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ASSESSMENT, OPTIONS, AND REMEDIAL WORK FOR LEAKING SEWAGE LAGOON IN KUGLUKTUK, NUNAVUT

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Abstract: The sewage lagoon in Kugluktuk, Nunavut is an earthen berm structure, rectangular shape, with a capacity of 126,000 m^3 of sewage retained by an HDPE lined single cell. The facility was commissioned in 2008 with a construction cost of $6.6 million. However, when the Hamlet began using the lagoon, two significant issues were observed. The first issue was tears in the lagoon liner, which prompted the need for immediate repairs on the liner. The second issue was "islands" in the lagoon associated with floating segments of the liner. A site inspection in 2014 reported that there was seepage from a segment of the toe on the east berm, potentially contributing to subsidence on the top of the berm in the same section as the seepage.

A site inspection of July 2015 confirmed that the segment of the east berm had subsided approximately 40 cm. Associated with this subsidence of slumping and seepage in the east berm, some segments of the west and south berms also identified to have localized slumping.

Several options were developed for remedial work on the lagoon which included (i) addition of a buttress to the failing berm, (ii) reconstruction of the failing berm, (iii) removal and replacement of the existing liner and (iv) repair of the existing liner. The remedial costs for these options ranged from $400,000 to $4.6 million. For purposes of comparison, an option for the application of a mechanical treatment was also developed, which would cost $18 million. The buttress addition would not guarantee that in the short term the leakage would stop, but it would improve berm and avoid the need to decant the lagoon the reduce the hydraulic pressure on the berm to prevent a catastrophic failure.

It was recommended that the pursuit of a relaxation of the effluent quality for the facility could allow the leakage to continue, and accommodate using the buttress to provide long term stability to the structure. The remedial construction work of a buttress structure was completed in 2016, and ongoing monitoring of the remedial work and the overall lagoon is continuing to determine if the buttress is an appropriate long term solution.

1 Introduction

Kugluktuk is located along the Arctic coast (67°49'N; 115°06'W) and has a population about 1,450 people (2006 census). The geology around the community is marine deposit and mainly composed of sands, rocks, silts and gravels with some organic material.

Figure 1: Kugluktuk sewage lagoon with white HDPE liner.

The sewage lagoon is a single cell, about 240 m x 200 m rectangular, constructed in 2008 with a 60 Mils HDPE liner on a sand bed. The outer slope of the berm is protected with compacted sand and a gravel layer constructed with a 3:1 slope. The lagoon was commissioned in 2008 for community sewage disposal, with an annual decanting of treated sewage.

Within a year of commissioning, an floating liner issue was identified, that was apparently caused by trapped gas under the liner. In 2010, a small hole was drilled into one of the “islands” and the trapped gas had the distinct smell of methane, which was likely produced from decomposing organic materials underneath the liner. A further inspection in 2014 reported that there was seepage from the toe of the east berm and a significant subsidence in the same section of the east berm as the seepage. The subsidence was readily visible with a sag in the fence line.

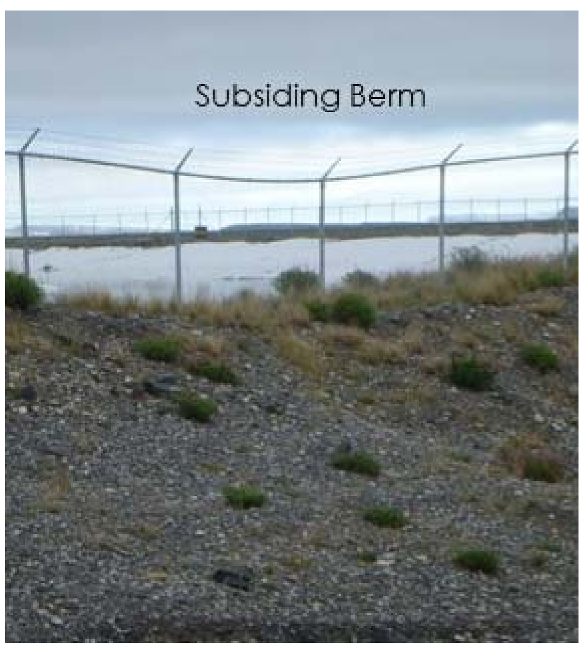

Figure 2: Forty centimetre subsidence in Kugluktuk sewage lagoon berm.

2 Site Inspection

A site inspection in 2015 verified the previous observations, and documented that the subsidence in the east berm of the lagoon was 42 centimetres at the centre of a berm length of 20 metres. A clear crack was also observed along the same section of the berm where the HDPE liner is keyed into the top of the berm.

Along the north side there were no significant elements of deterioration observed on the top of the berm. A lagoon overflow structure is located along the north side approximately half-way along the top of the berm. The overflow structure is 1 m wide section of the berm with erosion protected chute to permit a controlled overflow of sewage in the unlikely event that the water level increases to an unsafe level. The erosion protection chute consists of a channel lined with 60 mil HDPE and covered with rip rap. There was no significant deterioration observed on the top segments along the west and south berms.

The notable slumping along the east side berm is coincident with the area of subsidence in the top of the berm**.** Coincident with the slumping and subsidence is the seepage along the berm toe, and the extent of the seepage could not be determined because the toe of the berm lies within a wet area of an old sewage lagoon facility. The remainder of the berm base along the east side, and north side have no significant elements of deterioration.

The base of the berm along the west and south sides has several ponded areas which were causing localized slumping of the exterior slope of the berm**.** No other deterioration of the berm structure was visible in the areas.

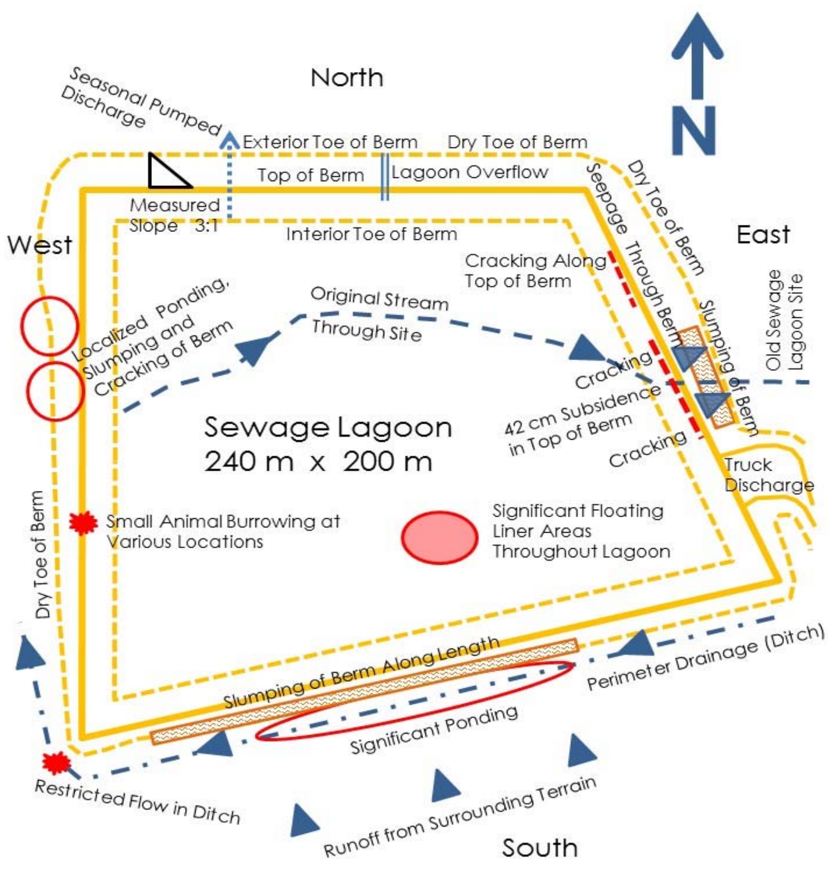

Figure 3: Lagoon features and issues observed at the Kugluktuk sewage lagoon.

3 Options for Short Term Remedial Action

Several options for site work were developed from a geotechnical assessment in terms of a preliminary remediation strategy. It is noted that these strategies would not address the causes of the deterioration, but only address the action to minimize the potential for a catastrophic berm failure.

The geotechnical assessment suggested that the installation of drainage conduits below the lagoon liner, or the installation of a buttress along a portion of the east berm, are possible short term remedial actions to minimize the potential for a berm failure. The installation of drainage conduit by directional drilling would require the mobilization of specialized equipment, and the associated crew to carry out the work. Directional drilling would also be subject to contractor availability.

Directional drilling would also provide a direct pathway for the effluent to discharge from beneath the lagoon without the benefit of treatment with the filtration through the soil in the berm. This would potentially create a non-compliant effluent discharge from the facility. In addition, with the variability of the base material, and the presence of bedrock, there may be limited success in installing a pipe by directional drilling.

The construction of an earth buttress would be a more cost effective measure in consideration of an earlier construction start up, and locally available equipment and granular materials. Conceptually, the placement of a buttress at the base and part way up the berm is likely the most logical short term remedial measure. In order to advance this measure, some combined seepage and slope stability assessments would be required to determine the current and future factor of safety. An opinion of the probable cost of a buttress to stabilize the berm on an interim basis was $170,000.

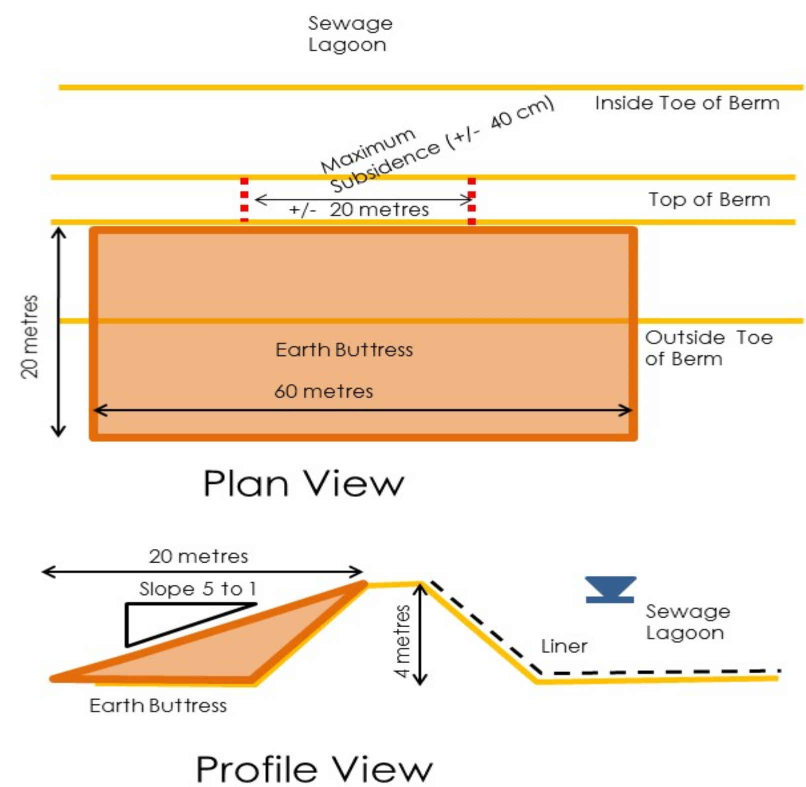

Figure 4: Earth buttress concept for Kugluktuk sewage lagoon.

4 Berm System

The berm structure for the sewage lagoon consists of a compacted granular structure 3.0 metres wide on top built to a height of approximately 3.5 metres above the surrounding terrain. The design analyses associated with the berm, and the lagoon did not include any geothermal analyses because permafrost degradation was not a concern to the overall design of the lagoon system. However, these analyses have become a more common practice for lagoon system designs with the anticipated impacts of climate change on permafrost. The slope of the berm is 3 to 1 on both the interior and exterior faces. An HDPE liner covers the inner face of the berm and compacted sand-gravel forms the outer slope.

4.1 Integrity of Berm System

A visual inspection determined some deterioration on the outer section of the berms on the east side, the west side, and the south side. Of these three areas of deterioration, the section along the east side was the greatest concern because of the coincidental subsidence in the top of the berm, the slumping of the exterior of the berm, and the seepage from the toe of the berm. These elements of deterioration of the east berm suggested the need for some short term remedial work, in the form of construction, or other action to minimize the possibility of a more serious catastrophic berm failure.

Of importance to the deterioration appears to be an underlying stream bed which bisects the sewage lagoon. The existence of the stream bed was confirmed with a visible channel in a satellite image. As well, the topographic information presented in the design drawings clearly identifies a low area corresponding to a stream channel.

There are five distinct conditions that may be influencing the berm deterioration. How each of these conditions are individually influenced the deterioration is unknown, and it may be very difficult or impossible to determine with the information available, and any additional information that may be potentially collected from the site.

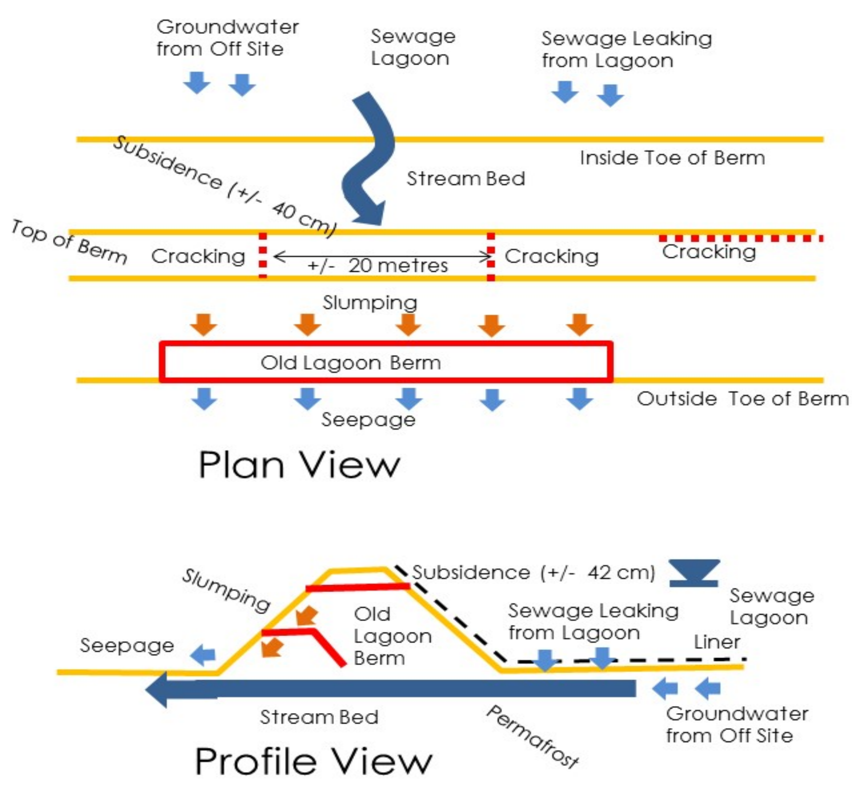

Figure 5: Conditions influencing deterioration of Kugluktuk sewage lagoon berm.

The potential influencing conditions are: permafrost underneath the berm that may be degrading; an old and potentially unstable stream bed beneath this section of the berm; flow from the leaking liner of the sewage lagoon; flow from "groundwater" originating from off site; and a potentially unstable berm from an abandoned lagoon that is situated beneath this section of the new lagoon.

4.2 Remedial Work on Berm System

The construction of a permanent earth buttress along a segment of the east berm will stabilize the berm from further deterioration, and also will provide additional filtration for any sewage through the berm. A geotechnical analysis would be necessary to provide an optimal design for this earth structure; however, a geotechnical site investigation may not be necessary because of the limited utility that the site information could provide to the design of the remedial work.

For the purposes of a conceptual design, a structure 60 metres long and 18 metres wide, with 5:1 slope was identified for construction. Some excavation beneath the buttress may be necessary to provide a stable foundation.

An alternative to the earth buttress would be the reconstruction of the berm structure to replace the segment of the berm that has been subsiding and slumping. This would stabilize the berm from further deterioration. For the purposes of a conceptual design, a structure 60 metres long was identified for construction; a sub excavation of 3 metres may be necessary to provide a stable foundation.

5 Containment System

The liner system consists of a 60 mil High Density Polyethylene (HDPE) geomembrane liner, a sand layer constructed beneath the liner; native material underlying the sand layer.

5.1 Integrity of Containment System

The liner experienced severe "floating", and leakage which is evident on the exterior berm slope. The "floating" liner may be caused by:

1. Underlying organic materials, which when the liner was installed, were not removed. When these materials decompose, there is a potential for the generation of gases, creating pockets of gas that uplift on the liner. The potential for decomposition of native organic materials to be cause is unlikely.
2. Leaking sewage, through the damaged liner, which has migrated beneath the liner and gases have formed from the biological decomposition. With the absence of a secondary containment and collection system, the sewage leakage cannot be controlled. In addition, the apparent lack of any form of venting does not allow the gases to escape.

There is also evidence that coarse rock may have been placed the liner and not a protective layer of sand. The coarse material would punctured the lagoon when it was filled.

5.2 Remedial Work on Containment System

A method to repair the liner without draining of the lagoon would be very challenging and would have a low probability of success. Directional drilling a subdrain collection system or vent pipes could be considered, but the ability of the system to collect all the leakage would be minimal. The location and extent of the leakage is not defined, so precise locations are not known and the characteristic of the underlying materials may not allow the drilling to be successful.

An attempt was made to penetrate the liner from the top edge, and add a subdrain pipe to collect the leakage through a flexible pipe. This procedure provided some removal of the accumulated sewage from beneath the liner, but it was ultimately not successful because the sand beneath the liner migrated into the extraction pipe.

As any option to repair the liner is not possible without a significant expense, however an incremental process may be appropriate. The current liner does not provide the complete containment as originally envisaged. An incremental remedial plan for the liner could include perforating the existing liner at the floating areas during the winter months, and then rely on the underlying soil structure of the berm to control the leakage from the lagoon. Further management of the leakage could consist of a collection ditch on the outside of the lagoon which directs the leakage to a control pond or sump, where it can be periodically emptied by pumping back into the lagoon itself.

Depending on the success of perforating and venting of the liner, it could become an on-going exercise to perforate the floating areas as they appear.

Unfortunately, other options require the draining of the lagoon and temporary storage and/or treatment of the wastewater during reconstruction.

The option with the highest potential for success would be the complete replacement of the liner. The lagoon would have to be drained, desludged, and the liner removed and discarded. The reconstruction would require:

- Berm repairs to address various issues of instability.
- Reconstruction to provide a competent base for the liner.
- Placement of a drainage capture system in the base, which would consist of layer of non-fractured drainage material, a series of collection pipes directed to a collection/monitoring chamber.
- Replacement of the liner consisting of a bentonite mat, a bituminous geomembrane, or plastic geomembrane.
- Adequate venting of primary liner, which is normally provided through the underlying subdrain system and flap vents on the liner at the top of the berm slope.

A hybrid of this solution could be to drain the lagoon, temporarily vent the problem areas and attempt to remove the sewage collecting under the lagoon, complete cleaning of the liner, and a repair of the liner. The existing liner could serve as the base for a interstitial collection layer with the placement of a new liner on top. Any remnants of leakage that could cause “floating” would be collected in the new interstitial layer, and the layer would also provide collection of potential leakage in the new primary liner.

6 Opinion of Probable Cost for Long Term Solution

Preliminary estimates for a long term solution were prepared based upon limited site information, and provide the approximate magnitude of the cost of the remedial work. This cost estimate was derived from lump sum or unit costs as identified in the construction cost information for a similar project.

Table 1: Cost Summary of Options for a Long Term Solution

Option	Description	Opinion of Probable Cost (Class D)
1	Buttress Addition	$386,000
2	Berm Reconstruction	$1,687,000
3	Temporary WWTP, Remove Existing Liner, Complete Pond Repair (includes berm reconstruction)	$4,128,000
4	Temporary WWTP, Repair Existing Liner, Complete Pond Repair (includes berm reconstruction)	$3,450,000
5	Construct New Pond, Remove Existing Liner, Complete Existing Pond Repair (includes berm reconstruction)	$4,672,000
6	Construct New Pond, Repair Existing Liner, Complete Existing Pond Repair (includes berm reconstruction)	$3,968,000
7	Construct Mechanical Treatment Plant	$18,713,000

7 Option Advantages and Disadvantages

Table 2 presents the advantage and disadvantages of the seven options developed for a potential long term solution.

8 Implementation and Further Action

The implementation of the remedial work has included the short-term action to design and construct a buttress structure to stabilize the east section of the berm. This construction was initiated in 2016 (November), and almost 60 percent was completed prior to end of the construction season due to available granular material, and difficulty in compacting the granular material. The work on the lagoon buttress was completed in October 2017.

After completion of the buttress construction, the leakage has continued, but in two distinct points at the toe of the berm. The subsidence in the berm was also remediated, and no further subsidence has been observed.

Further action is recommended to address the long term operation of the lagoon.

- Monitor the berm to determine any accelerated signs of berm failure; if accelerated failure is observed, then further remedial action should be advanced.
- Prepare a plan going forward that will address the long term stability of the berms, and the leakage to satisfy the current concerns of the regulators.
- Initiate a dialogue with the Nunavut Water Board for the consideration of a exfiltration lagoon facility, and the associated effluent quality considerations from the discharge through the soil structure.

Table 2: Options with advantages and disadvantages

Option	Description	Pros	Cons
1	Construct Buttress	• Least disruption to operations • Minimal cost	• Will not meet regulatory requirements for full containment
2	Reconstruct Berm (includes temporary WWTP rental and operational costs)	• Moderate cost	• Will not meet regulatory requirements for full containment • No assets gained from temporary wwtp rental and operational costs
3	Temporary WWTP, Remove Existing Liner, Complete Pond Repair (includes reconstruction of berm)	• Allows pond work to be undertaken without interrupting service	• High cost • No assets gained from temporary wwtp rental and operational costs
4	Temporary WWTP, Repair Existing Liner, Complete Pond Repair (includes reconstruction of berm)	• Allows pond work to be undertaken without interrupting service	• No asset gained from temporary wwtp rental and operational costs • Higher risk of secondary containment failure
5	Construct New Pond, Remove and Replace Existing Liner, Complete Existing Pond Repair (includes reconstruction of berm)	• Allows pond work to be undertaken without interrupting service • Least risk alternative	• High cost
6	Construct New Pond, Repair Existing Liner, Complete Existing Pond Repair	• Allows pond work to be undertaken without interrupting service	• High cost • Higher risk of secondary containment failure
7	Construct Mechanical Treatment Plant	• Allows pond work to be undertaken without interrupting service • Higher level of treatment possible	• Cost prohibitive • High annual operational costs • Complex operation