Hall Beach Sewage Lagoon

Prepared for:

The Hamlet of Hall Beach,
Nunavut, Canada

Prepared by:

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1. INTRODUCTION

1.1 PROJECT UNDERSTANDING

Ferguson Simek Clark was contracted to complete a planning study for the Hall Beach Sewage Treatment Systems for Community Government and Transportation, Government of Nunavut. The purpose of this study is to:

- Collect all relevant engineering and geotechnical reports, specifications, and drawings for review
- Obtain the 1999 Dillon report to undertake a critical review
- Travel to Hall Beach, consult with the Council and Hamlet staff, and discuss the project with CG&T representatives
- Inspect and survey the lagoon to determine its capacity
- Prepare a planning report that outlines various options for consideration to meet the 20-year needs of the community with each option including a Class D life cycle cost analysis
- Use a modified K-T (weighted factor analysis) to identify a preferred analysis
- Consultation with regulatory agencies to ensure rapid acceptance of plans

1.2 COMMUNITY INFORMATION

1.2.1 GENERAL

Hall Beach is located on the east shore of the Melville Peninsula at the position of 68°46′ N latitude and 81°12′ W longitude. Situated in the Foxe Basin of the Arctic Lowlands, it is located 840 km by air northwest of Iqaluit and 1650 km by air northeast of Yellowknife.

1.2.2 GEOLOGY AND TERRAIN

Due to depressions created during the glacial period, a resultant marine overlap is responsible for the low-relief topography of raised beaches and shallow lakes now found in the area. Marine sands and gravels cover the landscape, with fines in the depressions. The thin surface deposits are underlain by limestone bedrock.

The Hall Beach town site is situated on an elongated raised beach, oriented to the northwest. The beach is about 100 m wide. It is bordered on the east by the sea, and on the west by an elongated shallow water pond, 45 ha in area.

Hall Beach is located within the continuous permafrost zone. Materials located beneath the thin active layer are perennially frozen to a substantial depth.

1.2.3 VEGETATION

Grasses, mosses, and lichens sit in a thin organic layer on the surface. This organic layer is generally 0.3 m or less in thickness.

1.2.4 CLIMATE

Hall Beach receives an average of 10 cm of rainfall and 121 cm of snowfall per year. Mean annual precipitation totals 21.8 cm. July mean high and low temperatures are 8.4° C and 2.3° C. January mean high and low temperatures are -26.9° C and -34.8° C. Winds are generally northwest and annually average the velocity of 21.3 km/h.

1.2.5 COMMUNITY HISTORY AND ECONOMY

Hall Beach was named after Captain C.F. Hall, an American explorer who spent a number of years on the Melville Peninsula in the mid-nineteenth century. The Hall Beach area has been inhabited at various times since the thirteenth century. The Iglulik Inuit of the area were found to have lived a rich and varied lifestyle. The area supports a large population of walrus and whale, the staples of the Iglulik society. Marine mammal harvesting, hunting, trapping, and fishing still remain the major economic activities. The completion of the Foxe Main (Distance Early Warning) DEW line site in 1955 brought a wage economy to the area. The Inuit from outlying camps migrated to the community of Hall Beach to take advantage of steady income. The DEW-Line is now being minimalized. The cleaning of the DEW site will have unknown consequences on the ecology of the area and the economy of the Hall Beach.

The tourism industry constitutes a significant portion of the economy. Within travelling distance, historical interests and natural sites such as the Nunapariavik waterfalls attract tourists. The Hall Beach area is known for char fishing.

Building contractors, cartage, general retail, food, hotels, outfitters, and restaurants are some of the goods and services available in Hall Beach.

Hall Beach gained Hamlet status on April 1, 1978. The traditional name of the Community is "Sanirajak", meaning 'flat land'.

1.2.6 Transportation And Access

The GNWT operates a 1,646 m x 46 m certified Arctic 'B' gravel runway. Site facilities and services include the terminal building, navigational aids, and weather reading equipment. Scheduled flights are available via Iqaluit. Chartered flight service is also available.

Marine transportation is available from Eastern Arctic Sealift and Transport Canada (Montreal). Facilities include a beach landing, the old DEW-line dock, an offshore anchorage for a bulk fuel tanker, and the POL discharge via floater hose to shore manifold.

There is no land access to Hall Beach. Within the community there are 4.9 km of gravel surface roads. Calcium chloride is applied annually to 3.5 km of roads to act as a dust suppressant and surface-stabilizing agent.

1.2.7 General Demographic Information

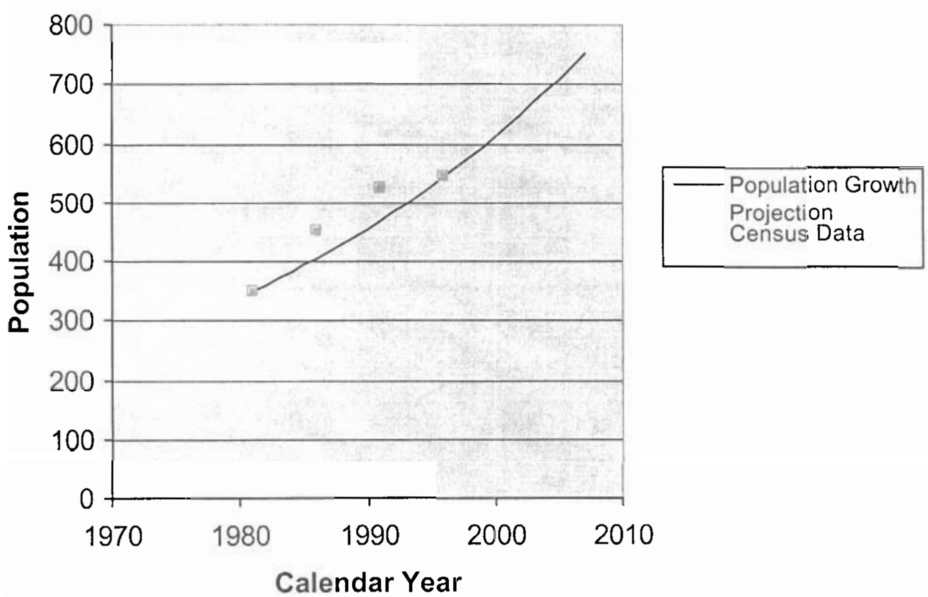
In the 1996 census, Hall Beach had a population of 543 people. The population estimate for 2001 is 629 people.

Table 1 shows the population of Hall Beach projected to the year of 2007. A per capita growth rate of 2.99% was determined between the 1981 and 1996 census years. Table 1.1 provides a population projection for Hall Beach. Figure 1.1 provides a plot of this population increase.

Table 1.1: Population Projections

Calendar Year	Population
1996	543
1997	559
1998	576
1999	593
2001	629
2004	687
2007	751

Figure 1.1 - Population Projection for the Hamlet of Hall Beach



1.3 SITE VISIT

Kelly Henderson, B. Tech. (Env.) and James Perry of Ferguson Simek Clark arrived in Hall Beach on September 16, 2001. They met with Johnny Pialak who was acting SAO at the time. They traveled to the sewage lagoon, took pictures and had some discussion dealing with community concerns.

The lagoon consists of two lagoons. The berms are mostly composed of gravel and a small quantity of sand. The berm located between the two lagoons has a ditch-like area that appears to allow flow between the two.

A ditch runs along the lagoon carrying waste from the lagoon to a wetlands area. The ditch starts near the road north of the lagoon and follows the length of the lagoon until it gets close to the second cell. At this point, the ditch flows toward the shoreline. Then a second ditch bisects this ditch perpendicularly. One end of this ditch ends in gravel and the other runs into the wetlands area. The ditch that travels to the wetlands seems to be the only one that carries sewage. The other had little evidence of sewage but did have a pile of garbage within it.

The community wants the lagoon to be relocated because of its proximity to town. Odours from the lagoon travel into town depending on wind conditions. They also have concern about children playing in the area. There is also unease about the lagoon's proximity to the ocean and contaminated water may enter.

At 15:00, a community meeting was held. One item discussed were possible locations for a new lagoon. Three possible sites were discussed and voted on. These were:

- 88°N 30°W (near airstrip) 1 vote
- 89°N 33°W (NE of present lagoon) 9 votes
- 90°N 22°W (5km past airport) 4 votes

After the meeting, we were informed of another possible choice for a lagoon. It is an abandoned lagoon at the Dew Line Site.

The lagoon was surveyed using a total station in the morning.

In the afternoon, a trip to all four possible sites of a new sewage lagoon took place. The day was so foggy we were unable to get to the exact location of three of these sites.

Each of the potential sites are discussed in Section 4.0.

2. BACKGROUND

2.1 WATER SUPPLY AND TREATMENT

The water source for the Hamlet and the Foxe Main DEW-Line station, Water Supply Lake, was converted to a bermed reservoir in 1956. It is situated 1.6 km west of the station and fed by a diversion from a dam.

2.2 WATER STORAGE AND DISTRIBUTION

There are no storage or pumping facilities within the community. The DEW-Line reservoir has a storage capacity of 600,000,000 litres.

Water is transported 4.6 km from the reservoir to the Hamlet by two trucks, a 1993 model (4546 L capacity) and a 1987 model (6819 L capacity). The Hamlet of Hall Beach delivers water five days per week. The operator usually makes ten deliveries per day. Newer homes on pressure water systems have 1135 L storage tanks, while older homes have 227 L tanks. All water deliveries are metered.

2.3 SOLID WASTE COLLECTION AND DISPOSAL

Solid waste is collected by the Hamlet twice per week using a 1992 Ford model F-350 stake truck. The solid waste management site (200 m^2) is situated on flat ground north of the Hamlet. Solid wastes are burned at the disposal site every day. Although gravel is readily available, the wastes are neither covered nor compacted. Bulky wastes are stored at a separate site (7,500 m^2).

2.4 SEWAGE DISTRIBUTION SYSTEM

The Transient Centre, Nursing Station, and Atanaarjuat School have been converted to a pump out system of sewage collection. Atanaarjuat School teaches grades K-11 with a staff of five teachers and five language specialists. Approximately 50% of the buildings are on sewage pump out and the remainder discharge grey water to the ground adjacent to the building.

Sewage is collected by two trucks, a 1987 model (4546 L capacity) and a 1993 model (6819 L capacity). The sewage is trucked 3 km to the primary treatment sewage lagoon (3,600 m^2). There is no bagged sewage service in the community.

2.5 PRESENT SEWAGE LAGOON SYSTEM

Shown in Figure 1, the sewage lagoon system of Hall Beach consists of two cells located 1.0 km north of the community. The community constructed a second lagoon in 1998 as a result of the increased generation of sewage. The two cells collectively occupy an area of 0.4 ha. The lagoon is surrounded by semi-permeable berms that allow the exfiltration of sewage eastward through overland creeks with the eventual discharge to the Foxe Basin. The sewage is treated through a combination of biological and settling processes within the adjacent wetlands.

A study in 1999, by Dillon Consulting Limited, proposed different additions to the collection and treatment system of the Hall Beach Sewage Lagoon. This proposed system would include a series of ditches to formalize the wetland treatment system. In addition, two wetland ponding areas would be constructed to increase the retention time of the sewage and to reduce BOD loading on the wetland system.

2.6 SEWAGE GENERATION PROJECTIONS

CG&T uses the MACA planning guidelines to project per capita water use as follows:

RWU x (1.0 + (0.0023 x Population))

Where:

- The RWU or residential water use is defined as 90 litres per capita/day (Lpcd)
- Ln is the natural logarithm
- A truck delivery system is used

The following sewage generation projections were prepared for the community of Hall Beach (Table 2.1). The determined per capita annual growth rate of 2.99% was used within this projection. The current projected water use was estimated at 103.02 Lpcd corresponding to a projected annual volume of 23,659,553 L. The projected water use in 2021 is 113.48 Lpcd corresponding to an annual volume of 46,976,194 L.

Table 2.1 Sewage Generation Projections for the Community of Hall Beach

Planning Year	Calendar Year	Total Population	Projected Water Use	Daily Projected Volume	Annual Projected Volume
		#	plod	Litres	Litres
	1996	543	101.24	54,973	20,065,282
	1997	559	101.58	56,805	20,733,834
	1998	576	101.92	58,703	21,426,540
	1999	593	102.28	60,670	22,144,375
	2000	611	102.65	62,708	22,888,357
0	2001	629	103.02	64,821	23,659,553
	2002	648	103.41	67,011	24,459,078
	2003	667	103.81	69,282	25,288,098
	2004	687	104.23	71,638	26,147,836
	2005	708	104.65	74,081	27,039,570
5	2006	729	105.09	76,615	27,964,637
	2007	751	105.54	79,245	28,924,440
	2008	773	106.01	81,974	29,920,447
	2009	796	106.49	84,806	30,954,195
	2010	820	106.98	87,746	32,027,296
10	2011	845	107.49	90,798	33,141,440
	2012	870	108.01	93,968	34,298,397
	2013	896	108.55	97,260	35,500,024
	2014	923	109.10	100,680	36,748,268
	2015	950	109.67	104,233	38,045,171
15	2016	979	110.26	107,926	39,392,878
	2017	1008	110.87	111,763	40,793,636
	2018	1038	111.49	115,753	42,249,806
	2019	1069	112.13	119,901	43,763,866
	2020	1101	112.80	124,215	45,338,418
20	2021	1134	113.48	128,702	46,976,194

3. REVIEW OF DILLON REPORT

Dillon Consulting Ltd. was retained to prepare a conceptual design of a sewage collection and treatment system using the existing exfiltration lagoons and some of the existing wetlands to the northeast. The objective was to prevent sewage from discharging directly into Foxe Basin. The design should estimate the 20-year hydraulic load of the system.

Dillon's final report was submitted October 5, 1999.

The report is comprised of six sections:

1. Introduction
2. Site Description
3. Treatment Requirements
4. Conceptual Design
5. Conclusion and Recommendations
6. Literature Cited

3.1 POPULATION

Dillon's 20-year population estimate is based on NWT Bureau of Statistics projections between the years of 1995 and 2006. Their 20-year population (2020) estimated at 2.41% is 1142 persons. Using Nunavut Bureau of Statistics data, FSC determined the population projection to be 2.99%. FSC projects the 2020 population to be 1101 people. These projections are comparable; therefore, the 20-year sewage flow calculations based on the MACA model are comparable.

3.2 Raw Sewage Characteristics

3.2.1 Strength

Dillon investigated the characteristics of the raw sewage effluent following from work within a report by Metcalf and Eddy in 1979. The Nunavut Water Board projects raw sewage characteristics based on the per capita rates shown in Table 3.2. The Nunavut Water Board projection demonstrates that parameters testing sewage quality decrease in value because of the dilution due to the increase in water use. Despite the differing methodology, the 20-year results are comparable as shown in Table 3.1.

Table 3.1 – 20-Year Projection of Raw Sewage Characteristics

Parameter	Dillon Projection	FSC Projection
BOD	400	397
TSS	350	423
VSS	275	Not Projected
NH_3	50	Not Projected
TKN	Not Projected	106
$T - PO_4$	15	20
Faecal Coliform (FC)	1.5E+07	8.4E+07

3.2.2 Contaminants of Concern

Dillon provides a brief description of each of the above parameters and selects three different parameters with which to compare future effluent quality. These parameters are the BOD, TSS, and FC.

The Nunavut Water Board uses the same parameters of effluent quality, however, the discharge of faecal coliforms to the marine environment in Hall Beach is not a concern as shellfishing is not an important consideration. Regardless, these parameters are important with regard to future sewage treatment options.

Table 3.2 - FSC Projection of Raw Sewage Quality

Census Population			543					
Census Year			1996					
% Population Increase			2.99					
Residential Water Use per capita			90	Litres				
BOD			45	g				
SS			48	g				
T-PO4			2.3	g				
TKN			12	g				
FC			9.50E+10	#				
Planning Year	Calendar Year	Total Population	Projected Water Use (Lpcd)	BOD (mg/L)	SS (mg/L)	T-PO4 (mg/L)	TKN (mg/L)	FC (#/dl)
	1996	543	101.2	444	474	23	119	9.4E+07
	1997	559	101.6	443	473	23	118	9.4E+07
	1998	576	101.9	442	471	23	118	9.3E+07
	1999	593	102.3	440	469	22	117	9.3E+07
	2000	611	102.6	438	468	22	117	9.3E+07
0	2001	629	103.0	437	466	22	116	9.2E+07
	2002	648	103.4	435	464	22	116	9.2E+07
	2003	667	103.8	433	462	22	116	9.2E+07
	2004	687	104.2	432	461	22	115	9.1E+07
	2005	708	104.7	430	459	22	115	9.1E+07
5	2006	729	105.1	428	457	22	114	9.0E+07
	2007	751	105.5	426	455	22	114	9.0E+07
	2008	773	106.0	425	453	22	113	9.0E+07
	2009	796	106.5	423	451	22	113	8.9E+07
	2010	820	107.0	421	449	21	112	8.9E+07
10	2011	845	107.5	419	447	21	112	8.8E+07
	2012	870	108.0	417	444	21	111	8.8E+07
	2013	896	108.5	415	442	21	111	8.8E+07
	2014	923	109.1	412	440	21	110	8.7E+07
	2015	950	109.7	410	438	21	109	8.7E+07
15	2016	979	110.3	408	435	21	109	8.6E+07
	2017	1008	110.9	406	433	21	108	8.6E+07
	2018	1038	111.5	404	431	21	108	8.5E+07
	2019	1069	112.1	401	428	21	107	8.5E+07
	2020	1101	112.8	399	426	20	106	8.4E+07
20	2021	1134	113.5	397	423	20	106	8.4E+07

3.3 Treatment Requirements

3.3.1 Hydraulic Loading

Dillon calculated the 20-year hydraulic loading for June to August using the assumption that seven months of accumulated frozen sewage will melt evenly. In addition, the projection for these months includes the daily sewage loading plus the estimated precipitation. September and October loading rates are calculated using the daily sewage production and the precipitation. The effect of evaporation and/or sublimation is ignored in Dillon's analysis. This projection results in a total daily hydraulic load of 470 m^3/day and 155 m^3/day respectively.

Dillon compares the loading to Heinke *et al.* (1993) who suggests that the hydraulic loading rate should be less than 800 m^3/day/ha. Heinke *et al.* (1993) reports in conclusion 7.1.3 page 213, that the hydraulic loading rate should not exceed 100 – 200 m^3/ha/day.

The wetland system at Hall Beach comprises of two wetlands connected by a ditch with a combined area of 6 ha. Both the hydraulic loading rates of 78 m^3/day/ha (June-August) and 26 m^3/day/ha (September-October) that were calculated by Dillon were below the Heinke recommendation.

FSC attempted to locate Dillon's source of the hydraulic loading rate. We reviewed two Dillon reports, "Sewage Treatment Using Tundra Wetlands" (1997) and "Feasibility Study for Wetlands Treatment, Wha Ti, NT (1999). Neither of these documents provided a source for this rate.

As mentioned above, Dillon assumes that seven months of accumulated frozen sewage will melt evenly over 90 days from June to August. FSC has reviewed the appended climate normals and the information indicates that ice will be accumulated for 8 months and the duration of the melt period is 60 days. For the FSC calculations below, the daily sewage generation value was obtained from the 20-year design sewage generation volume within Table 2.1. Evaporation and sublimation were not included in these calculations.

<u>Hydraulic loading from July to August:</u>

Daily sewage generation=	128.7 m^3/d
Pond storage (based on 8 months of accumulation)=	(128.7 m^3/d) x (8month) x (30days/month) = 30,888 m^3

Ice pack melt (melts evenly over 60 days)=	30,888 m^3/60 days = 515 m^3/d
Rainfall over 6 ha of wetland (72.1 mm of rainfall July- August)=	[(0.0721m) x (60,000m^3)] / (60 days) = 72.1 m^3/d
Total daily hydraulic loading=	**128.7m^3/d + 515m^3/d + 72.1m^3/d = 716m^3/d**

Hydraulic loading from September - October:

Daily sewage generation=	128.7m^3/d
Rainfall over 6 ha of wetland (48.5 mm of rainfall Sept-Oct)=	[(0.0485m) x (60 000m^3)] / (60 days) = 48.5m^3/d
Total daily hydraulic loading=	**128.7m^3/d + 48.5m^3/d = 177.2 m^3/d**

From November to June, the exfiltration pond and the wetland are frozen; consequently, there is no flow through the system.

The corresponding hydraulic loading rates are 119m^3/d.ha from July to August and 21.5m^3/d.ha from September-October both fall below the recommended loading rate of 800m^3/d/ha by Heinke *et al.* (1993).

Both the analyses by Dillon and FSC have determined that the Heinke recommended hydraulic loading rate would not be exceeded.

3.3.2 CONTAMINANT LOADING

Using a similar analysis, FSC has used Dillon's data to determine the contaminant loading (Table 3.3).

Table 3.3 - Calculated Contaminant Loading Using Dillon's Data

PARAMETER	JUNE TO AUGUST	SEPTEMBER TO OCTOBER	NOVEMBER
BOD	28.8 kg/d/ha	8.67 kg/d	FROZEN
TSS	25.2 kg/d/ha	7.58 kg/d	FROZEN
FC	NOT DETERMINED	NOT DETERMINED	FROZEN

Dillon writes that the Heinke contaminant-loading rate is 110 kg/ha.d. Heinke (1993) reports in conclusion 7.1.3 page 213, that the BOD_5 loading rate should not exceed 8 kg/ha.d. Dillon's source of the higher value is from a review of literature in section 6.2.3.1 where the 110 kg/ha.d has been suggested by three references. This higher value, however, was not recommended by Heinke.

Dillon's conclusion that contaminant loading rate for BOD_5 does not exceed Heinke's recommendation is incorrect for the June to August period.

Dillon does not consider the effect of primary treatment through the exfiltration pond. Heinke (1993) recommends pre-treatment to remove TSS and other course materials to reduce the ultimate load applied to the wetlands and improve their performance.

The FSC analysis of the contaminant loading estimates that with the pre-treatment in the exfiltration pond the raw sewage contaminant concentrations, Table 3.1, can be reduced by 40%.

Based on the equation used by Dillon,

Contaminant load (kg/d) = [(hydraulic load) – (rainfall)]*contaminant concentration

The FSC analysis is shown as:

Table 3.4 - Calculated FSC Contaminant Loading

PARAMETER	JUNE TO AUGUST	SEPTEMBER TO OCTOBER	NOVEMBER
BOD	25.5 kg/day/ha	3.2 kg/day/ha	FROZEN
TSS	27.3 kg/day/ha	3.4 kg/day/ha	FROZEN
FC	NOT DETERMINED	NOT DETERMINED	FROZEN

When compared to Heinke *et al.* (1993), the FSC calculations also exceed 8 kg BOD_5/day/ha.

3.3.3 DISCUSSION

Heinke's guidelines (1993) were one of a number of attempts to determine design guidelines for wetlands in the NWT. Dillon undertook three studies in the Kivalliq Region to improve on Heinke's work.

However, the results of that work again provided broad ranges for loading rates and could not address the concern of elevated "spikes" during the spring freshette or the effect of natural or background discharges.

As a result, Heinke (1993) remains the only design guidelines for Nunavut and NWT wetlands.

3.3.3.1 Alberta Environmental Protection Guidelines

Alberta Environmental Protection has published guidelines for the design of wetlands and overland flow systems. These are based on algorithms that consider both the input of sewage and the contribution of the wetland because of that input. The result of this analysis determines the size of the wetland required to treat a contaminant to a target effluent quality.

The algorithms are as follows:

$$A = (0.036 * Q/k) * LN((Ci-Cw) / (Ce-Cw))$$

Where,

A	=	Required wetland area, ha
Q	=	Design flow, m3/d
k	=	Areal rate constant, m/yr
Ci	=	Influent concentration
Cw	=	Wetland background limit, mg/L
Ce	=	Target effluent concentration
Co	=	Effluent concentration, mg/L
Amax	=	Maximum calculated area, for this study available wetland area

$$Co = Cw + (Ci-Cw)exp(-k*Amax / 0.0365*Q)$$

Where,

Co	=	Effluent concentration, mg/L
Amax	=	Maximum calculated area, for this study available wetland area

Alberta's guidelines have not been proven in northern climates. In addition, they are designed for an average temperature of 20°C. One must be conservative in applying these guidelines, as Hall Beach's average summer temperature is approximately 5.5°C.

Assuming that biological production rate is decreased by half as the temperature decreases from 20° to 10 °C , the again by half as temperature decreases to 5°C , the algorithms have been applied to the Hall Beach situation.

In addition, it is assumed that the raw sewage has already been treated in the exfiltration pond; the raw sewage concentrations of BOD and TSS will be reduced by 40%.

Therefore, this calculation results in an estimate area requirement of 3 ha of wetland at 5°C to address the effluent requirements for BOD and TSS (refer to Table 3.5). As mentioned earlier, the wetland site has a total area of 6 ha, therefore, fulfilling the required wetland area requirements.

Table 3.5 - Results of Alberta Environmental Protection Guidelines

Temperature	WETLAND AREA	Influent BOD (Ci)	Influent TSS (Ci)	Nunavut Water Board Guideline BOD	TSS	Effluent BOD (Co)	Effluent TSS (Co)
°C	(ha)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
20	6	238	254	100	120	16	24
10	6	238	254	100	120	21	24
5	6	238	254	100	120	48	24

3.3.3.2 U.S. Environmental Protection Agency Design Manual

The U.S. Environmental Protection Agency Process Design Manual for Land Treatment of Municipal Wastewater, Supplement on Overland Flow was used as another method to model the wetland at Hall Beach. The design manual is based on the following equation:

$$(Cz-C)/Co = A \exp(-kz/q^n)$$

Where:

Co	=	Concentration of BOD5 in applied wastewater, mg/L
Cz	=	Concentration of BOD5 at distance (z) down the terrace, mg/L
C	=	Minimum achievable effluent concentration, mg/L (5 mg/L)
A $\exp(-kz/q^n)$	=	All variables, except z, are empirically determined and have been developed into a family of curves, Fig. 3-1 and 3-2 of the Design Manual (curves are appended).

This design model, like the Alberta Environmental Protection Guidelines, was created in the South and has never been tested in the North. A correction factor cannot be applied to the equation because it is empirical. Another limitation of this model is that it only focuses on the BOD concentration and does not include the TSS concentration, nutrients or faecal coliform. Both concentrations must meet effluent levels specified by the Nunavut Water Board before being released into the marine environment.

The results of the U.S EPA equation require a 2.1 ha of wetland, meeting the restriction of the existing 6 ha wetland. However, using the FSC correction factor applied to the Alberta model to account for a lower temperature the wetland area is multiplied by four resulting in the estimated area of 8.4 ha to provide a target effluent BOD of 100 mg/L. If this model were valid, then, the wetland would be too small.

3.4 Conceptual Design

3.4.1 Wetlands

Once Dillon determined that the wetland area would be suitable for treating the liquid exfiltrating from the lagoons, they designed two ditches. These ditches would cut off flow from directly entering Foxe Basin and divert the sewage flow into the wetland. Dillon's design concepts are shown in the Figure 2, Drawing No.4 and Drawing No. 5, which follow.

3.4.2 Lagoon

Dillon compared their estimate of the volume of the sewage lagoons to their 20-year projected volume. They estimated the lagoons to be 12,000 m^3 and the 20-year ice pack demand requirement to be 27,237 m^3 concluding that the lagoon system required expansion.

Apparently, in 1998 the Hall Beach lagoons overflowed in the spring showing that the volume at that time was insufficient.

3.5 Cost Estimate

Dillon's cost estimate is shown in the following table:

Item	Estimated Quantity	Unit	Dillon Unit Cost	Total Estimated Cost
Main ditch - core excavation	1850	m^3	$12	$22,200
Side ditch #1 - core excavation	600	m^3	$12	$7,200
Side ditch #2 - core excavation	700	m^3	$12	$8,400
Main ditch - berm fill	3200	m^3	$0	$0
Sides and bottom of main ditch - 3/4" and 1/2" crush	450	m^3	$70	$31,500
Sides and bottom of side ditch #1 - 3/4" and 1/2" crush	150	m^3	$70	$10,500
Sides and bottom of side ditch #2 - 3/4" and 1/2" crush	170	m^3	$70	$11,900
Contingency 20%				$18,340
Total				$110,040

FSC's cost estimate based on Dillon's quantities is as follows:

Item	Estimated Quantity	Unit	FSC Unit Cost	Total Estimated Cost
Main ditch - core excavation	1850	m3	$15	$27,750
Side ditch #1 - core excavation	600	m3	$15	$9,000
Side ditch #2 - core excavation	700	m3	$15	$10,500
Main ditch - berm fill	3200	m3	$0	$0
Sides and bottom of main ditch - 3/4" and 1/2" crush	450	m3	$50	$22,500
Sides and bottom of side ditch #1 - 3/4" and 1/2" crush	150	m3	$50	$7,500
Sides and bottom of side ditch #2 - 3/4" and 1/2" crush	170	m3	$50	$8,500
Contingency 20%				$17,150
Total				$102,900

We have taken notice of Dillon's quantities, as they appear to be appropriate from their layouts. FSC uses different cost estimates based on our experience in the region for civil projects. The costs estimates are within ± 5%. This is an acceptable difference at the "Class D" planning stage.

3.6 CONCLUSIONS

Dillon has taken a reasonable approach to the analysis of this system; however, they have used incorrect Heinke loading rates.

Regardless, the solution of using wetlands to improve the effluent shows merit in our analysis. Certainly, the recommendation for increasing the size of the lagoon is correct.

FSC would have provided the same advise, however, we would have also recommended a detailed multi-year sampling program of the wetlands and further recommended a topographical survey be undertaken to look toward expanding the existing wetlands to accommodate the projected 20 year volumes.

4. RECOMMENDATIONS FOR HALL BEACH SEWAGE TREATMENT

4.1 7 MONTH STORAGE EXFILTRATION POND

Shown in Drawing C-1, a pair of exfiltrating ponds replaces the existing sewage lagoon. They are designed to have the capacity to hold the winter sewage production of Hall Beach and to perform primary treatment during the summer months.

The exfiltrating ponds will have total surface area of 19,400 m^2 at maximum capacity, with a maximum active working volume of approximately 27,000 m^3 with a total maximum volume (including dead storage) of 33,000 m^3.

OPTION 3: 7 MONTH STORAGE EXFILTRATION POND				
2 95 m x 95 m EXFILTRATION PONDS WITH THE USE OF THE EXISTING LAGOON AS SLUDGE STORAGE				
COST ITEMS	COST/UNIT	UNIT	TOTAL	TOTAL
ON SITE MATERIALS	$35.00	CUBIC METRE	23500	$822,500.00
REWORKING WETLANDS		1	1	$50,000.00
ENGINEERING AND CONTINGENCY	40%	N/A		$349,000.00
TOTAL COST				$1,221,500.00
LAGOON BERM SPECIFICATIONS				
Average height of exterior berm			2.8 m	
Average area of exterior berm			36.1 m^2	
Exterior berms are to be 99.4 m high, 8.0 m wide at the top with 3:1 external slopes and 2.5:1 internal slopes				
Interior berms are to be 99.4 m high, 2.5 m wide at the top with 2.5:1 slopes				

5. CONCLUSIONS

1. A larger exfiltration lagoon should be built in place of the existing structure on the existing site. This will minimize the costs involved with the construction of a sewage disposal system that will serve the 20 year needs of the community.

2. The exfiltration lagoon is to be designed with two cells, this will increase sewage treatment and also enable to community to close one cell at a time for sludge removal, if necessary.

3. A sludge storage area has not been included in this design, as sludge has not appeared to be a problem in the Hall Beach sewage disposal system. It is recommended that this should be studied in 5 to 7 years.

4. Reworking the existing wetlands to maximize wetland effluent treatment.

5. Excess material from the construction should be used at the municipal solid waste site for cover material. As this material is contaminated, there are few options for its use.

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