Wetland Treatment Conceptual Design, Arctic Bay, NT

Final Report

March 23, 1999

Wetland Sewage Treatment Conceptual Design, Arctic Bay, NT

Government of the Northwest Territories
Department of Public Works & Services

98-5187-01-01

Submitted by

Dillon Consulting Limited

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March 19, 1999

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Attention: Mr. David Parker, P.Eng.

Wetland Treatment Conceptual Design, Arctic Bay, NT

Dear Mr. Parker;

Dillon is pleased to submit six (6) copies of our Final Report for the above mentioned project. The report has been updated to reflect the comments that were raised in the council meeting held in the community on February 3, 1999. We understand from your recent communications that the community has adopted the recommendations from the report, and that the design is to proceed for the wetlands system. The design is proceeding, and we expect to make a submission shortly.

We would like to thank the Department of Public Works and Services for your assistance on this project, and the Hamlet of Arctic Bay for their participation and input during the council meeting.

We trust this meets your requirements and look forward to discussing this report with you.

Yours sincerely,
DILLON CONSULTING LIMITED

Kirk Guenther, P.Eng. for
Gary Strong, P.Eng.,
Project Manager

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1.0 INTRODUCTION

1.1 Background

Dillon Consulting Limited (Dillon) was retained by the Public Works and Services Department of the Government of the Northwest Territories (PWS GNWT), in conjunction with the Nunavut Water Board (NWB), to prepare a conceptual design of a wetland sewage treatment system to serve the community of Arctic Bay. The intention is to use a wetland system in conjunction with the existing storage lagoon, in order to meet the regulatory requirements for sewage discharge, as outlined in the *Guidelines for Municipal Type Wastewater Discharges in the Northwest Territories* (NWT Water Board, 1992). The planning horizon for the proposed system is 20 years, and consequently projections to the year 2018 are used in the conceptual design.

1.2 Wetland Systems in the NWT

Over 70% of the communities in the Northwest Territories (NWT) presently use lagoon-based systems for the treatment of sewage. However, recent fiscal restraint, together with the technical challenges associated with the development of lagoon-based systems has prompted the GNWT to consider alternative technologies. The use of natural "wetland" systems (including components such as tundra, open ponds, emergent grasses, fens, or bogs) has been identified as a promising alternative (Dillon, 1998).

To date, the majority of the natural wetland treatment systems in the NWT have not been engineered, but have been established as a consequence of discharging raw sewage into one location over time. Monitoring of these systems has suggested that they are meeting the overall objectives of sewage treatment. In addition, wetlands in the NWT generally have nutrient deficiencies, and consequently there are no concerns related to eutrophication, which is frequently a result of wetland discharges in southern regions. Therefore, the controlled discharge of sewage to northern, nutrient deficient wetlands acts to enrich the vegetation by providing essential nutrients for growth. The results of studies carried out by Dubuc *et al.* (1986) at Fontanges in the James Bay area, Lakshman (1983) at Humboldt, Saskatchewan and Reid Crowther (1990) at Yellowknife, NWT, confirm the observations that wetlands in the north have the potential to act as an efficient method of sewage treatment.

Three northern wetland systems presently operating, and recently studied by Dillon (1998) are those located in Baker Lake, Repulse Bay and Chesterfield Inlet. Results of the study of these systems indicated that the study areas were achieving tested removal rates of targeted parameters at efficiencies equal to or better than those expected from an annual storage lagoon.

1.3 Project Scope and Objectives

The objective of this project is to develop a conceptual design of a wetland sewage treatment system to work in conjunction with the sewage lagoon presently used at Arctic Bay. The proposed treatment system is to have the capacity to serve the Arctic Bay community for the next 20 years, and consequently, future projections to the year 2018 have been utilized in the design.

2.0 SITE DESCRIPTION

2.1 Location

The community of Arctic Bay is located in the northwestern region of Baffin Island, where it is situated on the banks of Adams Sound, a fjord leading to the Arctic Ocean (see **Figure 1**). Arctic Bay is connected by a 21 km road to Nanisivik, a mining town developed in the mid 1970's. The present sewage lagoon is located approximately 2.5 km west of the community of Arctic Bay.

According to the statistics published by MACA, the present (1998) population of the Arctic Bay community is 637.

2.2 Climate

Climate data summaries for Arctic Bay were obtained from Environment Canada as follows:

- mean high and low temperatures:
  - -July: 9.5°C and 1.7°C
  - -January: -25.9°C and -33.5°C

- mean annual precipitation:
  - -rainfall = 5.2 cm (over June - September)
  - -snowfall = 71.5 cm

The winds are typically north-northwesterly, and average (annually) 24 km/hr.

2.3 Topography, Geology and Soils

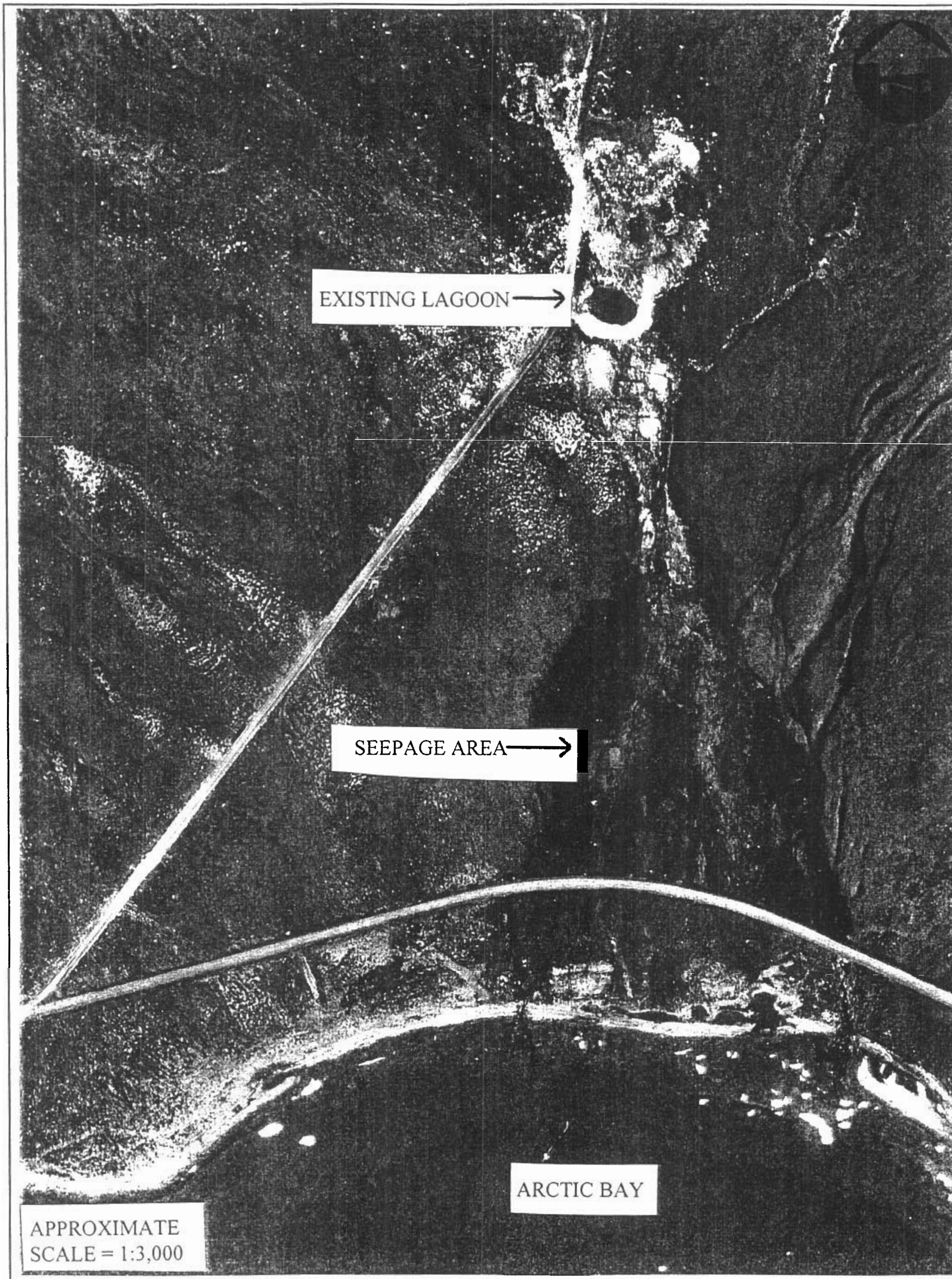
Arctic Bay is surrounded by high hills, the most prominent being the King George V mountain (564 m), located 1.6 km east of the community. The present lagoon is situated on level ground, which slopes gradually (17:1 slope) south to Arctic Bay (see Appendix A, Photo 1). The lagoon is situated approximately 400 m upslope of the bay (see **Figure 2**).

Underlying the sedges and grasses, a layer of clays mixed with gravel exists to a depth of approximately 0.5 m. Below that are layers intermixed with gravel, humus and tundra over continuous permafrost.

Figure 1 Site Location

DILLON CONSULTING	SITE LOCATION	PROJECT NO. 98-5187
	ARCTIC BAY WETLANDS SEWAGE TREATMENT	FIGURE NO.
AUGUST, 1998	CONCEPTUAL DESIGN - DRAFT REPORT	1

Figure 2 Existing Sewage Treatment Lagoon



DILLON CONSULTING	EXISTING SEWAGE TREATMENT LAGOON	PROJECT NO. 98-5187
AUGUST, 1998	ARCTIC BAY WETLANDS SEWAGE TREATMENT CONCEPTUAL DESIGN - DRAFT REPORT	FIGURE NO. 2

2.4 Hydrology

The natural hydrology in the immediate vicinity of the present lagoon consists of a various creeks travelling south towards Arctic Bay. The flow of these creeks becomes braided as it enters the seepage area of the present lagoon (see Figure 2). The flow from the creeks, in addition to the seepage from the present lagoon, travels under the road through culverts, and subsequently is discharged to Arctic Bay.

2.5 Vegetation

Characteristic vegetation found within the region encompassing Arctic Bay includes arctic willows, grasses, mosses, and lichens, growing on a humus "cover". More specifically, the area of the present lagoon hosts sedges (*family cyperaceae*) and cotton grasses (*eriophorum spp.*) (see Appendix A, Photo 2).

2.6 Present Lagoon System

The sewage lagoon system presently serving Arctic Bay is located approximately 2.5 km west of the community, situated adjacent to a run-off stream bed between the plateau and the water shoreline. The lagoon itself covers an area of approximately 1,200 m^2, surrounded by a permeable dyke (see Appendix A, Photo 3). As portions of the dyke have become plugged, sewage has breached it, and presently leaks through the southern berm at an uncontrolled rate. This rate will approximate the sewage discharge rate to the lagoon. The sewage seeps travel southward, via braided overland flow towards Arctic Bay (see Figure 2).

The ratio of residential to commercial/industrial input is typically very high in sewage generated by small northern communities similar to Arctic Bay (Dillon, 1998). Consequently, it is assumed that the sewage composition is essentially "domestic" in nature.

The sewage entering the existing system (via truck hauls) receives minor settling prior to leaving the lagoon (see Appendix A, Photo 4). It was noted by Reid Crowther (1997) that the plume at the shoreline consisted of relatively raw, untreated effluent. It has been estimated that the associated retention time of the sewage entering the existing system during the summer months (June-September) is approximately 30 days. During the winter months (October-May) a sewage ice pack forms, with inputs freezing immediately upon contact. The existing area containing the winter ice pack is located immediately southwest of the lagoon (see Figure 2). There are no discharges from the sewage ice pack to the seepage area during the winter months.

The present sewage generation rates exceed the holding capacity of the existing lagoon, as illustrated by the relatively raw, untreated nature of the effluent observed at the shoreline.

3.0 TREATMENT REQUIREMENTS

3.1 Future Projections

Experience has shown that the per capita quantity of municipal sewage generated by northern communities is approximately equal to the rate of water consumption (Dillon, 1998). Based on this theory, MACA has produced the population and water consumption/sewage generation projections for Arctic Bay (Table 1). Using these calculations, it is estimated that the average daily sewage generation for the community will be approximately 110 m^3 (35,000 usgal) in the year 2018 (the study horizon).

Table 1: Population and municipal sewage generation projections for Arctic Bay (GNWT, Municipal and Community Affairs)

Year	Population	Individual Sewage Generation (L/ca.d)	Community Sewage Generation (L/d)
1998 (year 0)	637	103.2	65,700
1999	651	103.5	67,400
2000	666	103.8	69,100
2001	682	104.1	71,100
2002	698	104.4	72,900
2003	714	104.8	74,800
2004	730	105.1	76,700
2005	747	105.5	78,800
2006	763	105.8	80,700
2007	780	106.1	82,800
2008	797	106.5	84,900
2009	815	106.9	87,100
2010	833	107.2	89,300
2011	852	107.6	91,700
2012	871	108.0	94,100
2013	890	108.4	96,500
2014	910	108.8	99,000
2015	931	109.3	101,700
2016	952	109.7	104,400
2017	973	110.1	107,200
2018 (year 20)	995	110.6	110,000

3.2 Contaminants of Concern

As no samples have been collected from the effluent at the existing treatment lagoon at Arctic Bay, the exact composition of the sewage is currently unknown. However, the composition can be inferred from published data on "typical" domestic sewage generated in northern communities, as displayed in Table 2.

Table 2: Typical trucked raw sewage characteristics (from Metcalf and Eddy, 1979)

Parameter	Concentration[1]
biological oxygen demand (BOD)	400
total suspended solids (TSS)	350
volatile suspended solids (VSS)	275
ammonia (NH_3)	50
total phosphorus (TP)	15
fecal coliform (FC)	1.5E07[2]

[1] all concentrations are in mg/L, except fecal coliform, which is in CFU/dL

[2] source: average concentration measured at Baker Lake (Dillon, 1998)

Brief descriptions of the effects of the parameters are provided below (Henry *et al.*, 1989):

- *BOD*:
  High BOD values in a receiving water equate to increased organic matter decomposition. The microbial activity of bacteria requiring oxygen for the decomposition process will reduce the dissolved oxygen of the receiving waters, in extreme cases to levels at which fish and additional aquatic fauna cannot survive. In addition, when all dissolved oxygen is depleted, anaerobic conditions occur, resulting in objectionable odours.

- *TSS/VSS*:
  Organic and inorganic particulates in sewage typically consist of settleable, floating and suspended solids that can result in unsightly deposits, odorous sludge banks and reduced penetration of sunlight through the water. Resultant decrease in photosynthetic activity of aquatic flora occurs with high TSS/VSS inputs to a receiving water.

- *NH_3/TP:*
  In general, increased additions of nitrates and phosphates can lead to eutrophication of receiving waters. Algal "blooms" associated with eutrophication can be toxic to some aquatic fauna, and are also associated with objectionable odours. However, wetlands in northern regions generally have nutrient deficiencies, and consequently there are no concerns related to eutrophication. In contrast, the controlled discharge of sewage to northern, nutrient deficient wetlands acts to enrich the vegetation by providing essential nutrients for growth. Therefore NH_3/TP are not considered to be

COCs for this site.

- *FC:*

  FC are human enteric pathogens which are known to cause waterborne diseases. FC consist of both pathogenic and nonpathogenic microorganisms, the former of which are considered toxic to aquatic fauna, and humans.

Therefore it is the BOD, SS and FC parameters which are the COCs inherent in domestic sewage, and consequently those that are targeted in effluent quality guideline criteria (as outlined in Section 3.3.3).

3.3 Treatment Requirements

As outlined in Heinke *et al.* (1993), the critically used parameters in the design of wetland systems are the hydraulic loading rate and the organic loading rate. These rates are used as a check to ensure that the aerobic conditions necessary for microbial activity prevail in the wetland ecosystem. The requirements for the treatment of sewage at Arctic Bay (using the 2018 projected generations, and the 2.3 ha treatment area proposed in Section 4.0), as compared to the recommended loading rates, are outlined in the following sections.

3.3.1 Hydraulic Loading

The calculation of the hydraulic loading rates is as follows:

JUNE:

total daily sewage generation	=	$^{110\ m3}$/d
ice pack (frozen accumulation of 8 months of generation)	=	($^{110\ m3}$) x (8months) x (30days/month) = 26,400m^3
ice pack seepage (melts evenly during June)	=	(26,400m^3) / (30days) = 880m^3/d
rainfall inputs (with treatment area of 2.3 ha, and 5.2 cm rain falling evenly over June-Sept)	=	[(5.2 cm) x (23,000m)] / (120days) = 10m^3/d
total daily hydraulic load	=	sewage generation + ice pack melt + rainfall
	=	$^{110\ m3}$/d + 880m^3/d + 10m^3/d
	=	**1,000m^3/d**

JULY, AUGUST& SEPTEMBER:

total daily sewage generation	=	110 m3/d
rainfall inputs (with treatment area of 2.3 ha, and 5.2 cm rain falling evenly over June-Sept)	=	[(5.2 cm) x (23,000m)] / (120days) = 10m^3/d
total daily hydraulic load	=	sewage generation + rainfall
	=	110 m3/d + 10m^3/d
	=	**120m^3/d**

OCTOBER - MAY:

Sewage accumulates in ice pack, therefore zero hydraulic load to the system.

It is recommended in Heinke *et al.* (1993) that the hydraulic loading rates for constructed wetland systems do not exceed 800m^3/ha.d. Using the available wetland treatment area of 2.3 ha (see Section 4.0), the hydraulic loading rates (in 2018) for the proposed system would be estimated at 435m^3/ha.d (June) and 50m^3/ha.d (July-September), thus well below the recommended maximum.

3.3.2 Contaminant Loading

The calculation of the contaminant loading rates, using the typical sewage characteristics outlined in Table 2, are as follows:

JUNE:

BOD load	=	[(hydraulic load) - (rainfall)] x BOD concentration
	=	[(1,000m^3/d) - (10m^3/d)] x 400mg/L
	=	(990m^3/d) x (0.4kg/m^3)
	=	**396kg/d**
TSS load	=	[(hydraulic load) - (rainfall)] x TSS concentration
	=	[(1,000m^3/d) - (10m^3/d)] x 350mg/L
	=	(990m^3/d) x (0.35kg/m^3)
	=	**347kg/d**

JULY, AUGUST& SEPTEMBER:

BOD load	=	[(hydraulic load) - (rainfall)] x BOD concentration
	=	[(120m^3/d) - (10m^3/d)] x 400mg/L
	=	(110 m3/d) x (0.4kg/m^3)
	=	**44kg/d**

TSS load	=	[(hydraulic load) - (rainfall)] x TSS concentration
	=	[(120m^3/d) - (10m^3/d)] x 350mg/L
	=	($^{110\ m3}$/d) x (0.35kg/m^3)
	=	**39kg/d**

OCTOBER - MAY:

Sewage accumulates in ice pack, therefore zero contaminant load to the system.

It is recommended in Heinke *et al.* (1993) that the BOD loading rates for free water surface constructed wetland systems do not exceed 110kg/ha.d. Using the available wetland treatment area of 2.3 ha (see Section 4.0), the BOD loading rates (in 2018) for the proposed system would be estimated at 172kg/ha.d (June) and 19kg/ha.d (July-September). With respect to the June BOD loading, the exceedance of the rate above the recommended value could likely be compensated for by the enhancement of aerobic conditions in the system, achieved by directing effluent flow through boulder fields, small ponds and depression areas.

3.3.3 Applicable Criteria

The *Guidelines for Municipal Type Wastewater Discharges in the Northwest Territories* (NWT Water Board, 1992) are used throughout the NWT as a baseline document upon which municipal sewage treatment systems are licensed and regulated. These discharge guidelines are used as target criteria for the Arctic Bay site (see Table 3).

No guideline value is presented for fecal coliform (FC) in the criteria. As results of previous studies have shown (Dillon, 1998), the mass of FC introduced to the wetland system following the melting of the sewage ice pack appears to be negligible. Consequently, the results suggest that the FC appear to be reduced from within the ice pack during the winter months.

Table 3: Applicable excerpts from the *Municipal Wastewater Effluent Quality Guidelines* (NWT Water Board, 1992)

Parameter	Guideline Value for Bay or Fjord
BOD	100 mg/L
SS	120 mg/L
FC	no guideline value

The guidelines listed above are presented on a concentration basis. To conceptualize the level of sewage treatment that these equate to, the numbers can be compared to the typical raw sewage characteristics (see Table 2) to identify the required percent removal prior to discharge to Arctic Bay. For illustrative purposes, the discharge concentrations are now presented below as an equivalent percent removal.

Biological Oxygen Demand (BOD_5) = 75%
Suspended Solids (SS) = 66%

The above removal percentages exclude the effects of dilution, which often play a significant role in reducing the contaminant concentrations in a wetland environment. Hence the removal efficiencies related to the proposed treatment system likely represent a conservative estimate.

4.0 CONCEPTUAL DESIGN

4.1 System Components

The components of the proposed wetlands treatment area include an ice pack holding area, a series of three berms for temporary ponding, and a redirection of the flow path of the natural creeks located immediately east of the wetland seepage area, flowing towards Arctic Bay. **Figure 3** illustrates the conceptual lay-out of the system.

4.1.1 Ice Pack Holding Area

Objective:

The objective of the ice pack holding area is to provide controlled discharge for the eventual seepage (upon melting) of the winter accumulation of sewage. The temporary holding of the melted sewage in the ice pack area would provide primary treatment, through the physical settling of solids, thus reducing the TSS loads.

Preliminary Design:

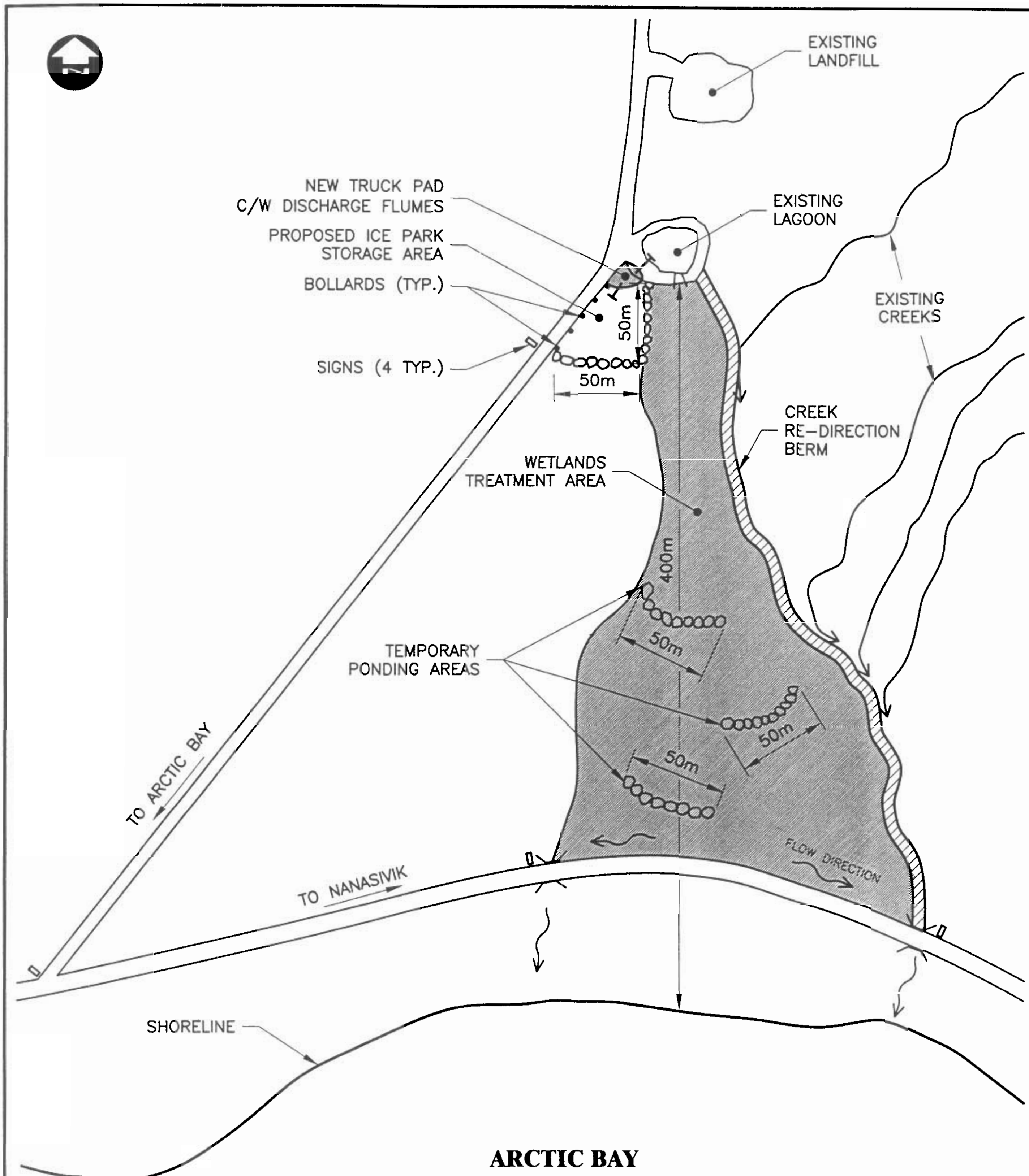
The proposed ice pack holding area is located immediately southwest of the present lagoon, and is approximately 1,250m^2 in size (see Figure 3). The design of the holding area berms uses a frozen core system, which allows the integrity of the holding area to be upheld during the extreme temperatures inherent in the region.

In the construction phase, a 3m wide "line" would be excavated following the path of the containment berm for the holding area. Excavation would occur to the interface with the underlying permafrost. The construction of a core berm would then be carried out, to a height of approximately 2m, using frost susceptible silts (see **Figure 4**). Theoretically, the core berm would eventually freeze directly to the underlying permafrost, thus facilitating the movement of frost up the core (Reid Crowther, 1997).

A protective covering of the core berm is necessary to prevent wind erosion and to act as an insulating blanket. The materials used for this should be a mixture of the overburden excavated during core construction, and coarse granular material.

A corridor for the discharge of the melted sewage into the downstream wetlands system should be included as shown in Figure 3, with a width of approximately 1.5m.

Figure 3 Proposed Wetlands Treatment System



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DILLON CONSULTING

PROJECT: PROPOSED WETLANDS TREATMENT SYSTEM

ARCTIC BAY WETLANDS SEWAGE TREATMENT CONCEPTUAL DESIGN – DRAFT REPORT

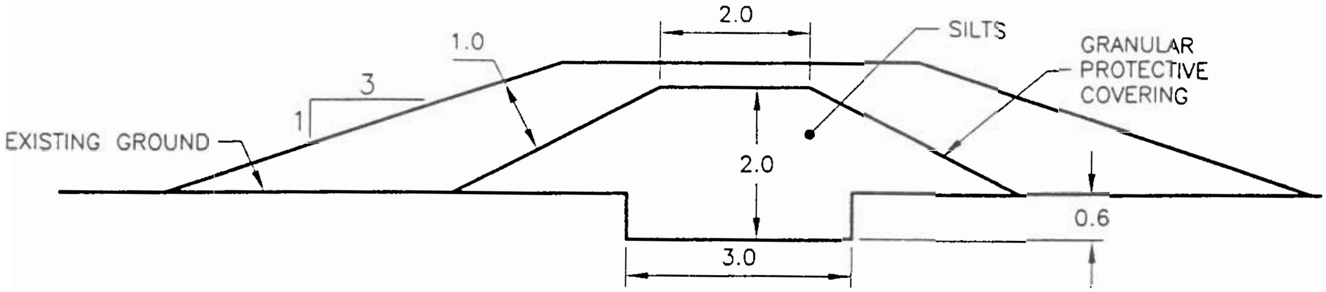
PROJECT NUMBER: 98–5187

DATE: AUG 98

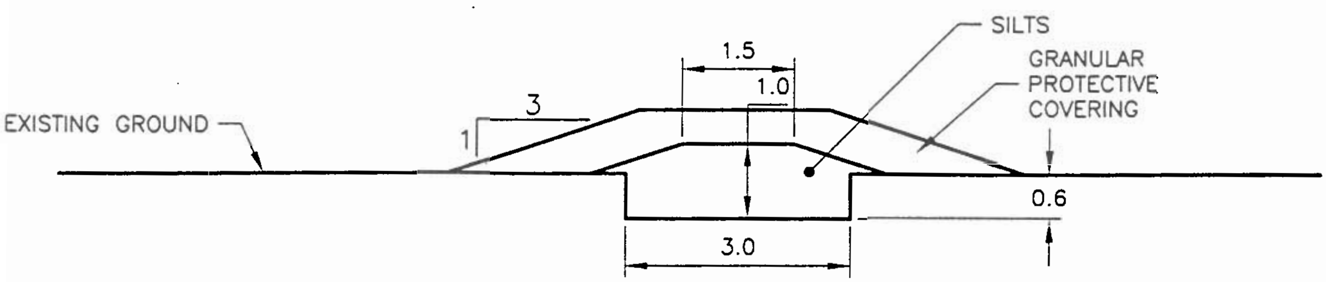
FIGURE NUMBER: 3

Figure 4 Cross Section of Berm Construction

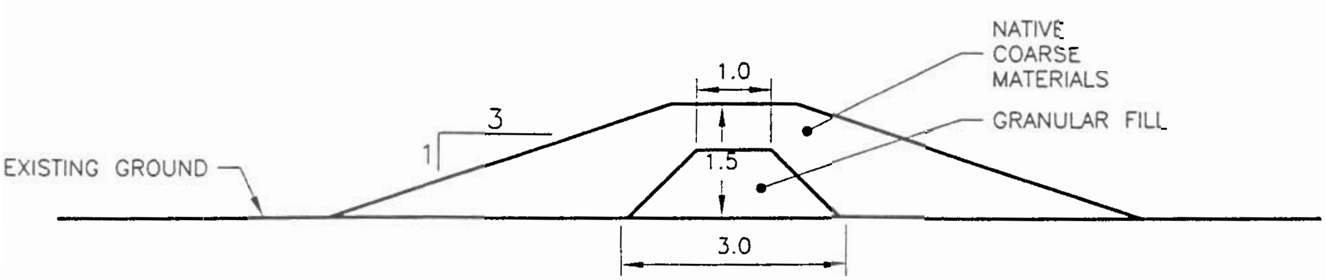
PROPOSED ICE PACK STORAGE AREA BERM:



PROPOSED PONDING AREA BERMS:



PROPOSED DRAINAGE RE-DIRECTION BERM:



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DILLON CONSULTING	PROJECT: CROSS SECTION OF BERM CONSTRUCTION	PROJECT NUMBER: 02-9971
		DATE: FEBRUARY 2002
	TITLE: ARCTIC BAY WETLANDS SEWAGE TREATMENT CONCEPTUAL DESIGN - PROJECT PLAN	FIGURE NUMBER: 4

4.1.2 Temporary Ponding Berm Series

Objective:

The objective of the wetland berm series is to provide temporary ponding areas between the existing lagoon and the discharge to Arctic Bay. The series of three berms will act to increase the overall retention time of the sewage in the wetland treatment area (the berms will each provide approximately 3 days holding time). This will enhance the microbial breakdown of the organics in the sewage, thus reducing the BOD load to the receiving water. The flow of effluent between the berms and to the bay will provide the aeration needed to maintain the aerobic environment - a necessary condition for the microbial breakdown of contaminants.

Preliminary Design:

The proposed temporary seepage ponds are located within the wetland treatment area, downstream of the present sewage lagoon (see Figure 3). It is proposed that three berms be constructed, to form the three ponds in series. The exact location of each of the three berms will be determined in the field at the time of construction ("field fit"). As with the ice pack holding area, the design of the pond berms utilizes a frozen core system, which allows the integrity of the holding area to be upheld during the extreme temperatures inherent in the region.

In the construction phase, a 3m wide "line" would be excavated following the path of the berm (located downstream of each pond) for the holding area (see Figure 3). Excavation would occur to the interface with the underlying permafrost. The construction of a core berm would then be carried out, to a height of approximately 1m, using frost susceptible silts (see Figure 4). Theoretically, the core berm would eventually freeze directly to the underlying permafrost, thus facilitating the movement of frost up the core (Reid Crowther, 1997).

A protective covering of the core berm is necessary to prevent wind erosion and to act as an insulating blanket. The materials utilized for this should be a mixture of the overburden excavated during core construction, and coarse granular material.

Discharge of the effluent would occur via seepage over and around the berms. The design target for the seepage is a 3-day retention time for the effluent within each "pond".

4.1.3 Natural Creek Flow Re-direction

Objective:

The objective of re-directing the flow of the adjacent natural creek is to prevent the addition of this input to the hydraulic loading of the wetland system.

Preliminary Design:

For the preliminary design of the controlled channel, it is assumed that a channel wall of native coarse materials, built upon a base of granular fill would be adequate to prevent the flow of the natural creek from entering the wetland system (see Figure 3). Once again, the exact location of the channel wall will be a field fit, determined at the time of construction.

4.2 Estimated Costs

The preliminary estimated costs of the proposed wetlands system are based on the following assumptions:

- the cost of the supply, load and installation of granular pitrun would be $\$25/m^3$ (adding inflation to the $\$24/m^3$ quoted in 1997 by the Department of Public Works and Services in Iqaluit in 1997);
- the cost of the excavation for the installation of the core system would be $\$12/m^3$;
- the cost of the granular fill would be $\$46/m^3$ (adding inflation to the $\$45/m^3$ quoted in 1997 by the Department of Public Works and Services in Iqaluit in 1997);
- the cost of the supply, load and installation of the silts would be $\$25/m^3$; and
- the material excavated for the berms would not require hauling, but would be used as protective cover material.

Based on the above assumptions, the approximate capital costs for the proposed system have been estimated at $119,450, as displayed in Table 4.

Table 4: Estimated capital costs for the proposed wetland treatment system

Item	Estimated Quantity	Unit	Unit Cost	Total Estimated Cost
ice pack holding area - core excavation	180m^3	m^3	$12	$2,200
ice pack holding area - berm silts	600m^3	m^3	$25	$15,000
ice pack holding area - berm protective covering	400m^3	m^3	$25	$10,000
ponding berms - core excavation	300m^3	m^3	$12	$3,600
ponding berms - berm silts	600m^3	m^3	$25	$15,000
ponding berms - berm protective covering	450m^3	m^3	$25	$11,000
creek re-direction - granular fill	1,800m^3	m^3	$46	$83,000
CONTINGENCY (20%)				$28,000
TOTAL				**$168,000**

Table 5: Improvements to Truck Turnaround Pad Area, and Access Roads

Item	Estimated Quantity	Unit	Unit Cost	Total
Granular Fill	1,000m3	m3	$25	$25,000
Flume	2	each	$5,000	$10,000
Bollards	10	each	$500	$5,000
Signs	4	each	$2,000	$8,000
CONTINGENCY (20%)				$10,000
TOTAL				**$58,000**

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the performance of the wetland sewage treatment systems presently operating in the north, it is reported that the study areas are achieving the targeted removal of parameters at efficiencies equal to or better than those expected from an annual storage lagoon. In addition, the results of numerous studies (see Section 1.0) have confirmed the observations that wetlands in the north have the potential to act as an efficient method of sewage treatment. The objective of this project was to develop a conceptual design of a wetland sewage treatment system to work in conjunction with the sewage lagoon presently used at Arctic Bay.

The proposed treatment system consists of a combination of an ice pack storage area, a series of three temporary ponding areas and a redirection of the flow of the adjacent creek. Combined, these components form a system which will add further retention time, treatment area and aeration to the existing system. It is recommended that the wetlands system conceptual design be implemented to serve the Arctic Bay community over the 20-year planning horizon.

6.0 LITERATURE CITED

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APPENDIX A

Site Photographs

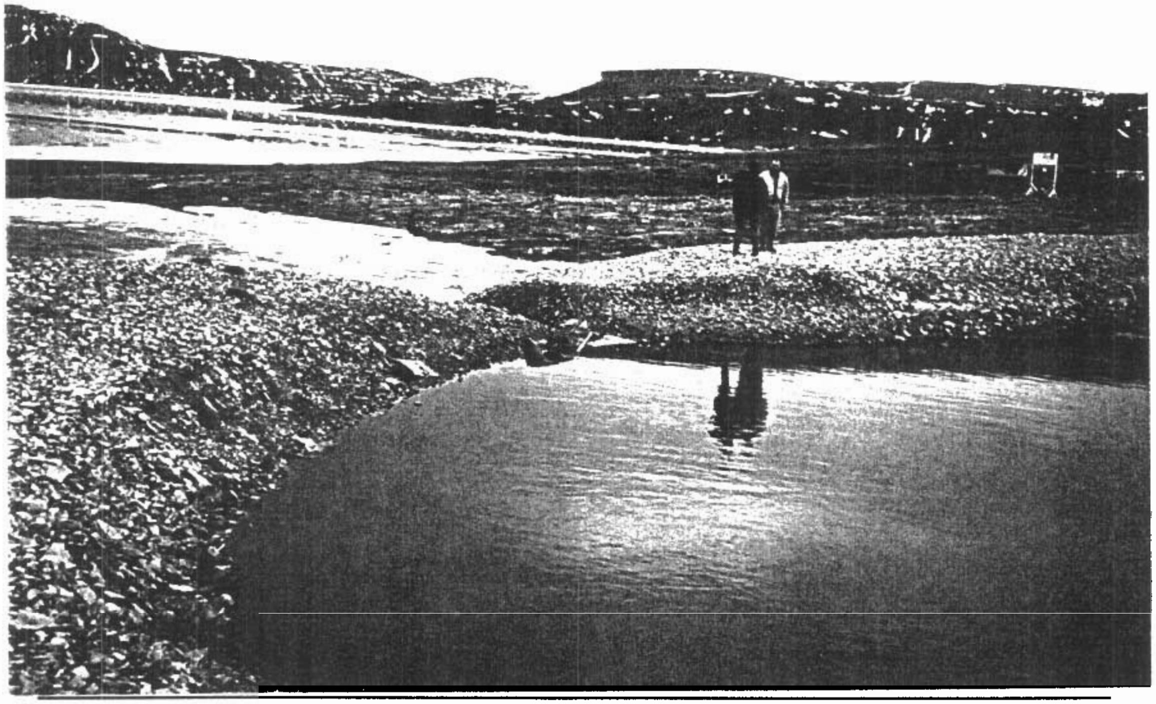

PHOTO 1: Existing sewage treatment lagoon, with seepage to Arctic Bay

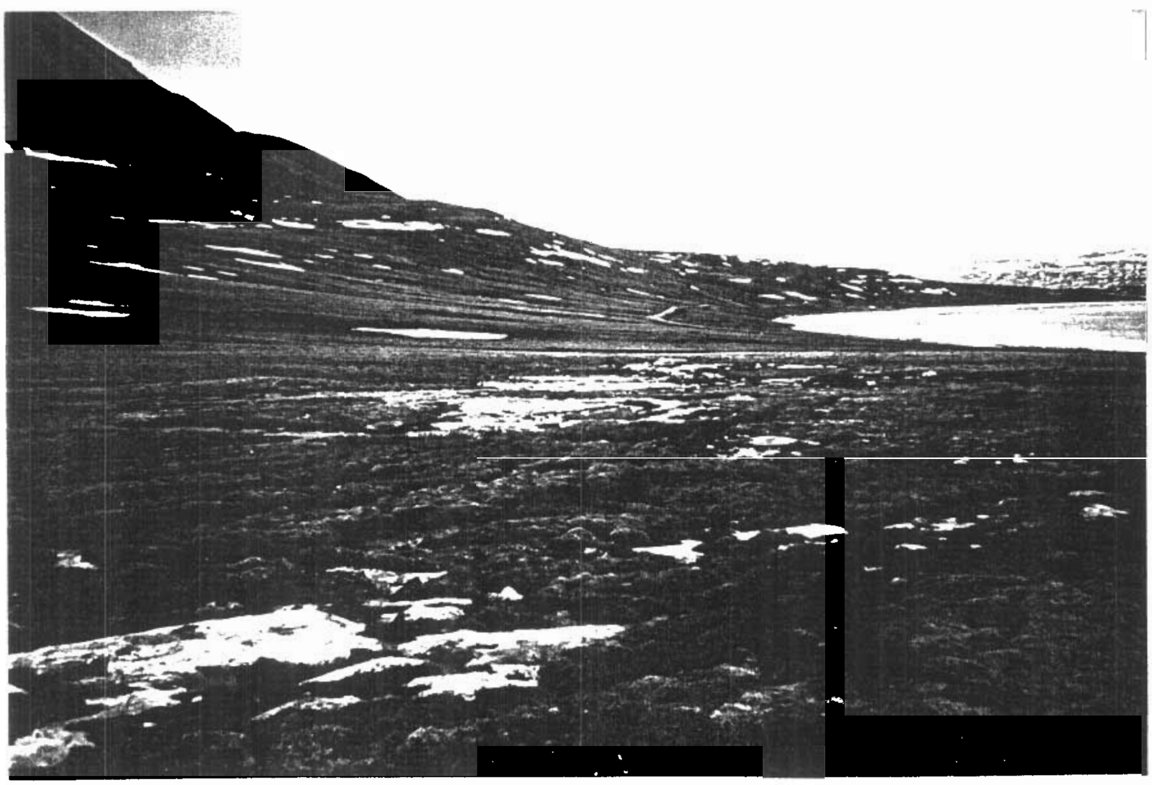

PHOTO 2: Vegetation present at the site (grasses, mosses and sedges)

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AUGUST 1998	ARCTIC BAY WETLANDS SEWAGE TREATMENT CONCEPTUAL DESIGN - DRAFT REPORT	PHOTO NOS. 1,2

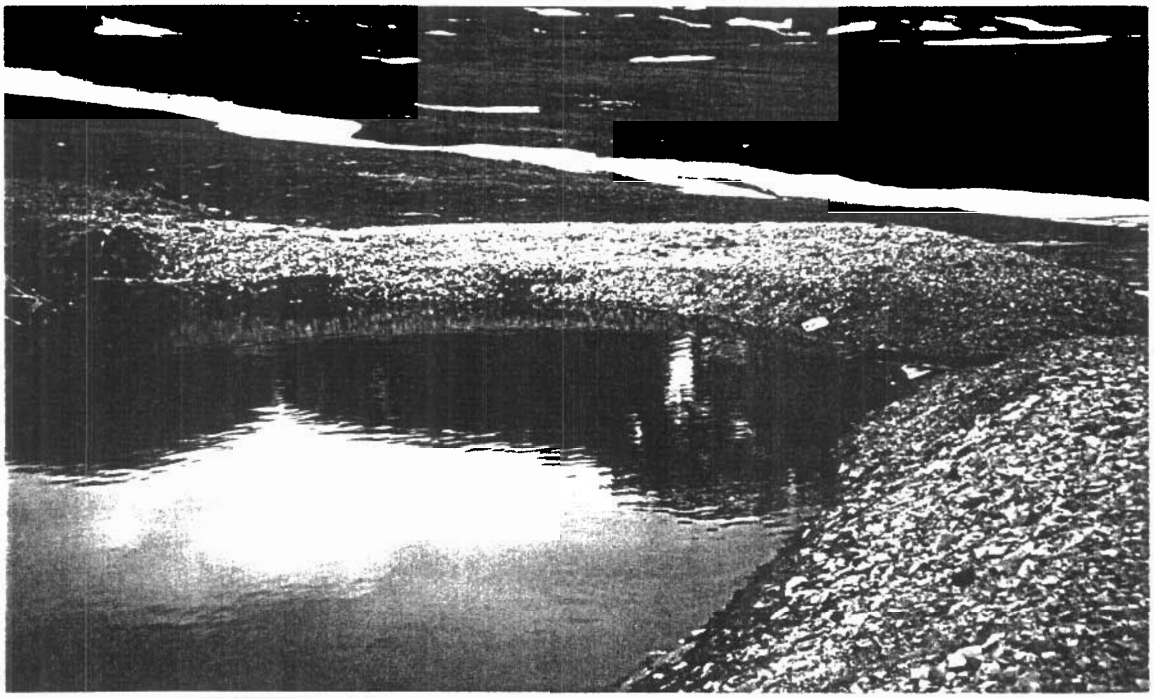

PHOTO 3: Permeable dyke enclosing existing lagoon

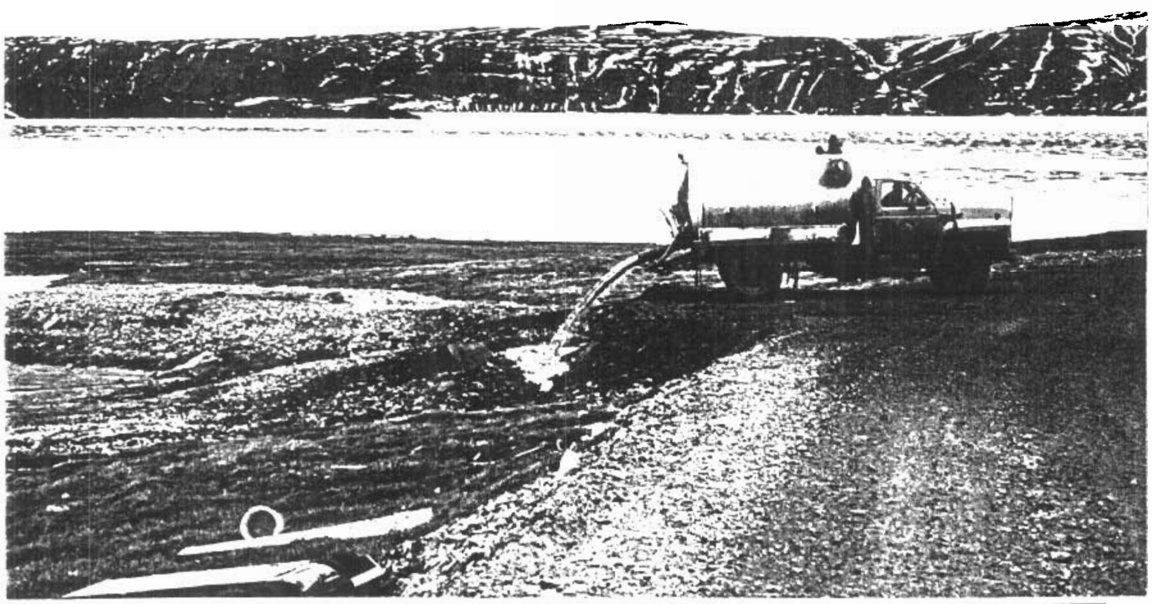

PHOTO 4: Present discharge method, via truck

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AUGUST 1998	ARCTIC BAY WETLANDS SEWAGE TREATMENT CONCEPTUAL DESIGN - DRAFT REPORT	PHOTO NOS. 3,4