Report of the Natural Tundra Wetland Sewage Treatment Facility

CORAL HARBOUR, NU

Prepared for:
Nunavut Water Board, in support of
Licence Renewal Application NWB
#COR0207, Hamlet of Coral Harbour

Prepared by:
Nunami Jacques Whitford Limited
Rankin Inlet, Nunavut

October 2007

Table of Contents

List of Drawings

1 Introduction

The Hamlet of Coral Harbour has submitted an application to the Nunavut Water Board (NWB) for renewal of its Water Licence NWB3COR00207. The application requests that the natural tundra wetland currently providing sewage treatment for the community be officially acknowledged as the "Sewage Disposal Facility" and that compliance with effluent discharge quality standards be met at the discharge from the wetland or facility. This report is intended to provide supplementary information to assist the NWB in its review of the application for re- licencing.

1.1 Community Information

The Hamlet of Coral Harbour is located on the south shore of Southampton Island in the northern portion of Hudson Bay, Nunavut. The geographic co-ordinates of the community are 64^0 08'N, 83^0 10'W. The location of the community is illustrated on Drawing 1 in **Appendix A**.

The Hamlet is situated in the zone of continuous permafrost in the Canadian Shield. Tundra vegetation overlies bedrock, which is mainly Paleozoic marine limestone. There are gravel and fine deposits in low-lying areas, scattered boulders, muskeg and exposed rocks, often in the form of ridges a few meters to a hundred meters or more in length, usually oriented north-south. The area is characterized by low relief and many shallow surface water bodies.

The average annual precipitation in the Coral Harbour area consists of 141 mm of rainfall and 1,319 mm of snowfall, resulting in an annual total of approximately 273 mm of precipitation as rain. The July mean high and low temperatures are 13.1^oC and 4.2^oC, respectively. The January mean high and low temperatures are -25.5^oC and -33.8^oC respectively.

The population of the community was estimated at 789 in 2006 by the Bureau of Statistics of the Government of Nunavut (Nunavut Bureau of Statistics, 2007). Economic activities include tourism, arts and crafts and public services. Electrical services are provided by the Nunavut Power Corporation, while the Hamlet provides trucked water, sewage and waste disposal services. The community has regularly scheduled air service. However, most supplies arrive annually by barge during the open water period.

1.2 Current Wetland Treatment System

Available documentation confirms that sewage has been discharged from sewage trucks to a location on the tundra approximately 3 km north of the community since at least 1984. In response to concerns expressed by regulatory authorities, a lagoon was constructed at the sewage drop off site in 2003. The lagoon was to operate as a typical storage and treatment lagoon, storing sewage for approximately 10 months each year followed by discharge in the fall. However, the berms of the lagoon are not impermeable and during the period between May and October effluent seeps through the berms in the east and south-east boundaries of the cell. Effluent leaving the detention cell flows through a tundra wetland in the same manner as before the lagoon was constructed. Currently, the lagoon provides some primary treatment through settling of solids. Wastewater effluent flows through the wetland in a combination of defined channels, overland and underground flows. Several ponds are present in the wetland, providing for increased retention time during treatment.

The wetland treatment area slopes from west to east, with an elevation drop of approximately 10m between the base of the lagoon and the proposed licence compliance point. The area is characterized by bedrock ridges interspersed with shallow deposits of fine grained soil. Vegetation typically consists of lichen and mosses on the ridges with shrubs and grasses in the areas where soil is present. Vegetation is lush along shorelines and low lying areas, likely as a result of the nutrients from the sewage effluent. Significant algae growth was observed in the pools and channels close to the lagoon; however, little algae were observed at the proposed SNP location. Geese and ducks frequent the wetland, primarily during spring. Caribou have also been observed in the wetland. No evidence of human activity in the wetland was observed during site visits

.

2 Introduction to Treatment Wetlands

2.1 Wetlands

Wetlands are defined as lands which are seasonally or permanently inundated by shallow water. There are various kinds of wetlands: **Natural Wetlands, Created Wetlands** and **Constructed Wetlands**. Created and constructed wetlands are artificial systems, designed and built for specific purposes. Created wetlands are those wetlands built for purposes other than wastewater treatment (e.g., recreation, habitat creation, mitigation). For example, Ducks Unlimited is a major constructor of created wetlands for habitat purposes.

Constructed wetlands consist of two main categories: those for water quantity control (stormwater wetlands) and those for water quality control - wastewater contaminants' removals/mitigations. The latter, to which the term constructed wetlands is more generally associated, can be used to treat municipal wastewaters (e.g., raw or partially pre-treated sewage), agricultural wastewaters (e.g., manure pile leachates) or industrial wastewaters (e.g., discharged process water and acid drainages from mining operations).

Both natural and constructed wetlands can be used for wastewater treatment (WWT) and where they do so they also are referred to as treatment wetlands.

Treatment wetlands will remove a variety of materials from any water passing through them. Surfaces under wetland water surfaces are all coated with microbial biofilms made up of complex communities of many kinds of bacteria, fungi and other microbes, and in them the bulk of WWT occurs (although some treatment also occurs in the plants directly and via planktonic microorganisms in open water areas).

Algae and aquatic plants in wetlands release oxygen as by-products of their growths. This increases the dissolved oxygen content in water and in soil/substrates in the vicinity of plant roots, thereby allowing aerobic microbial reactions to occur in an otherwise anoxic environment, supplementing the anaerobic reactions that also occur. Accordingly, wetlands can be used to treat pollutants which enter them in sewage streams, leachates, and/or surface runoff from non-point pollution sources by involving both aerobic and anaerobic removal mechanisms. Treatment wetlands therefore are kinds of natural, largely solar-powered WWT facilities.

The following are the main pollution removal processes involved in treatment wetlands:

SETTLING & FILTRATION

Suspended Solids		**Sediment**
Particulate COD	→	Sediment COD
Particulate Nitrogen	→	Sediment N
Particulate Phosphorus	→	Sediment P
Some Heavy Metals	→	Sediment

BIOACCUMULATION

plants, biota
Soluble Phosphorus → Organic P

plants, biota
Soluble Nitrogen → Organic N

plants
Some Heavy Metals → Phytoextraction

CARBON OXIDATION

bacteria, O_2
Organic Carbon → Carbon Dioxide

ANAEROBIC DIGESTION

bacteria
Organic Carbon → CO_2, Methane

NITROGEN MINERALIZATION

bacteria
Organic Nitrogen → Ammonia Nitrogen

NITRIFICATION

bacteria, O_2
Ammonia Nitrogen → Nitrate Nitrogen

DENITRIFICATION

bacteria, carbon
Nitrate Nitrogen → Nitrogen Gas

The use of wetlands for treating or polishing wastewaters has a number of advantages, including that they:

- Provide effective and reliable wastewater treatment;
- Are relatively inexpensive to adapt or even construct;
- Are relatively economical to operate and have low labour requirements;
- Are easy to maintain and have low energy requirements;
- Are able to accept varying quantities and concentrations of pollutants;
- Are quite tolerant of fluctuating hydrologic and contaminant concentration conditions;
- Provide various indirect aesthetic benefits (e.g., habitat, green space, recreation); and
- Can be readily associated with other kinds of natural WWT facilities (e.g., lagoons, detention cells, sedimentation ponds, biofilters) to provide enhanced WWT.

However, using treatment wetlands for WWT is not a panacea. There are disadvantages to the use of these wetlands for WWT, including that they:

- Require large land areas;
- Are ecologically and hydrologicaly complex;

- Can lead to pest problems (e.g., mosquitoes);
- May not prove practical in some situations where local conditions (topography, drainage, soils, etc.) are not suitable;
- If constructed, may require some time before optimum efficiency is achieved;
- Do not have many years of experience to draw on so far as demonstrated technology is concerned;
- May be unfamiliar to regulatory authorities who may not have precedents;
- Be subject to erroneous negative perceptions as many early ones were mis-designed; and
- Operate at lower efficiencies during winter.

2.2 Natural Wetlands

Natural wetlands are those areas wherein, at least periodically, the land supports predominantly hydrophytes (water-loving plants) and whose substrate is predominantly un-drained hydric (i.e., saturated anoxic) soils, or where the substrates are non-soil and are saturated with water or covered by shallow water at some time during the growing season each year (Hammer, 1996). Flooding-intolerant vegetation is absent from them. Natural wetlands are found in surface depressions, and alongside streams, lakes and the sea; they often provide the interfaces between fully aquatic and terrestrial ecosystems. Waters in natural wetlands are generally less than two meters deep (and often very much shallower), and may stand/flow both on the surface and sub-surface in/via soils and substrates. Regular to erratic drying cycles may occur in all or part of natural wetlands. Water level fluctuations are normal in them, and morphologies usually are complex, with many flow channels, backwaters, and other heterogeneous areas.

Around the world, there are many names for different kinds of natural wetlands (e.g., tidal marshes, billabongs, carrs, mires, and mangrove swamps to name only a few) but the official designations for them in Canada are: marshes, swamps, bog, fens and shallow open water wetlands.

Marshes are areas permanently or periodically inundated and dominated by stands of emergent herbaceous vegetation such as cattails and reeds. Waters in them are neutral in pH, relatively high in dissolved oxygen and nutrients, and are generally moving. Open water areas in them may also contain floating plants (e.g., duckweed) and submergent plants (e.g., wild celery). As with other herbaceous vegetation-dominated natural wetlands, a few bushes and trees may also grow in marshes.

Swamps are wooded natural wetlands with water-logged sub-surface areas in which shrubs, bushes (e.g., willow, dogwood) and trees (e.g., white cedar) are the dominant vegetation, although some herbaceous plants are usually present among them. Waters in swamps tend to be standing or slowly moving most of the time.

Bogs are peat-covered low/no flow areas dominated by Sphagnum moss and other ombiotrophic (isolated from water sources other than precipitation) and acidophilic (thriving under acidic conditions) vegetation. Waters in bogs are low in pH, calcium, magnesium and nutrients (nitrogen and phosphorus compounds). While moss and similar herbaceous plants are the most prevalent vegetation, where conditions allow, some shrubs, low bushes and trees such as white cedar, tamarack and black spruce may grow in them too.

Fens are another kind of peatland typified by high water tables and slow internal drainage. Like bogs, herbaceous plants are the dominant vegetation in them (e.g., leather leaf), although a few shrubs (e.g., bog rosemary) and trees (e.g., willows) also may be present. Waters in fens tend to be mineral rich.

Shallow Open Water natural wetlands are ponds (potholes, sloughs, depressional basins) of standing or flowing water transitional between lakes and marshes. They often have emergent herbaceous plants growing on their peripheries and in shallower areas, and floating and submergent vegetation in the open water.

Natural wetlands are biologically extremely diverse. Seasonal and annual variations in a wetland can dramatically alter vegetation, microbial communities and wildlife in and around the wetland. Natural wetlands are ecologically important as they: provide habitat and corridors for wildlife movement; aid in flood control; protect shorelines from erosion; control and store surface water; trap sediments; immobilize contaminants and nutrients; and maintain and improve water quality.

Natural wetlands are generally used for WWT only if they already exist convenient to a wastewater source. Because of their heterogeneous natures, where they are used for WWT, very much larger areas are required for them to ensure adequate treatment. In the past, a commonly accepted hydraulic loading rate (wastewater flow rate over wetland area) for natural wetlands treating domestic sewage was 27.6 ha of wetland surface area per 1000 m^3/d of sewage flow introduced (expressed more commonly as 0.36 cm/d), but more recent studies indicate that up to 7 cm/d can be appropriate if conditions are right, some pre-treatment has occurred, and the wetland can be “engineered” to ensure maximum contact between the wastewater being treated and the vegetation/microbial biofilm matrices in the wetland (Knight *et al.*, 1987). However, a more conservative recommendation is for 50 ha/1000 m^3/d (0.2 cm/d) for municipal wastewaters (Kadlec & Knight, 1996), especially where cold weather conditions are encountered and there is untreated ammonia nitrogen in the wastewater being treated.

It is important to note that the addition of a wastewater to a natural wetland will dramatically alter its ecology and biology. Temperature, flow regime, pH, water levels, plant growth/speciation, etc., will change. Nutrient-deficient, standing-water ones such as bogs may be converted into flowing systems and the plants in them will proliferate in the new positively stressed conditions that favour their growth.

2.3 Constructed Wetlands

Constructed wetlands (CWs) for WWT represent an environmental/biological technology (ecotechnology) that is now well developed. Unlike the situation with natural wetlands, water flow (and water level) in a CW is controlled, water is always present, and the plants used in them are often monocultures of herbaceous emergents such as cattails or reeds. Hydraulic design is for maximum wastewater/biofilm contact. Wetland plants are dormant in winter and pollutant removal from biological reactions becomes slower as the water temperature drops.

Modern CWs often consist of a number of individual, often rectilinear basins (cells) connected in series and surrounded by berms of earth, clay, rock, or concrete. Wastewater being treated in them often flows in either a single flow path (train), or in two or more parallel trains of one or more cells. These passive treatment systems (CW systems) also can include a variety of ancillaries (e.g., pumps, ditching, cascades, land treatment fields). Surge ponds and lagoon cells often complement the vegetated CW cells, (both in front and/or behind the CW cells) and are themselves regarded as cells of the CW system. There are many tens of thousands of these natural systems treating wastewaters of all sorts worldwide.

Three types of vegetated cells are used in CW systems: **pond** cells, **free water surface** (FWS) cells, and **sub-surface flow** (SSF) cells.

Pond wetlands, as the name suggests, are simple shallow pools, usually vegetated with emergent wetland vegetation (e.g., cattails) around the peripheries (10 to 30% of area) and having some portion of their surface consisting of open water in which submergent and/or floating wetland vegetation is growing. They are most commonly used in conjunction with other types of wetlands cells (e.g., as re-aeration basins between FWS cells in the common marsh (FWS) - pond-marsh kind of CW treatment system.) Pond wetlands provide quiescent areas where sediments and some of the suspended solids in a wastewater can settle out. Hence, pond wetlands are good methods for dealing with any suspended solids, and the biological oxygen demand (BOD), oil & grease, pesticides & herbicides, fertilizers, heavy metals and other organics which become associated with them in many wastewaters. (Pond wetlands differ from WWT lagoons in that they are always deliberately vegetated with wetland plants and most lagoons are not. In addition, they are usually shallower than WWT lagoons, and hence tend to be more aerobic than often-deeper, facultative lagoons [due to easier surface re-aeration]).

Free water surface (FWS) CWs are artificial marsh ecosystems in which water flows on the surface through largely emergent herbaceous wetland vegetation (e.g., cattails). In them, the submerged portions of the wetland plants, as well as the wetland soil/sediment and detritus, act as substrates for microbial biofilms. These biofilms and physical filtration are responsible for much of the removals of contaminants from wastewaters passing through them. FWS constructed wetlands are the most common type of constructed wetland in North America.

With sub-surface flow (SSF) CWs, the wastewater being treated flows just under the surface of porous materials (substrates) consisting of beds of gravel, sand or rock. SSF wetland cells may be horizontally fed (HSSF cells), or the wastewater may move vertically in the substrates (VSSF cells). With SSF CWs, wetland vegetation grows out of the substrate surfaces (usually gravel) of the wetland cells and it is possible to walk dryshod on their normally dry surfaces if one can get in among the normally dense stands of emergent vegetation. Microbial aerobic and anaerobic biological reactions in the highly porous biofilm/root system matrix in the interstices of the gravel substrate of a SSF CW are responsible for most of the pollutant removals from wastewaters passing through, not the wetland plants.

SSF CWs are smaller and more efficient than FWS CWs, but often are more costly to build because of higher design and substrates costs. Full scale, SSF wetlands treating relatively high volumes of influent (>15 L/s) are already operating treating stormwater (Higgins & MacLean, 1999), and ones treating even larger volumes of water are being designed and built.

The ultimate in constructed wetlands is the engineered wetland. Engineered wetlands (EWs) are advanced forms of CWs that involve more active manipulation of process conditions than is usual for ordinary, constructed wetlands (which are largely passive systems). For example, EW systems may involve aspects such as cell aeration, the addition of chemicals and/or energy, active phytoremediation, and/or use of specialty substrates that chemically interact with certain wastewater pollutants. Engineered wetland cells can be of the pond, FWS or SSF varieties, but are more commonly SSF ones.

As mentioned above, the removal of many pollutants such as ammonia in a treatment wetland is dependant on microbially-mediated aerobic transformations. The needed oxygen for such reactions can be supplied by wetland plants which “pump” air to microbes in their root zones but there is only a limited amount of oxygen that can be provided in this way. Various other ways are used to overcome this limitation. A simple one is to provide open water areas where surface re-aeration can restore dissolved oxygen to the wastewater being treated, and the marsh-pond-marsh design mentioned above has often been used to facilitate this. Another way is to add air to the wetland cells by placing mechanical aerators in pond cells or open water areas of FWS CWs, or by using submerged perforated or diffuser piping through which air is introduced into the water or under the substrates in SSF wetland cells. By improving aeration, ammonia nitrification rates can be increased to over 95%. With semi-passive EW systems (as compared to passive, ordinary CWs) mechanical methods such as sub-surface aeration from blowers or compressors is often used to greatly enhance performance.

2.4 Treatment Wetlands in the Arctic

Over 45% of all natural wetlands lie above 45º North Latitude, and these are largely tundra, muskeg, taiga and coastal marsh wetlands. Prior to the division of Nunavut from the Northwest Territories, the territories had the second highest total of natural wetland area in Canada, second only to Ontario.

Peatlands of various sorts (bogs, fens) dominate northern natural wetlands. An important northern kind of arctic natural wetland is the **tundra wetland**, a kind of bog/pond mixed wetland. Tundra wetlands may be viewed as almost the natural analogues of marsh-pond-marsh constructed wetlands, and consist of combinations of boggy areas and small ponds. The latter are spongy accumulations of living and dead Sphagnum moss, lichens and other vegetation; the dead plants usually only partly decomposed. Water flow through these areas is partially sub-surface and partly via surface channels. The other aspect of tundra wetlands is numerous shallow ponds that have no drainage to groundwater in the short summers due to underlying permafrost. Frost heaving during winter creates ridges and depressions with unique polygon configurations. In summer in the north, long days lead to the proliferation of algae in tundra wetland ponds, and photosynthesis leads to highly oxic conditions in them.

Three arctic natural treatment wetland systems (Baker Lake, Repulse Bay & Chesterfield Inlet) were studied by Dillon (1997). In the study, Dillon cited work by Hartland-Rowe and Wright (1974) at Hay River and Reid Crowther (1990) at Yellowknife, which, along with other studies indicated that wetlands in the north have the potential to provide efficient secondary and tertiary treatment. Dillon indicated that over the sampling period (early/late June to late August/early September), all three wetlands exhibited pollutant removal rates equal to or better than that expected from an annual storage lagoon.

Jacques Whitford (2003a) reviewed the sewage treatment facilities in Yellowknife, NT, which combines an initial "lagoon" (actually a series of connected natural ponds converted to WWT use) followed by a series of natural wetlands. Jacques Whitford concluded that the best available technology to achieve compliance with the most stringent effluent standards was to convert the system into an engineered wetland; one which would combine the lagoon treatment with aeration (and possibly chemical phosphorus precipitation in the lagoon), followed by natural wetland treatment in wetland areas "engineered "to enhance wastewater/wetland contact.

A review of Chesterfield Inlet's wetland treatment system in 2003, by Jacques Whitford, recommended further study involving field and lab sampling and analyses. Preliminary results presented by Jacques Whitford demonstrated that the long hours of sunlight in summer in the arctic enabled algae to persist in an oxygen generating mode that resulted in water supersaturated with oxygen. This situation enhances sewage breakdown. In addition, the consumption of carbon dioxide by algae resulted in pHs often greater than 10 which, while above licence guidelines, created conditions in the wetland where ammonia stripping to very low levels occurred

3 Tundra Wetland Performance Evaluation

3.1 Analysis

A number of investigations have been undertaken to evaluate the treatment performance of the tundra wetland in Coral Harbour. A summary of key findings is presented below.

UMA Engineering Ltd., Coral Harbour Sewage and Solid Waste Improvements (1994)

This study was summarized in the 2002 FSC Report, with the key findings including:

- Sewage discharge should be into a “lagoon” with discharge control. The main purpose of the lagoon would be to retain solids and it would not be expected to treat other contaminants.
- Existing natural wetlands downstream of the lagoon should provide adequate treatment.
- Mechanical treatment was not recommended due to extreme operating conditions, including temperature, the distance and limited access for maintenance, intermittent high strength waste, and limited availability of trained personnel.

Arctic Environmental Services Review of Natural Wetlands System (1994)

Arctic Environmental Services (AES) was commissioned by the Government of the Northwest Territories to determine the effectiveness of the existing natural wetlands treatment system and to identify any necessary changes to address public health concerns. Key findings included:

- The existing natural wetland provided good effluent treatment, with 90% removal of BOD/TSS and ammonia within 600 m from the sewage truck discharge point. The first two downstream ponds had a combined detention time of 94 days, and the next pond had a detention time of 236 days.
- There was no reason to enhance the flow patterns through the wetland system.
- A wastewater analysis indicated heavy metals were not present in effluent, but there was a negative impact on water quality from landfill leachate seeping from the Hamlet’s landfill located alongside the sewage discharge point.
- Flow from the sewage discharge point was to the east and south.

Ferguson Simek Clark (FSC) – Sewage Treatment and Solid Waste Improvements (2002)

The objective of this study was to develop a design for a new access road, dumpsite and sewage detention pond. Key findings included:

- The total area covered by the existing natural treatment wetland system was estimated at approximately 10.5 ha, which includes approximately 7 ha of ponds and the remaining 3.5 ha covered by soils. Primary vegetation in the area was reported to be cotton grasses and sedges.
- Effluent flows were predominantly to the southeast towards the ocean. Effluent flows were reported through the toe of the expanding solid waste facility.
- The existing natural wetland system is sufficient for treating sewage for the next 20 years.
- Flow attenuating berms to direct the effluent were recommended.

Jacques Whitford Limited - Study of Wetland Sewage Treatment Area (2005)

Jacques Whitford conducted an investigation of the Tundra Wetland Sewage Treatment Area in 2004, involving a site investigation to evaluate effluent flow directions, collection and analysis of effluent and water samples throughout the wetland and an overall evaluation of the effectiveness of the wetland in meeting current and anticipated regulatory requirements. A geotechnical investigation of the detention cell berms and surrounding areas was also undertaken. Key findings of the study included:

- The tundra wetland is effectively treating sewage effluent from the detention cell to existing Water Licence effluent quality standards and anticipated criteria to be implemented by Environment Canada;
- Toxicity testing confirmed that effluent at the proposed compliance point in the wetland is not toxic to fish;
- Metals were detected in effluent, likely resulting from landfill leachate;
- The wetland could meet treatment requirements for a 20 year planning horizon;
- Flow diversion berms should be installed in three key locations to divert effluent flows during periods of high flow (spring freshet).

Community and Government Services, Site Investigation Report for the Sewage Disposal System in the Hamlet of Coral Harbour (2005)

CGS Staff conducted effluent sampling at locations in the wetland (locations sampled by Jacques Whitford in 2004) in July and August 2005. Based on the analytical results from the samples collected, CGS concluded that effluent discharged from the detention cell met current water licence effluent quality standards and CCME Water Quality Guidelines for the Protection of Aquatic Life at the proposed compliance point in the wetland treatment area.

Community and Government Services, Analysis of the Sewage Wetland in Coral Harbour (2006)

CGS Staff conducted additional effluent sampling in June and July 2006 at locations sampled in 2005. CGS concluded, with the exception of some metals, effluent met current water licence effluent quality standards at the proposed compliance point in the wetland treatment area. Metals in excess of CCME guidelines were detected in some samples, likely a result of landfill leachate which also enters the tundra wetland.

Schematic Design Report - Nunami Jacques Whitford (August 2007)

This report summarizes the results of site visits during the spring and summer of 2007 and presents options for the Hamlet to achieve compliance with effluent quality standards in its current and future water licence. Key findings of this report include:

- Treatment of sewage effluent in the tundra wetland during spring is achieving compliance with licence effluent quality standards;
- Based on effluent loading rates and wetland size, the tundra wetland is capable of meeting effluent quality standards for a 20 year horizon;
- Recognition of the tundra wetland as the “Sewage Disposal Facility” was a more practical and cost effective method of treating municipal sewage than repairing the lagoon;
- Improvements to the tundra wetland to address the concerns of inspection agencies should be undertaken as a commitment under the new licence, including installation of diversion berms to divert potential effluent flows away from the community during periods of high flow, and signage should be installed to advise the public of the extent of the wetland treatment area.

3.2 Summary

The treatment performance of the Natural Tundra Wetland Sewage Treatment Area has been subject to numerous studies since 1994. All investigations concluded that the wetland was effectively treating the sewage effluent and could continue to do so in the future. Review of analytical data from effluent samples collected throughout the wetland annually since 2004 confirms that the wetland is currently treating sewage effluent to effluent quality standards contained in the Hamlet's current Water Licence. However, the Water Licence specifies compliance be achieved at the discharge from the "Sewage Disposal Facilities" which is considered to be the discharge from the detention cell. The current licence does not formally recognize the treatment provided by the tundra wetland. An examination of the existing lagoon has concluded that it is not practical or cost effective to repair the lagoon. Therefore, it is proposed that the next Water Licence issued to the Hamlet recognize the tundra wetland as the "Sewage Disposal Facility" with compliance with effluent quality standards to be met at the outflow of the wetland, sampling station # 5. Several enhancements to the wetland are proposed to be undertaken during 2007/08 to address concerns expressed by inspection personnel over the past several years. The proposed "Sewage Disposal Facility" to be recognized in the next Water Licence is described in the following section.

4 Proposed Sewage Disposal Facility

4.1 Introduction

The Hamlet of Coral Harbour requests that the natural tundra wetland that has effectively treated municipal sewage for the past 20+ years be formally recognized as the "Sewage Disposal Facility" in its next water licence. The facility will include the existing detention cell (lagoon) and the natural tundra wetland described in this report and outlined on Drawing # 3. Compliance with effluent quality standards contained in the licence would be met at the discharge from the wetland, sampling station # 5, illustrated on Drawing #3.

The capacity of the wetland to treat sewage over the long-term can be calculated based on loading rates and area of treatment. In the past, a commonly accepted hydraulic loading rate (wastewater flow rate over wetland area) for natural wetlands treating domestic sewage was 27.6 ha of wetland surface area per 1000 m^3/d of sewage flow introduced (expressed more commonly as 0.36 cm/d), but more recent studies indicate that up to 7 cm/d can be appropriate if conditions are right, some pre-treatment has occurred, and the wetland can be "engineered" to ensure maximum contact between the wastewater being treated and the vegetation/microbial biofilm matrices in the wetland (Knight et al., 1987). However, a more conservative recommendation is for 50 ha/1000 m^3/d (0.2 cm/d) for municipal wastewaters (Kadlec & Knight, 1996), especially where cold weather conditions are encountered and there is untreated ammonia nitrogen in the wastewater being treated.

Based on the conservative natural wetland sizing criteria of 50 ha/1000 m^3/d (0.2 cm/d), the minimum size of a natural wetland to treat the 2027 annual sewage generation rate (47,857 m^3 or 131 m^3/d) would be 6.6 ha. The boundary of the proposed natural wetland treatment system encloses an area of approximately 480,000 m^2 of which 80,000 m^2 are shallow bodies of water and 400,000 m^2 are boggy areas. With the proposed berm construction and the tundra wetland area defined as illustrated in Figure 3, the working tundra wetland size is estimated to be at least 200,000 m^2 or 20 ha. The tundra wetland is much larger than the 6.6 ha of minimum natural wetland size needed under conservative assumptions. The detention cell constructed in 2003 has a surface area of approximately 2.6 ha. Based on these calculations and assumptions, the natural wetland has sufficient area to treat wastewater for the next 20 years.

4.2 System Enhancements

The proposed wastewater treatment system begins at the current disposal location. Sewage haulers transport untreated sewage to the existing sewage detention cell and dispose of the wastewater in the cell. The detention cell begins the treatment process. During the cold period of the year (October to May) effluent will freeze within the lagoon. During melt and the warmer months effluent seeps through the detention cell berms and enters the natural tundra wetland where it flows through a combination of channels, ponds and overland and underground flows, eventually discharging to a large lake (Sampling Station # 5). On occasion during the spring freshet when high flows are encountered, partially treated effluent may flow toward the community. Flow diversion berms are proposed to direct this water back to the east and towards the proposed compliance point. The location of these berms is illustrated in Drawing 3 in Appendix A.

The berms will be constructed on the native ground material and will be located between bedrock outcrops. Coarse gravel will be placed on the ground to a height of 500 mm. A 300 mm layer of sand will be placed on top of the gravel layer. An impermeable high density polyethylene (HDPE) liner will be placed on the sand layer. The liner will be anchored into the berm and into the native ground material as best as practical. The liner will then be covered by another 300 mm layer of sand. The entire berm will then be covered with 600 mm of coarse gravel to provide erosion control and provide a surface for driving on the berms to inspect their effectiveness and complete maintenance, if necessary. A cross section of the diversion berm is shown in Drawing 4 in Appendix A.

By leaving the native ground material in place, the permafrost layer should build up over time and provide an impermeable layer to prevent water from flowing under the liner material. The liner will be anchored as deep as possible; however, shallow bedrock will limit the anchor trench depth in some areas. The liner will also be anchored in the diversion berm to hold it in place during the next layer of material placement.

In addition to the diversion berms signs are proposed to be constructed and installed along the perimeter of the wetland to advise the public of the existence of the wetland treatment area. Proposed wording for the signs is as follows: “Natural Tundra Wetland Sewage Treatment Area, Public Use Not Recommended”. This message would appear in English and Inuktitut.

5 References

Arctic Environmental Services Ltd. (AES), 1994. “Review of the Natural Wetlands Sewage Disposal System at Coral Harbour, NWT”. Prepared for the Department of Municipal and Community Affairs, Government of the Northwest Territories.

Dillon Consulting Limited. 1998. “Sewage Treatment Using Tundra Wetlands.” Prepared for the Department of Municipal and Community Affairs, Government of the Northwest Territories.

Department of Community & Government Services, 2005. “Site Investigation Report for the Sewage Disposal System in the Hamlet of Coral Harbour.”

Department of Community & Government Services, 2006. “Analysis of the Sewage Wetland in Coral Harbour.”

EBA Engineering Consultants Ltd., 2004. “Draft Sewage Dyke Evaluation, Coral Harbour, NU. Submitted to Jacques Whitford Limited.

Ferguson Simek Clark Engineers and Architects, March 2002. “Coral Harbour Sewage Treatment and Solid Waste Site Improvements” Prepared for the Department of Community Government and Transportation, Government of Nunavut.

Hartland-Rowe, R.C.B and P.B. Wright. 1974. “Swamplands for Sewage Effluents, Final Report.” Environmental - Social Committee, Northern Pipelines, Department of Indian and Northern Affairs. Ottawa, Ontario.

Higgins, and MacLean, 1999. “Constructed Wetland Treatment Systems for Airport Stormwater Runoff Which Do Not Attract Wildfowl,” Presentation to SAE G-12 Committee, Glycol Deicing, J. Higgins, and M. MacLean, Nov. 9, 1999, Washington, DC, USA.

Indian and Northern Affairs Canada, 2003-06. “Water Licence Inspection Reports”. Nunavut Water Board Licence # NWB3COR0207.

Jacques Whitford Limited, 2003. “Fiddler’s Lake Sewage Lagoon Treatment Study”. Prepared for the City of Yellowknife. Yellowknife, Northwest Territories.

Jacques Whitford Limited, 2003b. “Environmental Liability Assessment at Chesterfield Inlet, Nunavut.” Prepared for the Hamlet of Chesterfield Inlet. Nunavut.

Jacques Whitford Limited, 2005. “Study of Wetland Sewage Treatment Area, Coral Harbour, Nunavut.” Prepared for the Department of Community and Government Services, Government of Nunavut.

Kadlec & Knight, 1995 “Treatment Wetlands” R. Kadlec & R. Knight, (First Edition), CRC Press, Boca Raton, FL.

Knight et al., 1987 “Performance Of A Natural Wetland Treatment System For Wastewater Management”, R. Knight, T. McKim, and H. Khol, *J. Water Pollut. Control Fed*., 59:746-754.

Nunami Jacques Whitford, 2007. “Schematic Design Report, Natural Tundra Wetland Sewage Treatment Area Design, Coral Harbour, Nunavut” Prepared for the Department of Community and Government Services, Government of Nunavut.

UMA Engineering Ltd. 1994. “Coral Harbour Sewage and Solid Waste Improvements: Design and Operations Concept Report.” Prepared for the Department of Municipal and Community Affairs, Government of the Northwest Territories.

Appendix A Drawings

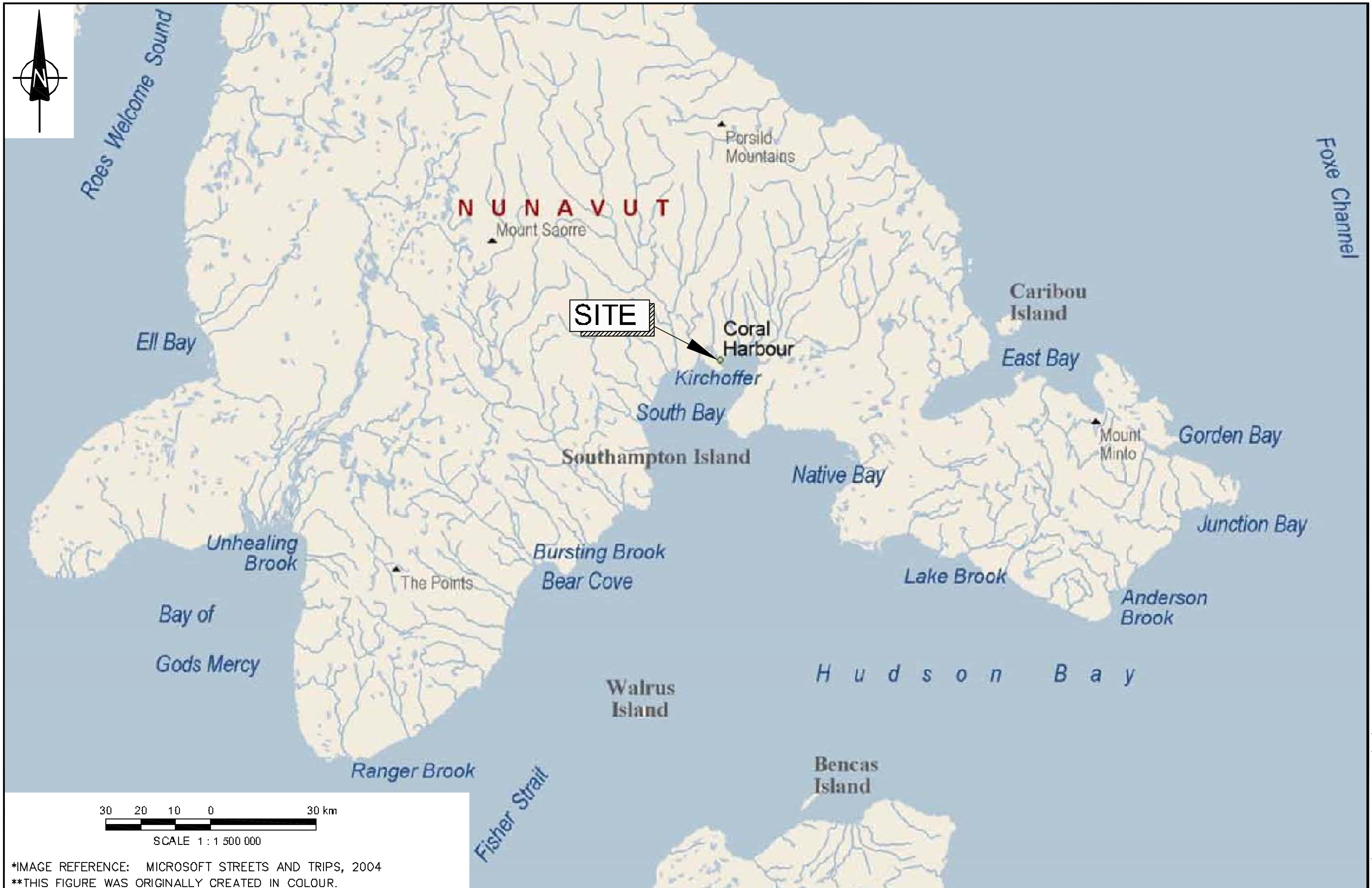
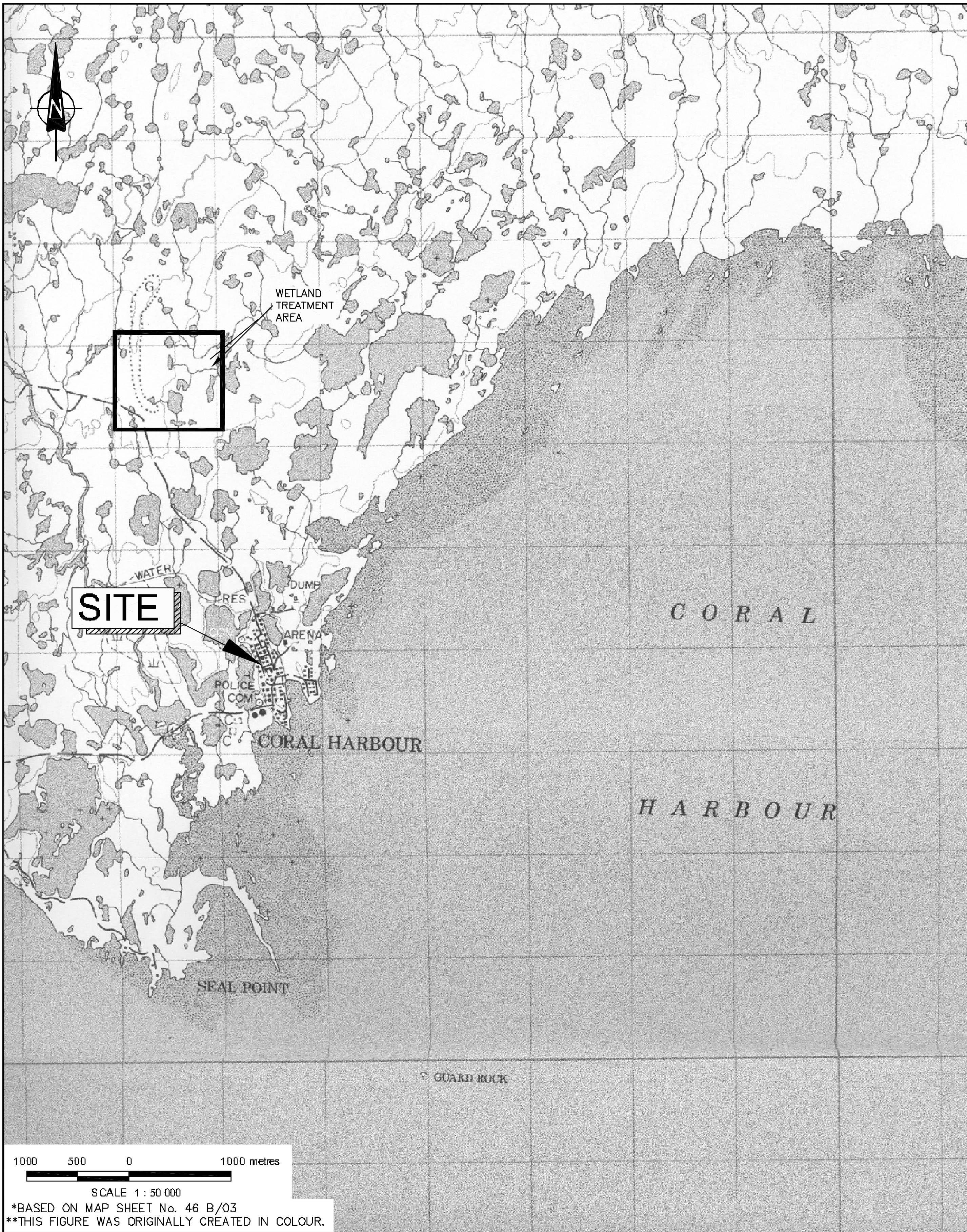


*IMAGE REFERENCE: MICROSOFT STREETS AND TRIPS, 2004
**THIS FIGURE WAS ORIGINALLY CREATED IN COLOUR.

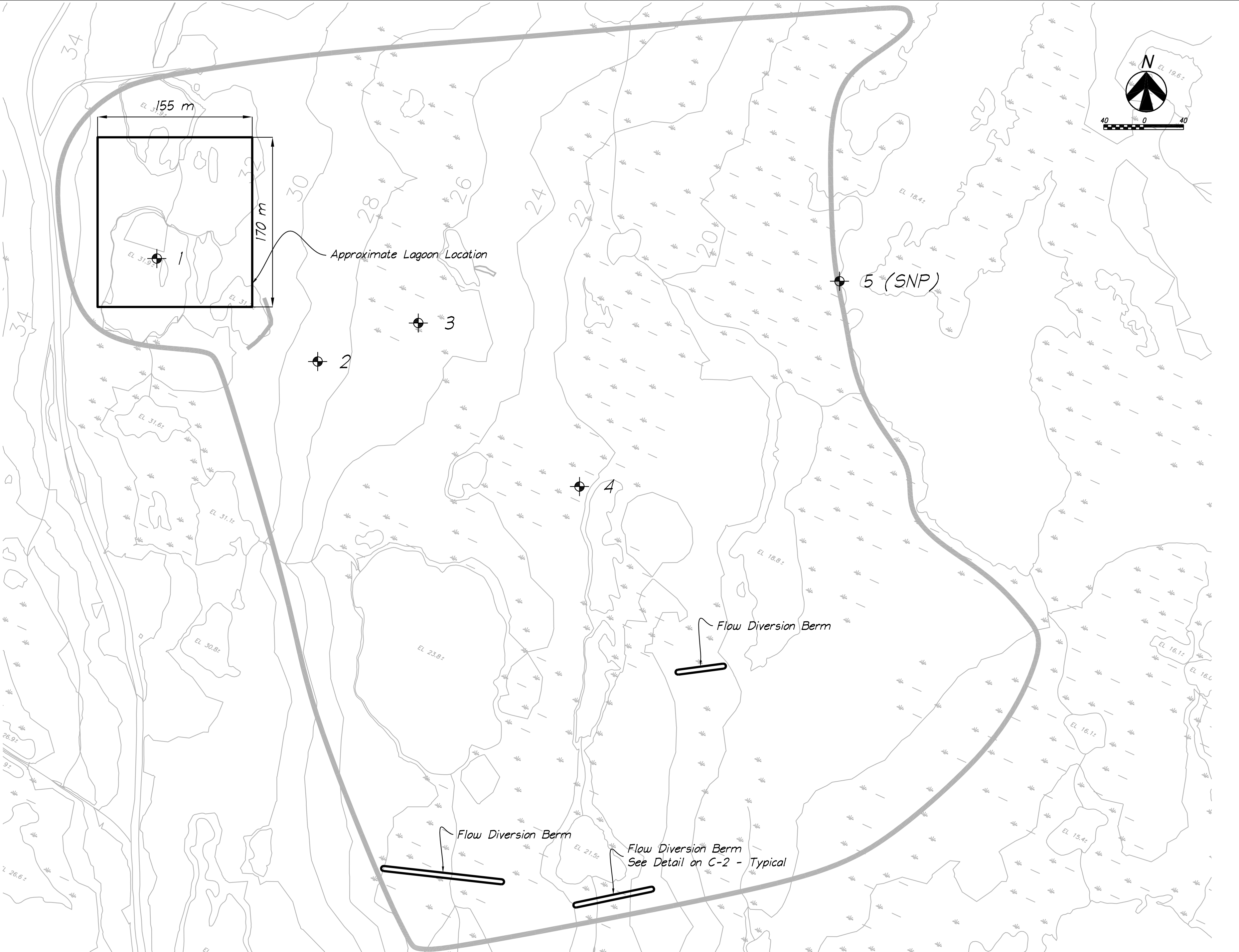
Jacques Whitford	SCALE: 1 : 1 500 000	CLIENT : GOVERNMENT OF NUNAVUT DEPARTMENT OF COMMUNITY AND GOVERNMENT SERVICES	DRAWING NO. 1
	DATE: 06/12/04	TITLE : SITE LOCATION PLAN	
	DRAWN BY: LDP	CORAL HARBOUR SEWAGE SYSTEM	
	APPROVED BY:	CORAL HARBOUR, NORTHWEST TERRITORIES	

\\Other_off\NTY\NTY71091\71091-1.dwg 06/12/04



Jacques Whitford	SCALE: 1 : 50 000	CLIENT : GOVERNMENT OF NUNAVUT DEPARTMENT OF COMMUNITY AND GOVERNMENT SERVICES	DRAWING NO. 2
	DATE: 08/12/04	TITLE : **SITE PLAN**	
	DRAWN BY: LDP	CORAL HARBOUR SEWAGE SYSTEM	
	APPROVED BY:	CORAL HARBOUR, NORTHWEST TERRITORIES	

\\Other_off\NTY\NTY71091\71091-3.dwg 06/12/04



Draft - Not For Construction

Jacques Whitford NAWE
Jacques Whitford NAWE, Inc
4444 Centerville Road, Suite 140
White Bear Lake, MN 55127
651-255-5050
651-255-5060 (fax)

Rev	Date	Description
0	8/15/07	Issue for Review

GOVERNMENT OF NUNAVUT DEPARTMENT OF COMMUNITY AND GOVERNMENT SERVICES
PROPOSED SYSTEM IMPROVEMENTS
CORAL HARBOUR SEWAGE SYSTEM
CORAL HARBOUR, NORTHWEST TERRITORIES

Site Map

#3

1023336-Fig 1.dwg

K:\1023336 Coral Harbour\dwg\1023336-Fig 1.dwg

Appendix B Site Photographs

Interior of Lagoon looking east

Lagoon looking east from Truck discharge location

Main effluent seep outside SE corner of lagoon

Secondary Seep outside south side of lagoon, approximately 20m west of main seep


Looking west across wetland to lagoon


Looking east from lagoon, across wetland

Flow in wetland east of lagoon


Pond in Wetland

Wetland vegetation in area of defined flow.

Wetland vegetation in area of diffuse flow

Sampling at Station 5 (proposed SNP Point); flow is from right to left of picture.


Sampling Station 5, looking east into large lake