1.0 INTRODUCTION

1.1 General

The Hamlet of Resolute Bay is serviced by a water supply system that uses a utilidor system to deliver water to houses and commercial users, and collect the sewage from these users. The water supply and sewage disposal systems are comprised of several components, namely:

- The raw water source known as Char Lake
- The Char Lake pumphouse
- The water supply line from the Char Lake pumphouse to the Water Treatment Plant (WTP)
- The utilidor system that is comprised of the water distribution system and the sewage collection system
- The Sewage Treatment Plant
- The sewage outfall.

The above components are shown in **Figure 1.1** and will be described in more detail in the body of the report. Previous studies (UMA 1996) assessed each of the system components for condition, expected remaining life and required remedial action to be undertaken to extend the current facility life to 20 years. The results of this study indicated that in general the facility components are well maintained, and will meet the Hamlet's requirements for the next 20 years. The exception is the utilidor system that has experienced a number of failures over the past 5 to 7 years. The increase in failures is of significant concern to the utilidor maintainers and the Hamlet Council.

The GNWT, Department of Municipal and Community Affairs (MACA) owns the assets of the water and sewer systems. The Department of Public Works & Services (DPW&S) completes the operation and maintenance on the systems. The GNWT has identified the transfer of the community assets to the communities as a priority. In this vein, the GNWT intends to transfer the water and sewer system to the Hamlet of Resolute Bay. Prior to the transfer of the facilities, the systems are to be upgraded to meet the requirements of the Hamlet for the 20 year design life. Dillon was retained to review the system in this light, and develop an upgrading plan for the sewage and water systems assuming that the piped distribution system will be maintained in the community. Three reports were produced, namely;

Volume 1 - Utilidor Upgrade
Volume 2 - Water System Building Assessment

Volume 3 - Sewage treatment and Future System Expansion

Figure 1.1 Water Supply and Sewage Disposal System

1.2 Scope of work

The scope of work for this volume relates to the sewage discharge and the potential for the future expansion of the utilidor system.. A summary of the scope of work is described below:

- Complete a review of the existing documentation.
- Complete a site investigation to update the previous work.
- Complete a community consultation to determine the current perception of the impacts to the environment created by the sewage discharge.
- Debrief the system operator on his concerns, and review the system operator's records of the system.
- Complete a hydraulic model of the system to determine the requirement for system upgrades as the community grows.

2.0 EXISTING DATA REVIEW

2.1 Community Data

Resolute Bay is located on the south coast of Cornwallis Island and is about 1,660 km north east of Yellowknife and 1,550 Km north west of Iqaluit. The community is located at latitude N74-43-01 and longitude W94-58-10 (NAV CANADA). The average daily minimum and maximum temperatures for July and January are 1.3°C & 6.8°C and -35.8°C & -28.5°C respectively. An average of 50.4 mm of rainfall and 97.3 cm of snowfall for a total of 139.6 mm of precipitation is received each year (Environment Canada).

The community was founded in the early 1970's when it was decided to relocate the existing community from the beach area near the existing south camp to the present location. The development of the community and the initial infrastructure was based on a projected population of some 1,500 people. The expected growth was not realized and the current population is slightly less than 200 persons.

2.2 Population Projection

To be able to develop the system requirements it is necessary to determine the design flow rates for the piped system. The flow rates are based on the population of the community and the expected per capita consumption. The historic populations and per capita water use rates are based on the records found at the Hamlet's office, MACA's records and in previous reports (UMA, 1993, 1996). The population projections are based on the data supplied by the Bureau of Statistics. These are as follows:

Table 2.2.1
Population Projects from the Bureau of Statistics

Year	Population
1991	171
1992	174
1993	178
1994	181
1995	184
1996	197
2001	224

2006	238

The consumption is based on the formula developed by MACA (MACA, 1986) and on the historic consumption of the community. The formulae for predicting water consumption of communities with piped water distribution and populations less than 2,000 people is:

Daily Consumption = 225*(1 + 0.00023 * (Population)) * Population

Based on this formula and the population projections shown in Table 2.2.1, the projected annual consumption for the Hamlet of Resolute Bay for the next 20 years can be predicted. The system uses bleed water from the watermains to provide freeze protection to the sewermains. The bleed water is not metered. The total water pumped into the system is metered, and the individual consumers are metered. The resultant of the water supplied to the system and the metered volume of the consumers is the total of the system losses. The total system losses include the bleed water, losses due to watermain breaks, and water losses within the system. Prior to 1996, this value was fairly constant at approximately 38,000 m^3 per year. As a result of increased problems with the system the amount of bleed water has increased in 1996 to 52,000 m^3 and again in 1997 to 56,000 m^3. At the time of reporting, the Hamlet was projecting an annual total consumption for 1998/99 of 55,000 m^3 of which 45,000 m^3 would be the bleeders and other system losses. For the purposes of water consumption projections the value of 45,000 m^3 of bleed water and other system losses is used. The projected annual consumption is shown in **Table 2.2.2.**

2.3 System Description

The following is a description of the complete water and sewage system from the up gradient intake to the down gradient sewer outfall. **Figure 2.1** illustrates this system in a schematic diagram.

Char Lake

- A ductile iron gravity intake line extends from Char Lake to wet wells in the Char Lake Pump House.
- Char Lake Pump House tempers the water using a hot water injection into the wet wells. Diesel fired boilers are used to heat the injection water. The tempered water is pumped through the 150 mm heat traced and insulated HDPE Water Supply Main to the Water Storage Reservoir at the Water Treatment Plant (WTP).
- Two jockey pumps and two demand pumps are operated in the Char Lake Pump House. Typically one jockey pump operates 24 hours a day, with one demand pump coming on for less than one hour per day. The second jockey pump and second demand pump are on-line standby pumps and are brought on-line automatically if the first pump fails.
- The Char Lake Pump House pumps are controlled from a level controller located in the Water

Storage Reservoir. The controller has a high level alarm, jockey pump off, jockey pump on, demand pump off, demand pump on, and low level alarm control levels.

- A standby diesel engine generator is situated in the Char Lake Pump House in case of loss of power to the Pump House.

Table 2.2.2 Population and Consumption Projections

Figure 2.1 Existing System Schematic

Water Treatment Plant

- The Water Storage Reservoir is a steel 530 m^3 vertical steel tank constructed above grade. The tank is insulated and is freeze protected by the use of hot water injection.
- The Water Treatment Plant uses diesel fired boilers to provide tempering water for the Water Storage Reservoir hot water injection.
- The distribution water to the community is chlorinated using calcium hypochloride through injection pumps.
- The WTP uses pumps to provide distribution flow. The pressure is maintained at approximately 170 kPa (25 psi) at the WTP (October 1998 reading), and approximately 600 kPa (85 to 90 psi) at the low end of distribution system. The difference between the discharge pressure and the low end main pressure is the result of the static head difference in the mains due to elevation changes. The supply pump runs continuously at a constant rate of 1,700 rpm. The flow to the distribution mains is not regulated. Whatever water is not used within the distribution system is returned to the reservoir through the 150 mm return line.

Utilidor

- The distribution system is a looped HDPE insulated pipeline. The pipes are mostly 200 mm in diameter with two sections of 150 mm supply line and a 150 mm return line.
- Water is supplied to users (approximately 60 buildings) through a 20 mm copper heat traced (Stage 1A only) and insulated services. A return service is also installed from each building to the water main. Flow is moved continuously through the supply and return services by a small recirculation pump (1/4 h.p.) located in each building.
- The return water is directed back to the Water Storage Reservoir.
- The building sewage is collected using 100 mm insulated HDPE sewers to the sewer mains.
- The water and sewer services are in a common insulated jacket. The latent heat from the recirculation of the water services is used to freeze-protect the sewer service.
- Bleed water from the water mains is also used to provide freeze protection to the sewer mains during power failures when the water service recirculation pump is not operating
- The sewer mains are gravity run 150 mm insulated HDPE. These are installed in the same trench as the watermain.
- The sewermains and watermains are accessed through common concrete cast in place Access Vaults (AVs). The AVs contain all valves, hydrants, pipe connections and sewer clean outs.
- The sewer main is freeze-protected by the use of bleed water from the watermain to the sewermain. The bleeders are unmetered and located in the AVs.

Sewage Discharge

- The sewer mains join at the low end of the community and flow by gravity to a comminutor building.

- The sewage is macerated in this facility and discharged by gravity through an outfall pipe to the shore line of the marine environment.

There have been several changes to the system since the original design. Some of these changes have been incorporated into the O&M manuals. The changes recorded during the site investigation completed on October 20 to 22, 1998 are from the discussions with the DPW Maintainer, Mr. Neil MacDonald, the Hamlet Administration, Mr. Dan Leman & Mr. Ralph, and from the existing documentation are as follows:

- A heat trace has been installed in the Water Supply Line from the Char Lake Pump House to the WTP in 1993. Five access vaults have been installed along this line as well. (Record Drawings)
- Two jockey pumps have been installed in the Char Lake Pump House.
- The utilidor heat trace system was abandoned in 1984 due to corrosion problems.(UMA, 1996)
- All electrical devices and service were removed from the Access Vaults in 1998. This includes the sump pumps, heat trace, and AV heaters. (N. Macdonald)
- The line to Block 1 is abandoned due to a freeze-up prior to 1986. The Health Centre water service currently uses the abandoned water main as a carrier pipe. The other buildings in this area are connected to the water and sewer mains between AV2 & 3. (N. MacDonald) The sewer service to the Health Centre is still in operation (D. Leman).
- The Hydrant in AV 20 was removed prior to 1986.
- AV 15 was never installed during the original construction. (N. MacDonald)
- A new hydrant was installed in 1998 in AV 13, (N. MacDonald)
- The valves in AV3 were replaced in 1998. These are the valves that were indicated to leak in the UMA 1996 report, but were incorrectly identified as AV2 valves in the UMA report (N. MacDonald).
- A new valve was installed in AV30 in 1998. This allows the section of main between AV21 and AV30 to be shut off. (N. MacDonald)
- The ventilation systems for the WTP and Char lake Pump House have been disabled and are blocked up in the winter. Combustion air for the facility burners is supplied through building envelope infiltration. It is reported by the DPW Maintainer that the buildings are very leaky and have poor insulation.

With respect to the utilidor system, there are no known changes made from the original construction other than the changes noted above. The complete system description and components is found in three sets of O&M Manuals. Copies of these manuals are stored in the community, DPW&S Iqaluit, and DPW&S Yellowknife.

3.0 REGULATORY COMPLIANCE OF THE UTILIDOR SYSTEM

3.1 The Public Health Act

The NWT Public Health Act (PHA) regulates the supply of potable water to consumers, and the methods for the collection of waste in the NWT. The applicable sections of the PHA are the"Consolidation of Public Water Supply Regulations, P-23" (PHA P - 23) and the "Consolidation of Public Sewerage Systems Regulations" (PHA P - 22). No other sections of the Public Health Act would relate directly to the water supply and sewage collection system. With respect to the utilidor system the requirements are set out in the in Part III of the PHA-P23.

The utilidor meets the requires of Part III of PHA-P23 except for the requirements of section 20.9 which states:

> "Where water and sewer pipes are contained in a utilidor, there shall be adequate provision for drainage in order to prevent contamination of the water supply during repairs to the system."

The AV's contain both water and sewer pipes. The sewer clean out covers have been removed to allow infiltration water to drain out of the AVs. This is an annual problem, as each spring run off water enters the AV and must be removed. This occurs from about June to October (N. MacDonald) and then the remaining water is pumped out of the AVs. The clean out cover remains open year round. This creates concern that in the event of a water main break a negative pressure in the watermain can be created within an upstream AV from a syphoning effect of the down stream main. If the watermain is not completely sealed, or during the repair of the water main, there is the possibility of cross contamination from the open sewer clean out. This is greatly reduced if the clean out is closed and sealed prior to the start of any maintenance on the water main system.

The PHA P - 22 has two requirements that are of issue for the utilidor system. The first is the same as described above. The second is the requirement for treatment for the sewage. The PHA P - 22 states in Part IV article 9:

> "Sewage treatment systems shall be designed to provide for adequate protection of the receiving water considering the possible uses of the receiving water"

This issue does not particularly relate to the operation of the utilidor system, but is raised as the UMA, 1996 report indicates that the Public Health Department required that sewage treatment is needed to meet the requirements of the Department. Based on the above section of the act, which is the only section of the PHA that addresses sewage treatment, there appears to be no specific requirement for treatment other than to protect the receiving body of water.

4.0 MODELLING

4.1 Water Distribution Network

4.1.1 Introduction

This section summarizes the development of the water distribution analysis model for the existing system and the 5 year proposed residential development in Resolute Bay, NT. Results of the analysis and recommendations are included.

4.1.2 Existing Conditions

There is approximately 2,500 m of pipe in the water distribution system. All water mains are 200 mm HDPE pipe with the exception of three 150 mm sections. A constant pressure of 150 kPa (20 psi) is provided at the water treatment plant to the distribution system. There are 20 mm bleeds into the sanitary sewer in AV17, AV19, AV22, and AV25. The outflow through these bleeds is approximately 5.25 l/s each.

The water is constantly being recirculated within the system with the aid of a 150 mm return line to the water treatment plant.

4.1.3 Future Conditions

An area to the southwest of the current community is proposed for 37 new residential lots. This will require approximately 1,090 m of 200 mm additional water main. A commercial area to the northwest is proposed but not expected to be developed within the next 5 years and therefore not included in the scope of this project. The connections to the existing system will be made at AV17 and AV11.

4.1.4 Hydraulic Model (EPANET)

EPANET is a computer program that performs extended simulation of hydraulic and water quality behaviour within pressurized pipe networks. A network can consist of pipes, nodes, pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, and the height of water in each tank during a multi-time period simulation. EPANET Version 1.1e was developed by the Water Supply and Water Resources Division, National Risk Management Research Laboratory of the U.S. Environmental Protection Agency in Cincinnati, Ohio.

4.1.4.1 Model Setup and Assumptions

Since the network is relatively small, each pipe is modelled individually. Existing details such as slopes, diameters, elevations and the configuration were obtained from the as-built drawings obtained from PW&S. Elevations and slopes for the proposed development were interpreted from contour mapping. A schematic diagram is shown for existing conditions in **Figure 4.1** and for future conditions in **Figure 4.2**.

The Hazen-Williams head loss equation is used. (h=fn(C,d,L,q))

The Hazen-Williams coefficient (C) for HDPE pipe is assumed to be 110.

The return line to the water treatment plant is modelled with a check valve to ensure one direction of flow. The node at the end of the return line is modelled as a reservoir with a constant elevation equal to the inflow elevation at the plant. The water reservoir is modelled with a constant head of 17.3 m to simulate the a constant pressure of 150 kPa (20 psi) leaving the plant.

Demands in Resolute Bay are based on an estimated number of units of 63 in the existing model and 113 for the future conditions, and 5 people per unit.

Unit consumption rates are as follows:

Average Day	225 Lpcd
Maximum Day	450 Lpcd
Peak Hour	900 Lpcd

Total water use in a community can be estimated as a function of residential water use(RWU) (MACA, 1986).

Total water use=RWU*(1+(.00023*population)) for a community of less than 1000 people.

Total water use is used in the model, residential and commercial flows are not distinguished.

The allocation of demands is based on the as-built drawings and approximated for the future development. For both existing and future conditions the following scenarios are modelled. Average day demand, maximum day demand, peak hour demands and average day demands plus fire flow at the worst location. The results of these runs is in appendix A.

Figure 4.1 EPANET Resolute Bay October 1998 Existing Conditions Schematic

Figure 4.2 EPANET Resolute Bay October 1998 Future Conditions Schematic

The fire flow rate based on MACA criteria is 3600 l/min for 2 hours during average day demands. Fire flows were simulated at the edges of the network and at the highest elevations to determine the worst case scenario and verify fire flows can be met. For existing conditions a fire at AV4 has the lowest pressures associated with it but the minimum pressure of 150 kPa can be easily maintained. For future conditions a fire at AV201 has the lowest pressures associated with it, but again the minimum of 150 kPa is maintained throughout the system.

The model was also run with pipe diameters of 150 mm instead of 200 mm to determine if the pipe size can be reduced, as the Community has not grown to the anticipated size. The model indicates that the 150 mm size is not sufficient to maintain the fire flow requirements.

4.2 Sanitary Sewer System

4.2.1 Introduction

This section summarizes the utilization of the existing sanitary sewer system, and estimates the peak hour flows for the 5 year proposed residential development in Resolute Bay, NT. Results of the analysis and recommendations are included.

4.2.2 Existing Conditions

There is approximately 2,500 m of sanitary sewer pipe. Most sewers are 150 mm HDPE pipe with five 200 mm sections at the downstream end of the system. There are 20 mm bleeds into the sanitary sewer in AV17, AV19, AV22, and AV25. The inflow through these bleeds is approximately 5.25 l/s each.

4.2.3 Future Conditions

An area to the southwest of the current community is proposed for 37 new residential lots. This will require approximately 768.5 m of 200 mm additional sewer pipe. A commercial area to the northwest is proposed but not expected to be developed within the next 5 years and therefore not included in the scope of this project. The connection to the existing system will be made at AV32. In addition to the existing 20 mm bleeds into the sanitary sewer, they were also added to AV201 and AV203 to prevent freezing.

4.2.4 Capacity Utilization Analysis

The full flow capacity of a circular pipe can be calculated using Manning's equation (Q=1/n*(A*R^2/3*S^1/2).

Model Setup and Assumptions

Each pipe with its details is identified in the spreadsheet shown for existing conditions in Table 4.1 and for the proposed development in Table 4.2. Existing details such as slopes, diameters, and the configuration were obtained from the as built drawings obtained from PW&S. Slopes for the proposed development were interpreted from contour mapping.

A schematic diagram is shown for existing conditions in **Figure 4.11** and for future conditions in **Figure 4.12**. The Manning's n coefficient for HDPE pipe is assumed to be 0.013.

Demands in Resolute Bay are based on an estimated number of units of 63 in the existing model and 113 for the future conditions, and 5 people per unit.

Unit consumption rates are as follows:

Average Day	225 Lpcd
Maximum Day	450 Lpcd
Peak Hour	900 Lpcd

Total water use in a community can be estimated as a function of residential water use(RWU) (MACA, 1986).

Total water use=RWU*(1+(.00023*population)) for a community of less than 1000 people.

It is assumed that waste water is equal to water use.

Results

Nearly all pipe in the system have adequate capacity to carry the peak hour flows. The exception is between AV11 and AV32 in the existing system due to a small slope, and between AV 11 and AV35 in the future system. The problem is solved by replacing the sewer pipes at these locations with 250 mm diameter pipe.

Figure 4.11 EPANET Resolute Bay October 1998 Existing Conditions Schematic

Figure 4.12 EPANET Resolute Bay October 1998 Future Conditions Schematic

5.0 IMPACT STUDY

5.1 Introduction

This section presents an overview of the Environmental Impact Study (EIS) of the Hamlet's current sewage discharge practices to Resolute Bay. This study was initiated as a follow-up to a previous water and sewer facilities study by UMA Engineering Ltd. (1996). That study identified potential concerns relating to the Hamlet's sewage discharge with respect to health issues and components of the Federal Fisheries Act relating to the discharge of a deleterious substance.

The UMA Report reviewed the correspondence from the Baffin Region Medical Health Officer, and indicated that the sewage disposal system does not comply with the Public Health Act because, "*the discharge of sewage is directly into the ocean without any prior treatment*". However, the sewage does receive some treatment in the form of dilution from the bleed water.

There is uncertainty whether or not the sewage discharge complies with the Federal Fisheries Act as it relates to the introduction of a deleterious substance to a waterbody. It is not known if the current discharge would be considered deleterious, however, the UMA report states that the preparation of a DFO position brief on Resolute Bay is being considered. Currently, the status of the development of this position paper is unknown.

This EIS is based on existing environmental information for Resolute Bay, discussions with local residents, and Dillon's experience with similar studies (e.g. Repulse Bay Sewage Discharge -Preliminary Impact Assessment 1998). A major component of the EIS is a review of potential impacts of sewage discharge to the marine environment based on existing information. The EIS characterizes the existing environment of Resolute Bay including physical habitat characteristics, water quality, and marine flora and fauna. As part of this task data gaps or deficiencies have been identified to provide direction for a more detailed environmental assessment.

5.2 Potential Impacts of Discharging Sewage Waste to the Marine Environment

When wastewater is discharged to marine waters there are possible implications for the surrounding marine environment. The following discussion is intended to provide background regarding the potential environmental impacts of sewage to the marine environment.

The Department of Indian Affairs and Northern Development (DIAND, 1987), indicates that the principal 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 (DO) 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 (not an issue in Resolute Bay)

- *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.

Of particular concern relating to impacts to the receiving environments is a potential decreased DO 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. Problems can arise where there is inadequate dilution or dispersion of an arctic communities sewage discharge which may result in anoxic conditions in the marine environment even when discharge is at relatively low volumes of sewage. DO reductions can also be exacerbated due to the long periods of ice-cover that effectively prevent atmospheric re-aeration. DIAND (1987) concluded 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 DO 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 zone. 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) reported alterations in the benthic community associated with a sewage outfall discharging to the mud flats of the Fraser River estuary increased. The authors observed an increase in the number of individuals, biomass, and species with increasing distance from the discharge. The extent of impacts to the benthos community is dependent on many factors such as: 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).

The potential impact of micro-organisms may also be a concern when sewage is discharged into Arctic marine waters. Faecal coliforms, such as *E. coli*, may contaminate local invertebrate species and hence pose a risk to human health if any of these organisms are harvested for consumption by the residents. Shellfish are of particular concern because they are filter feeders and tend to concentrate bacteria in their tissues. This makes shellfish harvesting for human consumption a potential risk. 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).

It is suggested by DIAND, 1987 that sewage discharge to the marine environment from small northern communities may have an insignificant environmental impact at a regional level. There could be minimal impact at the local level if sewage is discharged to a not well-mixed waters where the effluent is not 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 Resolute Bay, both in the present and predicted for future years, are relatively small.

5.3 Existing Environment

Information regarding the existing environment of Resolute Bay is extremely limited, and is generally restricted to marine studies completed in the early 1970's (see summary by Buchanan and Ragnit 1978).

Several of the studies provide descriptions and information regarding the general marine biological characteristics of the Resolute Bay and Wellington Channel. Study components include physical measurements, phytoplankton, zooplankton, benthos, and fish.

The following sections provide brief summaries for each of these components or areas:

5.3.1 Physical Environment

The physical data summarized in this section is related to tides and winds. Tidal influences experienced by Resolute Bay are considerably less than those observed in other areas in the eastern Arctic. Resolute Bay has a mean tidal variation of 1.3 m and a maximum tidal variation of 2.1 m (UMA 1996).

Wind speed and direction information is particularly noteworthy as they have a direct effect on physical oceanography of an area and can play an important role in the behaviour and distribution of any pollutant. Mean wind speeds for Resolute Bay are reported to be between 10.4 and 12.6 mph with a predominant wind direction from the northwest (Bitello 1973 *cited in* Buchanan and Ragnit 1978).

5.3.2 Water Quality

Water quality monitoring has been completed periodically for the sewage discharge to Resolute Bay The water quality data includes a small sub-set of parameters from the final sewage discharge into Resolute Bay as well as from a station located 5-10 meters down current of the final discharge. Additional water quality information is available for comparative purposes for run-off from the solid waste disposal facility and for Char Lake waters.

Water quality data related to the sewage discharge are parameters pH, conductivity, total suspended solids, dissolved solids, biochemical oxygen demand (BOD), turbidity, total nitrogen, ammonia-N, nitrate, total phosphorus, and coliform bacteria. The effluent has not been characterized with respect to other parameters of potential concern such as metals or organics. Metal levels have been evaluated however, for the run-off from the solid waste disposal facility and for Char Lake.

The results of water quality monitoring completed between 1992 and 1997 for the Resolute Bay sewage discharge are presented in Table 5.1. Relevant guidelines and criteria have been included for comparison where possible. The solid waste site is not the subject of this assessment and is not discussed further in this report.

Generally, water quality is quite variable between sampling periods, although in all cases within relevant guidelines or criteria. The high variation is not surprising given that sampling likely took place over a wide range of physical conditions and as such may reflect tidal differences, wind- and wave-induced differences, etc.

Table 5.1

Water Quality Parameters at the sewage discharge to Resolute Bay and at a station located 5-10meters downcurrent of the discharge (data supplied by DIAND).

Parameter	Guideline/ Criteria	Sewage Discharge at End of Pipe (Stn 1571-3)					Resolute Bay[1] (Stn 1571-4)	Water Licence Criteria
		July 17, 1992	June 28, 1993	Aug. 17, 1994	July 26, 1996	July 8, 1997	July 17, 1992	
CONVENTIONAL PARAMETERS								
pH	7.0-8.7[2]	7.2	7.24		7.82	8.00; 8.03	7.39	6 to 9
Conductivity (uS/cm)	-	450	304			201	420	
Total Suspended Solids (mg/L)	1203	27	19	<3	10	15; 15	26	80
Dissolved Solids (mg/L)	-			260				
BOD (mg/L)	1003				76	15; 18		120
Turbidity (NTU)	-		15	2.9				
NUTRIENTS								
Nitrates/ Nitrites (mg/L)	-	<0.01	1.26	2.21			<0.01	
Ammonia-N (mg/L)	124			1.41	0.721	0.561; 0.597		
Nitrate (mg/L)	-			2.2				
Total Phosphorus (mg/L)	-	1.3	1.115	0.219			0.691	
BACTERIA								
Total Coliform (CFU/dL)	-				300,000	2,600,000		
Faecal Coliform (CFU/dL)	-				110,000	210,000		

Notes:

1- Resolute Bay 10m down current from discharge pipe.

2- CCME Interim Marine and Estuarine Water Quality Variable (December 1996)

3- Effluent discharge to a marine bay or fjord (Guidelines or the Discharge of Treated Municipal Wastewater in the Northwest Territories, 1992)

4- BCMoELP (Nordin 1990) *cited in* BCMoELP (1995) - water quality criteria for saltwater life. Ammonia to (T = 0°C; Salinity 30g/kg; pH = 7.6)

The range of pH, 7.0 to 8.7, is 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. During the July 1992 sampling, the pH 5-10 meters down current of the effluent discharge point is almost 0.2 pH units higher that the pH at the point of discharge (Table 5.2) indicating that the sewage effluent may be resulting in a slight decrease in pH in the immediate vicinity of the discharge.

TSS levels were some what variable between sampling periods which is not surprising given that sewage strength will vary over the day. Diurial testing of the sewage discharge would be required to determine daily/weekly peaks for this parameter.

The Faecal and Total Coliform tests varied considerably (10 fold) over the tests. Like TSS this is an indication of varied sewer strengths. The fact that the FC levels are high when the BODs is low can not be explained. Logically, these levels should follow somewhat similar trends.

5.3.3 Phytoplankton

The following information regarding phytoplankton communities is summarized from Bain *et. al.* (1977 *cited in* Buchanan and Ragnit 1978).

Common "spring" phytoplankton species reported in the area include *Nitzschia grunowii,* followed to a less extent by *Nitzschia seriata*, and *Thalassiosira nordenstioeldii.* Common "Summer" phytoplankton species include *Chaetoceros socialis*. No differences in phytoplankton populations observed between sites sampled under ice and those sampled in open water, most likely due to the presence of strong southward moving currents in Wellington Channel. Similarity, phytoplankton communities demonstrated no consistent depth preference, again most likely due to physical influences such as tidal action and light intensity.

Phytoplankton communities reported along the Resolute Passage ice-edge sampled in early July exhibited low standing stock and differed considerably in composition from populations in the Wellington Channel.

Particularly noteworthy is a study by Welch and Kalff (1975 *cited in* Buchanan and Ragnit 1978) which presents measurements of marine photosynthesis and respiration in Resolute Bay. The authors reported chlorophyll concentrations in the water ranging from 0.001 - 0.1 mg/m^3 during the winter to 15 mg/m^3 in August. This information could potentially provide an interesting comparison to current conditions within Resolute Bay.

Potential impacts to phytoplankton populations due to the sewage discharge to the bay are expected to be minimal and restricted to the area in the immediate vicinity of the discharge point. Increased loadings of nutrients may result in a localized increase in phytoplankton productivity, however the magnitude of this increase would be determined by overall nutrient loadings, characteristics of the mixing zone, and physical aspects such as tidal and weather (ie. wind, waves, etc.) effects.

5.3.4 Zooplankton

Thirty-five zooplankton species were identified by Bain *et al.* (1977). The community was numerically dominated by copepods such as *Pseudocalanus* spp., but in terms of biomass the community was dominated by the copepods *Calanus glacialis* and *Calanus hyperboreus*. Barnacle nauplii were also extremely abundant in some samples. Unlike phytoplankton, pelagic and under-ice fauna are generally less abundant (Green and Steele 1975 *cited in* Buchanan and Ragnit 1978).

As with phytoplankton, potential impacts to zooplankton populations inhabiting Resolute Bay would most likely be minimal and restricted to the area in the immediate vicinity of the discharge point. Increased phytoplankton productivity due to nutrient loadings could potentially result in an associated increase in zooplankton productivity, but any increases would be expected to be small.

5.3.5 Benthic Invertebrates

Dominant benthic invertebrates reported (Green and Steele 1975 *cited in* Buchanan and Ragnit 1978) in Resolute Bay include:

- clams (*Mya truncata*)
- brittle star (*Ophiura sarsi*)
- starfish (*Lepasterias groenlandicus*)
- mud shrimp (*Sclerocrangon boreas*)
- isopods (*Munnopsis typica*)
- whelk (*Buccinum belcheri*)

Motile invertebrates such as amphipods are often concentrated at the tidal surface and as such provide an important food source to shorebirds and seabirds and fish, particularly Arctic char (Ellis and Wilce 1961).

Benthic invertebrates, including shellfish, within the sewage discharge area could potentially be impacted by contaminant loadings. Unlike phytoplankton and zooplankton which are directly influenced by tides and water currents, benthos form a relatively sedentary population which continually exposed (to varying degrees) to diluted sewage and associated contaminants, and as such, the health of the organisms reflect the quality of the environment they inhabit. Shellfish, such as clams can also bioaccumulate various contaminants such as metals. Shellfish also filter out coliform bacteria from the water column, resulting in a potential health risk to humans if the shellfish are harvested.

5.3.6 Fisheries and Marine Mammals

Available information regarding fish and marine mammal communities is extremely limited for Resolute Bay.

Fish species reported in the area include arctic cod (*Boreogadus saida*), and ninespine stickleback (*Pungitius pungitius*). All fish were found to be actively feeding on amphipods Several species of marine mammals are reported in the Resolute Bay area including Narwhal (*Monodon monoceros*), bowhead (*Balena mysticetus*), and white whales (*Delphinapterus leucas*)

Given the relatively low levels of discharge of sewage to Resolute Bay, fish and marine mammals communities are not likely to be directly impacted. Nutrient enrichment of the bay may in fact result in a localized increase in primary and secondary production (phytoplankton, zooplankton, benthos) which could potentially provide a greater food source for fish.

5.4 Public and Regulatory Agency Consultation

In an effort to further determine the status of a “Position Paper or Brief”(UMA 1996) regarding current sewage treatment and disposal for the Hamlet of Resolute Bay and authored by Fisheries and Oceans Canada and/or Environment Canada, several attempts have been made to contact appropriate staff from both federal agencies. However, no new information has been provided to establish what requirements may or may not be needed to further explore regulatory issues. This being the case, it is still unclear whether or not there are issues and concerns relating to sewage disposal that justify those requirements of the *Act*.

On November 4, 1998 an information session and consultation meeting was held at the Hamlet of Resolute Bay. This session was to provide Hamlet administrators and residents information regarding this study. An introduction to this study was provided to identify the scope of work being completed. The main focus of the meeting was to discuss the current and historical operational practices of sewage outfall and the perceived and potential environmental effects of the discharged wastes to the marine environment.

Consultation with the community consisted of an evening meeting at the Hamlet’s community center. The meeting received publication through radio, television and newsprint media one week and again, one day prior to the event to ensure that community members were given adequate notice and the opportunity to attend.

Approximately 20 members of the community, including three Hamlet councilors and the Hamlet’s Senior

Administrative Officer (SAO), attended the session. Dillons' staff presented a study overview and described the intended scope of work through the use of overhead slides. One member of the community assisted in the presentation of materials to the community group by providing language translation services for both the presentation of information and follow-up inquiries from local residents. A copy of Dillon's presentation is provided in Appendix 1.

Provided below is a summary of those comments, questions and discussions brought forward by community members at the meeting;

- During certain times of the open water season and when specific wind patterns exist the smell of sewage is very apparent within the Hamlet;

- What were the concerns raised under the NWT Health Act, with respect to the sewage issue?

- What is a cut off population for which the existing type of utilidor facility structure is not appropriate?

- How far out into the bay does effluent travel beyond the immediate discharge point?

- During the open water season the beach or shoreline area, in the vicinity of the sewage outfall, is used as an access point for boating;

- The current discharge location is not considered appropriate, as it is limiting the community development, small boat access, and there are olfactory problems during the summer period;

- Successful hunters will bring their animals (primarily seals) to the beach area where they are partially butchered;

- Some hunting does occur in Resolute Bay. Baffin Health Board was to have conducted a study to determine any impact from the sewage outfall. Therefore the people of Resolute Bay submitted some food samples (seals, whales that were captured from all over, including the Bay) to DFO, but no results are available so far. Some seal liver and fat studies were also to have been conducted;

- Due to DFO's long-time presence in Resolute, they should be able to provide some information and documents to Dillon with respect to sewage issues;

- Resolute Bay is not a heavily fished area, due to the lack of fish. Shellfish and clams are not typically collected from the Bay area, but it was suggested that they be studied as these food items are considered as a delicacy by the local people;

- Schools of cod are noted to inhabit the bay area in the vicinity of the outfall, especially when forced close to the shore as a result of feeding whales in the area;

- The bay area is not specifically used by the community for fishing and the cod that are forced into the near shore area are not typically fished;

- Raw sewage is visible along the shoreline area in close proximity to the outfall location;

- No particular care is taken with respect to the substances being flushed. It is unknown (to the people of Resolute) whether DPW has any problems with their cleaning facility;

- There were several questions raised with respect to the acceptability of the current system (only grinding, no treatment) and constant flow towards the Bay. The community suggested that they would like an upgrade to a cleaning process to be done (e.g., filters at the very least) or any other appropriate improvement;

- Although significant concerns regarding the discharge of sewage at this location were not voiced, the potential impacts of the discharged sewage to the marine environment were identified as not being well known to the community;

- Should there be the potential for impact to the marine environment at this location it was noted that further study should be conducted to confirm it's significance and to identify/incorporate potential changes to the current sewage treatment system that would minimize those impacts and any community concern;

- One alternative identified was the relocation of the piped outfall location from its' existing location to a location south along the shoreline away from shoreline areas of use;

- Deep water discharge (e.g., 10-20 m off shore) would also be an acceptable alternative, from the prospective of the boat access, quick freezing which typically happens in the winter (which would be avoided if the discharge would be somewhere further from the shore), and to establish a deeper water discharge location and the enhancement of potential mixing;

- Discussion included the identification of requirements of the federal *Fisheries Act* and how it might apply to the current sewage treatment system and discharge at Resolute Bay;

- Compliance requirements of the Nunuvat Water Board and the associated water licence were also discussed resulting in the identification of current and historical licence compliance with the required discharge requirements.

In summary, no significant issues were raised by the community with regard to the discharge of sewage to the marine environment. However, they acknowledged that they were not totally familiar with what maybe the potential impacts. Certain activities that involve the processing of hunted seals and other mammals are conducted within the Bay and near shore areas the sewage smells and wastes are obvious to the residents at certain times. Certain food items, such as clams, are opportunistically harvested from the outfall area. Based on these issues it was noted that further consideration of these potential impacts should be reviewed.

6.0 REMEDIAL SYSTEM NEEDS

6.1 Water Mains

Future Capacity

The system was designed for a population of 1,500 people and a consumption of 225 lcd. The total daily average consumption for the original design was approximately 340,000 l/day. The projected 20 year demand based on the current growth rate and bleeder rate is approximately 183,000 l/day. Section 4 developed and completed a model for the distribution system to verify that there is sufficient capacity for the peak demand and the fire flow requirements. The model indicates that the fire flow demand is met by operating a valve in AV3 during the fire flow conditions. This should be verified as part of the standard operating procedures for the facility Maintainer.

One section of sewer main AV11 to AV32 is required to be increased to 250 mm to meet the design flows.

The flow requirements for the proposed new subdivision can be met through the expansion of the existing system. The new areas can be serviced with a 150 mm pipe line for the Water mains and the sewer mains.

The model was also run using 150 mm piping throughout the system. This run indicates that the 150 mm size will not meet the 20 year demand of the community. Therefore all replacement piping should maintain the 200 mm pipe size for the water main.

It should be noted that a significant amount of the system capacity is consumed through the use of the bleeders. These bleeders are not metered for flows. It would be useful to have actual measurements of the bleeder flows, bleed water temperature, as well as sewer pipe temperatures throughout the system. These measurements can be used to assess the required bleeder rates with the indent to reduce the overall bleed water consumption. As the community expands, this will become necessary to allow for the expansion of the system beyond the 20 year horizon to the 40 year planning horizon. The metres can be mechanical type metres, identical to house water metres. They should be read on a weekly bases and recorded by the Hamlet, and/or the system Maintainer. The cost to install the metres would be approximately $2,000 per unit.

The measurement of the sewer temperatures should be completed for each leg of the sewer system. This will allow for the balancing of the bleed water. The sewer flow temperature should be measured weekly and recorded by the Hamlet and/or DPW&S Maintainer. The temperature metres can be installed for approximately $1,000 per unit.

Once a year of data is collected, the information can be used to determine the required flows on a seasonal bases for the bleeder system. This will need to be fine tuned through the continued recording of the bleeder flow metres and the sewer temperature readings.

6.2 Sewage Discharge

The limited water quality data collected from the sewage discharge to Resolute Bay, and a sampling location 5-10 metres down current from the discharge location, tends to indicate that there is localized impacts to the marine receiving environment. The extent or magnitude of these impacts cannot be determined in detail based on the extremely limited data collected to date for water quality and for the biota inhabiting the marine receiving environment.

The Hamlet of Resolute Bay currently meets the discharge requirements of their water licence issued by the Nunavut Water Board. It is also apparent from the results that the strengths of the sewage could be increased two or three times and still meet compliance. This may occur in the bleeding rate is decreased over time.

Regardless of the bleeder rate, the total mass loadings of the contaminant to the receiving environment will remain consistent. The long term environmental and human impacts are more related to the mass loading, rather than the concentration of the discharge. There are impacts related to "shocks" to the marine system created by sudden increases in the contaminants of concern. This would be related to at shore organisms, only. As such, a reduction in the bleeding rate by 1 or 2 fold is not expected to impact the effects of the sewage and the receiving environment. To determine the long term impact of the sewage mass loadings, there is the requirement to collect and assess data at the marine environment. A summary is shown in **Table 5.2**.

Table 5.2
Summary of Information Required for Detailed Impact Assessment

Information/Data Required	Rationale
Physical	
- tidal information, wind speeds, wind directions, wave climate, etc.	- this information will help determine the magnitude and extent of any plume, etc. - also help address any dilution issues - much of this information should be readily available from Environment Canada
Chemical (i.e. water and sediment quality)	
- more detailed characterization of effluent and receiving environment water quality.	- current annual sampling results do not provide the necessary detail to assess diurnal variation in effluent characteristics - the current program also does not assist in the determination of the spatial extent of any effluent plume - this information would be used to determine average effluent concentrations
- include a control location in any sampling program perhaps in an adjacent bay	- control site data will provide a good comparison to sewage discharge results
- evaluation of dissolved oxygen levels within Resolute Bay	- given concerns with respect to oxygen depletion in the bay it would be worthwhile to determine oxygen levels in the bay particularly under the ice-cover.
- characterize sediment quality with the receiving environment	- determine distribution of any contaminants within the marine sediments - sampling program would be designed to delineate impacts from the sewage discharge and those potentially from the solid waste disposal site.
Biological	
Shellfish, such as clams (*Mya truncata)* should be sampled to assess potential shellfish contamination	- elevated coliform levels observed in the vicinity of the discharge could potentially result in shellfish contamination - clams are also excellent biomonitors for other contaminants such as metals.
Benthic-invertebrate communities	- benthic invertebrates provide excellent indicators of overall environmental quality - benthos information can be related back to water and sediment quality data to assess impacts

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APPENDIX A

Pipe Network Model Results

APPENDIX B

Cost Estimate Data

APPENDIX C

Impact Study - Community Consultation

TABLE OF CONTENTS

Page No.

TABLE OF CONTENTS (Continued)

Volume 3 - Sewage Treatment and Future System Expansion

Final Report - Revision 1

May, 1999

Volume 3 - Sewage Treatment and Future System Expansion
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