGE TRANSPORTATION - LIFT STATION AND FORCEMAIN OPTION

LOCATION OPTION A

Item	Units	Unit Rate	Annual Quantity	Annual Cost	Assumptions / Notes
Liftstation Power	kW.hr	$1	120,000	$120,000	Based on data from Cold Region
Liftstation Maintenance	LS	$40,000	1	$40,000	
Liftstation Heating and Ventilation	LS	$40,000	1	$40,000	
Forcemain Maintenance	l.m.	$50	1,600	$80,000	Based on data from Cold Region
			Subtotal	**$280,000**	
			40% contingency	**$112,000**	
			Annual O&M Cost	**$392,000**	

LOCATION OPTION B

Item	Units	Unit Rate	Annual Quantity	Annual Cost	Assumptions / Notes
Truck Sewage Extra Distance	LS	$70,000	1	$70,000	Based on data from Cold Region
Liftstation Power	kW.hr	$1	90,000	$90,000	Based on data from Cold Region
Liftstation Maintenance	LS	$40,000	1	$40,000	
Liftstation Heating and Ventilation	LS	$40,000	1	$40,000	
Forcemain Maintenance	L.m	$50	1,000	$50,000	Based on data from Cold Region
			Subtotal	**$290,000**	
			40% contingency	**$116,000**	
			Annual O&M Cost	**$406,000**	

Appendix G SNOW DRIFTING ASSESSMENT MEMORANDUM

RWDI
CONSULTING ENGINEERS & SCIENTISTS

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Fax: 519.823.1316

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Guelph, Ontario, Canada
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December 24, 2014

Mr. Ken Johnson, M.A.Sc., MCIP, P.Eng.
Senior Environmental Engineer and Planner
Stantec
10160 - 112 Street, Suite 500
Edmonton, AB
T5K 2L6

Re: Preliminary Snow Drift Assessment
Wastewater System Access Road
Cape Dorset, NU
RWDI Reference No. 1500864

Email: kenneth.johnson@stantec.com

Dear Ken,

The following provides our initial overview of the potential mitigation concepts for the snow drift conditions on the existing access road to the wastewater system in Cape Dorset, Nunavut. Our next step would be a teleconference to discuss the enclosed and the possible mitigation that could be implemented to minimize snow accumulations on the access road.

Introduction

The existing access road to the wastewater system experiences significant snow drift accumulations. The primary purpose of this consultation is to qualitatively review the details of these accumulations and provide conceptual mitigative options to minimize snow drifting onto the access road. This assessment focused on the local topography and road orientation with respect to prevailing winter winds as these design aspects will have the greatest impact on snow drift conditions on the access road, and the overall effectiveness of mitigation strategies.

Our assessment is based on a review of the following information:

- photographs of the snow drift accumulations currently experienced on the road, provided by Stantec;
- information regarding the surroundings based on topographic plans;
- a meteorological assessment of the prevailing winter winds in Cape Dorset; and
- our past experience and professional judgment with snow drifting in the Arctic.

Wind Data

Meteorological data from the Cape Dorset Airport for during the winter months for the period 1984 to 1996 were used as reference for wind and snow drift potential in the region. The historical wind data were analyzed to determine the wind directions that would most often be associated with drifting snow. The data are summarized in Figure 1. The following meteorological conditions were assessed for the winter months (October through May):

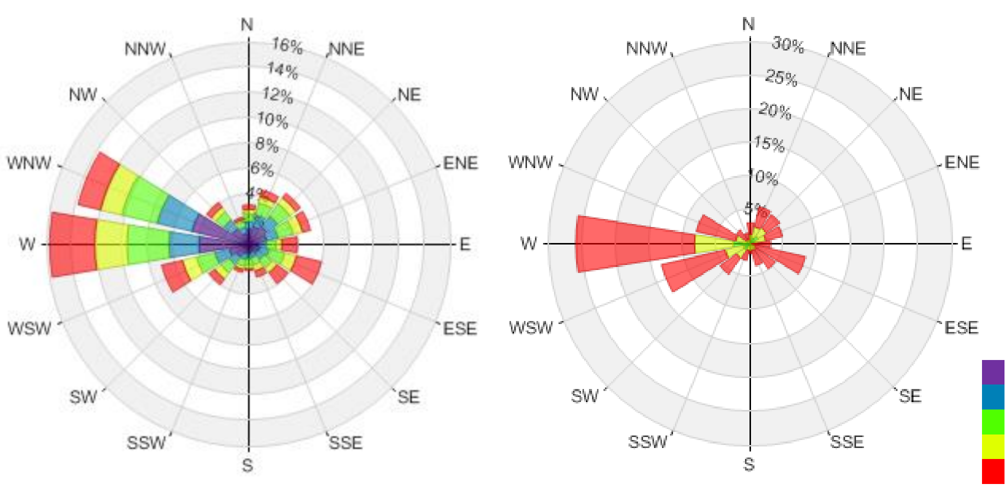
- Winds greater than 15 km/h; and
- Blowing snow events.

The movement of drifting snow at low wind speeds is negligible. A threshold wind speed of 15 km/h was therefore used to determine the predominant winds that are associated with snow movement around Cape Dorset. The 15 km/h wind speed is measured at the weather station anemometer, which is typically located on a mast approximately 10 m above the ground. Winter winds with blowing snow represent higher wind speeds often associated with storm events and significant drifting.

The analysis of winter winds greater than 15 km/h (refer to the left wind rose in Figure 1) indicates that the west and west-northwest winds are the most prevalent, with secondary winds from the easterly directions.

When considering the snow drift conditions for an Arctic site, the analysis considering blowing snow events provides the best indication of the key directions as snow transported during blowing snow events is the primary source for accumulations in these climate regions. The left wind rose in Figure 1 indicates that the west and west-southwest are prevalent, with secondary winds from the easterly directions.

For this consultation, we have focused on the westerly winds as these are likely the ones producing the most significant drift accumulations along the access road.



Percentage of Snow over All Winds: 10.1%

Wind Speed km/h	Probability (%) Winter Winds	During Snowfall	Blowing Snow
16-20	24.4	0.0	0.4
21-25	15.3	0.0	1.3
26-30	18.2	0.0	9.1
31-35	11.7	0.0	21.8
>35	15.6	0.0	67.4

Figure 1 – Directional Distribution (%) of Winter Winds (Blowing From) – Cape Dorset Airport (1984-1996)

Snow Drift Accumulations

The topography of a region plays a significant role in the formation of snow drift accumulations. As seen in Figure 2, the majority of the access road is situated on the downwind side of the hills that encompass the wastewater lagoon for the prevailing westerly winds. Wind is accelerated as it passes over hills resulting in scouring of snow from the windward side of hills and deposition in the low pressure zones on the leeward side of the hills. While the position of the road with respect to the topography is the primary factor in the undesirable drift formations that occur, it is not expected that a re-orientation of the access road will prove to be beneficial. In any orientation that maintains a reasonable slope, the road will still need to run along the leeward side of one of the hills and thus would experience similar drifting accumulations.

Figure 2 – View of the existing access road looking west (Image courtesy of GoogleEarth$_{TM}$)

Potential Mitigation

In many instances, the implementation of snow fencing is enough to significantly improve snow drift conditions. However, a snow fence requires a significant downwind fetch that will act as a snow catchment zone in order to be effective. The local topography along the access road will make it difficult to effectively locate the fence such that the access road is not within this catchment region. As a result, while the construction of a snow fence may improve the conditions for some of the road, it is not expected that it would be sufficient to mitigate all of the problematic areas.

Other mitigation strategies could include the addition of barriers that include overhead protection over the road to help shelter the roadway, or the design of wind deflectors that will direct wind toward the roadway to help scour away snow rather than allow it to accumulate. As the effectiveness of these options will be highly dependent on the local wind flow patterns caused by the topography of the area, it is recommended that consideration be given to developing the details of these features using physical model testing in a water flume wind and snow simulator or similar approach.

Conclusions

The topography of the region around the Cape Dorset wastewater lagoon results in significant snow drift formations along the access road and limits the effectiveness of traditional mitigation strategies. It is expected that a combination multiple localized strategies will need to be developed to improve the drift conditions along the entire length of the access road. RWDI will provide further guidance on potential snow drift mitigation strategies in consultation with the design team.

Closing

Our next step would be a teleconference to discuss the enclosed and the possible mitigation that could be implemented to minimize snow accumulations on the access road.

Should you have any questions or require additional information, please do not hesitate to call.

Yours very truly,

ROWAN WILLIAMS DAVIES & IRWIN Inc.

Jan Dale, M.E.Sc., P.Eng.
Senior Engineer / Associate

John Alberico, M.Sc., CCEP
Senior Project Manager / Principal

JD/mdlc