NWB3REP

Repulse Bay, Wetlands Sewage Treatment System

Impact Assessment

June 1998

Repulse Bay, Wetlands Sewage Treatment System
Repulse Bay, NT

Government of the Northwest Territories
Department of Municipal & Community Affairs

97-4495-02

Submitted by

Dillon Consulting Limited

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1.0 INTRODUCTION

1.1 Background

Natural wetland systems have been identified as being a potential alternative for sewage treatment to lagoon based systems, due to their relatively low cost and their effectiveness at treating sewage. However, many of the wetland treatment systems in the north have not been engineered, but have been established from discharging raw sewage in one location over time. In order to better understand the utilization of wetlands for sewage treatment in the north, a study was undertaken by Dillon Consulting Limited (1997) entitled "Sewage Treatment Using Tundra Wetlands". This report examined existing wetland systems in the northern communities of Baker Lake, Chesterfield Inlet, and Repulse Bay. The stakeholders involved in this study include Environment Canada, Municipal and Community Affairs (MACA), and the Nunavut Water Board.

Dillon Consulting Ltd. was additionally retained by MACA to complete a Preliminary Impact Assessment in relation to the wetland sewage treatment system in Repulse Bay. The preliminary assessment was initiated as a follow-up to previous sewage treatment studies for this community to assist in determining if the existing wetland sewage treatment system is sufficient and whether release of the treated wastewater to the marine system is resulting in a significant impact.

The hamlet of Repulse Bay is located on the northern shore of Repulse Bay, on the south side of Rae Isthmus between the Gulf of Boothia and Southhampton Island (Latitude 66°32'N, Longitude 86°15'W) (**Figure 1-1**). The 1997 population for Repulse Bay is 597.

1.2 Scope

This assessment of the Wetland Sewage Treatment System is limited to the Hamlet of Repulse Bay and will be used to assist in the identification of potential impacts to the receiving water body. As part of this study, water, sediment, and benthos were collected at three locations within Repulse Bay during the late summer/fall season of 1997 prior to ice-up in order to coincide with the water quality sampling period from the previous year.

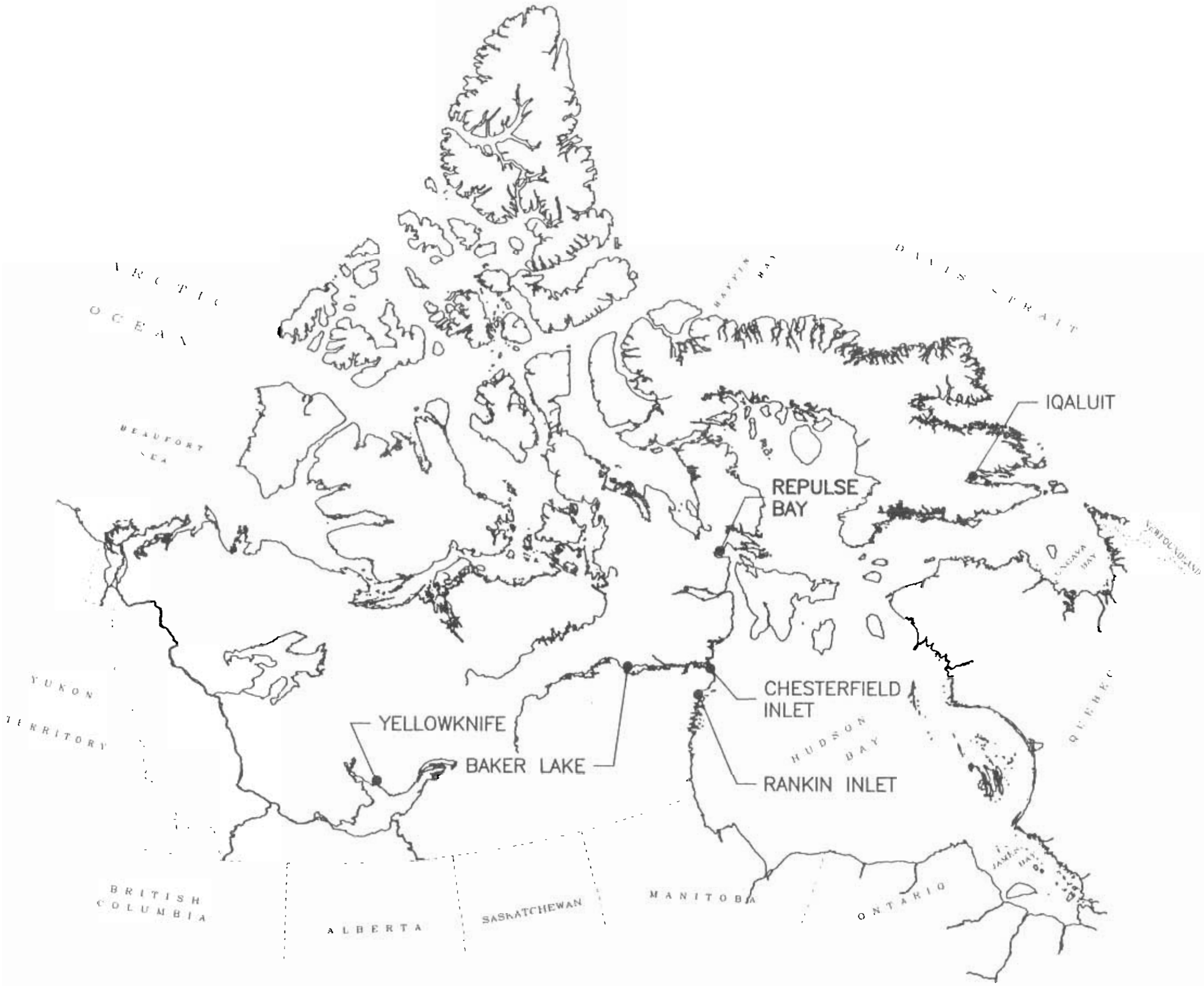
1.3 Objectives

The objectives of the Assessment are as follows:

- to determine if discharge from the wastewater treatment system is resulting in an impact to the receiving environment based on comparisons to control data; and
- to compare results from the Repulse Bay data to those from existing literature;

1.4 Characteristics of the Existing Sewage Treatment System

The sewage treatment system in Repulse Bay is located in a valley approximately 50 metres wide, with exposed bedrock surfaces found to the north and south of the valley (**Figure 1-2**). There are three main ponds in the valley (known as P1, P2, and P3) through which sewage flows 1.3 kilometres from its discharge point to the receiving environment on the shore of Repulse Bay.



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DILLON CONSULTING	PROJECT REPULSE BAY SEWAGE TREATMENT SYSTEM IMPACT ASSESMENT	PROJECT NUMBER 97-4495-02
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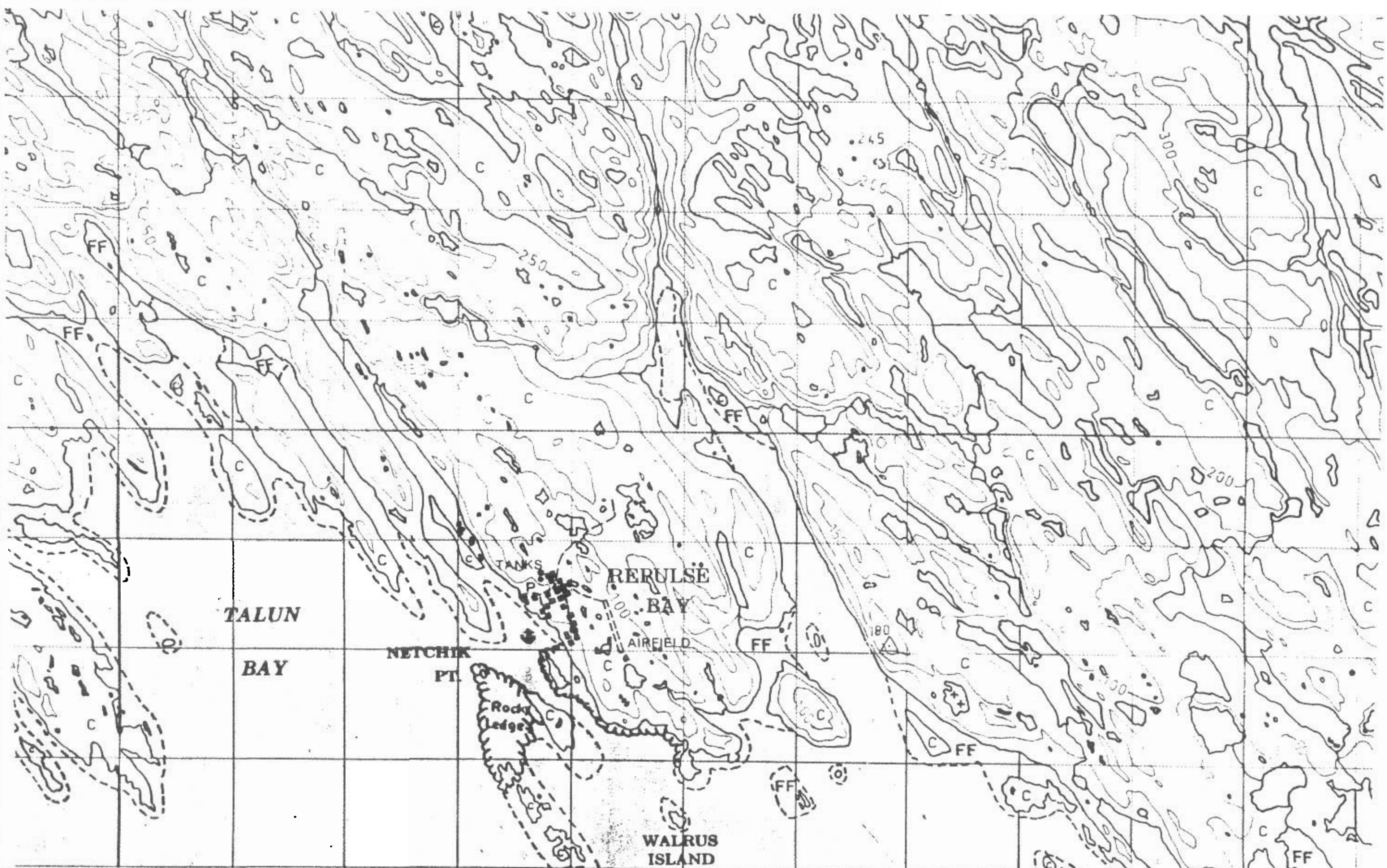
	TITLE REGIONAL SETTING	FIGURE NUMBER FIGURE 1-1



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PROJECT: REPULSE BAY SEWAGE TREATMENT SYSTEM IMPACT ASSESMENT

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FIGURE NUMBER: FIGURE 1-2

The sewage treatment system of Repulse Bay has been categorized into three distinct areas (Dillon Consulting Ltd., 1997), which are characterized below:

Area 1

The boundaries of this area have been defined as beginning where collection vehicles discharge sewage to where the sewage flows into Pond P1(a distance of approximately 100 metres). The ground slope has been previously estimated to be 5:1 for the first 25 metres and 30:1 for the remaining 75 metres. A sewage ice pack is known to form upgradient of Pond 1 when temperatures are below freezing (i.e. from late September to May) which melts the following spring. Furthermore, this ice pack has been estimated to be 35 metres wide on the valley side slope (Dillon Consulting Ltd., 1997), resulting in approximately 0.35 Ha between the discharge point and Pond P1 being used to carry sewage during maximum spring flow conditions. Sewage flows through more defined channels later in the season.

Area 2

Area 2 includes Pond P1 and the vegetated area between Pond P1 and Pond P2. Pond P1 has an area of approximately 6000 m^2 and an average depth of 0.70 metres. Once sewage flow passes through this pond, it flows overland approximately 700 metres to Pond P2. Late-season flows take place in more defined channels than earlier in the year, with two main channels on either side of the valley being utilized.

Area 3

This area includes Ponds P2, P3, and the discharge to Repulse Bay. Pond P2 has an approximate surface area of 7000 m^2 and a depth of 0.85 metres. Sewage flows from this pond about 100 metres to Pond P3, which has an approximate surface area of 1500 m^2 and an average depth of 0.50 metres. Flows between these ponds occur through a single defined channel. The distance from Pond P3 to the marine discharge location is approximately 100 metres, with this stretch consisting of mainly bedrock and boulders.

Repulse Bay Wetland Vegetation

The wetland vegetation of Repulse Bay is dominated by herbaceous plants typical of a sedge meadow/fen wetland (Dillon Consulting Ltd., 1997). Of all the sampled plots, sedges of the genus *Carex* make up most of the herbaceous plant cover, followed by the family Gramineae (Grass Family) and *Dryas intergrifolia*. Shrub tundra vegetation was found to represent 8 % of the sampled plots, and included species from the birch/willow and low shrub communities (Dillon Consulting Ltd., 1997). The aquatic plant community was found to be comprised of *Myriophyllum exalbescens* (spiked water mil-foil) and algae. In addition, mosses and lichens made up an average of 20 % of the sampled plots (Dillon Consulting Ltd., 1997).

2.0 METHODS

2.1 Background Literature Search

The literature search was conducted using the library, the Internet, and any relevant resources/documents in Dillon's possession. Specifically, studies that pertained to effects/monitoring of sewage discharge to wetlands and marine waters were sought, with particular emphasis placed on sewage discharge in the North. In addition, published guidelines with respect to marine water quality and sediment quality were obtained where possible.

2.2 Data Collection

Sampling Locations

Water and sediment samples was collected on August 21, 1997, at three locations within Repulse Bay which are described below and illustrated in **Figure 2-1**:

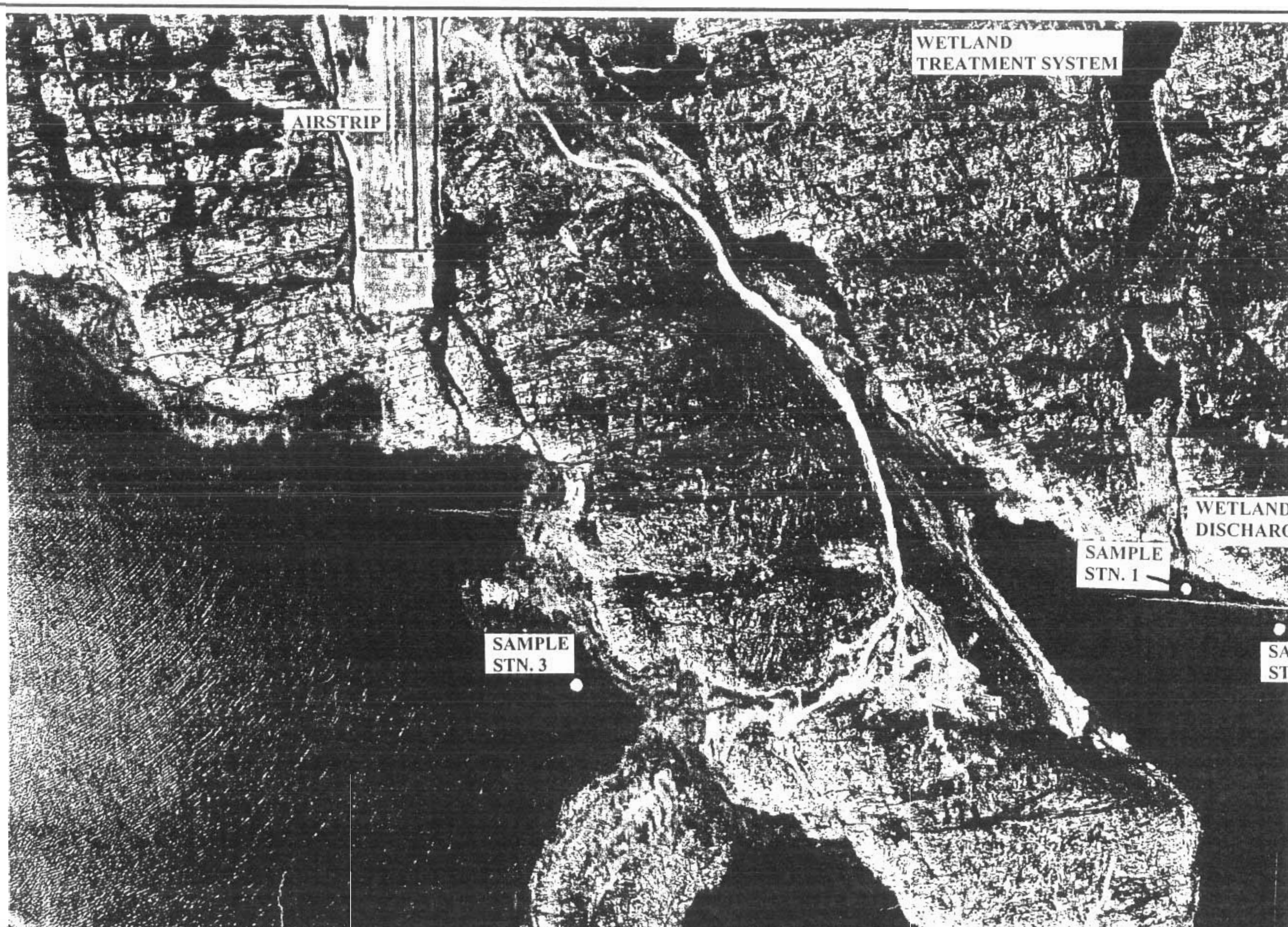
Sampling Site	Depth (m)	Location
1	1.0	at the wetland outfall
2	2.0	down-gradient of the wetland outfall, between the outfall and Simialuk Island
3	2.0	approximately 650 m southeast of the south end of the airstrip, in a small bay around the point from the wetland outfall

Site 3 served as a control site, as it was removed from the potential effects of sewage discharge and exhibited the same general natural characteristics as Sites 1 and 2.

Water Sampling

Water samples were taken at each site in duplicate using grab sample techniques and were stored in the appropriate preservative. Samples were then sent to TAIGA Environmental Laboratory (Department of Indian Affairs and Northern Development) in Yellowknife for analysis. The water samples were tested for the following parameters:

- Temperature
- Dissolved Oxygen
- Conductivity
- pH
- Turbidity
- Total Suspended Solids (TSS)
- Total Dissolved Solids
- Nitrate + Nitrite
- Nitrate-N
- Ammonia Nitrogen
- Total Phosphorus
- Ortho-Phosphorus
- Dissolved Phosphorus
- Total Coliforms
- Fecal Coliform
- Fecal Strepticocci
- Biochemical Oxygen Demand (BOD_5)



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DILLON CONSULTING

REPULSE BAY SEWAGE TREATMENT SYSTEM
IMPACT ASSESMENT

SAMPLING LOCATIONS

97-4495-02

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FIGURE 2-1

Water samples were also tested for the following trace metals:

- Total and Dissolved Cadmium
- Total and Dissolved Cobalt
- Total and Dissolved Chromium
- Total and Dissolved Copper
- Total and Dissolved Iron
- Total and Dissolved Manganese
- Total and Dissolved Nickel
- Total and Dissolved Lead
- Total and Dissolved Zinc

Sediment Sampling

Duplicate sediment grab samples (except Site 3, where only one sample was obtained) were taken with the use of an Eckman dredge at each site. Sediment samples were then sent for chemical analysis to TAIGA Environmental Laboratory where the following parameters were measured:

- % Clay - particle size
- % Sand - particle size
- % Silt - particle size
- % Organic matter
- Ammonia Nitrogen
- Potasssium - soil
- Total Phosphorus

Sediment samples were also tested for the following trace metals:

- Total Cadmium
- Total Iron
- Total Aluminum
- Total Copper
- Total Nickel
- Total Lead
- Total Zinc

2.3 Impact Assessment

The impact associated with releasing sewage discharge to marine waters at Repulse Bay will be assessed based on data collected at Sampling Sites 1, 2, and 3. More specifically, water and sediment quality will be compared between sites closest to the discharge outfall (Sites 1 and 2) and the reference location (Site 3). In addition, Site 1 data collected in 1997 will be compared to previous measurements taken in 1996 at the downstream sampling point (Dillon Consulting Ltd. 1997). Based on the results of the water and sediment surveys, comparisons with existing water and sediment quality guidelines, and the background literature search, potential environmental impacts resulting from the use of the wetland sewage treatment system at Repulse Bay will be assessed.

3.0 RESULTS AND DISCUSSION

3.1 Background Literature Search

Water Quality Improvement through the use of Wetlands

Wetlands are very important in improving water quality, as they remove or convert pollutants such as organic matter, metals, suspended solids, and excess nutrients like nitrogen and phosphorus (Hammer and Bastian, 1989). Wetland plants can substantially increase their biomass through the absorption and assimilation of nutrients, thereby increasing ambient oxygen levels as a by-product of their growth. This in turn provides aerobic bacterial decomposers with an oxygen source for breaking down organic matter.

Potential Impacts of Discharging Sewage Waste to the Marine Environment

When wastewater is discharged to marine waters, such as at the community of Repulse Bay, there are possible implications for the surrounding environment. Some of the following discussion relates to untreated sewage and its discharge to marine waters, in contrast to the sewage of Repulse Bay, which is receiving treatment as it passes through a wetland before entering the marine environment.

According to the Department of Indian Affairs and Northern Development (DIAND, 1987), the principle components of sewage and the potential effects of these components to the receiving water body can be summarized in the following manner:

- *Organic Matter*: organic compound degradation may reduce the dissolved oxygen concentration of a receiving water body
- *Settleable Solids*: the benthic community structure may be altered if settling solids modify the particle size distribution of the sediments; localized anaerobic conditions may be a consequence of organic sediment decay
- *Inorganic Nutrients*: increased nitrogen and phosphorus levels could lead to increased primary production and hence decreased dissolved oxygen levels from microbial degradation of plant biomass at the sediments
- *Pathogenic Organisms*: the receiving water body may receive disease-causing bacteria and viruses
- *Residual Chlorine*: any chlorine remaining in the effluent that was used to reduce pathogenic micro-organism levels may be toxic to fish
- *Suspended Solids*: increased turbidity may alter fish migration patterns and reduce the amount of light available for photosynthesis
- *Floatables*: slowly degradable materials (i.e. fats, oils, plastic, rubber) may be aesthetically offensive if floating on the receiving water surface

Several of the impacts mentioned above are expanded upon in the following discussion as they relate to sewage discharge from coastal communities into the marine environment.

One such impact, as discussed previously, is a decreased dissolved oxygen concentration due to the breakdown of organic matter, as well as the oxidation of hydrogen sulfide, ammonia, methane and iron compounds (DIAND, 1987). Anoxic conditions have been known to cause fish mortality in marine waters. Birtwell *et al.* (1983), for example, found that fish experienced mortality in the vicinity of a major sewage treatment plant in the Fraser River estuary, British Columbia, due to anoxic conditions. In addition, the toxicity of the sewage effluent at this location was suggested to be attributed to the low oxygen levels (Birtwell *et al.*, 1983). This fish kill, however, took place during calm and warm weather in a southern climate. It is likely that the colder Arctic conditions coupled with relatively low volumes of sewage discharge from northern communities would not lead to anoxic conditions in the marine environment. In addition, DIAND (1987) stated that negligible decreases in dissolved oxygen levels could be expected in Arctic waters due to the small size of any one outfall, if dilutions greater than 100 to 200:1 are achieved.

The dissolved oxygen content immediately above the sediment and in its interstitial spaces may also decrease significantly due to organic compound decomposition. If the water at the level of the sediment were to become anoxic, this would have implications for the benthic and fish communities inhabiting this area. In fact, Birtwell *et al.* (1983) suggested that the sediment chemical environment was a factor in the observed decrease in fish numbers near the sewage outfall of the Fraser River estuary. The accumulation of particulate organic matter may also have an effect on benthic invertebrates in the area and alter the relationships between benthic and pelagic trophic levels. Otte and Levings (1975), for example, found that the benthic community was altered as the distance from the sewage outfall in the Fraser River estuary increased. Specifically, there was an increase in the number of individuals and biomass on the mud flat, which was accompanied by an increase in species (Otte and Levings, 1975). The extent of the species composition change will be affected by the degree of deposition, the presence or absence of toxic materials, the decomposition rate of the organic matter, and any change to the characteristics of the sediment (i.e. particle size) (DIAND, 1987).

In addition to organic loading and decreased dissolved oxygen levels being potential consequences of sewage discharge, nutrient levels may increase in the marine environment, resulting in the stimulation of primary production. Welch (1980) has suggested that enhanced primary production as a result of increased nutrient levels may lead to increases in zooplankton production and biomass. However, during the open-water season, Arctic marine waters are likely nitrogen-limited, in addition to being light-limited when the sea is covered with ice (DIAND, 1987). Thus, it is unlikely that nitrogen loading from the relatively small sewage outfalls in the north will result in stimulating primary production to any noticeable degree. Furthermore, because zooplankton and phytoplankton are moved continuously through well-circulated areas, any local changes in species composition would likely not significantly alter the structure of the community (DIAND, 1987).

If chlorine is used to reduce pathogenic micro-organism levels within the sewage, it is possible that it may be toxic to fish in the vicinity of sewage discharge. In particular, chlorination may be a problem when water is ice-covered and dispersion of the plume of effluent is restricted (DIAND, 1987).

Finally, the potential impact of micro-organisms may also be a concern when sewage is discharged into Arctic marine waters. For example, fecal coliform and *E. coli* may contaminate local invertebrate species and hence pose a risk to human health if any of these organisms are consumed. In particular, shellfish, which are filter feeders, concentrate bacteria in their tissues. This makes shellfish harvesting for human consumption a potential risk as they can be eaten raw. Coliform bacteria have a much higher survival in the Arctic, due to the cold temperatures and because there is less ultra violet light to provide natural disinfection in the winter months (DIAND, 1987). According to the Nunavut Water Board, the maximum average effluent concentration for fecal coliform is not to exceed 1×10^6 CFU/100 millilitres. According to Pearson and Rosenberg (1978), five zones related to the influence of sewage discharge can be identified within the marine environment:

- an abiotic zone
- a zone of opportunists (i.e. high numbers, few species)
- a zone of decreased, low abundance, and high diversity
- a transition zone to typical communities
- typical communities

It is evident that sewage discharge to the marine environment from northern communities may have a significant environmental impact. However, there would be minimal impact if sewage is discharged to well-mixed waters where the effluent can be diluted. Any effects to the receiving water from raw or partially treated sewage may be limited to localized benthic impacts (DIAND, 1987). In addition, sewage generation rates for Repulse Bay, both in the present and in future years, are relatively small (i.e. 1997 - 42 m^3/day; 1998 - 43 m^3/day). Furthermore, effluent discharged to Repulse Bay is not in a raw form, but is receiving treatment through the wetland system described earlier in this report.

3.2 Water Quality

The results of water quality analyses for samples collected from the three stations in Repulse Bay are presented below in Tables 3.1 (general water quality parameters) and 3.2 (trace metals).

As indicated in Table 3.1, dissolved oxygen levels at all three sampling sites are maintained over 10 mg/L, demonstrating that oxygen is not limiting in the vicinity of the sewage outfall. Oxygen concentrations exceed the 8.0 mg/L minimum recommended for marine and estuarine waters in the Canadian Water Quality Guidelines (1996). Decreased dissolved oxygen levels, typically associated with the discharge of sewage, due to the breakdown of organic matter, as well as the oxidation of compounds such as hydrogen sulfide, ammonia, methane and iron compounds are not found in Repulse Bay. The high oxygen levels are consistent with the findings of DIAND (1987) who stated that negligible decreases in dissolved oxygen levels could be expected in Arctic waters due to the small size of any one outfall, particularly if large dilutions are achieved.

Water pH is consistent between sampling locations and falls within the range of 7.0 to 8.7 recommended by the Canadian Water Quality Interim Guidelines for marine and estuarine environments (CCME 1996). The guideline also states that within this range, pH should not vary by more than 0.2 pH units from the natural pH expected at that time. This is intended to protect marine organisms which have narrow pH tolerances. The pH at station 1 is 0.2 pH units higher that the pH at station 2 and 3 (Table 3.1), indicating that the sewage effluent may be resulting in a slight increase in pH in the immediate vicinity of the discharge, at least during low tide when the samples were collected. During low tide the discharge consists of a mere trickle which travels over a gravel-cobble beach prior to entering the ocean.

Interestingly, turbidity was found to be highest at Site 3 (the control site), indicating that turbidity levels near the outfall are acceptable and should not result in a negative impact on photosynthesis in that area. Generally in estuarine environments, phytoplankton species are adapted to natural variations in turbidity and suspended solids.

Table 3.1 Results of conventional, nutrient, and bacteria water quality parameters for samples collected from Repulse Bay

Parameter	Guideline/Criteria	Sampling Site					
		1A	1B	2A	2B	3A	3B
Temp. (°C)	-	4	4	4	4	4	4
Diss. Oxygen (mg/L)	min 8.0 mg/L[1]	10.8	10.8	10.98	10.98	12.1	12.1
Conductivity (umhos)	-	29000	29000	29000	29000	29000	29000
pH	7.0 - 8.7[1]	8.4	8.4	8.2	8.2	8.2	8.2
Turbidity (NTU)	-	0.4	0.3	0.3	0.3	0.8	0.7
TSS (mg/L)	180 mg/L[2]	61	12	212	68	16	55
T. Diss. Solids (mg/L)	-	36500	36800	36700	36400	36800	37200
Nitrate+Nitrite (mg/L)	-	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Nitrate-N (mg/L)	-	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Ammonia-N (mg/L)	8.7 - 14.0[3]	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
T. Phosphorous (mg/L)	-	0.055	0.053	0.05	0.051	0.049	0.05
Ortho-Phosphorous (mg/L)	-	0.058	0.059	0.059	0.059	0.056	0.059
Diss. Phosphorous (mg/L)	-	0.048	0.045	0.05	0.046	0.045	0.046
T. Coliforms (CFU/dL)		<1	<1	<1	<1	<1	<1
Fecal Coliform (CFU/dL)		<1	<1	<1	<1	<1	<1
Fecal Strepticocci (CFU/dL)		<1	3	2	<1	4	2
BOD_5		14	8	9	9	8	9

1 - CCME Interim Marine and Estuarine Water Quality Variable (December 1996)
2 - Nunavit Water Board Guidelines
3 - BCMoE (Nordin 1990) *cited in* B.C. MoELP (1995) - water quality criteria for saltwater life (T = 5°C, Salinity = 30 g/Kg, pH = 8.2-8.4)

Table 3.2: Trace metal analysis results(μg/L) for water samples from Repulse Bay. Marine Guidelines for selected metals have been included for comparative purposes

Parameter	Marine Guidelines and Criteria (BCMoELP, 1995)	1A	1B	2A	2B	3A	3B
T. Cadmium	0.1 μg/L maximum[1] 9 μg/L - 4 day average; 43 μg/L - 1 hr average [2]	·0.1	0.1	0.1	0.1	<0.1	0.1
D. Cadmium	na	0.2	0.2	<0.1	<0.1	0.1	0.1
T. Cobalt	na	0.5	0.5	0.5	0.5	0.4	0.5
D. Cobalt	na	0.6	0.7	0.6	0.5	0.5	0.4
T. Chromium	50 μg/L - 4 day average; 1100 μg/L- 1 hr average [2]	2.2	2.2	1.8	2.3	2.4	2.4
D. Chromium	na	1.5	1.8	1.9	1.8	1.6	1.2
T. Copper	3 μg/L maximum[3] ; <=2; 30-day average[3]	65	70.3	73.4	78	77.6	83.5
D. Copper	na	33.6	51.4	51	53.1	55.8	60.7
T. Iron	50μg/L [4]	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012
D. Iron	na	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012
T. Manganese	100 μg/L [2]	0.8	1	0.8	0.8	0.8	0.8
D. Manganese	na	0.6	0.7	0.6	0.7	0.6	0.6
T. Nickel	8.3 μg/L - 4 day average; 75 μg/L- 1 hr average [2]	5.7	6.1	6.4	6.6	6.3	6.3
D. Nickel	na	5.0	5.1	5	5	5.2	5.3
T. Lead	140 μg/L maximum[5]; <=2; 30-day average[5]	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
D. Lead	na	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
T. Zinc	86μg/L- 4 day average; 95 μg/L - 1 hr average [2] saltwater plants affected at levels as low as 19 μg/L[2]	9.2	13.7	5.2	5	5.1	5
D. Zinc	na	2.3	2.3	2.5	3.4	2.8	4.5
T. Aluminum	none proposed	n/a	n/a	n/a	n/a	n/a	n/a

Sources cited in BCMoELP (1995): 1 - Canadian Council of Resource and Environment Ministers (1987); 2 - US EPA (1986); 3 - Singleton (1987) ; 4 - National Academy of Sciences (1972); 5 - Nagpal (1987)

TSS values were highly variable between duplicates at each site and there appeared to be no obvious between-site variability, with the exception of sample 2A which registered a TSS level of 212 mg/L. It is suspected that the elevated value may be the result of organic debris such as a piece of macrophyte or wood which was contained in the water sample. The high within site variability is not surprising given that suspended solids consist of both inorganic mineral particles and organic living and detrital materials. Geophysical processes, such as riverine inputs and tidal movements, and biological processes, such as plankton blooming and invertebrate filter-feeding, interact to produce complex spatial and temporal distributions in coastal systems (CCME 1996).

Suspended solids concentrations recorded for Repulse Bay are slightly higher than those measured by Pomeroy (1984 *cited in* CCME 1996) in the vicinity (1000m) of a sewage treatment plant effluent diffuser near Nanaimo, British Columbia. All values, however, with the exception of the 2A sample, were lower than the Nunavut Water Board TSS guideline of 180 mg/L.

Several water quality parameters were similarly low at all three sampling sites, which included Total Phosphorus, Total Coliforms, and Fecal Coliform. This trend demonstrates a minimal impact of wetland sewage treatment on the marine environment with respect to these parameters. BOD_5, in contrast, was higher in Sample 1A compared to other sampling sites; however, this value was still well below the guideline level of 120 mg/L set by the Nunavut Water Board.

Trace metal analysis revealed that there were no major differences in metal concentrations in water samples collected from each site (Table 3.2). The British Columbia Ministry of the Environment, Lands, and Parks (MoELP) provides a summary of approved and working criteria for water quality including total metal levels (MoELP 1995). This summary includes guidelines and criteria established by Canadian and U.S. federal agencies, as well as those determined by the province of British Columbia.

Relevant guidelines are presented for comparative purposes in Table 3.2. In most cases, with the exception of copper, levels were well below established criteria. Total copper concentrations are higher than the B.C. guideline (maximum of 3 μg/L) established for the protection of marine and estuarine aquatic life, although it appears that the Repulse Bay area is characterized by naturally-occurring elevated copper levels. Total copper levels were similar for all sites, including the control location, ranging from 65 to 83.5 μg/L. It is quite likely that resident marine organisms have become acclimated to these higher naturally-occurring copper concentrations. It must also be stressed that the B.C. guideline is based on the results of laboratory acute toxicity tests on shellfish embryos, and may not reflect complex processes that occur in the natural environment.

Table 3.3 provides a comparison of common water quality parameters measured one year apart at Sites 1 (this study) and RPB-01 (Dillon Consulting Ltd. 1997). BOD levels have remained consistent between years. TSS was higher in 1997, although this is to be expected considering that Site 1 is just down-gradient of the outfall and station RPB-01 was located slightly upstream of the wetland outfall. Ammonia-nitrogen, nitrate+nitrite, and total phosphorus were higher in 1996 than in 1997. Fecal coliform levels were all below detection limits during both years.

Table 3.3 Common Water Quality Parameters Measured at 1996 Wetland Outfall Site (RPB-01) and at 1997 Wetland Outfall Site (Site 1).

Parameter	RPB-01[1]	Site 1[2]
BOD_5 (mg/L)	10	11
TSS (mg/L)	5	36.5
Ammonia-N (mg/L)	0.183	<0.002
Nitrate + Nitrite (mg/L)	0.037	<0.008
T. Phosphorus (mg/L)	0.17	0.054
Fecal Coliform (CFU/dL)	<10	<1

1 - Sampled on August, 21, 1996, Dillon Consulting Ltd. (1997)
2 - Mean for 2 replicate samples

3.3 Sediment Quality

The physical and general chemistry characteristics of sediment samples collected from Repulse Bay in 1997 are presented in Table 3.4. The physical characteristics of sediments at each site were highly variable, with the sediments collected from station 1 at the wetland outfall consisting of almost entirely of sand, compared to stations 2 and 3 which were characterized by higher percentages of gravel. Station 2 also had a larger silt component compared to other locations. This higher percentage of silt is reflected in the slightly higher organic content and the higher concentrations of ammonia-N and potassium found at this site (Table 3.4).

Table 3.4: Physical and general chemistry parameters for sediments collected from Repulse Bay.

Parameter	Sampling Site					
	1A	1B	2A	2B	3A	3B
% Clay	0.01	0.8	4.5	3.5	0.8	n/a
% Sand	87.5	86.1	41.5	45.1	32.9	n/a
% Silt	0.16	2.7	19.3	21.2	2.9	n/a
% Gravel and larger	12.33	10.4	34.7	30.2	63.4	-
% Organic Matter	1	0	1	2	1	n/a
Ammonia-N (mg/kg)	2.97	1.13	4.25	9.09	1.36	n/a
Potassium - soil (mg/kg)	71.6	88.0	115	108	42.0	n/a
Total Phosphorous (mg/kg)	0.985	0.397	0.377	0.41	0.765	n/a

Table 3.5 provides a comparison of sediment metal levels found in Repulse Bay with documented guidelines

and criteria for marine sediments. The observed metal concentrations in Repulse Bay including immediately below the outfall were below low effects ranges determined by the National Oceanographic and Atmospheric Association's (NOAA). These criteria are determined based on systematic analysis of chemical data and simultaneous measures of biological effects.

3.4 Benthic Invertebrates

The benthic invertebrate community inhabiting Repulse Bay is dominated by marine amphipods. Based on visual observations during sediment and water sampling, the amphipod densities appeared higher at the discharge location than at the other two sampling stations. The higher densities observed at station 1 may be due to the shallower water depth at this site or to differences in substrate characteristics. Amphipods were observed throughout the water column and were not necessarily associated with specific sediment types or macrophytes.

Table 3.5: The results of trace metal analysis for sediments collected from Repulse Bay in 1997.

Parameter	Marine Guidelines and Criteria	1A	1B	2A	2B	3A
Cadmium	1.2 μg/g, effects range low[1] 9.6 μg/g, effects range medium[1]	<0.2	<0.2	<0.2	<0.2	<0.2
Copper	34 μg/g, effects range low[1] 270 μg/g, effects rangemedium[1]	4.4	4.4	3.2	2.7	3.7
Iron	na	0.33(wt%)	0.32(wt%)	0.42(wt%)	0.38(wt%)	0.3(wt%)
Nickel	21 μg/g, effects range low[1] 52 μg/g, effects range medium[1]	3.8	3.5	4.2	3.9	4.1
Lead	33 μg/g, EPA interim criterion[2] 47 μg/g, effects range low[1] 220 μg/g, effects range medium[1] 130 μg/g, major biological effects[3]	4.6	8.8	2.2	13.2	45.4
Zinc	120μg/g, effects range low[4] 270 μg/g, effects range medium[4]	4	3	6	4	4
Aluminum	na	1770	1340	1980	1910	1410

Notes:

1 - NOAA's National Status and Trends Program, Sediment Quality Guidelines Trace Elements (Long *et* al. 1995 *cited on* www-orca.nos.noaa.gov/projects/nsandt/sedimentquality.html; *May 28, 1998)*
2 - EPA interim criterion in sediment with 1% organic carbon (Bolton *et al.* 1985 *cited in* MoELP 1995)
3 - criterion based on results of sediment quality triad evaluations (Chapman 1986 *cited in* MoELP 1995)
4 - criterion based on the results of the National Status and Trends Program of NOAA (Long and Morgan 1990 *cited in* MoELP 1995)

4.0 SUMMARY

Overall, the treated sewage discharge to Repulse Bay does not appear to be impacting the marine environment. Following are some general conclusions regarding water quality, sediment quality, and benthic-invertebrate communities in Repulse Bay.

Water Quality

1. Water quality is generally acceptable within Repulse Bay. Generally the levels of all water quality parameters including metals were similar at all sites including the control location.

2. Copper was the only parameter to exceed published marine guidelines, although it is suspected that, given the presence of high copper levels at all sites including the control, that the concentrations reflect naturally occurring elevated copper concentrations.

3. Common water quality parameters measured one year apart in the vicinity of the outfall have, for the most part, remained relatively consistent between years.

Sediment Quality

1. Physical characteristics of sediments at each site were highly variable. Station 1 was characterized by a high percentage of sand, compared to stations 2 and 3 which were characterized by higher percentages of gravels. Station 2 also had a larger silt component compared to other locations.

2. Observed metal concentrations in Repulse Bay including immediately below the outfall were below published low effects ranges for the marine environment.

Benthic Invertebrates

1. The benthic invertebrate community inhabiting Repulse Bay is dominated by marine amphipods. Based on visual observations during sediment and water sampling, the amphipod densities appeared higher at the discharge location than at the other two sampling stations, although their numbers did not appear to be related with any specific habitat parameter (i.e. sediment type, the presence of macrophytes, etc)..

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Government of the Northwest Territories
Department of Public Works
Project No. 85-5512

Nuviq Luktujuq Pumphouse and Truckfill Station
Repulse Bay, N.W.T.

DESIGN CONCEPT BRIEF

16 March, 1987

3077-01

GCG DILLON
Consulting Engineers and Planners

GCG DILLON
Consulting Engineers and Planners

16 March, 1987

OUR FILE 3077
YOUR FILE: 85-5512

Government of the Northwest Territories
Dept. of Public Works and Highways
Engineering Division
Yellowknife, N.W.T.
X1A 2L9

RECEIVED
Gov't of the N.W.T.
MAR 17 1987
Dept

Attention: Mr. Vincent Tam, P.Eng.

Dear Sir

Re: Repulse Bay Water Supply

Enclosed are 10 copies of the final design brief for this project for your distribution and review.

We trust you will find this in order.

Yours truly,

GCG DILLON CONSULTING LIMITED

John A. Clark

John A. Clark, P.Eng.

GCG DILLON CONSULTING LIMITED
BOX 55, 2ND FLOOR, URBANIA BUILDING, 5101-51 STREET, YELLOWKNIFE, N.W.T. X1A 2N6 (403) 920-4555
TELEX 034-45583

Nuviq Luktujuq Pumphouse & Truckfill Station

REPULSE BAY, N.W.T.

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1. Introduction

1.1 *Setting*

The community of Repulse Bay is located near the Arctic Circle at 66° 32' N latitude and 86° 15' W longitude, on the south shore of the Rae Isthmus which joins the Melville Peninsula with the mainland, District of Franklin, Northwest Territories. For the administrative purposes of the Government of the Northwest Territories it is part of the Keewatin, Region, with regional headquarters in Rankin Inlet, N.W.T.

The community of Repulse Bay is situated on a narrow rocky strip of land bounded by Repulse Bay on the west and south, the airstrip to the east and rocky hills to the north.

The surrounding topography is heavily glaciated terrain typical of the Canadian Shield.

There is little soil in the area. There are several small scattered deposits of granular material in the area.

The climate is typical of many coastal Arctic communities in that it is relatively dry and cold with precipitation only slightly exceeding evapotranspiration losses. Northerly and northwesterly winds predominate throughout the year, with southeasterly winds also frequent in the spring and summer months.

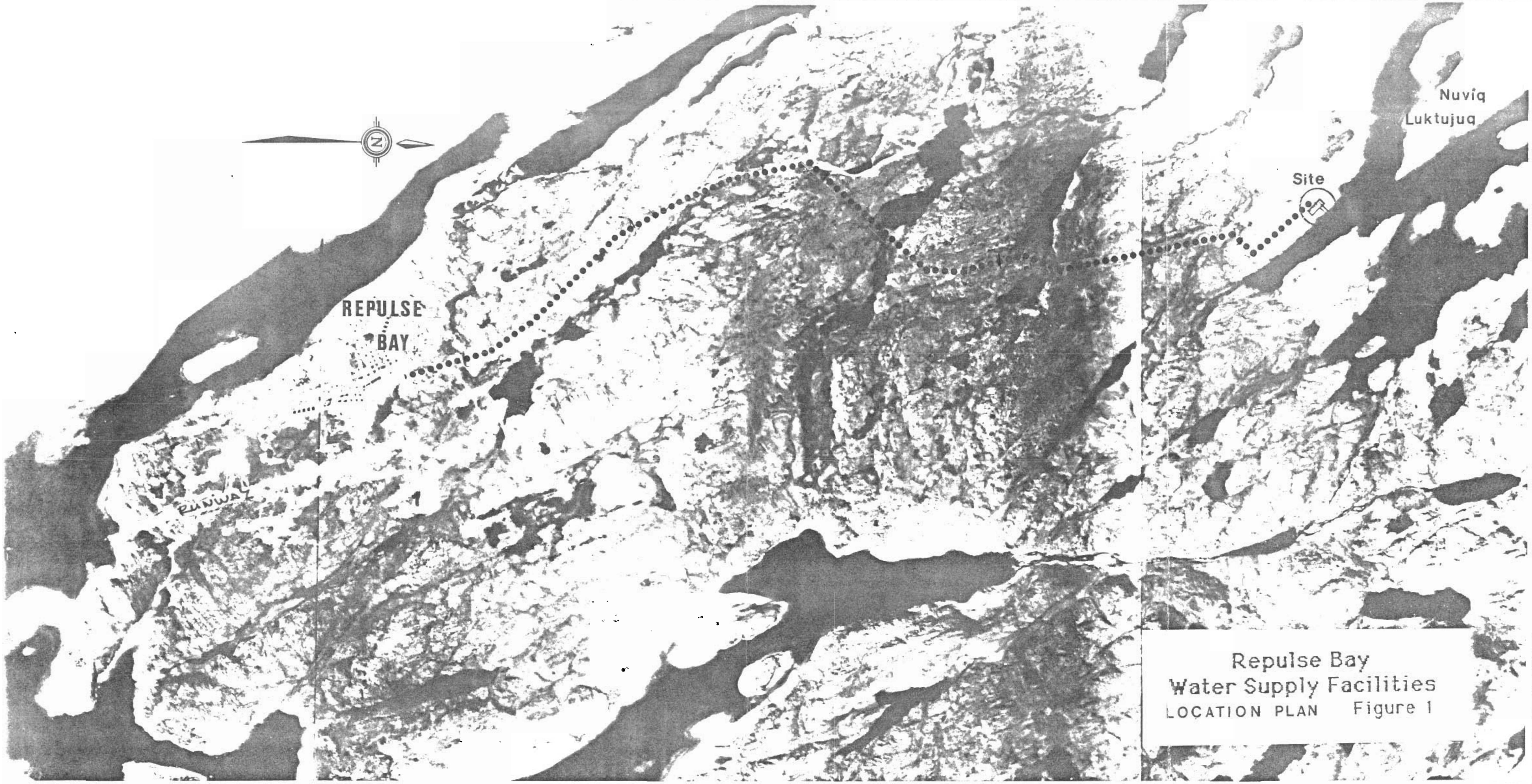
The population of Repulse Bay at the 1981 census was 345. The Hamlet reported the 1984 population to be 377. The GNWT Bureau of Statistics has projected the 2000 population at approximately 562 and this has been extrapolated to approximately 640 within the 20 year design life of the water supply facility.

2.2 *Background*

GCG Dillon was retained to provide engineering services for a potable water intake, truckfill station and related works to be constructed in the 1988/89 fiscal year for the Government of the Northwest Territories.

The location of the source had been determined after the completion of a planning study investigated alternative sources.

As shown on Figure 1 the site selected for the water supply source is located approximately 4.5 km north of the community on *Nuviq Luktujuq* (Lake With Many Inlets). The site is accessed by a road constructed in recent years. It is subject to snow drifting in a few locations.



Repulse Bay
Water Supply Facilities
LOCATION PLAN Figure 1

1. EXISTING GARBAGE SITE

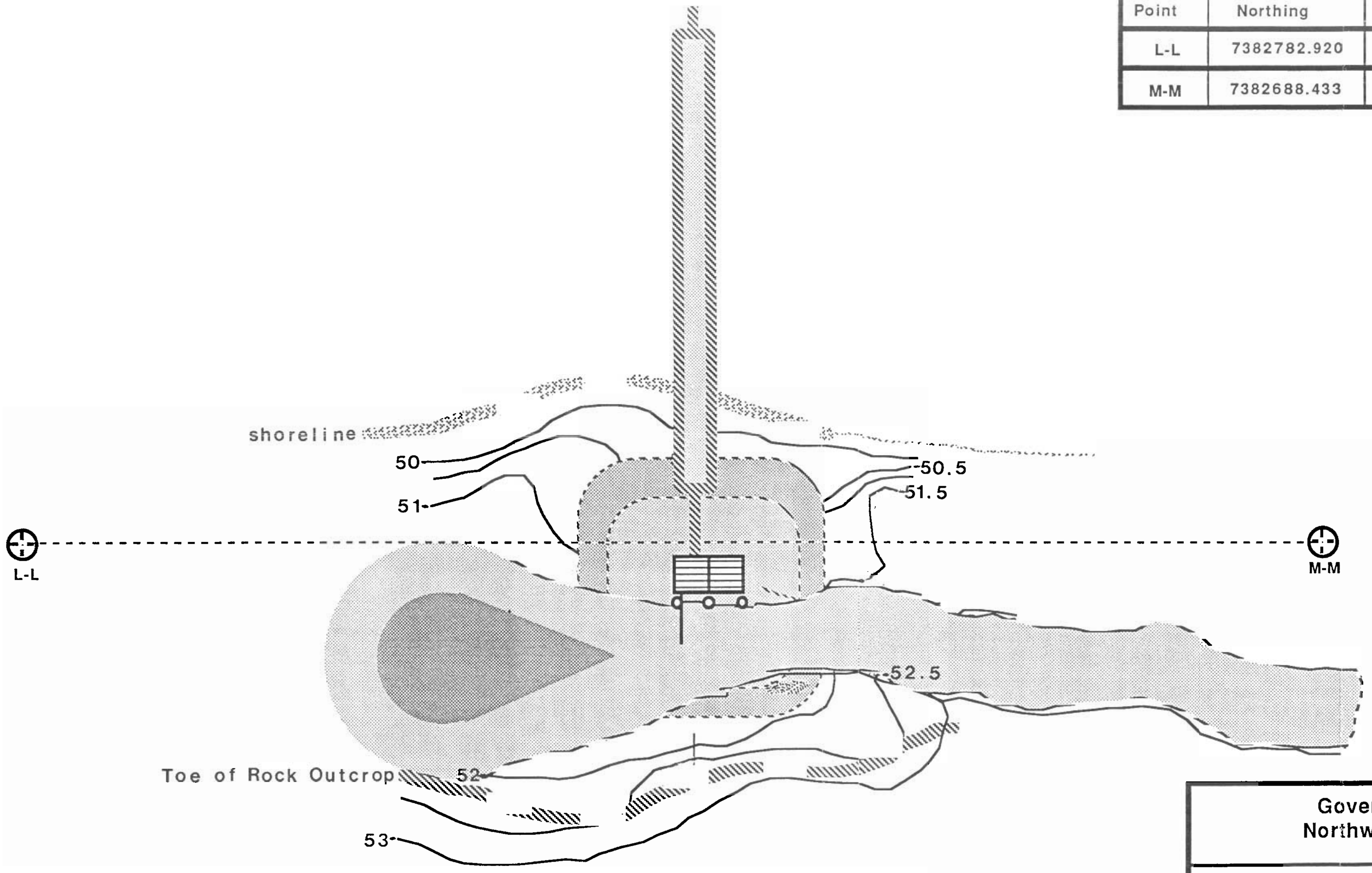
GCG DILLON
Consulting Engineers and Planners

PROJECT NO. 3077 MARCH 1987

Control Points

(From Preliminary Site Survey Contour Map/ DPW&H - 86-03)

Point	Northing	Easting	Elevation
L-L	7382782.920	533106.065	52.00
M-M	7382688.433	533200.398	51.78



Government of the Northwest Territories	
REPULSE BAY WATER SUPPLY	
Site Plan	
Scale: 1:500 0 metres 25	
GCG Dillon Consulting Proj. No.: 3077	87-01

FIGURE 2

A field trip was undertaken in October, 1986. During the field trip a site reconnaissance was completed with representatives of the GNWT. A topographic survey of the proposed site and soundings along the projected intake line were completed by GCG Dillon personnel. Figure 2 shows the topography of the site.

The site consists of a sloping strip of land bounded by the lakeshore on the northeast and a rock ridge on the southwest. The termination of the access road bounds the southern end of the site. The site is slightly vegetated and littered with cobbles and stones ranging from approximately 75 to 500mm in size.

This design brief is intended to set out design parameters and assumptions, present information gathered during the preliminary engineering phase, develop conceptual designs for the facility, and to provide capital and operating cost estimates over the life of the facility.

2. Design Criteria and Assumptions

2.1 *Design Criteria*

Statement of Objective:

To provide water supply and related facilities to ensure the Hamlet of Repulse Bay of a *safe*, *reliable* source of potable water. The facilities must function in a very *harsh*, *remote* environment with a *minimum of maintenance*. Ease and simplicity of operation in all conditions must be inherent in the facilities.

In addition, having passed these tests the facilities must be *cost-effective* over their expected operating life.

Goals:

- Public Safety;
  Potable water with minimum risk of public health dangers. No hazardous structures or facilities to which the public has casual access.

- Operator Safety;
  No undue hazards to operators or maintainers should exist within the facility.

- Reliability;
  Capable of either withstanding or recovering from occurrences which can be reasonably expected to occur during its operating life without critical damage. It must be capable of operation during all normal conditions.

- Maintenance;
  All routine maintenance must be within the capabilities of the operator without recourse to tradesmen or specialized tools. As much non-routine maintenance as possible should be within the operator's capabilities.

- Operation;
  Operation must be simple and, as much as possible, intuitive. Controls must be easily operable in the environment in which they are located. For example, controls located outside must be operable by an operator with mitts.

- Cost-effective;
  Facilities must be cost-effective considering capital cost, operating cost and maintenance cost.

Constraints:

- harsh climate
- short construction season
- remote location
- no local tradesmen
- limited local availability of material and equipment
- all components must be transportable by sealift or air

Criteria:

- on-line standby for equipment critical to the operation of the facility (primarily pumps and power supply)
- capable of recovery from freezing without critical damage
- capable of start-up under adverse conditions
- provision of shelf spares for parts with limited life such as lights and fuses
- provision of and storage for 1 year supply of consumables (except fuel)
- minimum truckfill rate of 1000 L/min
- major alarm conditions must be immediately conveyed to operator.

2.2 *Design Assumptions*

Where appropriate, design assumptions are from the National Building Code of Canada for the more severe of the nearest listed centres. Where large discrepancies exist assumptions were derived from data obtained from other sources.

1. Climate

Design Temperature	January:	-41°C (2 1/2%, NBCC[1]-C. H.)
	July:	18° C (2 1/2%, NBCC-C. H.)
Interior Temperature	10° C (assumed)	
Design Wind Speed[2]	105. km/hr (30 year return period)	
Ground Snow Load[3]	3.1 kPa (derived, NBCC-C.H.)	
Freezing Degree Days	5000 (°C-days, CCAI[4])	
Thawing Degree Days	550 (°C-days, CCAI)	
Heating Degree Days	11200 (°C-days below 18°C, CCAI)	
Ice Thickness	2.5 m (assumed)	

---

1 Supplement to the National Building Code of Canada, 1985.
Nearest listed centres: R.I.-Rankin Inlet C.H. -Coral Harbour

2 Since Hourly Wind Pressures in NBCC differ greatly for the nearest listed centres, Rankin Inlet and Coral Harbour, wind data was obtained from Climate of the Canadian Arctic Islands for Pelly Bay and Hall Beach and from the Atmospheric Environment Service of the Federal Department of the Environment. Pelly Bay is the nearest centre while Hall Beach and Coral Harbour are approximately the same distance from Repulse Bay. Coral Harbour has exceptionally high winds and is probably not typical of the region.

3 Since Ground Snow Loads in NBCC differ greatly for the nearest listed centres, annual snow accumulation data was obtained from Climate of the Canadian Arctic Islands. Annual snow accumulation (1% probability) is 133.9cm in Cambridge Bay,166.4cm in Pelly Bay and 266.7cm in Coral Harbour.

4 Climate of the Canadian Arctic Islands

2. Seismic

Zonal Acceleration (Za)	1 (NBCC- C.H.)
Zonal Velocity (Zv)	0 (NBCC - C. H.)
Zonal Velocity ratio	0.05 (NBCC - C. H.)

3. Physical

1986 Lake Level	49.7 m ASL (October)
1986 Flood Level (Site)	Not evident (snow cover)
Design Foundation Elevation	51.2 m ASL (assumed)
Truck Size	6.2m L x 2.4 m W x 2.2 m H
Turning Radius	12.8m
Road Width	7m

4. Consumption

Population	1984:	377
	2007:	640
Consumption[5]	1988:	13,200,000 L
	2007:	19,700,000 L

Year–by–year consumption projections are contained in Section 7.

5 Based on figures in Repulse Bay Water Supply, Sewage and Solid Waste Disposal Pre–design Study : M.M. Dillon, 1984

3. Concept Description

3.1 *Access Road*

Access to Nuviq Luktujuq is provided by a road constructed by forces of the Hamlet of Repulse Bay in 1985. Re–alignment of some portions of the road to minimize snow drifting is planned but is not included in the scope of this project.

3.2 *Electrical Power Supply*

A previous economic analysis carried out by others assessed the choice between on–site power generation and constructing a power line from the community. As a result of this analysis, on–site generation has been selected by GNWT.

3.2.1 Electrical Load

In order to size the genset electrical loads were estimated. The table below shows estimated loads under various conditions.

			Electrical Loads			
Description	**Unit Load**	**Units**	**Maximum Conn. Load**	**Normal Max. Load**	**Winter Idle Load**	**Summer Idle Load**
1 Pumps (5)	6.0 kW	2	6.0 kW	6.0 kW	0.0 kW	0.0 kW
2 Intake Heat Trace	1.4 kW	4	(1)2.2 kW	(2)1.6 kW	(3)1.6 kW	(4)0.8 kW
3 Truckfill Heat Tr.	0.2 kW	1	0.2 kW	0.2 kW	0.2 kW	0.2 kW
4 Building Heat	1.0 kW	2	2.0 kW	1.0 kW	1.0 kW	0.0 kW
5 Bdg. Serv. & Cntr.(6)	1.0 kW	1	1.0 kW	1.0 kW	0.1 kW	0.1 kW
			11.4 kW	9.8 kW	2.9 kW	1.1 kW
Percentage of rated capacity: (10 kW engine-generator unit)			**114%**	**98%**	**29%**	**11%**

Notes:

(1) Intake heat trace includes 1 freeze protection cable at 0.8 kW and 1 thawing cable at 1.4 kW.

(2) Intake heat trace includes 2 freeze protection heat trace at 0.8 kW.

(3) Intake heat trace includes 2 freeze protection heat trace at 0.8 kW.

(4) Intake heat trace includes 2 freeze protection heat trace at 0.4 kW.

(5) 5 hp pump motor / 6 kW running load.

(6) Includes lighting, controls, receptacles, disinfection pump, door heaters & other loads.

Motor starting will increase the generator loading substantially for a few seconds. It is intended to momentarily drop out resistance heating loads until the pump motor starting load is removed and the load is stabilized.

Engine manufacturers recommend that the genset be continuously loaded to at least 50% of capacity to optimize engine life. Previous truckfill designs with on-site power generation facilities have attempted to achieve this by by removing all non-essential loads, such as the heat trace cable and building heat, while pumping.

There are occasions when it may be desirable or necessary to run a pump for extended periods. Non–pumping loads cannot always be dropped while pumping for extended periods. For example, it is possible that while thawing an intake a pump would be run continuously in conjunction with the heat trace cables.

The building heat load could be dropped for extended periods since the heat loss from the pump room is small and conduction through the partition wall from the engine room will partly offset the loss. This would result in only a negligible lessening of electric load since the heater provides only a 1 kW connected load and would normally draw power for short periods only. The reduction is not enough to allow down–sizing the genset.

Engine suppliers sometimes recommend adding a dummy resistance load while the genset is idling to achieve a more balanced load condition. However, whatever savings are achieved in maintenance costs are at the expense of increased fuel costs. At this time we cannot recommend adding load unless it will achieve a worthwhile objective in it's own right, as well as providing a load for the genset.

Another option is to reduce the generator size by excluding thawing heat trace loads. Auxiliary generation would be provided in the form of a small portable generator which would be brought into use while thawing a frozen intake. In this way the main gensets could be sized for intake freeze protection loads only.

GNWT has expressed concerns about the availability of portable equipment, such as a small generator, when it is most needed.

Engine-generator sizing is based on thawing an intake with two heat trace cables while operating the pump and heat trace in the other intake.

3.2.2 Prime Mover

A 13 kW output prime mover is required to power the 10 kW alternator. GNWT has expressed a preference for Lister air–cooled units where power is generated on–site.

Philosophies for sizing a prime mover differ. There is a trade–off between a larger engine running at a lower speed and a smaller engine at higher speed. The trade–off is difficult to analyze quantitatively, particularly in the absence of operating cost records for both configurations. Fuel costs may be lower with a smaller engine but maintenance costs are likely to be lower with a larger unit and lower speeds.

It may be worthwhile to closely monitor the operations and maintenance of whichever configuration is selected to obtain an operations and maintenance database on which to base future power supply decisions.

The prime mover will be a Lister TR2 air-cooled 2 cylinder diesel engine. The prime mover will be sized to handle the maximum load which can reasonably be expected to occur while minimizing fuel and maintenance costs. A 10kW Lima MAC-R alternator will be close-coupled to the prime mover.

There are two alternative configurations for engine oil supply. Rather than an extended sump (not available for this unit) a 'dry sump' configuration is available. A replacement oil pump is fitted to the engine and connected to a large oil tank. The total volume of oil in this tank is continuously circulated through the engine.

Alternately, a replenisher can be fitted to gravity feed fresh oil from a small tank to the sump as it is consumed. The flow is controlled by a level controlling valve. A sight glass would be fitted to the tank.

For continuous operation with periodic operator checks the replenisher alternative is preferable since it is less complex and requires less space. Oil changes would be no more demanding than for normal operation since only the 4.5 L in the sump require changing. With a dry sump the entire contents of the external tank (perhaps 50 L) would have to be changed although changes could be less frequent.

Engine oil consumption is estimated to be approximately 10 L/month.

3.2.3 Standby

An identical engine generator set will be provided as standby with an automatic transfer switch. Westinghouse Robonics is the preferred transfer switch. Staticraft electronic engine controller and Mechron battery charger will be provided. Batteries will be housed in the engine room.

Either unit will be capable of 'lead' operation with standby capability from the other, or 'lag' unit.

The two genset units should be run on a cycle that ensures one unit will see more service than the other. This cycle should be tied to the maintenance schedule.

For example, one unit could be run for three weeks and the other for one week . This would ensure the standby unit will be exercized regularly while also ensuring the prime unit accumulates more running time than the standby unit.

The operator will select the operating cycle and will manually change the 'lead' and 'lag' designation.

3.2.4 Fuel Supply

One of the options for fuel supply is a 1135 L inside tank. This would provide approximately 25 days fuel storage at estimated consumption rates. The tank would be protected by a spill containment structure to minimize the possibility of fuel spillage onto the building floor. A small spill basin should be placed under the tank fill and overflow pipes as well.

If more fuel capacity is required it would be provided outside the building in a larger tank. This would require spill protection, transfer piping and pumps and an inside day tank with spill protection.

A major concern about fuel storage is protection of the water supply from fuel contamination. All tanks and fill points will require spill containment whether located outside or inside. Inside storage is further contained by the building itself should a spill occur and breach the containment.

An outside storage tank is more vulnerable to breach by vandalism or accident. Transfer piping outside the building is also vulnerable.

The more frequent filling required of the smaller inside tank increases the possibility of spillage slightly, however the smaller oil quantity would also cause less damage and would be easier to clean up.

The choice is one of owner preference. Outside storage is expected to add approximately $10,000 to the cost of the facility. Inside storage is assumed for the purposes of this document.

The tank will have a transmitted alarm setting at approximately the 1/4 full mark. A local alarm (warning light only) will be provided at the 1/3 or 1/2 full mark.

3.3 *Intake*

Two intake configurations were considered. These were a wet–well with buried intake pipe and an inclined shaft configuration. Advantages and disadvantages of each are discussed below. Figure 3 shows a profile along the line of the proposed intake.

3.3.1 Wet–well

A wet–well configuration comprises a waterproof, insulated well excavated into the lake shore with an intake pipe and intake below the ice bottom.

Advantages of the wet–well configuration include providing a storage volume of water relatively close to the discharge point, perhaps permitting use of slightly smaller pumps than otherwise required. Pumps are readily accessible for withdrawal and maintenance. If larger capacity pumps are required in the future the increase in pump capacity is relatively easy to achieve.

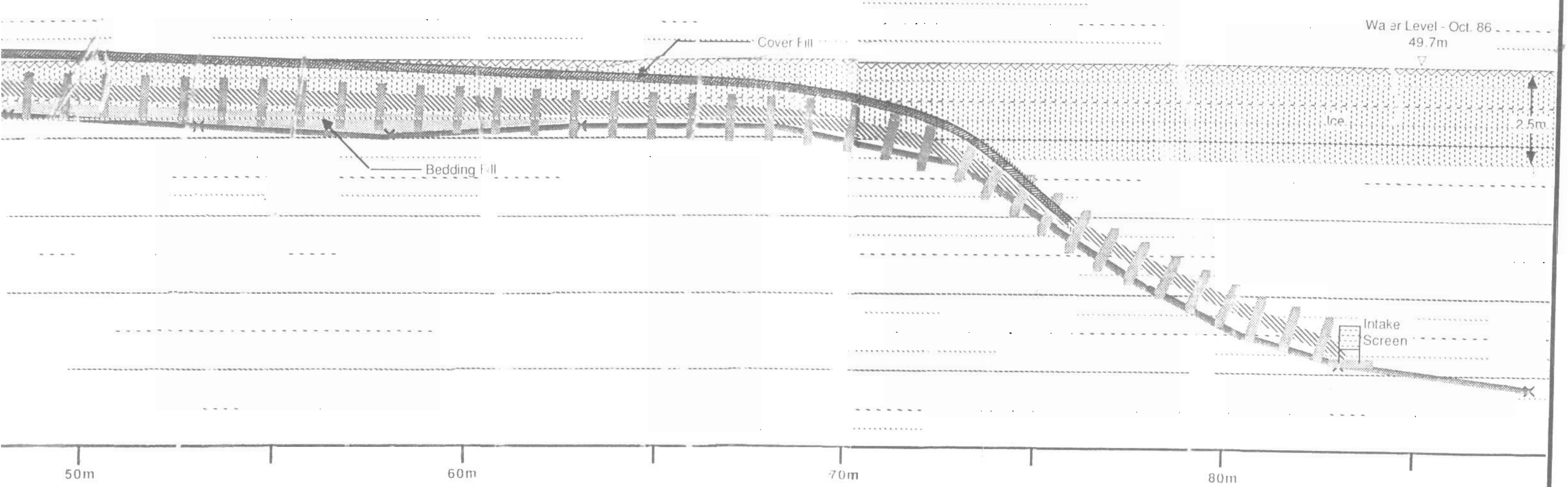
Disadvantages include difficult and often expensive construction procedures. A relatively complex structural foundation excavated in rocky ground or bedrock would be required. A considerable length of trench (40m) for the intake pipe would also have to be excavated through rock to a depth of at least 3m. Excavation dewatering may present problems during construction. In-situ construction of the wet–well liner would be difficult under wet conditions and prefabricated rings (concrete, steel, or polyethylene) would probably be required, increasing freight costs. A wet–well would have to be anchored to prevent flotation when it is empty.

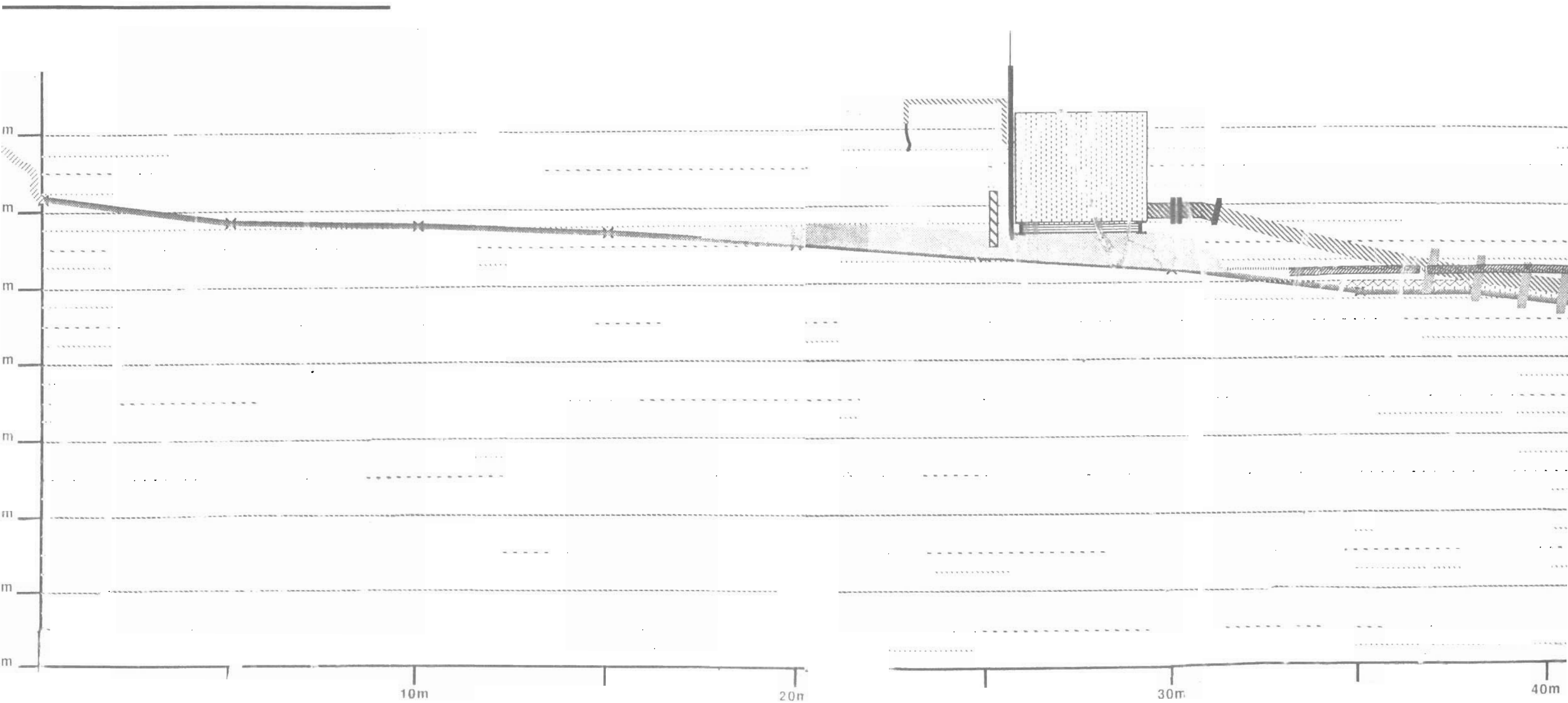
Excavation would almost certainly require significant blasting for both the wet–well and the intake. Removal of the blast rock would require the services of a backhoe, which would have to be mobilized to Repulse Bay for one year, from sealift to sealift.

As discussed below the selection of pumps for a wet–well is practically limited to submersible vertical turbine pumps, as it is for an inclined shaft intake. Removal and replacement of these pumps in a wet–well would be less time consuming than for pumps in an inclined shaft. Removal of the intake freeze protection heat trace cable would present a significant challenge in a wet–well configuration, perhaps requiring de–watering of the wet–well. Replacement could be frustrating as well since the cable or duct would have to be pushed into the intake.

A thorough geo–technical investigation should be performed to assess excavation requirements, dewatering requirements, foundation requirements and the thermal effects of the wet–well and trench on the permafrost regime if a wet–well is to be given further consideration.

Repulse Bay Water Supply		
Concept Sketch Intake Profile		
GCG Dillon	Figure 3	87-01





10m
20m
30m
40m

3.3.2 Inclined Shaft

The inclined shaft intake as developed and refined in the Northwest Territories has been used successfully in several communities. It consists of an insulated casing pipe laid along the lake bottom until the desired depth is reached, covered with granular material where mechanical protection from ice damage is required. Ballast is attached to the casing to ensure it has negative buoyancy. Freeze protection is provided. Submersible vertical turbine pumps and discharge pipes are inserted in the casing pipe.

Significant excavation is most often not required and the construction could be completed using equipment presently in Repulse Bay.

The building foundation can be quite simple and skid mounted buildings could be used .

Pump maintenance requires pulling the pump and discharge pipe from the casing. While requiring more time than for removing similar pumps from a wet–well, this task has been performed successfully many times by local labour in many communities. When difficulties have occurred in the past they have generally been associated with mechanical damage to the casing, for example crushing by ice. Proper bedding and cover of the casing will minimize the chances of this happening.

3.3.3 Pumps

At first glance a wet–well would seem to provide an opportunity to use different, perhaps more efficient, types of pumps. However the selection should be limited to those types with a submerged suction. Past experience with 'self-priming' pumps in some other northern communities has not always been good.

A wet–well/dry–well configuration would allow the use of small end suction centrifugal pumps without the priming problems, but at significantly increased construction cost.

Vertical turbine pumps with hollow shaft electric drivers mounted on the floor above the wet–well have a good record of performance in other communities. They require a very stable foundation however, since if they are not mounted precisely vertically, they may self-destruct. They require considerable care and skill to install, remove and reinstall. Technicians may have to be imported from the south for a 2 or 3 day period when service is required.

Vertical turbine submersibles have been used with considerable success in the past at many northern locations. They are inexpensive and can be serviced by local forces. They can be considered expendable, with a new pump purchased and shipped in for less than the cost of imported labour to service other vertical turbine pumps. Life cycle cost estimates include pump replacement at 5 year intervals.

Submersible vertical turbine pumps in a wet–well should be enclosed in a shroud to ensure a flow of cooling water past the pump motor. This is not required if they are mounted in an inclined shaft casing.

Total pumping time for this station is projected to be approximately 200 hours in the early years of its life and 330 hours towards the end of the design period. It may not be worthwhile expending a great deal of capital cost to slightly improve the pumping efficiency of low running time pumps.

Submersible vertical turbine pumps are recommended for this facility, whether an inclined shaft or wet–well configuration is chosen.

It is recommended that an inclined shaft intake be used in Repulse Bay.

Further discussion in this section assumes an inclined shaft intake and submersible vertical turbine pumps.

3.3.4 Casing

The intake casing is proposed as 300mm Series 45 (minimum) HDPE pipe insulated with 25mm of polyurethane insulation. The insulation thickness chosen will depend on a balance between freeze protection and the prevention of overheating from the heat trace. Protecting the insulation will be either a polyethylene jacket or wrap, 3.8mm thick.

Ballast will be provided by means of concrete weights. The weights will extend above the present shoreline to a point beyond expected flood levels. Adequate ballast will be provided to allow for the buoyancy of the HDPE pipe and insulation plus at least 10% air content in steeply inclined sections (more air content will be allowed for in shallow, flat sections) in the casing pipe. The intakes will be covered with an earth berm and armoured with riprap from above flood level to below the anticipated lowest ice level. A large amount of material suitable for rip–rap is located near the site.

Casing joints will be pre-flanged to avoid the necessity of mobilizing a large butt-fusion machine. It is expected the casing entry to the building will be prefabricated. Loads will be transmitted to the building skid frame or floor slab rather than the wall panel. Adjustment will be provided outside the building for final hook-up to the intake casing. Shear stress at the point of attachment will be carried by a mechanical fitting rather than the butt fusion.

The angle of the intake casing to the horizontal is expected to be about 15°. A bend in the casing pipe will accommodate this deflection while still allowing passage of the pumps.

A 100mm pump discharge pipe is proposed in order to keep the friction loss in the discharge pipe low and thus minimize the pump power required.

Freeze protection will be running continuously. This will ensure that the engine-generator set is partly loaded a great deal of the time to improve the operating life of the genset. High limit shutoff sensors will be incorporated to protect the HDPE pipe rather than rely on the self–limiting characteristics of the heat trace.

The heat trace will be enclosed in water resistant copper ducts if not rated for direct immersion. Termination will be at a plug and receptacle. A spare heat trace will be provided in each casing. This spare cable can be made operational if desired to thaw a frozen intake as quickly as possible.

Pull cables will be attached to the pumps with the ends coiled inside the building. It will be necessary to ensure that the pumps can be pulled without getting hung up in the casing pipe. A cable puller will be provided to aid pump removal.

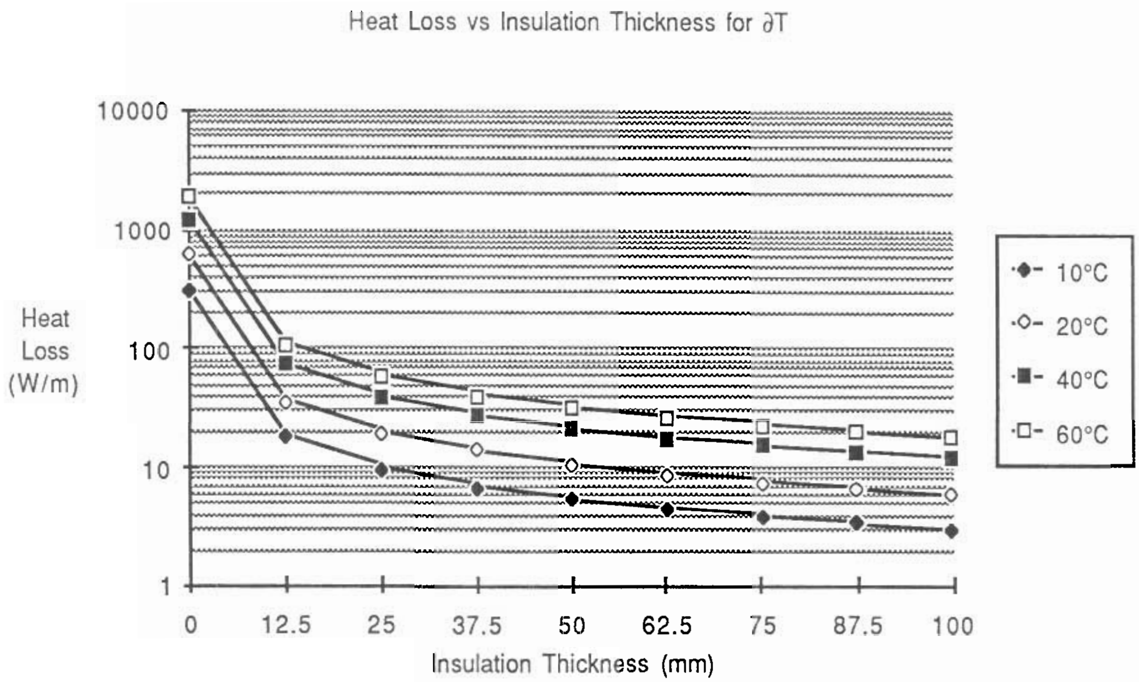
Pumps will be mounted on skids or wheels to ensure cooling flow around the full circumference of the pump and facilitate easy withdrawal.

3.3.5 Heat Transfer

An analysis[1] was carried out to assess insulation thickness and heat trace power draw.

The accompanying graph shows the heat loss for various insulation thicknesses and temperature differentials for the exposed casing in air.

1 Calculations using formulæ from Pre-Insulated Pipe Design, Installation and Operation, DuPont Canada, Inc., 1982



It can be seen that in winter conditions (∂T= 45°C, Ta= –45°C, Ti= 0°C) one heat trace (39.4 W/m) will supply enough energy to maintain the casing at or above freezing with an insulation thickness of 37.5mm. This section will draw 328 W per casing. In summer conditions (∂T= 10°C, Ta= 13°C, Ti= 23°C) the draw will be 60 W per casing.

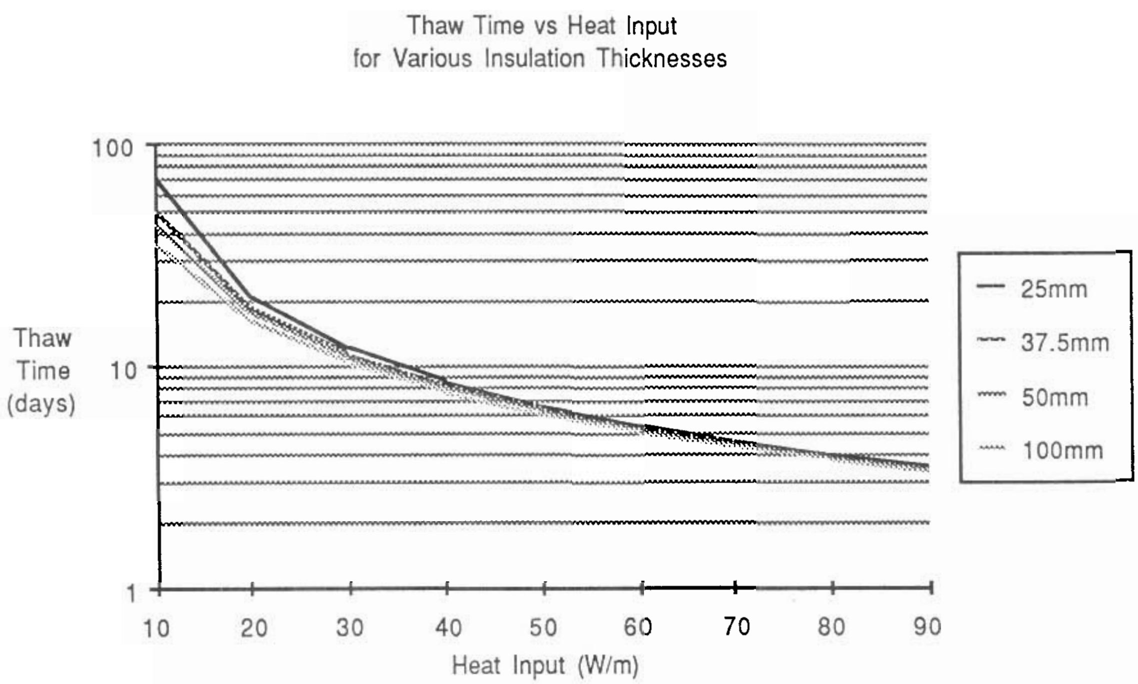
For the section underwater with 37.5mm of insulation in winter (∂T=23°C, Ta=0°C, Ti=23°C) the heat loss should be 16 W/m and the draw 160 W per casing. In summer (∂T=17.5°C, Ta=5°C, Ti=23°C) heat loss is expected to be 12 W/m and the draw 600 W per casing.

Five metres of casing is above the water covered with earth. This can be assumed to have a slightly more stable thermal environment than the section exposed to air and consequently a more uniform heat loss. It is assumed that this section will have a heat loss of 30 W/m and 20W/m in winter and summer conditions respectively. The power draw would be 150 W per casing in winter and 100 W per casing in summer.

Heat loss in the ice in winter is difficult to calculate. The section is long and will account for a great deal of the overall power draw. A length of 40 metres at an average ∂T of 23°C has been assumed. This would result in a heat loss of 16 W/m and a draw of 640 W per casing.

Power draw is therefore calculated to be 1280 W per casing in winter and 760 W per casing in summer.

A related issue is the time to thaw a frozen intake. It has been calculated that the thickness of insulation has little effect on the thaw time after a basic thickness has been applied. The thaw time is much more dependent on the heat input as shown on the accompanying graph.



In the event of a frozen intake it is expected that both the operating and spare heat trace cable would be energized for a maximum energy input of 78.7 W/m. Once the casing has warmed up to freezing temperature 5 to 6 days is likely to be required to thaw the casing.

We have not calculated the time required to warm the intake to the freezing point as this will depend on the length of time it is permitted to cool down after freezing. It is suggested that thawing commence as soon as possible upon freezing.

It is recommended that 37.5mm of insulation be applied to the intake casing from the building line to a level at least 0.5m below minimum anticipated ice bottom elevation.

In general, with owner generated power it may be desirable to apply no insulation below the freezing level in order to increase engine generator load. In this case the uninsulated length would would be only 8 to 10 metres and the additional load would not be significant.

3.4 *Truckfill Station*

3.4.1 Building

Figure 4 shows the proposed building layout. Figure 5 and Figure 6 show interior and exterior elevation views respectively.

A Bally modular-panel building with R-34 insulation is proposed. Outside dimensions are expected to be 3.5m x 7.0m. A partition wall will separate the potable water piping and related equipment from the power generation and switching components. Separate access will be provided to each room. Mortise locks are proposed for the doors.

Rather than surface mounting an outside control panel it is proposed that the panel be mounted inside with access to the truck driver provided through a small Bally–supplied door with lock. This will keep electronic components warm without auxiliary heat. Components would be accessed from the rear of the panel.

3.4.2 Floor System

Floor systems investigated included a skid–mounted system and a cast–in–place concrete slab on grade.

A cast–in–place slab on grade requires a well compacted gravel foundation pad. Adequate structural strength is required to minimize cracking which would result from movement of the pad or underlying ground.

Insulation would consist of 100mm of extruded polystyrene board under the slab.

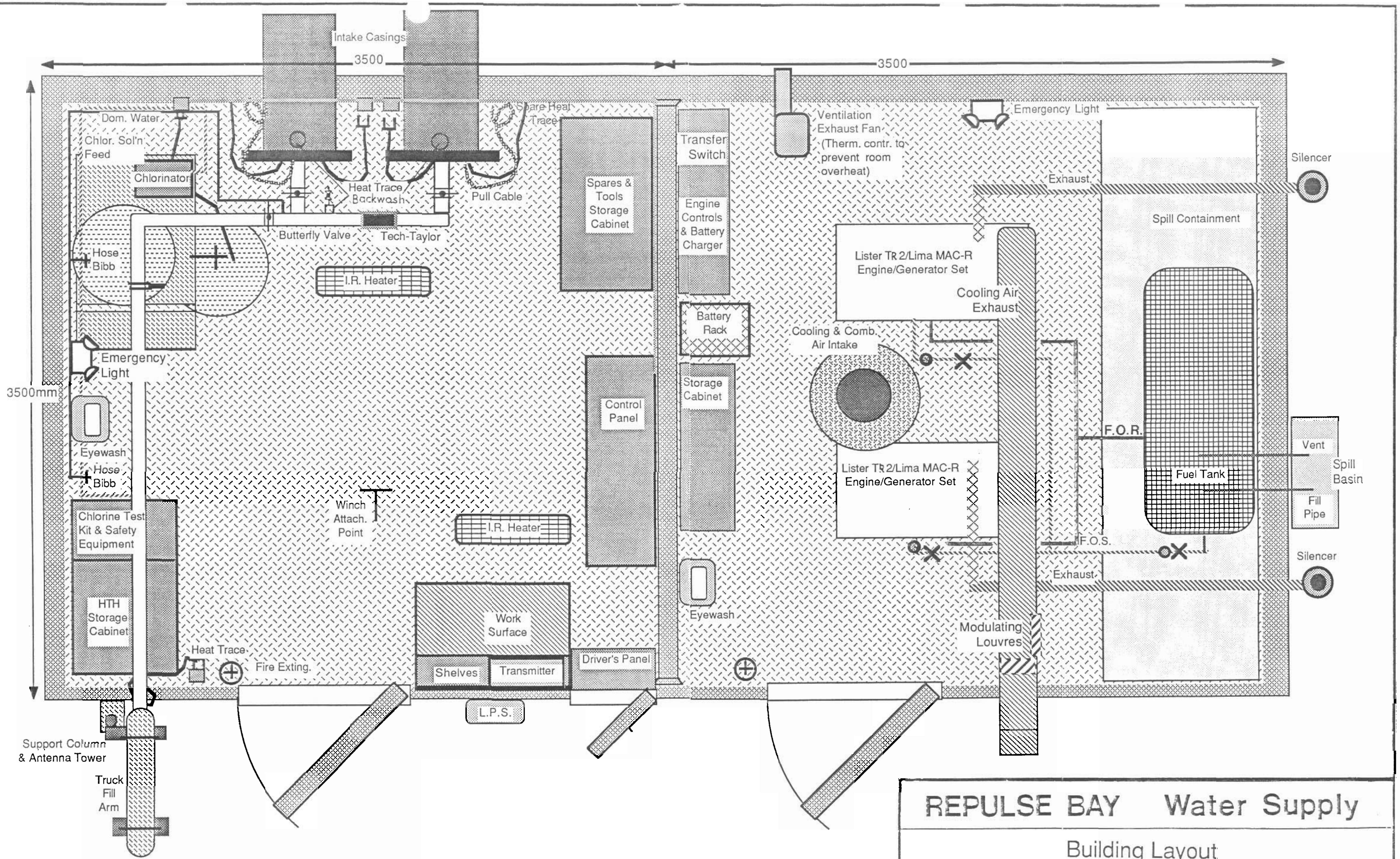
Excavation, formwork, insulation, placing reinforcement, mixing and concrete finishing would be the major labour requirements for this system. Labour is expected to require about 14 days for a 4 man crew.

Shipping weight is approximately 3850 kg. This includes insulation, reinforcing steel, form materials and cement. Mixing equipment is not included in this weight since it will be required for ballast weights in any case.

A skid–mounted frame with cast–in–place concrete deck could be pre–fabricated or assembled at the site. The frame components will be pre-fabricated and would bolt together. Corrugated metal deck and shear studs would be field welded to the frame, welded wire fabric reinforcement placed and the floor slab poured and finished.

Insulation would be provided by extruded polystyrene board fastened to the underside of the deck material. Loads such as the engine-generator units, truckfill arm and intake casings would be transferred directly to the frame.

Labour required is expected to be about 6 days (4 man crew). Shipping weight is approximately 3550 kg.



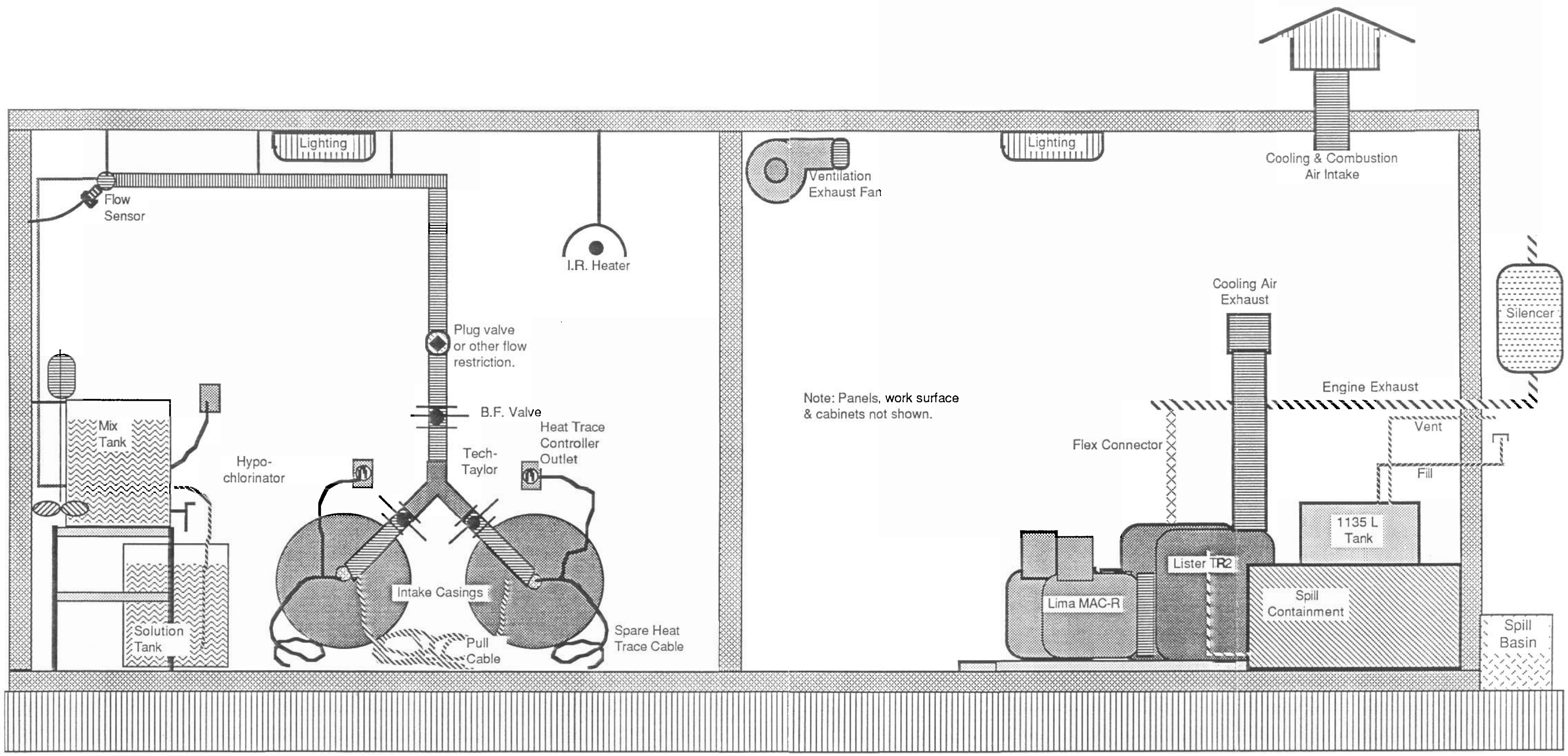
REPULSE BAY Water Supply

Building Layout

GCG DILLON
Consulting Engineers and Planners

MARCH 1987

DRAWING NUMBER
FIGURE 4



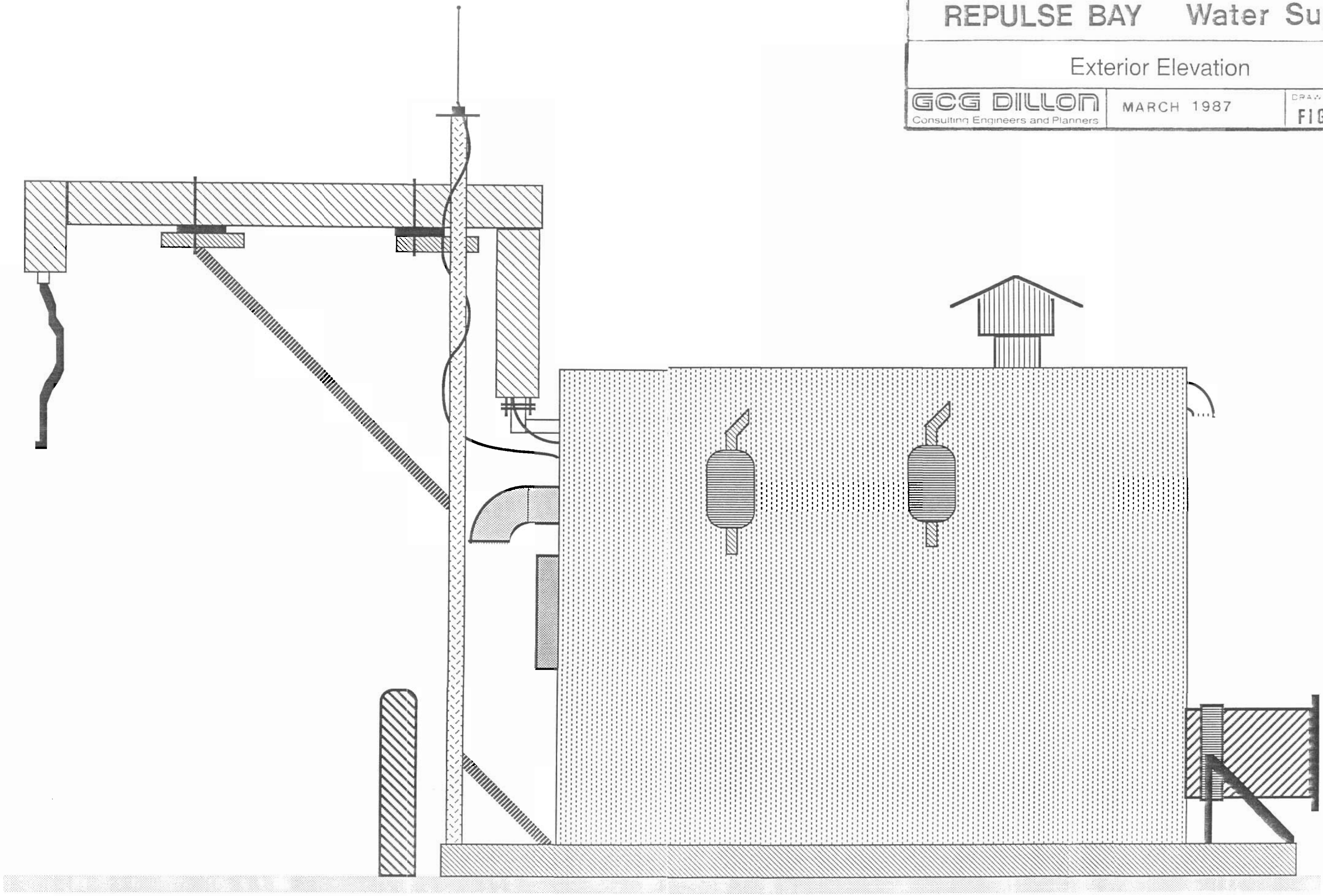
REPULSE BAY Water Supply

Interior Elevation

GCG DILLON
Consulting Engineers and Planners

MARCH 1987

DRAWING NUMBER
FIGURE 5



REPULSE BAY Water Supply

Exterior Elevation

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Consulting Engineers and Planners

MARCH 1987

DRAWING NUMBER
FIGURE 6

Instead of the concrete deck a timber deck could be mounted in the frame. This would reduce the welding requirement and eliminate concrete work. Less insulation would be required than with a concrete deck. The deck would consist of 38 x 89 studs nailed together on edge and covered with 5mm checker plate. Labour requirements are expected to be similar to those for the concrete deck, however the greatest labour requirement would be for nailing the deck.

Shipping weight would be approximately 4300 kg.

Either of the skid mounted systems is preferable to a grade slab on the basis of the on-site labour requirement and isolation from ground movements.

Contractors may prefer to pre-fabricate the truckfill station rather than assemble it on site. Either of the skid–mounted systems is suitable.

3.4.3 Process

Discharge pipes will exit the casings through a water resistant plug, along with power supply cables and other cables. Each discharge pipe will be fitted with an isolation valve. Provision will be made for casing backwash.

A Tech-Taylor two-way wye valve will be fitted to allow on-line standby without operating the isolation valves. A 'V–port' ball valve will be as a control and shut–off valve. This will allow throttling of the flow to produce head–loss necessary for proper operation of the Tech–Taylor valve.

Piping will be galvanized steel, 100mm Ø, Victaulic-style grooved joints.

Provision will be made for thawing the insulated truckfill discharge arm electrically. The arm will also be removable to facilitate repair or replacement in case of damage. The insulation will be jacketed with 18 gauge galvanized metal.

Flow metering will be by means of a small paddle wheel sensor with rate-of-flow indicator and totalizer.

Disinfection will be provided by a small adjustable stroke and frequency metering pump. Provision will be made for dry storage of hypochlorite powder and test equipment.

Start/stop will be by means of a switch located in the driver's panel accessible from outside of the building, and by a switch located at the outer end of the truckfill arm. A remote flow quantity readout and a countdown timer will be provided in the driver's panel. The truck driver will have the capability of switching to the standby pump from this panel.

3.4.4 Building Services

Heat for the pump room will be provided by a 1 kW infrared electric radiant heater. A backup unit will be provided, thermostatically controlled at a lower set point than the main unit.

The generator room will not require a radiant heating unit. Provision will be made to exhaust hot air from near the ceiling if the room overheats due to radiant heat from the engine. This exhaust air flow will by controlled by louvres to prevent stratification in the engine room. Modulation of the engine cooling air exhaust to the engine room interior will provide for warming of the room during extreme weather.

Oil pan and battery warmers are not expected to be required since the room is expected to be quite warm

The engine cooling air intake will be roof mounted with cooling air exhausted to the outside through the wall of the generator room.

Fluorescent lighting will be provided inside and 'quick strike' low pressure sodium vapour (or other lighting cabable of rapidly reaching a useful intensity) outside.

Convenience receptacles will be provided at various points inside and outside the building.

Alarms will be routed through a radio transmitter as well as the alarm annunciator panel. The pumphouse operator and Hamlet or DPW&H office would be alerted to a major alarm condition by a pager. The alarm system will have battery backup and will be cycled to transmit for 5 minutes every 30 minutes to extend battery life. Transmission would be for a minimum of 24 hours.

Extra pagers will be provided to allow for recharging. The number and distribution of pagers will be determined by the owner. Major alarms only will be transmitted. These include low & high building temperature, engine failure and low fuel. Provision can also be made for voice transmission through the alarm system.

Minor alarms will be displayed at the alarm annunciator panel only.

General safety equipment will include fire extinguishers, first aid kit, eyewash stations. Goggles, apron and gauntlets for mixing hypochlorite will be provided.

Emergency lighting will be switched so batteries are not exhausted before operator arrives.

3.5 *Site Work*

Site work consists primarily of the truck turn-around, building pad and intake protection.

The turn-around will have a radius of 12.8m. This corresponds to the minimum RTAC2 turning radius for a 9m (overall) long vehicle. Water trucks currently in use have a length of 6.2m. Width of the turnaround will be 7m.

The turnaround will be situated on the existing gravel fill at the site and will be built up a minimum of 0.300m above the surrounding ground.

The truckfill building pad will be built up to provide a finished pad elevation of 51.2m ASL. This is 1.5 metre above the October, 1986 lake level.

Granular material will be used to cover the intake casing pipes. Riprap from near the site will be used as armour against ice and flood damage.

Snow drifting at the site will likely occur downwind from the building. The truck turnaround is located across the wind and should minimize blockage of the turnaround. As the site is confined there is not a lot more that can be done to minmize drifting. Since the prevailing wind is parallel to the valley snow fencing or ridging may be helpful. This need should be assessed during the first few years of operation.

3.6 *Operating Sequence*

Key to the operating concept of the truckfill station is that truck drivers do not have access to the inside of the station. The sequence is:

1. Truck driver opens panel access door, sets timer and pushes 'start' button, or helper pushes start button on truckfill arm.
2. Pump starts; flow activates hypochlorinator and 'pumping' light.
3. Pump remains in operation until 'stop' button is pressed or timer times out.
4. Time delay prevents restart of pump while pump is turbining.

In case of pump failure the driver can select the standby pump with a selector switch. In case of power failure standby genset automatically starts.

4. Major Components

Component		Comments
1.	Intake Casing	-300mmØ Series 45 (min.) HDPE casing -extruded or wrapped black HDPE jacket -37mm HD polyurethane foam insulation -pre-flanged lengths -angle and stress relief at upper end -fibre reinforced fittings -double concrete weights -30% air allow. in shallow water -15% air allow. in deep water -backwash capability <u>Standard of Acceptance</u> Du Pont pipe, Shaw or Urecon insulation system
2.	Intake Screen	-6.0mm opening -copper alloy <u>Standard of Acceptance</u> Johnson
3.	Pipe Bedding and Cover	-40mm nominal maximum. -450mm minimum riprap
4.	Pumps	-3.7kW, 1000L/min @ 15m TDH -suitable for horizontal operation -208V, 3Ø -no check valve -propylene glycol filled motor bearings -min. 50mm clear between pump & casing -lockout during drainback <u>Standard of Acceptance</u> Myers 6S527[1]

[1] Pleuger QN65 may be acceptable depending on headloss for final design

5.	Discharge pipe	-100mmØ, Series 80 HDPE Standard of Acceptance DuPont
6.	Freeze protection	-32.8 (minimum) W/m self-limiting w/ integral ground -plug-in connection Standard of Acceptance Thermon TSX-12-1-CB
7.	Controller	-high limit cut-off only Standard of Acceptance Urecon URSS1-2 c/w ammeters
8.	Building	-prefab panels w/ R34 urethane insul. -insulated ceiling and exterior roof -insulated floor -rainshield, door heaters, mortise locks -weather tight wall & roof penetrations -approx. 3.5m X 7.0m c/w interior partition -skid-mounted or slab on gravel pad -white interior, blue exterior -manufacturer supplied 450 X 760 door for driver's panel -checker plate or concrete floor -structural steel frame of required for wind or snow loads Standard of Acceptance Bally
9.	Wye Valve	-100mm Ø Standard of Acceptance Tech-Taylor
10.	Interior Piping	-Schedule 40 seamless or ERW, galvanized -grooved end or plain end couplers -slope to drain back, no checks in system -lugged butterfly valves Standard of Acceptance Victaulic Crane or Jenkins

11.	Hypochlorinator	-twin tank setup c/w mixer & stand -38 L/hr feed pump -pump interlocked with flow switch -corporation stop injector fitting c/w check valve -chlorine test kit colorimeter <u>Standard of Acceptance</u> Wallace & Tiernan 45-100 Hach DR-100 direct reading chlorine meter
12.	Metering	-paddlewheel type -non-reset totalizer & flow indicator inside -reset totalizer in driver's panel -countdown timer outside -inside display in m3 -outside display in 10L or 100L increments <u>Standard of Acceptance</u> Signet Mk515 Flosensor Signet Mk575 Accumuflo inside Signet Mk579R outside Eagle HP5 CYCL-FLEX Model 9 timer
13.	Exterior Panel	-push button start/stop in panel & on truck fill arm -pumping indicator, flow switch controlled -wait indicator during drainback -switch select standby pump -timer meter -mounted inside building -access through small lockable door -push-to-test pilot lights (all panels)
14.	Truck Fill Arm	-sloped to drainback -insulated with 50mm urethane foam -18 ga. metal jacket -heat trace for thaw -various length hoses c/w Kamlock <u>Standard of Acceptance</u> Continental Rubber 'Blue Arctic'

15. Building services	-2 electric infrared heaters, 1kW ea. -separate thermostats -different setpoints, 1 heater is backup -no heater in generator room -fluorescent interior lighting -low pressure sodium vapour (quick strike) exterior lighting (or similar) -120V service outlets as required -1 hose bib for hypochlorinator -1 hose bib for general use -work surface, shelf & cabinet storage
16. Fuel Supply	- 1135 L fuel tank inside generator room -spill containment for 1250 L -black iron pipe for fuel system -transmitted alarm at 1/4 full level -fuel filter, shutoff valve, mechanical fire shutoff -spill basin -local alarm at 1/2 full level
17. Engine-generator sets	-2 identical units for lead-lag operation -air-cooled, suitable for continuous operation -heavy duty vibration isolators -10 kW -lube oil replenisher (or dry sump) for extended operation -oil drip pan underneath <u>Standard of Acceptance</u> Lister TR-2 engine Lima MAC-R alternator Staticraft EC-120 controller Mechron CR2F battery charger Westinghouse Robonics LR0 transfer switch c/w overvoltage protection w/ Agastat or Omron timers Renn oil replenisher

18.	Alarms	-radio transmission 5min/30min -24 hr min. battery life -sealed 'gelcell' batteries, 100Ahr *Transmitted* -low & high building temperature -engine failure -low fuel *Annunciator only* -standby pump selected -standby genset running -low fuel
19.	Spares	-1 chemical feed pump -1 exterior light bulb -minimum 4 interior fluorescent tubes -12 of each pilot light type -2 of each relay type -1 of each switch type - 2 of each timer type -12 of each fuse type (including equipment fuses) -1 of each coil and contact type for magnetic starters -2 of each heater type (starter heaters) -3 of each voltage sensing relay -2 thermistors c/w full length leads -2 pump splice kits -2 fire extinguisher charges (powder & cartdridge) -1 submersible pump -6 eyewash refills
20.	Consumables	-1 year supply required -calcium hypochlorite -engine lube oil -oil, fuel and air filters -chlorine tests

21. Safety Equipment

-2 fire extinguishers, 1 in each room
-eyewash stations, 1 each room
-dust mask for HTH powder
-neoprene apron
-gauntlet style chemical resistant gloves
-goggles

<u>Standard of Acceptance</u>

Ansul A20E Fire extinguisher c/w Foray chemical
Levitt Safety DB7052 eyewash
York Model 1482 personal respirator

5. Operations and Maintenance Requirements

Operations and maintenance requirements have been estimated from data obtained from the GNWT, manufacturers, suppliers and general knowledge. Estimates were compared with information available from the Broughton Island station which has been operating approximately 2 years.

5.1 *Truckfill*

-hypochlorite mixing	(0.5 hour every 2 week)	1 hr/mo
-gen. operator checks	(3 hr/wk incl. 0.5 hr travel)	12 hr/mo
-general maintenance	(0.5 hour/week)	2 hr/mo

5.2 *Power Supply*

-change lead/lag & sim. power failure	(0.5 hour/month)	0.5 hr/mo
-genset check	(1 hr/wk incl. 0.5 hr travel)	4 hr/mo
-change oil filter	(0.5 hour/2 weeks)	1 hr/mo
-change fuel filter	(0.5 hour/20 days)	1hr/mo
-maint. checks & adj.	(2 hour/month)	2 hr/mo
-major checks, clean & adjust	(4.5 hour/90 days)	1.5 hr/mo
-annual overhaul	(18 hour/year)	1.5 hr/mo
		26.5 hr/mo[1]

[1] Operation and maintenance time for the truckfill station has been approximately 23.3 hr/mo according to GNWT data.

6. Capital Cost Estimates

6.1	*Site Development*		
	Turn-around & foundation pad	20,000.	20,000.
6.2	*Intake*		
	Casing and weights	175,000.	
	Berm	15,000.	
	Riprap	10,000.	200,000.
6.4	*Building*		
	Supply	25,000.	
	Erection	25,000.	50,000.
6.5	Mechanical		
		40,000.	40,000.
6.6	Electrical		
		50,000.	50,000.
6.7	Power Generation		
		60,000.	60,000.
6.8	Freight & Miscellaneous		
		50,000.	50,000.
	Total		470,000.

7. Life Cycle Cost Estimates

Table 1 presents life cycle cost estimates. Estimates are based on water consumption projected in the Planning Study completed in 1984 by M.M. Dillon Limited, and current fuel price and freight rates.

Life cycle cost estimates include initial and replacement capital requirements, operating costs and maintenance requirements.

Engine-generator set replacement is projected at one unit at 5 year intervals. Pump replacement is projected at one pump after six years initially and then at 5 year intervals. Heat trace replacement is projected at 2 units after six years and at five year intervals thereafter.

Life Cycle Cost Estimates

Year	Consump.	Pumping	Idle	Fuel Quant.	Fuel Cost	Mainten.	Capital	Total	Comments
1987	0.00E+00L	0hr	0hr	0L	$0	$0	$500,000	$470,000	
1988	1.32E+07L	220hr	8540hr	14014L	$10,651	$22,400		$33,051	
1989	1.35E+07L	226hr	8534hr	14023L	$10,658	$22,400		$33,058	
1990	1.39E+07L	231hr	8529hr	14032L	$10,664	$22,400		$33,064	
1991	1.42E+07L	237hr	8523hr	14041L	$10,671	$22,400		$33,071	
1992	1.46E+07L	243hr	8517hr	14050L	$10,678	$22,400		$33,078	
1993	1.49E+07L	249hr	8511hr	14059L	$10,685	$22,400	$15,000	$48,085	Genset
1994	1.53E+07L	254hr	8506hr	14068L	$10,691	$22,400	$4,000	$37,091	Pump & heat
1995	1.56E+07L	260hr	8500hr	14077L	$10,698	$22,400		$33,098	trace
1996	1.59E+07L	266hr	8494hr	14086L	$10,705	$22,400		$33,105	
1997	1.63E+07L	271hr	8489hr	14094L	$10,712	$22,400		$33,112	
1998	1.66E+07L	277hr	8483hr	14103L	$10,719	$22,400	$15,000	$48,119	Genset
1999	1.70E+07L	283hr	8477hr	14112L	$10,725	$22,400	$4,000	$37,125	Pump & heat
2000	1.73E+07L	289hr	8471hr	14121L	$10,732	$22,400		$33,132	trace
2001	1.77E+07L	294hr	8466hr	14130L	$10,739	$22,400		$33,139	
2002	1.80E+07L	300hr	8460hr	14139L	$10,746	$22,400		$33,146	
2003	1.83E+07L	306hr	8454hr	14148L	$10,752	$22,400	$15,000	$48,152	Genset
2004	1.87E+07L	312hr	8448hr	14157L	$10,759	$22,400	$4,000	$37,159	Pump & heat
2005	1.90E+07L	317hr	8443hr	14166L	$10,766	$22,400		$33,166	trace
2006	1.94E+07L	323hr	8437hr	14175L	$10,773	$22,400		$33,173	
2007	1.97E+07L	329hr	8431hr	14184L	$10,780	$22,400		$33,180	
Total Cash Requirement					$214,303	$448,000	$557,000	$1,189,303	

Net Present Value: 4%, 20yr	$139,907	$292,715	$529,198	$920,313
Net Present Value: 8%, 20yr	$97,259	$203,636	$504,533	$759,475
Net Present Value: 12%, 20yr	$71,304	$149,389	$482,445	$656,208

Notes:

1 Fuel=(0.285(L/kWh eng. out.)*10.95 kW*pump time)+(0.143(L/kWh eng. out.)*10.95 kW*idle)
2 Fuel cost=0.76/L
3 Maintenance=(26.5hr/mo*$50/hr*12mo)+(consumables)+(annual overhaul)
4 Consumables= $5000/yr (1% of capital cost)
5 Genset replacement=$10000 repl.+$3000 freight+$1200 labour+$800 airfare, accom. & misc
6 Labour=$50/hr incl vehicle & benefits
7 Water consumption from 1985 Planning Study - M.M. Dillon

8. Decisions & Recommendations

Several decisions are implicit in this document. Some are of minor consequence and the choice of options has been assumed, especially where the matter is of a technical nature. Others are of a major nature and have been identified for discussion and resolution by the Client.

The following major decisions arise from this design brief and should be addressed as the project proceeds. Decision required and options are listed below along with a summary discussion weighing alternatives against objectives. Analysis of alternatives against objectives are qualitative and subjective except where a more rigorous analysis has been completed for specific objectives. Recommendations are provided where appropriate.

1. Fuel storage

Alternatives; Inside or outside storage

Cost-effectiveness is not greatly affected. Reliability is not greatly affected. Maintenance favours inside tank. Operation favours outside tank. Safety favours inside tank.

Recommendation: *Owner preference*

2. Intake configuration

Alternatives; Wet well or inclined shaft

Cost effectiveness favours inclined shaft. Reliability favours wet well slightly. Maintenance is not greatly affected. Safety is not affected. Construction logistics favours inclined shaft.

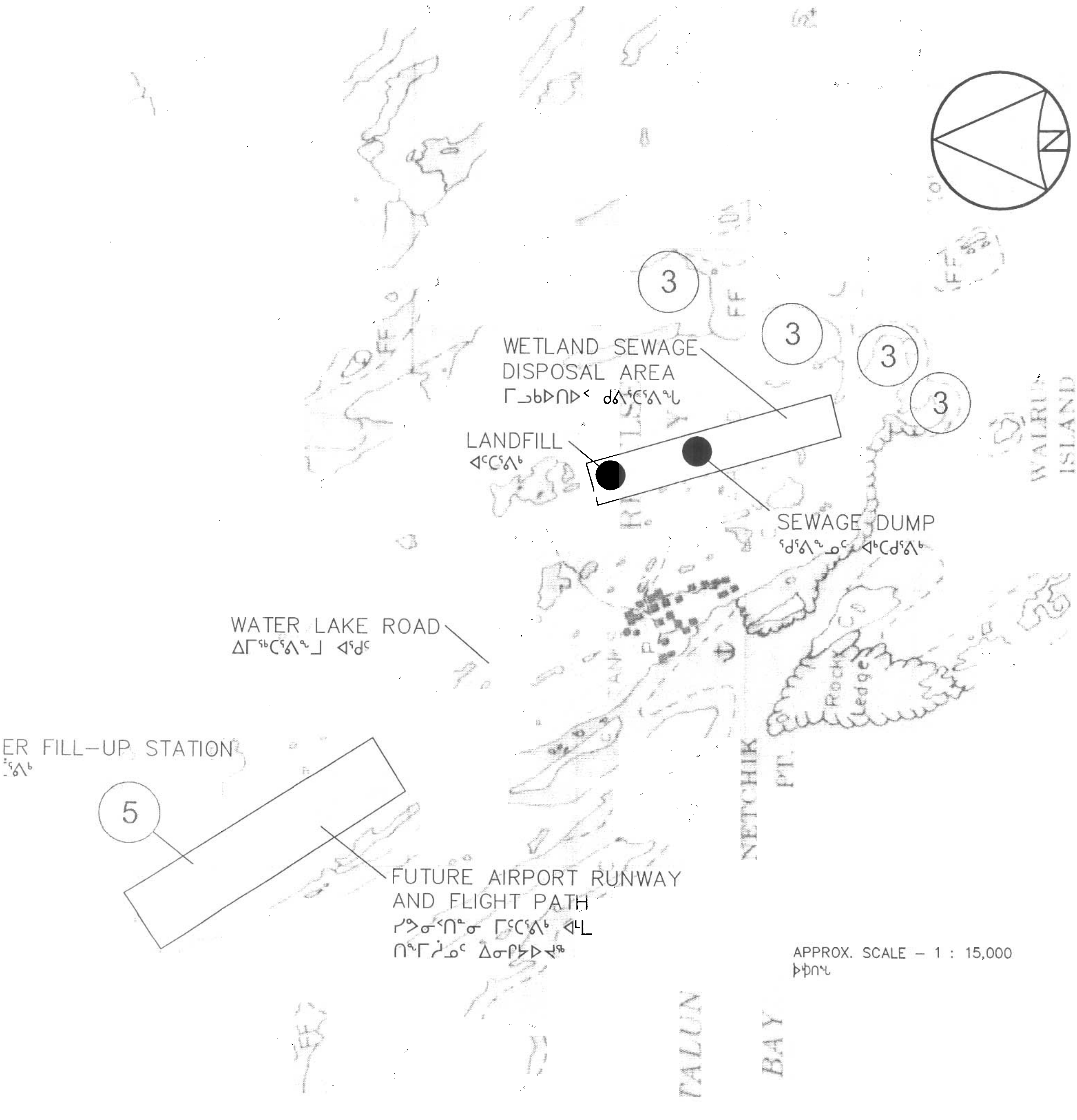
Recommendation: *Inclined shaft intake.*

3. Floor System

Alternatives; Concrete slab on grade or skid-frame system

Capital cost favours skid-frame. Reliability favours skid frame. Maintenance is not affected. Operation is not affected. Safety is not affected. Construction logistics favours skid-frame.

Recommendation: *Skid-frame.*


WETLAND SEWAGE DISPOSAL AREA
LANDFILL
SEWAGE DUMP
WATER LAKE ROAD
ER FILL-UP STATION
FUTURE AIRPORT RUNWAY AND FLIGHT PATH
APPROX. SCALE – 1 : 15,000
WALRUS ISLAND
NETCHIK PT.
TALUN BAY
Rock Ledge
3
3
3
3
5