Appendix V5-7A

2009 Marine Baseline Report, Hope Bay Belt Project

Hope Bay Mining Limited

2009 Marine Baseline Report, Hope Bay Belt Project

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2009 MARINE BASELINE REPORT, HOPE BAY BELT PROJECT

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Project #1009-002-07

Prepared for:

NEWMONT™
NORTH AMERICA

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Executive Summary

Engineers and Scientists

Executive Summary

Environmental baseline studies were conducted by Rescan Environmental Services Ltd. (Rescan) in 2009, on behalf of Hope Bay Mining Ltd. (HBML), for the Hope Bay Belt Project. The Hope Bay Belt Property is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the south shore of Melville Sound. The nearest communities are Omingmaktok (Bay Chimo; 75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

The environmental baseline program conducted in 2009 was based on the plan to develop multiple deposits in the belt. The 2009 program was also based on Newmont's priorities as of early 2009, which included regulatory compliance with the existing Doris North Project permits and licences. Baseline work was primarily focused on the north end of the belt in 2009. This report presents the findings of the 2009 marine baseline study, and includes a comparison to historical data.

The primary objective of the 2009 marine program was to collect additional marine baseline data relevant to the planned project to support permitting and project design. The marine baseline program included the following components: the vertical structure and dissolved oxygen content of the water column (winter and summer), water quality (winter and summer), sediment quality (summer), phytoplankton (summer), zooplankton (summer), and benthos (summer). Three distinct marine basins near the Project area were surveyed between April and August, 2009: Roberts Bay, Hope Bay, and Reference Bay. Roberts Bay and Hope Bay were included in the baseline sampling program as these areas could potentially be influenced by future Project activities, and Reference Bay (east of Roberts Bay) was selected as a marine reference site. The following text provides a brief summary of the various components sampled as part of the 2009 marine baseline program.

<u>Water Column Structure and Dissolved Oxygen</u>

Winter thermohaline data were collected at 12 sites in Roberts Bay, one site in Reference Bay, and 15 sites in Hope Bay in April/May, 2009. Sampling stations were covered in snow and ice, with ice thickness averaging 184±6 cm in Hope Bay and 165±18 cm in Roberts Bay. The water columns of all three embayments were vertically stratified, with pycnoclines occurring at 10 to 15 m depth. Several sites in Roberts and Hope bays showed signs of 'brining', or brine rejection, evidenced by the high salinity of the surface water and decreasing salinity towards the top of the pycnocline layer.

Summer thermohaline data were collected at seven sites in Roberts Bay and nine sites in Reference Bay in August 17, 2009. The surface layer in Roberts Bay was warmer and less saline in summer than in winter because of the increased solar radiation and enhanced riverine inputs during the summer. There was strong vertical stratification at the deeper seaward sites as the deep waters maintained the high densities observed in winter. There was very little difference in the thermohaline structure moving from the head to entrance of Roberts Bay, indicating that riverine inputs were quite low during the August sampling period. The thermohaline characteristics of Reference Bay in August were very similar to those observed in Roberts Bay. Both bays had pycnocline depths near 10 m.

Winter dissolved oxygen concentration and saturation profiles were collected at four sites in Roberts Bay, one site in Reference Bay, and seven sites in Hope Bay in April/May, 2009. At vertically stratified sites, oxygen levels were highest above the pycnocline and lowest below. In Roberts Bay, deep water oxygen concentrations were generally between 8 and 9 mg/L and approached 60% saturation. The presence of a sill at the entrance to Roberts Bay would restrict the flow of bottom water into the embayment, which could lead to reduced deep water oxygen replenishment. This is typical of fjordal systems. In Hope Bay, dissolved oxygen concentrations (9.0–10.1 mg/L) and saturation levels (70–80%) in deep waters were higher than those recorded in the deep basin in Roberts Bay. At the mouth of Reference Bay (REFW), winter dissolved oxygen concentrations in both the surface and deep water were higher than those measured in Roberts and Hope bays. Station REFW is located in a region where enhanced tidal flushing of water through a constriction and over a sill may replenish oxygen levels and remove the build-up of settling material. This would reduce the potential for bacterial remineralization and associated oxygen consumption.

Summer dissolved oxygen profiles were collected from six sites in Roberts Bay and two sites in Reference Bay in August 17, 2009. The dissolved oxygen profiles collected in August were distinctly different than those gathered in winter. In both Roberts and Reference Bays, surface and deep water dissolved oxygen concentrations were similar, while the highest concentrations occurred near the pycnocline. In the deeper northern sites of Roberts Bay, surface dissolved oxygen concentrations were generally near 10 mg/L and increased as temperatures decreased towards the pycnocline. This suggests that the lower surface oxygen concentration was partly due to the lower solubility of oxygen in higher temperature water. However, since phytoplankton often accumulate at the pycnocline interface, particularly during periods of nutrient-limitation (which was present in Roberts Bay at this time), it is possible that this enhanced oxygen content at the pycnocline was caused by higher photosynthetic activity. Deep water dissolved oxygen concentrations and saturation were slightly lower in Reference Bay than at comparable depths in Roberts Bay.

To determine the light characteristics in the Project area, Secchi depth measurements were collected in Roberts and Reference bays in August, 2009. In both embayments, light penetration was high. The upper and lower bounds of the euphotic zone were between 21.6 and 40.6 m in both bays. This was far below the typical pycnocline depth (~10 m), indicating that surface layer phytoplankton were contained within an optimal light field and some net photosynthesis would be possible in the deep layer. It also suggests that benthic primary production would be possible at quite deep depths in the coastal Project region.

<u>Water Quality</u>

Winter water quality samples were collected from five sites in Roberts Bay, one site in Reference Bay, and six sites in Hope Bay in April/May 2009. Winter pH levels were nearly identical at all stations, ranging from 7.54 to 7.77. Concentrations of total suspended solids ranged from below detection (<3 mg/L) to 25 mg/L, and turbidity levels were generally low at most sites (<0.4 NTU).

Winter nutrient levels were generally similar among sites from all bays, and slight vertical concentration gradients were apparent for some nutrients. Nitrate, orthophosphate, and silicate concentrations were slightly lower at the surface than in deep waters, particularly at the Roberts Bay and Hope Bay sites. Ammonia and nitrite levels were usually below analytical detection limits. Vertical gradients of total organic carbon (TOC) were opposite of the nutrient profiles as the surface concentrations were usually higher than measured at depth. Vertical gradients characterized by higher TOC and lower nutrients at the surface than at depth suggest that phytoplankton growth was occurring at Roberts Bay, Hope Bay, and Reference Bay sites during the winter sampling period.

Similar to nutrient profiles, winter concentrations of total and dissolved metals in the water column tended to be similar among sites. Concentrations of certain micronutrients (e.g., iron, manganese) were reduced at the surface compared to deep waters at some sites, indicative of algal uptake of these trace metals. One of the most notable differences among embayments was the concentration of chromium, which tended to be below detection in Roberts and Reference bays, but was naturally elevated at Hope Bay sites, averaging 0.066 mg/L across all Hope Bay sites and depths and reaching a maximum of 0.082 mg/L at HB12. Conversely, mercury concentrations in Hope and Reference Bays were generally below analytical detection limits, but in Roberts Bay, mercury levels were occasionally elevated, reaching a maximum of 0.000096 mg/L. Winter water quality parameters were generally below Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of marine aquatic life, with the exception of chromium in Hope Bay and mercury in Roberts Bay.

Summer water quality samples were collected from seven sites in Roberts Bay and two sites in Reference Bay in August, 2009. Late summer pH levels were slightly lower at Reference Bay sites (average of 7.67) than at Roberts Bay sites (average of 7.80). Concentrations of total suspended solids ranged from 3.8 mg/L to 10.4 mg/L and tended to increase with depth, suggesting that suspended particles were settling out of the surface layer. Turbidity ranged from 0.19 NTU to 0.74 NTU among sites. Unlike TSS, turbidity was highest in surface waters and tended to decrease below the pycnocline.

Deep water nutrient concentrations measured in summer samples tended to be similar to winter levels. The main seasonal difference in nutrient profiles was that surface concentrations of nitrate, orthophosphate, total phosphorus, and silicate were all markedly lower in summer than in winter. The trend was most evident for surface nitrate which dropped from 0.054 mg/L in winter (average of all sites) to below the detection limit (<0.006 mg/L) in late summer. This depletion of nitrate suggests that phytoplankton growth during the summer was likely limited by the availability of nitrate. Similar to the seasonal nitrate trend, surface orthophosphate dropped from 0.038 to 0.015 mg/L and surface silicate dropped from 1.4 to 0.64 mg/L from winter to summer. Total phosphorus concentrations and trends were very similar to orthophosphate, suggesting that orthophosphate made up the majority of the total phosphorus pool. Summer nitrite concentrations were always below the detection limit, and ammonia concentrations tended to be near or below the analytical detection limit. Total organic carbon concentrations remained relatively consistent in deep waters from winter to summer, but average surface total organic carbon levels increased from 0.89 mg/L in winter to 1.1 mg/L in summer, and reached a maximum summer concentration of 1.7 mg/L in Reference Bay. These pronounced vertical trends in nutrients and TOC indicate that algal growth was occurring in surface waters of Roberts and Reference Bays, as would be expected.

Concentrations of several metals varied markedly between the winter and summer sampling periods. As seen with the macronutrients (nitrate, phosphate, and silicate), surface concentrations of micronutrients including cadmium and molybdenum were slightly drawn down in the summer, while deep water concentrations were relatively constant from winter to summer. The opposite trend was observed for total iron, as surface concentrations increased from winter to summer, while bottom water concentrations were near or below detection limits (<0.005 mg/L). This depth gradient suggests that iron may be entering Roberts and Reference bays through riverine or atmospheric sources. Summer chromium and mercury concentrations were always below analytical detection limits. All metal concentrations were below CCME guidelines in samples collected during summer. Overall, metal concentrations in Roberts and Reference bays were generally comparable.

Sediment Quality

Sediment quality samples were collected from 11 sites in Roberts Bay and 3 sites in Reference Bay in August, 2009. Marine sediments were composed mainly of sand, silt, and clay, with little gravel. Concentrations of several parameters co-varied with the fine particle composition of the sediment. Sites with sediments consisting of mostly clays and silts tended to contain the highest concentrations of total organic carbon, aluminum, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, and zinc. Conversely, sites with coarser sediments tended to contain the lowest concentrations of these parameters. Concentrations of copper in some sediment samples from Roberts and Reference bays and chromium in some samples from Roberts Bay were naturally higher than CCME interim sediment quality guidelines for the protection of marine aquatic life. Concentrations of polycyclic aromatic hydrocarbons in Roberts and Reference bays were always below analytical detection limits and CCME guidelines.

Phytoplankton

Phytoplankton biomass and taxonomy samples were collected from seven sites in Roberts Bay and two sites in Reference Bay in August, 2009. Phytoplankton biomass (as chlorophyll *a*) was low at all sites and depths sampled, ranging from below detection (<0.04 µg chl *a*/L) in most samples to a maximum of 0.18 µg chl *a*/L. Nitrate-limitation could explain the low phytoplankton biomass, because summer nitrate concentrations were extremely low in surface waters of Roberts and Reference bays.

Phytoplankton abundance ranged from 120,030 to 298,020 cells/L. Abundance at the Roberts Bay offshore site (ST6) was at least 100,000 cells/L higher than at any other site. Reference Bay phytoplankton abundances were within the range observed at Roberts Bay sites.

The phytoplankton assemblage at most Roberts Bay sites was numerically dominated by the marine chrysophyte *Dinobryon balticum*. Cryptomonads were also abundant in Roberts Bay. However, dinoflagellates and other taxa (*Ebria tripartite, Myrionecta rubra*) generally dominated the algal assemblage in terms of carbon biomass as a result of their much larger cell size compared to chrysophytes and cryptomonads. Very few chrysophytes were observed in Reference Bay, and the algal assemblage was numerically dominated by cryptomonads. Dinoflagellates accounted for the largest proportion of phytoplankton biomass in Reference Bay, though cryptomonads, diatoms, and other taxa also made significant contributions.

Phytoplankton taxa richness and Simpson's diversity were variable among sites. Taxa richness ranged from 11 to 17 taxa, and Simpson's diversity ranged from 0.12 to 0.61. Site RP3 in Reference Bay had the lowest level of phytoplankton diversity, which is attributable to the numerical dominance of cryptomonads at this site.

Zooplankton

Zooplankton samples were collected from seven sites in Roberts Bay and two sites in Reference Bay in August, 2009. Zooplankton abundance ranged from 8,388 to 16,529 organisms/m^3. Abundance levels at the Reference Bay sites were within the range observed at Roberts Bay sites.

At the near-shore sites of Roberts and Reference bays, the zooplankton assemblage was dominated by calanoid copepods and cladocerans. At the sites located further offshore, calanoid copepods remained the dominant taxa; however, larvaceans (pelagic tunicates) replaced cladocerans as the second most abundant taxa. Zooplankton taxa richness ranged from 16 to 24. Richness levels were lower in the near-shore Roberts Bay sites (16 to 17 taxa) than in the offshore Roberts Bay and

Reference Bay sites (23 to 24 taxa). Simpson's diversity index was similar among sites, ranging from 0.57 to 0.73.

Benthos

Benthos samples were collected from 11 sites in Roberts Bay and 3 sites in Reference Bay in August, 2009. Benthos density was highly variable among sites, ranging from 288 to 40,100 organisms/m^2. Some sites with the lowest benthos densities were located in the Glenn Outflow receiving environment. Benthos densities in Reference Bay sites were within the range observed in Roberts Bay sites.

The benthos taxonomic assemblage was variable among sites. Harpacticoid copepods, polychaete worms, and bivalves each dominated the benthos communities at different sites within Roberts and Reference Bays. Cumaceans and amphipods were also commonly found in benthos samples. Average benthos richness ranged from a single taxon to 22 taxa. Taxa richness was highly variable, with no apparent spatial trends. Simpson's diversity ranged from 0 to 0.84 among sites. With the exception of a benthos-poor site in Roberts Bay, the least diverse sites were all characterized as having sandy substrates dominated by harpacticoid copepods.

Acknowledgements

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Table of Contents

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2009 MARINE BASELINE REPORT, HOPE BAY BELT PROJECT

Table of Contents

List of Appendices

List of Figures

FIGURE **PAGE**

List of Tables

TABLE **PAGE**

1. Introduction

1. Introduction

The Hope Bay Belt Property is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the south shore of Melville Sound (Figure 1-1). The nearest communities are Omingmaktok (75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

The property consists of a greenstone belt running in a north/south direction, approximately 80 km long, with three main gold deposit areas. The Doris and Madrid deposits are located in the northern portion of the belt, and the Boston deposit is located in the southern end. The northern portion of the property consists of several watershed systems that drain into Roberts Bay, and a large river (Koignuk River) that drains into Hope Bay. Watersheds in the southern portion of the belt ultimately drain into the upper Koignuk, which drains into Hope Bay.

Newmont Mining Corporation (Newmont) acquired the property in 2008, and initially decided to consider the property as a whole to evaluate various options for responsible, long-term development of the belt. However, as of the fall of 2009, Hope Bay Mining Ltd. (HBML), a fully owned subsidiary of Newmont, has decided to proceed with developing the already-permitted Doris North Project, which consists of a two year underground gold mine in the north end of the belt.

The environmental baseline program conducted in 2009 was based on the plan to develop multiple deposits in the belt, as indicated in Figure 1-2. The 2009 program was also based on HBML's priorities as of early 2009, which included regulatory compliance with the existing Doris North Project permits and licences. Baseline programs for ecosystem mapping, vegetation, soils, and socio-community were deferred to 2010. Baseline work was primarily focused on the north end of the belt in 2009.

Results from the 2009 environmental baseline program are being reported in a series of reports, as follows:

- 2009 Hydrology Baseline Report;
- 2009 Meteorology Baseline Report;
- 2009 Freshwater Baseline Report;
- 2009 Freshwater Fish and Fish Habitat Baseline Report;
- 2009 Marine Baseline Report; and
- 2009 Marine Fish and Fish Habitat Baseline Report.

In addition, baseline information obtained during 2009 was used to generate various compliance reports as specified in the Doris North Project Certificate (e.g., the Wildlife Monitoring & Mitigation Program Report), the Doris North Type A Water Licence, and the Doris North Roberts Bay Jetty Fisheries Authorization. Archaeology work was also conducted in 2009 and is being reported separately.

Figure 1-1

Hope Bay Belt Project Location

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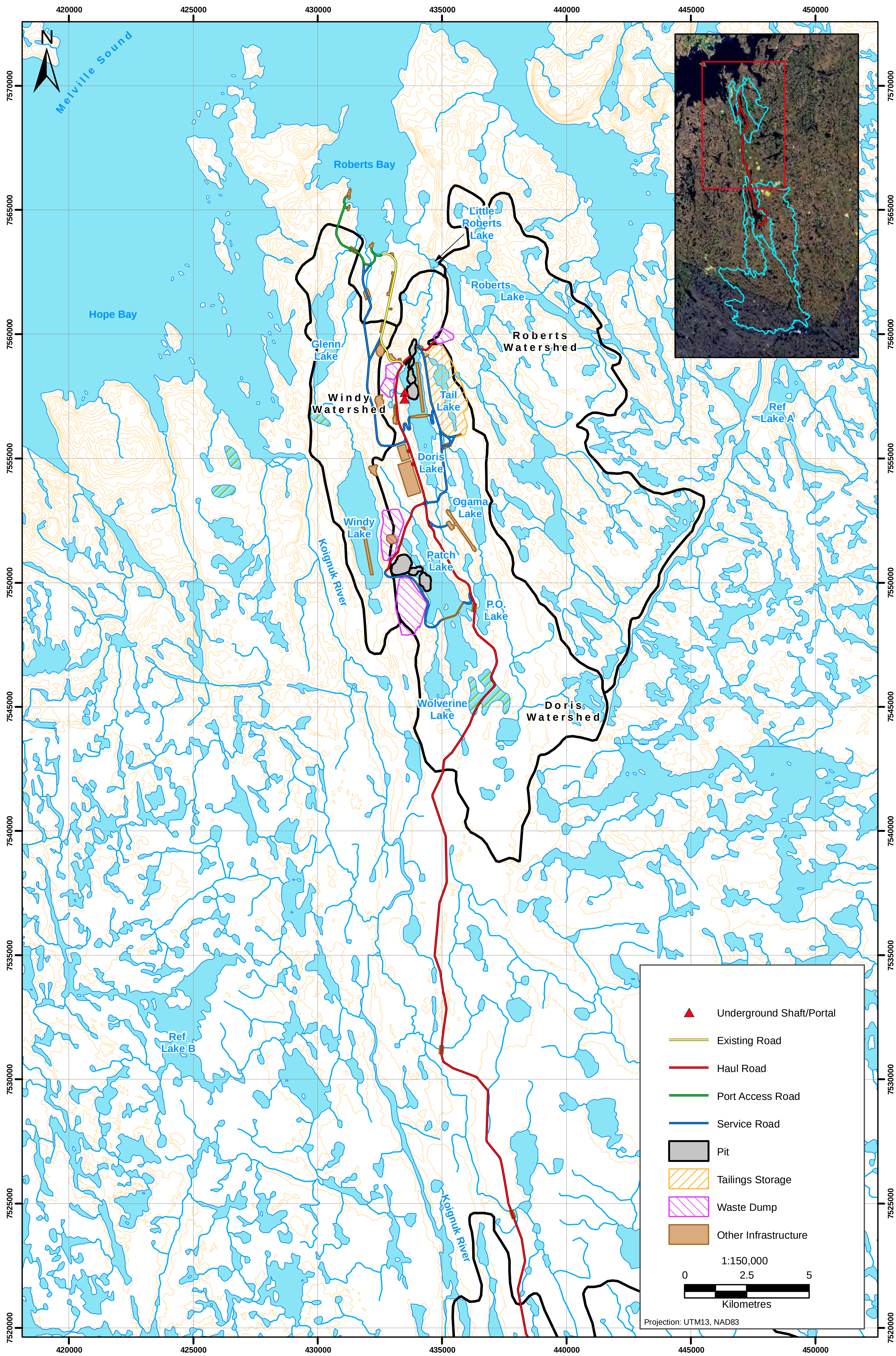

Figure 1-2

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Site Layout Options Considered for 2009 Baseline Program

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Figure 1-2

This report presents the results from the marine portion of the 2009 environmental baseline program. The 2009 marine baseline program involved a characterization of the physico-chemical and biological components of the marine environment around the Hope Bay Belt Project area. The marine baseline program included the following components: the vertical structure and dissolved oxygen content of the water column (winter and summer), water quality (winter and summer), sediment quality (summer), phytoplankton (summer), zooplankton (summer), and benthos (summer). Three distinct marine basins near the Project area were surveyed between April and August, 2009: Roberts Bay, Hope Bay, and Reference Bay. Roberts Bay and Hope Bay were included in the baseline sampling program as these areas could potentially be influenced by future Project activities, and Reference Bay was selected as a marine reference site.

Analytical results from all samples collected as part of the 2009 marine baseline program are provided in the appendices to this report. Chapter 2 of this report presents the sampling locations and methods used for the 2009 marine baseline work, and Chapter 3 presents the results of the marine baseline program. Historical methods and results from past studies in the Project area are included in Chapters 2 and 3.

2. Methods

2. Methods

The 2009 marine baseline surveys were conducted during two seasons (winter, summer) in three embayments (Roberts Bay, Hope Bay, and Reference Bay) in the Hope Bay Belt Project area. A three-person sampling team (including an Inuit assistant) conducted winter sampling in all three bays during the ice-covered period from April 28 to May 7, 2009, as well as summer sampling in Roberts Bay and Reference Bay from August 14 to August 20, 2009. During the winter sampling program, the following environmental components were included in the survey: water column physical structure, dissolved oxygen profiles, and marine water quality. The summer sampling program included these components, but was expanded to include marine sediment quality, as well as benthos, phytoplankton, and zooplankton community characteristics.

2.1 SAMPLING LOCATIONS AND DESIGN

The 2009 marine baseline survey was designed to capture the spatial and seasonal variability of physico-chemical and biological parameters in the Project area. Historical marine baseline data exists for localized geographical areas in Roberts and Hope bays, but the 2009 marine program surveyed the entire spatial extent of Roberts Bay (winter and summer), Hope Bay (winter), and Reference Bay (summer). 2009 was the first time that sampling was conducted in Reference Bay. Table 2.1-1 lists the parameters measured in each sampling program during 2009.

Table 2.1-1. Winter and Summer Marine Surveys, Hope Bay Belt Project, April–August, 2009

Sampled Parameters	Roberts Bay	Hope Bay	Reference Bay
Water Column Structure			
Salinity	W, S	W	W, S
Temperature	W, S	W	W, S
Dissolved Oxygen	W, S	W	W, S
Euphotic Zone Depth	S	-	S
Water Quality			
Physical, Anions, and Nutrients	W, S	W	W, S
Metals (Total and Dissolved)	W, S	W	W, S
Biology			
Phytoplankton Biomass	S	-	S
Phytoplankton Abundance, Taxonomy, and Diversity	S	-	S
Zooplankton Abundance, Taxonomy, and Diversity	S	-	S
Benthos Abundance, Taxonomy, and Diversity	S	-	S
Sediment Quality			
Particle Composition, % Moisture	S	-	S
Organic Content, Nutrients, PAH	S	-	S
Total Metals	S	-	S

S = Summer (August), W= Winter (April/May)

The winter sampling was designed to collect information to support the potential for dewatering into Hope Bay (via the Koignuk River), and to collect 'worse-case scenario', under-ice water in Roberts Bay and Hope Bay when dissolved oxygen concentrations would be lowest (reduced photosynthesis) and water chemistry concentrations would be highest (limited biological uptake). In Hope Bay, general physical oceanographic profiles (salinity, temperature, and dissolved oxygen) were collected at 15 sites (HB sites) covering much of the inner section of the bay (Figure 2.1-1). Water quality samples were collected at six of these sites. In Roberts Bay, physical oceanographic profiles were performed at 12 sites (WT sites - Winter Transect) including a north–south (WT1–WT8) and east–west transect (WT9–WT11), which encompassed the entire bay. Water quality samples were collected at five sites: four along the north–south transect, and a single site in southeastern Roberts Bay (WT0). A winter reference site (REFW) was located at the entrance of Reference Bay. A single physical oceanographic profile was taken at this site as were water quality samples. Sampling was conducted from May 2 to May 7, 2009 in Hope Bay, from April 28 to May 7, 2009 in Roberts Bay, and on April 29, 2009 at REFW.

Summer sampling was carried out in Roberts Bay and Reference Bay. Sampling in Roberts Bay was designed with two objectives in mind: 1) to gather baseline oceanographic data for the entire embayment, and 2) to collect baseline data relevant to future shipping infrastructure (e.g., deep water port, fuel dock, fuel tank farm) that could be built in Roberts Bay. The first objective focussed on the water column features throughout the embayment and collected environmental data that was influenced by freshwater inputs and summer biological activity (unlike winter). The second objective focussed on the chemical and biological characteristics of the sediments relevant to future potential infrastructure. For the first objective, sampling was conducted along a 5-site, north–south transect (ST - Summer Transect), similar to the winter marine program (Figure 2.1-2). Physical oceanographic profiles, water quality, and biological (phytoplankton and zooplankton) samples were collected at each site (ST2–ST6). Similar information was collected at single sites near Little Roberts Outflow in southeasten Roberts Bay (ST0) and near Glenn Outflow in southwestern Roberts Bay (ST1). For the second objective, an additional 11 sites were sampled along the western periphery of Roberts Bay for sediment quality (particle size, nutrients, metals, and hydrocarbons) and benthic invertebrate community characteristics. Water column and sediment characteristics were collected at ST2. Physical profiles, water quality and phytoplankton, and zooplankton samples were collected on August 14, August 15, and August 16, 2009, respectively.

Sampling in Reference Bay was designed to act as a reference site for Roberts Bay. On August 17, 2009, physical oceanographic profiles (salinity/temperature, DO, Secchi depths) were taken at nine sites along the entire mid-channel of Reference Bay (Figure 2.1-3). Water quality and phytoplankton (biomass and taxonomy) samples were collected at a pelagic site (REF4) and a near-shore site (RP3) on August 18, 2009, and zooplankton (abundance and taxonomy) samples were collected on August 19, 2009 at the same locations. Sediment quality and benthos (abundance and taxonomy) samples were collected along a three-site transect at the western head of the inlet on August 17, 2009.

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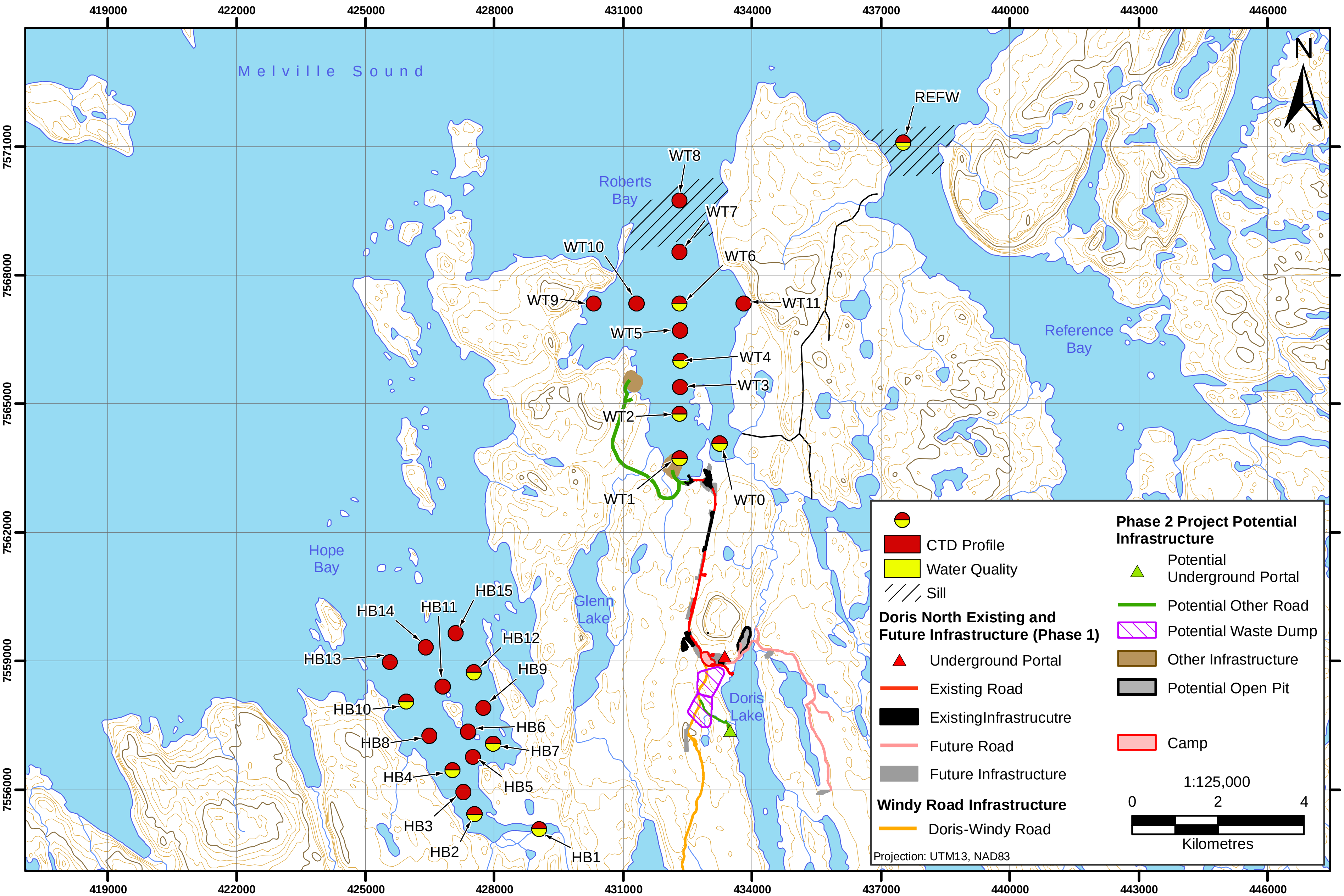

Figure 2.1-1

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Winter Marine Sampling Locations, Hope Bay Belt Project, April/May 2009

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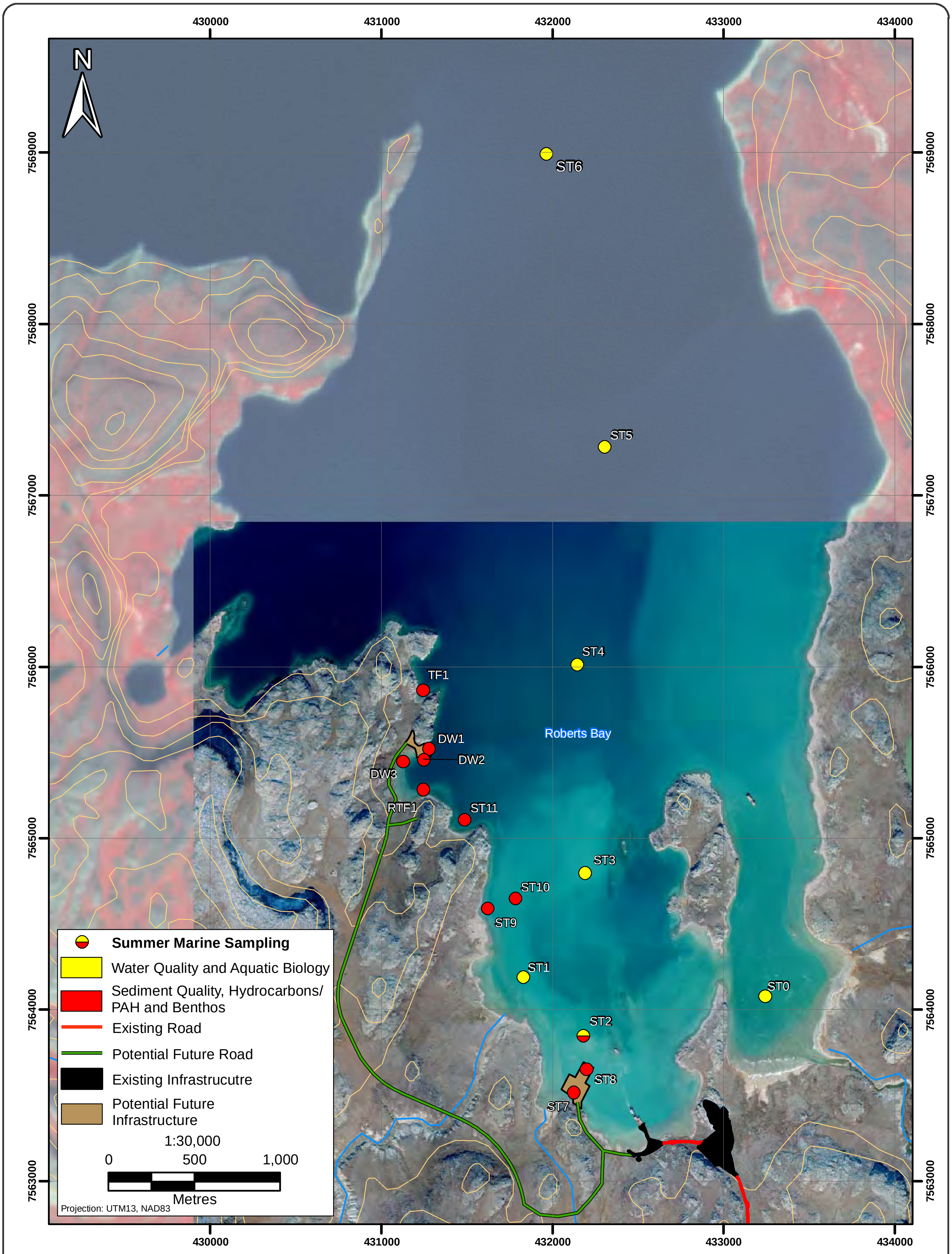

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Figure 2.1-2

Roberts Bay Summer Marine Sampling Locations, Hope Bay Belt Project, August 2009

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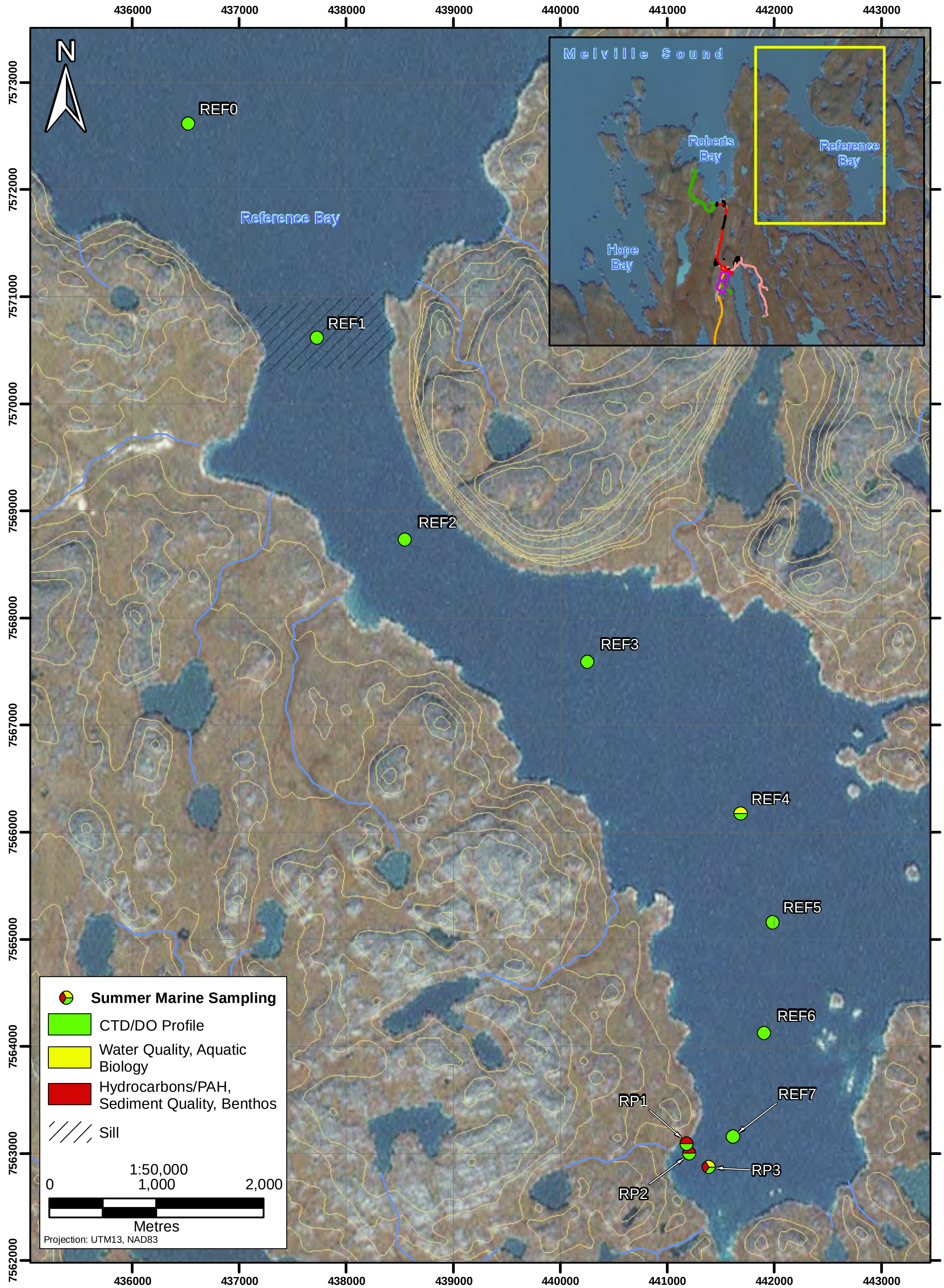

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Reference Bay Summer Marine Sampling Locations, Hope Bay Belt Project, August 2009

Figure 2.1-3

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2.2 SAMPLING METHODS

Table 2.2-1 provides a summary of sampled parameters, replication, sampling dates, and sampling equipment used. Full descriptions are provided in the following text.

Table 2.2-1. Marine Sampling Details, Hope Bay Belt Project, 2009

Monitoring Parameter	Location	Sample Replication and Depths	Sampling Dates	Sampling Device
Winter Marine Physical Oceanography				
Salinity/Temperature, Dissolved Oxygen (DO) profiles, Secchi depth	Roberts Bay (12 sites) Hope Bay (15 sites) Reference Bay (1 site)	n=1/site	April, May	Conductivity-Temperature-Depth (CTD) probe; DO meter
Winter Marine Water Quality				
Physical, anions, nutrients, total and dissolved metals, total organic carbon (TOC)	Roberts Bay (5 sites) Hope Bay (6 sites) Reference Bay (1 site)	Deep Sites: n=1/site @ 1 m below the surface, 4 m above pycnocline, 4 m below pycnocline, mid-deep layer + 20% replication; Shallow: n=1/site @ 1 m below the surface, 2 m above sediments + 20% replication	April, May	Niskin sampling bottle
Summer Marine Physical Oceanography				
Salinity/Temperature, DO profiles, Secchi depth	Roberts Bay (7 sites) Reference Bay (CTD - 9 sites; DO - 2 sites)	n=1/site	August	CTD; DO meter; Secchi disc
Summer Marine Water Quality				
Physical, anions, nutrients, total and dissolved metals, TOC	Roberts Bay (7 sites) Reference Bay (2 sites)	Deep Sites: n=1/site @ 1 m below the surface, 4 m above pycnocline, 4 m below pycnocline, mid-deep layer + 20% replication; Shallow: n=1/site @ 1 m below the surface, 2 m above sediments + 20% replication	August	Go-Flo sampling bottle
Summer Sediment Quality				
Particle size, nutrients, TOC, total metals, polycyclic aromatic hydrocarbons (PAH), extractable hydrocarbons (EPH)	Roberts Bay (11 sites) Reference Bay (3 sites)	n=3/site	August	Ponar grab
Summer Benthos				
Density and taxonomy	Roberts Bay (11 sites) Reference Bay (3 sites)	n=3/site	August	Ponar grab; 500 µm sieve; 10% formalin preservation
Summer Phytoplankton				
Biomass (chl *a*) Abundance and taxonomy	Roberts Bay (7 sites) Reference Bay (2 sites)	n=3/site @ 1 m below the surface	August	Go-Flo sampling bottle; Lugol's solution preservation
Summer Zooplankton				
Abundance and taxonomy	Roberts Bay (7 sites) Reference Bay (2 sites)	n=3/site; vertical hauls	August	Birge-style net; 202 µm mesh; 10% formalin preservation

2.2.1 Water Column Structure and Dissolved Oxygen

2.2.1.1 Winter

The underlying water at the winter sampling sites was accessed by drilling a 10-inch diameter hole through the ice. Ice thickness was recorded and the bottom depth measured using a weighted, metred line. A vertical profile of temperature, salinity, conductivity, and density was collected using an *in situ* conductivity, temperature, and depth (CTD) probe. The probe was lowered through the water column (at an approximate speed 0.5 m/s) on a cable to within a few metres of the sea floor. The data logged during this process was immediately transferred to a computer in the field. Data from the downcast was used for interpretation. Salinity profiles were plotted from the acquired data to determine the pycnocline depth, from which water quality sampling depths were determined. Following the CTD casts, vertical profiles of dissolved oxygen (DO) concentration and percent saturation were collected at 1 m intervals to within 2 m of the sediments (or to a maximum depth of 30 m) using a YSI dissolved oxygen meter.

2.2.1.2 Summer

CTD and DO profiles were collected from the side of an aluminum boat. The logged and recorded data was processed in the same fashion as that collected in winter. Secchi depths were measured to determine the light penetration at each site. A 30-cm white disc was placed over the shaded side of the boat and lowered until it disappeared from sight. It was raised into view and lowered until it disappeared a second time. This was recorded as the Secchi depth (D_s). The 1% ($Z_{1\%}$) and 0.1% ($Z_{0.1\%}$) euphotic zone depths were computed by first calculating the proper light extinction coefficient (k) from D_s, then calculating the euphotic zone depth based on the appropriate light extinction coefficient. The 1% euphotic depth is the depth of the water column where 1% of the surface irradiance reaches. It represents the depth where the gross water column photosynthetic production is the equivalent of the gross water column respiration; thus, there is net production of carbon synthesis above this depth. It is often known as the compensation depth. The 0.1% euphotic depth is the depth of the water column where 0.1% of the surface irradiance reaches. This represents the depth where photosynthesis can occur. The 1% and 0.1% euphotic depths are calculated as follows:

Light extinction coefficient:

$$k\ (m^{-1}) = 1.7/D_s$$

where k is the light extinction coefficient for non-turbid waters (1.7; Parsons et al. 1984),

Euphotic Depth (1%):

$$Z_{1\%}\ (m^{-1}) = 4.6/k$$

Euphotic Depth (0.1%):

$$Z_{0.1\%}\ (m^{-1}) = 6.9/k$$

2.2.2 Water Quality

Water quality samples (winter and summer) were collected based on the water column structure as determined by the CTD profiles initially collected at a specific site. At deep sites, four depths were sampled: 1 m below the surface, 4 m above the pycnocline, 4 m below the pycnocline, and at mid-depth of the deep layer. At shallower sites with clear vertical stratification, samples were collected at 1 m below the surface, and 2 m above the sediment layer. Samples were collected at 1 m below the surface at shallow sites with no stratification. For Quality Assurance/Quality Control (QA/QC) purposes, replicate samples were collected at 20% of the sample depths.

An adapted 'skinny' Niskin bottle was used to collect water during winter sampling. This bottle is designed to 'trip' and collect discrete samples during freezing temperatures. To avoid metal contamination, the tripping mechanism used acid-cleaned silicone tubing within the interior of the bottle. A dual rope system was used to achieve bottle closure and to ensure the collection of discrete samples. During summer sampling, all water samples were collected using a 5 L Go-Flo sampler. Both sampling bottles (Niskin/Go-Flo) were acid-cleaned at ALS Laboratory Group facilities (Vancouver, BC) prior to use in the field. All analytical sample bottles were rinsed three times before filling.

In the field, preservatives were added as appropriate. A set of travel blanks, field blanks, and equipment blanks (5–10% of total samples) were processed and submitted with the water samples as part of the QA/QC program. This identified potential sources of contamination to the actual field samples. All samples were sent to ALS in Yellowknife, NT, within their recommended holding times.

Table 2.2-2 presents the water quality parameters analyzed, and ALS's detection limits. Realized detection limits were occasionally higher than the theoretical detection limits due to interference from other parameters.

Table 2.2-2. Baseline Marine Water Quality Parameters and Detection Limits, Hope Bay Belt Project, Winter and Summer 2009

		Detection Limit	
Parameter	**Units**	**Winter**	**Summer**
Physical Tests			
pH	pH	0.1	0.1
Total Suspended Solids	mg/L	3	3
Turbidity	NTU	0.1	0.1
Anions			
Bromide (Br)	mg/L	0.05	5
Chloride (Cl)	mg/L	0.5	50
Fluoride (F)	mg/L	0.4	0.75
Sulfate (SO4)	mg/L	0.5	50
Nutrients			
Ammonia (as N)	mg/L	0.005	0.005
Nitrate + Nitrite (as N)	mg/L	0.006	0.006
Nitrate (as N)	mg/L	0.006	0.006
Nitrite (as N)	mg/L	0.002	0.002
Ortho Phosphate (as P)	mg/L	0.001	0.001
Total Phosphorus (as P)	mg/L	0.002	0.002
Silicate (as SiO_2)	mg/L	0.005	0.025

(continued)

Table 2.2-2. Baseline Marine Water Quality Parameters and Detection Limits, Hope Bay Belt Project, Winter and Summer 2009 (completed)

		Detection Limit	
Parameter	Units	Winter	Summer
Organic Carbon			
Total Organic Carbon	mg/L	0.5	0.5
Total and Dissolved Metals			
Aluminum (Al)	mg/L	0.005	0.005
Antimony (Sb)	mg/L	0.01	0.005-0.01
Arsenic (As)	mg/L	0.0002	0.0002
Barium (Ba)	mg/L	0.005	0.005
Beryllium (Be)	mg/L	0.05	0.025-0.05
Bismuth (Bi)	mg/L	0.05	0.025-0.05
Boron (B)	mg/L	1	1
Cadmium (Cd)	mg/L	0.00002	0.00002
Calcium (Ca)	mg/L	0.5	0.5
Chromium (Cr)	mg/L	0.05	0.025-0.05
Cobalt (Co)	mg/L	0.00005	0.00005
Copper (Cu)	mg/L	0.00005	0.00005
Iron (Fe)	mg/L	0.005	0.005
Lead (Pb)	mg/L	0.00005	0.00005
Lithium (Li)	mg/L	0.5	0.025-0.05
Magnesium (Mg)	mg/L	1	1
Manganese (Mn)	mg/L	0.00005	0.00005
Mercury (Hg)	mg/L	0.00001	0.00001
Molybdenum (Mo)	mg/L	0.005	0.005
Nickel (Ni)	mg/L	0.00005	0.00005
Phosphorus (P)	mg/L	3	3
Potassium (K)	mg/L	20	20
Selenium (Se)	mg/L	0.0005	0.0005
Silicon (Si)	mg/L	0.5	0.5
Silver (Ag)	mg/L	0.001	0.0005-0.001
Sodium (Na)	mg/L	20	20
Strontium (Sr)	mg/L	0.01	0.01
Thallium (Tl)	mg/L	0.01	0.005-0.01
Tin (Sn)	mg/L	0.01	0.005-0.01
Titanium (Ti)	mg/L	0.1	0.1
Uranium (U)	mg/L	0.00005	0.00005
Vanadium (V)	mg/L	0.1	0.05-0.1
Zinc (Zn)	mg/L	0.0005	0.0005

2.2.3 Sediment Quality

Sediment quality samples were collected during the summer season in Roberts Bay (11 sites; August 16–17, 2009) and Reference Bay (three sites; August 17, 2009). Triplicate samples were collected at each site (Figures 2.1-2 and 2.1-3) using a ponar grab sampler, with replicates gathered 5-20 m apart. Sampling depths are provided in Table 2.2-3. Once at the surface, each sediment sample was carefully transferred onto a white tray, photographed, and described for colour, texture, biological material, and other characteristics. The top 2 cm of sediment was scraped into Whirl-Pak bags and sent to ALS (Yellowknife, NT) for analysis. Samples were refrigerated (in darkness) until they were shipped on the first available flight out of camp. Table 2.2-4 presents the sediment quality parameters that were analyzed and their detection limits.

Table 2.2-3. Baseline Marine Sediment Quality Sampling Depths, Hope Bay Belt Project, August 2009

Site	Sampling Depth (m)
Roberts Bay	
ST7	2
ST8	8
ST2	7
ST9	2
ST10	13
ST11	8
RTF1	3
TF1	2
DW3	1
DW2	13
DW1	13
Reference Bay	
RP1	5
RP2	9
RP3	14

Table 2.2-4. Baseline Marine Sediment Quality Parameters and Detection Limits, Hope Bay Belt Project, August 2009

Parameter	Unit	Detection Limit	Parameter	Unit	Detection Limit
Physical Tests			**Total Metals (cont'd)**		
% Moisture	%	0.1	Phosphorus (P)	mg/kg	50
pH	pH	0.1	Potassium (K)	mg/kg	200
			Selenium (Se)	mg/kg	0.5
Particle Size			Silver (Ag)	mg/kg	0.1
% Gravel (>2 mm)	%	1	Sodium (Na)	mg/kg	200
% Sand (2.0 mm - 0.063 mm)	%	1	Strontium (Sr)	mg/kg	0.5
% Silt (0.063 mm - 4 µm)	%	1	Sulphur (S)	mg/kg	100
% Clay (<4 µm)	%	1	Thallium (Tl)	mg/kg	0.5
			Tin (Sn)	mg/kg	5
Leachable Anions and Nutrients			Titanium (Ti)	mg/kg	1
Total Nitrogen	mg/kg	0.02	Vanadium (V)	mg/kg	2
			Zinc (Zn)	mg/kg	1

(continued)

Table 2.2-4. Baseline Marine Sediment Quality Parameters and Detection Limits, Hope Bay Belt Project, August 2009 (completed)

Parameter	Unit	Detection Limit	Parameter	Unit	Detection Limit
Plant Available Nutrients					
Available Ammonium (as N)	mg/kg	0.8	**Polycyclic Aromatic Hydrocarbons**		
Available Nitrate (as N)	mg/kg	2	Acenaphthene	mg/kg	0.005
Available Nitrite (as N)	mg/kg	0.4	Acenaphthylene	mg/kg	0.005
Available Phosphate (as P)	mg/kg	1	Anthracene	mg/kg	0.004
			Benz(a)anthracene	mg/kg	0.01
Organic Carbon			Benzo(a)pyrene	mg/kg	0.01
Total Organic Carbon	mg/kg	0.1	Benzo(b)fluoranthene	mg/kg	0.01
			Benzo(g,h,i)perylene	mg/kg	0.01
Total Metals			Benzo(k)fluoranthene	mg/kg	0.01
Aluminum (Al)	mg/kg	50	Chrysene	mg/kg	0.01
Antimony (Sb)	mg/kg	10	Dibenz(a,h)anthracene	mg/kg	0.005
Arsenic (As)	mg/kg	0.5	Fluoranthene	mg/kg	0.01
Barium (Ba)	mg/kg	1	Fluorene	mg/kg	0.01
Beryllium (Be)	mg/kg	0.5	Indeno(1,2,3-c,d)pyrene	mg/kg	0.01
Bismuth (Bi)	mg/kg	20	2-Methylnaphthalene	mg/kg	0.01
Cadmium (Cd)	mg/kg	0.1	Naphthalene	mg/kg	0.01
Calcium (Ca)	mg/kg	50	Phenanthrene	mg/kg	0.01
Chromium (Cr)	mg/kg	2	Pyrene	mg/kg	0.01
Cobalt (Co)	mg/kg	2	Total PAHs	mg/kg	0.04
Copper (Cu)	mg/kg	1	d10-Acenaphthene (SS)	%	-
Iron (Fe)	mg/kg	50	d12-Chrysene (SS)	%	-
Lead (Pb)	mg/kg	2	d8-Naphthalene (SS)	%	-
Lithium (Li)	mg/kg	2	d10-Phenanthrene (SS)	%	-
Magnesium (Mg)	mg/kg	50			
Manganese (Mn)	mg/kg	1	**Extractable Hydrocarbons**		
Mercury (Hg)	mg/kg	0.005	EPH10-19	mg/kg	200
Molybdenum (Mo)	mg/kg	0.2	EPH19-32	mg/kg	200
Nickel (Ni)	mg/kg	5	LEPH	mg/kg	200
			HEPH	mg/kg	200

2.2.4 Phytoplankton

Phytoplankton samples were collected during the summer season at the same sites and during the same time as water quality collection (Figures 2.1-2 and 2.1-3).

2.2.4.1 Biomass (as chlorophyll a)

Phytoplankton biomass samples were collected at seven sites in Roberts Bay (August 15, 2009) and two sites in Reference Bay (August 18, 2009). Triplicate samples were gathered at each depth collected for water quality samples using a 5 L Go-Flo water sampler. All samples were transferred into 1 L plastic bottles and stored in a cool, dark cooler until being returned to camp later in the day. Once at camp, the samples were filtered onto 0.45 µm filters, which were wrapped into aluminum foil, and stored frozen. Chlorophyll samples were hand carried to Vancouver, BC, to ensure they remained frozen, and sent to ALS (Vancouver, BC) for analysis.

2.2.4.2 Taxonomy, Abundance, and Diversity

Phytoplankton taxonomy samples were collected at seven sites in Roberts Bay (August 15, 2009) and two sites in Reference Bay (August 18, 2009). Triplicate samples were gathered at each site from 1 m depth using a Go-Flo water sampler. Each sample was transferred into a 1 L plastic bottle and preserved in the field with Lugol's Iodine solution. The samples were kept cool and dark until they were shipped to David Cassis at the University of British Columbia for enumeration, carbon-based biomass estimates, and identification. Taxa richness and Simpson's diversity index were calculated from taxonomic results.

2.2.5 Zooplankton

Zooplankton abundance and taxonomy samples were collected at seven sites in Roberts Bay (August 15, 2009) and two sites in Reference Bay (August 18, 2009). Samples were collected using a Birge-style zooplankton net (202 µm mesh size) fitted with a flowmeter. Vertical hauls were conducted at deep sites (>20 m; ST4–ST6, REF4), oblique tows at shallower depths (5–20 m; ST1–ST3, RP3), and a horizontal tow at the shallowest site (3 m; ST0). Oblique and horizontal tows were conducted by slowly dragging the net behind a moving aluminium boat. Flowmeter readings were taken before and after net deployment. Once at the surface, the net was fully rinsed (from the outside of the net) to move the organisms caught on the mesh into the cod-end at the bottom of the mesh. The contents of the cod-end were transferred to a 500 mL plastic jar and preserved with 5–10% buffered formalin. The samples were kept cool and dark until being shipped to Applied Technical Services Ltd. (Victoria, BC) for enumeration and identification. Taxa richness and Simpson's diversity index were calculated from taxonomic results.

2.2.6 Benthic Invertebrate Community (Benthos)

Benthos samples were collected during the summer season in Roberts Bay (11 sites; August 16-17, 2009) and Reference Bay (three sites; August 17, 2009). Triplicate samples were collected at each site (Figures 2.1-2 and 2.1-3) using a ponar grab sampler, with replicates being gathered 5–20 m apart. Sampling depths are provided in Table 2.2-3. Once at the surface, 1 L of each sediment sample was transferred into a 500 µm sieve bucket and rinsed until free of sediments. The remaining debris was placed into a labelled plastic jar and filled with 10% buffered formalin. Samples with high sand content did not pass through the sieve bucket. These samples were divided into four subsamples and placed into separate plastic jars without sieving. These were filled with 10% buffered formalin and gently agitated to fully distribute the preservative throughout the sample. All benthos samples were sent to Columbia Science (Courtney, BC) for enumeration and identification. Taxa richness and Simpson's diversity index were calculated from taxonomic results.

2.3 HISTORICAL MARINE SAMPLING

Summaries of historical sampling methodologies in the Hope Bay Belt area are presented in Tables 2.3-1 through 2.3-5. A summary of the historical sampling sites are presented as maps in Figures 2.3-1 through 2.3-4.

Table 2.3-1. Summary of Historical Marine Water Quality Sampling, Hope Bay Belt Project

	Year								
	1996	1997	1998	2004	2005	2006	2007	2008	2009
Sampling Month(s)	August	August	July	July, August, September	July, August, September	May*, July, Aug, Sept	May*, July, Aug, Sept	July, August, September	April*, August
Sampling Depths	surface	surface and deep	surface and deep	mid-column	mid-column	mid-column (May); surface and deep (July, Aug, Sept)	surface and deep	surface and deep	Surface at shallow sites; 4 depths at deep sites
Physical	none	Secchi Depth, DO and Temp. profiles	Secchi Depth, DO and Temp. profiles	Secchi Depth, DO and Temp. profiles	Secchi Depth, DO and Temp. profiles	Secchi Depth, DO and Temp. profiles	Secchi Depth, DO and Temp. profiles	Secchi Depth, DO and Temp. profiles	Secchi Depth (August only), DO and Salinity/ Temp. profiles
Analytical Parameters	Physical, nutrients, anions, total and dissolved metals	Physical, nutrients, anions, dissolved metals	Physical, nutrients, anions, dissolved metals	Physical, nutrients, anions, total and dissolved metals	Physical, nutrients, anions, total and dissolved metals	Physical, nutrients, anions, dissolved metals	Physical, nutrients, anions, dissolved metals	Physical, nutrients, anions, total and dissolved metals	Physical parameters, nutrients, anions, total and dissolved metals
QA/QC	Split samples, Travel/ Field Blanks	Split samples, Replicates, Travel Blanks	Split samples, Replicates, Travel Blanks	Replicates, Travel/Field/E quipment Blanks	Field/Equipm ent Blanks	Replicates, Field Blanks	Replicates, Field Blanks	Replicates, Field/Equipm ent Blanks	Replicates, Field/Travel/Equi pment Blanks
Field Methodology	2 L G-FLO Bottle	5 L GO-FLO Bottle	5 L GO-FLO Bottle	Kemmerer Bottle Sampler	Kemmerer Bottle Sampler	Kemmerer Bottle Sampler	Kemmerer Bottle Sampler	Kemmerer Bottle Sampler	2 L Niskin (April); 5 L GO-FLO (August)
Sampled Sites	Roberts Bay (5 sites)	Roberts Bay (5 sites) Hope Bay (3 sites)	Roberts Bay (5 sites) Hope Bay (3 sites)	Roberts Bay (1 site)	Roberts Bay (1 site)	Roberts Bay (1 site)	Roberts Bay (1 site) Hope Bay (1 site)	Roberts Bay (1 site) Hope Bay (1 site)	Roberts Bay (April/ August) (5 sites/ 7 sites) Hope Bay (May) (6 Sites) Reference Bay (August) (2 sites)

** - represents under-ice season*

Table 2.3-2. Summary of Historical Marine Sediment Quality Sampling, Hope Bay Belt Project

	Year			
	1997	**1998**	**2002**	**2009**
Sampling Month(s)	August	July	September	August
Sampling Methods	Ekman Grab	Ekman Grab	Ekman Grab	Ponar Grab
Data Collected	Moisture, TOC, Total Metals	Visual descriptions	TOC, pH, Total Metals, Particle Size, Hydrocarbons	TOC, pH, Nutrients, Total Metals, Particle Size, Hydrocarbons
Replicates	n=1	n=1	n=5	n=3
Sampled Sites	Roberts Bay (5 sites)	Roberts Bay (5 sites)	Roberts Bay (4 sites)	Roberts Bay (11 sites)
	Hope Bay (3 sites)	Hope Bay (3 sites)		Reference Bay (3 sites)

Table 2.3-3. Summary of Historical Marine Phytoplankton Sampling, Hope Bay Belt Project

	Year		
Year	**2006**	**2007**	**2009**
Sampling Month(s)	September	July, August, September	August
Sampling Device	Kemmerer Bottle Sampler	Depth-integrated Water Sampler	GO-FLO sampler
Data Collected	Chlorophyll *a*, phaeophytin *a*	Abundance, biovolume, taxonomy, chlorophyll *a*, phaeophytin *a*	Abundance, carbon content, taxonomy, chlorophyll *a*, phaeophytin *a*
Depths	3 m	3 m	1 m
Replicates	n=3	n=3	n=3
Sampled Sites	Roberts Bay (1 site)	Roberts Bay (1 site)	Roberts Bay (7 sites)
		Hope Bay (1 site)	Reference Bay (2 sites)

Table 2.3-4. Summary of Historical Marine Zooplankton Sampling, Hope Bay Belt Project

	Year	
	2007	**2009**
Sampling Month(s)	July, August, September	August
Sampling Device	Wisconsin net; 152 µm mesh size	Birge-style net; 202 µm mesh size
Data Collected	Abundance, biomass, and taxonomy	Abundance and taxonomy
Replicates	n=1	n=3
Sampled Sites	Hope Bay (1 site)	Roberts Bay (7 sites)
		Reference Bay (2 sites)

Table 2.3-5. Summary of Historical Marine Benthos Sampling, Hope Bay Belt Project

	Year		
Year	**1997**	**1998**	**2009**
Sampling Month	August	July	August
Sampling Equipment	Ekman; 493 µm sieve	Ponar; 500 µm sieve	Ponar; 500 µm sieve
Replicates	n=1	n=1	n=3
Sampled Sites	Roberts Bay	Roberts Bay	Roberts Bay
	(3 sites)	(3 sites)	(11 sites)
		Hope Bay (3 sites)	Reference Bay (3 sites)

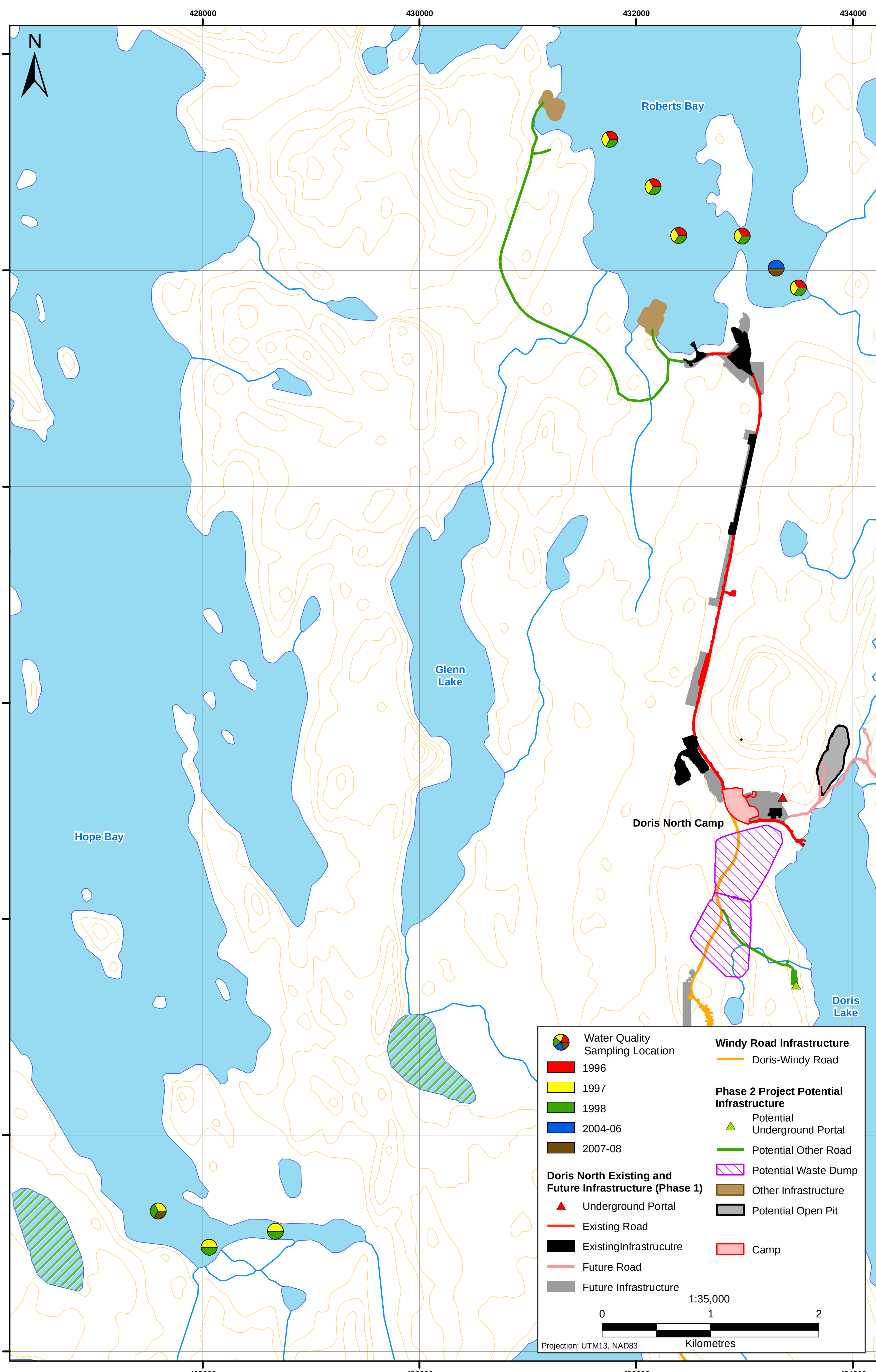

Figure 2.3-1

Historical Marine Water Quality Sampling Locations, Hope Bay Belt Project

Figure 2.3-1

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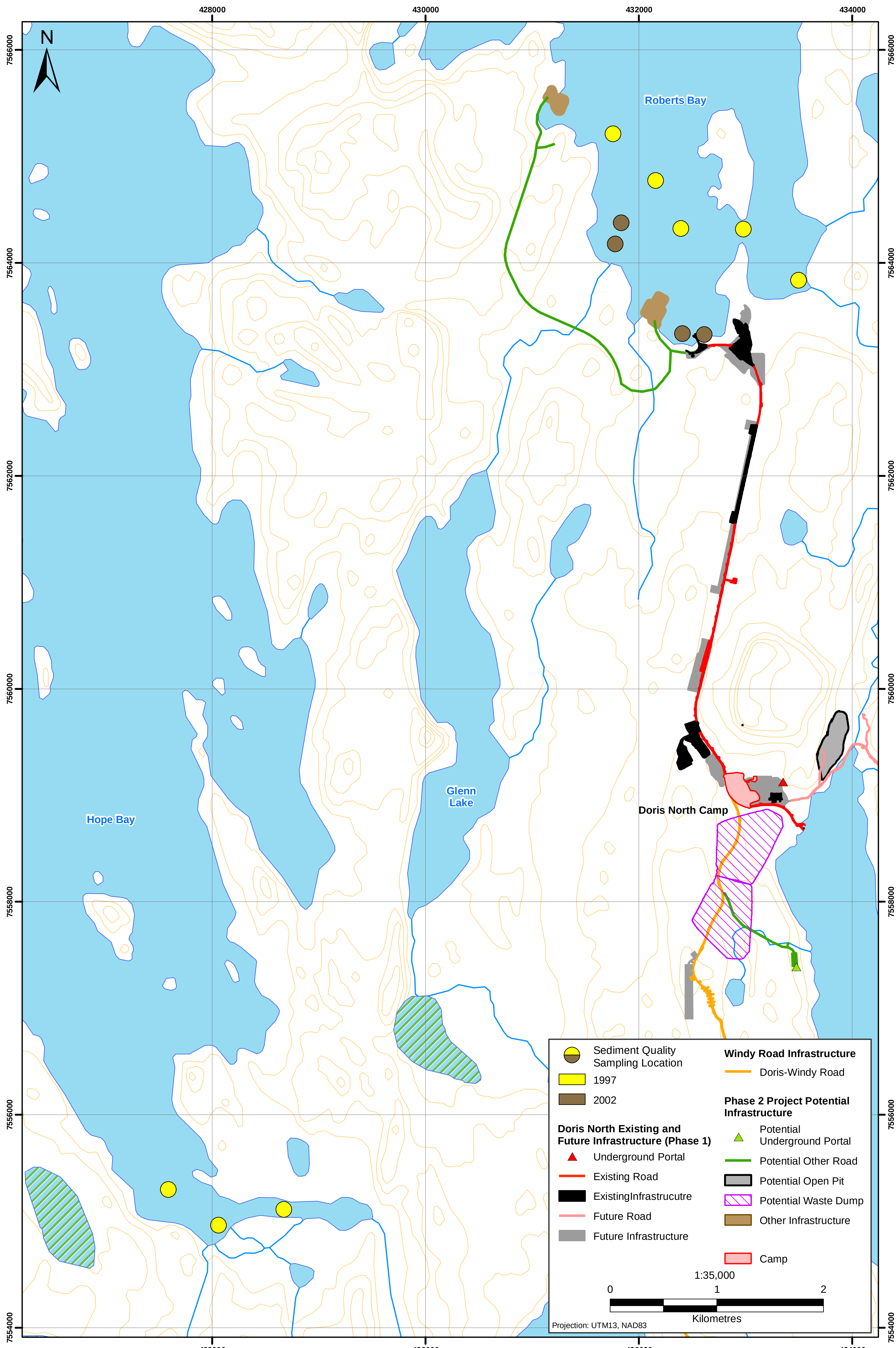

Figure 2.3-2

Historical Marine Sediment Quality Sampling Locations, Hope Bay Belt Project

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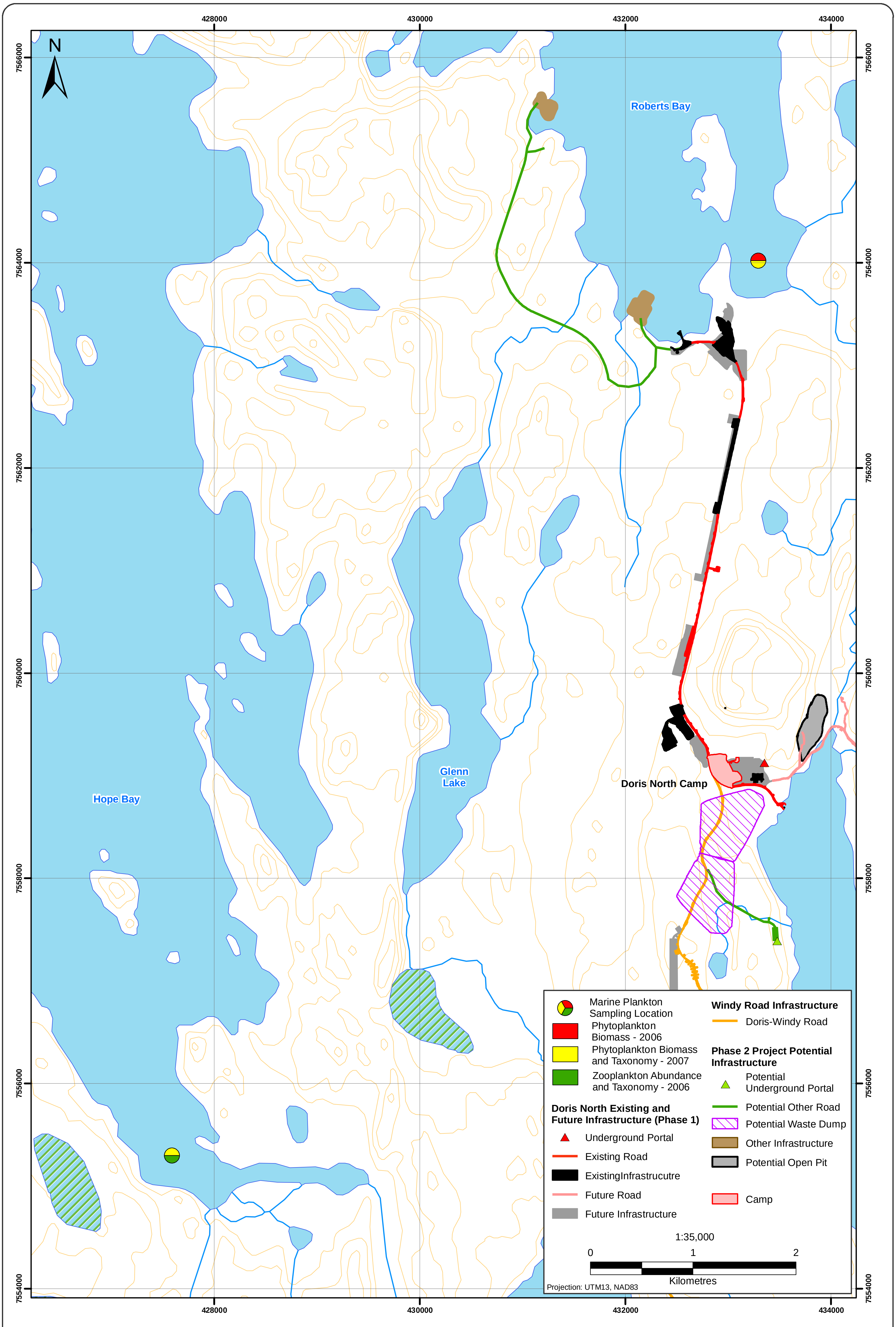

Figure 2.3-3

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Historical Marine Plankton Sampling Locations, Hope Bay Belt Project

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Figure 2.3-3

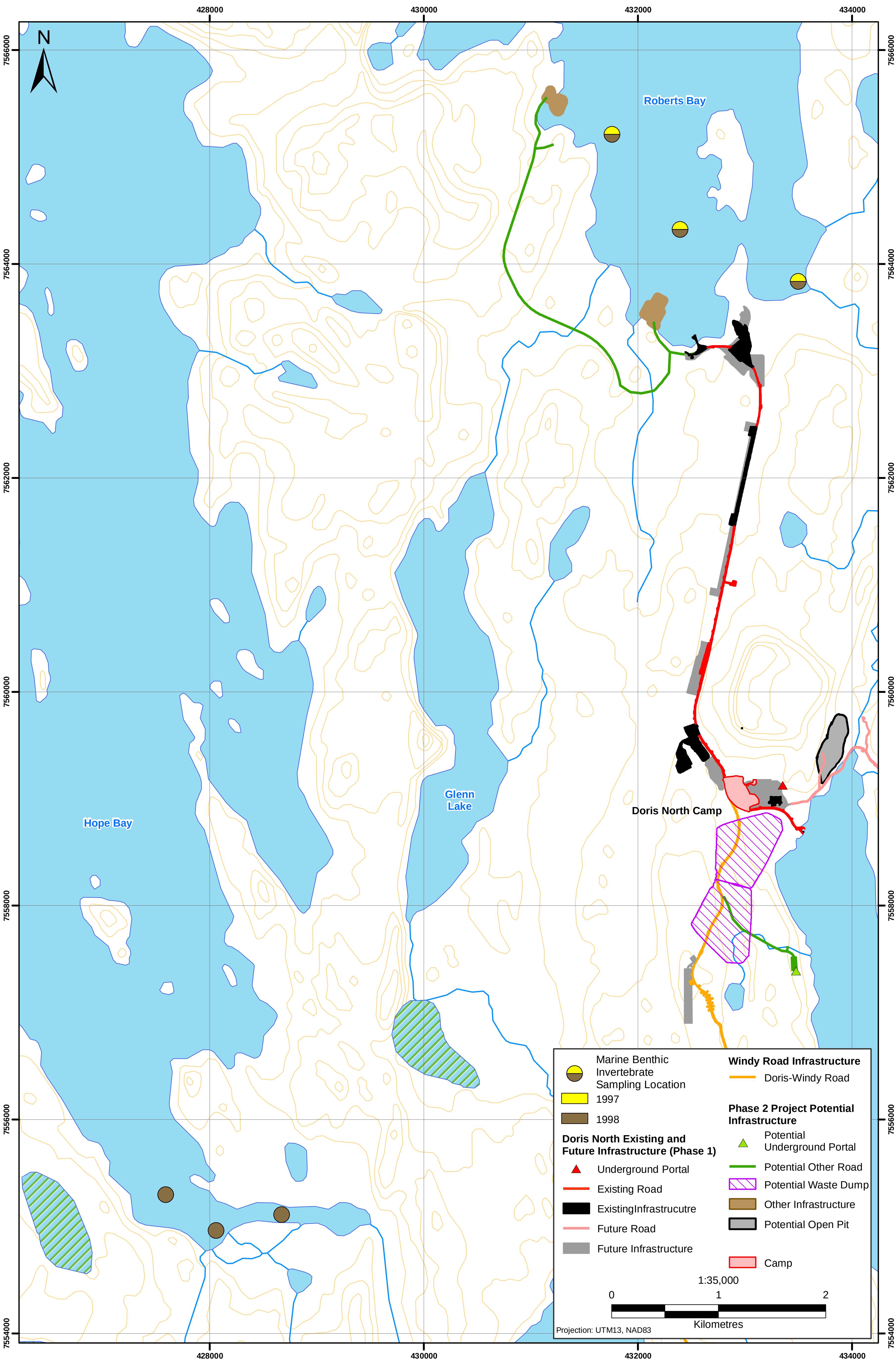

Figure 2.3-4

Historical Marine Benthic Invertebrate Sampling Locations, Hope Bay Belt Project

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3. Results and Discussion

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3. Results and Discussion

Physical, chemical, and biological oceanographic sampling was conducted in three distinct basins near the Project area between April and August, 2009. Roberts Bay, the central-most embayment, is a small, broad fjord with a shallow sill (~30 m) located just north of the constriction that separates inner Roberts Bay from the outer portion that connects to Melville Sound. Roberts Bay receives inflow from a few small streams (primarily from Glenn Outflow and Little Roberts Outflow), and maximum depths can exceed 75 m in the inner section. To the west, Hope Bay is a broad inlet with free connection to Melville Sound. It is interspersed with many islands and islets and receives much of its freshwater from the Koignuk River, the largest riverine system in the immediate Project region. It had the deepest depths sampled during the marine baseline program (>80 m). The final inlet is Reference Bay, a typical fjord to the east of Roberts Bay, which is long (~10 km), deep (>60 m), with a constriction and sill (~20 m) located near its mouth. Steep cliffs border this fjord to the east and the principal freshwater source is from the Angimajug River.

3.1 SNOW AND ICE COVER

Winter marine sampling was conducted in Roberts Bay and Hope Bay during late April and early May, 2009. Ice thickness during this period ranged between 130 cm and 200 cm in Roberts Bay and 175 cm and 194 cm in Hope Bay (Table 3.1-1). The average ice thickness was slightly higher and less variable in Hope Bay (184±6 cm) than in Roberts Bay (165±18 cm). Snow cover ranged from 1 cm to 35 cm with Roberts Bay having higher coverage (mean: 19.4 cm) than Hope Bay (mean: 13.1 cm). No ice measurements were taken at REFW in Reference Bay.

Table 3.1-1. Snow and Ice Cover in Roberts and Hope Bays, Hope Bay Belt Project, April/May 2009

Bay	Ice Depth (cm)	Snow Depth (cm)
Roberts Bay		
(n=11)		
Mean	165.0	19.4
SD	18.4	9.4
Max	200	35
Min	130	1
Hope Bay		
(n=15)		
Mean	184.1	13.1
SD	6.0	8.5
Max	194	28
Min	175	2

3.2 WATER COLUMN STRUCTURE

3.2.1 Winter

3.2.1.1 Roberts Bay and Reference Bay

Conductivity, temperature, and depth (CTD) casts were conducted at 12 sites in Roberts Bay (WT0 to WT11) and 1 site in Reference Bay (REFW) during two time periods. Six casts were completed between April 28 and April 30, 2009 (WT0, WT1, WT2, WT4, WT6, and REFW), and eight casts were performed on May 7, 2009 (WT3, WT5–WT11). Site WT6 was profiled in both April and May. April casts coincided with the collection of dissolved oxygen profiles and water quality samples. Profiles of the thermohaline structure (temperature and salinity) in Roberts and Reference bays are presented in Figures 3.2-1 to 3.2-5. The full dataset is provided in Appendix 3.2-1.

During the April thermohaline survey, upper water column salinities were usually above 26.5 and always above 26 (Figure 3.2-1). Site WT2 had the least dense surface water with the lowest surface salinity (~26.2) and warmest surface water (-0.8°C) of the five sampled locations. The most landward site, WT1, also had reduced surface density (i.e., lower salinity, higher temperature) compared to the seaward sites (WT4 and WT6). The seaward sites showed distinct vertical stratification with pycnocline depths between 12 and 15 m. Here, surface salinities of 26.6–26.8 increased with depth, reaching a maximum of 27.7 at 48 m at WT4. Interestingly, the more landward site, WT4, had higher deep water density (i.e., salinity) than WT6. Water quality analysis also showed that sodium and chloride concentrations (the primary constituents of seawater) were higher at WT4 than WT6, thus corroborating the CTD results. This indicates that the winter-long brine rejection in the shallow landward section of Roberts Bay was forming a density current that was sinking over the shelf break into the deep water near WT4.

The outer sites also showed signs of 'brining', or brine rejection, evidenced by the high salinity of the surface water and decreasing salinity towards the top of the pycnocline layer. As ice forms in saline environments, brine rejection is the process by which salt is released into the underlying waters, creating density-driven convections in the surface layer. This occurs at a temperature of -1.4°C and a salinity of 26 (i.e., levels observed in the surface waters of WT4 and WT6 during the April survey). This suggests that the ice sheet in the outer regions of Roberts Bay was expanding in thickness at the time of sampling.

At the winter Reference Bay station, REFW, thermohaline profiles were less defined than in Roberts Bay (Figure 3.2-1). Surface temperature and salinities were similar to those in Roberts Bay, but the vertical density gradient was less pronounced. Since the REFW site is located over a sill and within a constriction, enhanced vertical mixing and bottom-generated turbulence would be generated in this region as tidal water is forced through the complex bathymetry.

The second CTD survey was conducted a week after the first set of casts (May 7, 2009). Unlike the April CTD survey, the May survey was completed in a single day and the north–south transect began more seaward (WT3) and extended into outer Roberts Bay (WT8; Figure 3.2-2). An east–west transect was also completed (Figure 3.2-3). As seen in the first CTD survey, the north–south thermohaline profiles showed strong vertical stratification and evidence of brining (Figure 3.2-2). Thermohaline profiles from the outermost sites (WT5 through WT8) of the north–south transect were largely similar, while WT3 had slightly fresher and warmer surface water. This may have been due to reduced brine rejection (water was below -1.0°C) or groundwater inflow (all inflowing riverine systems were frozen).

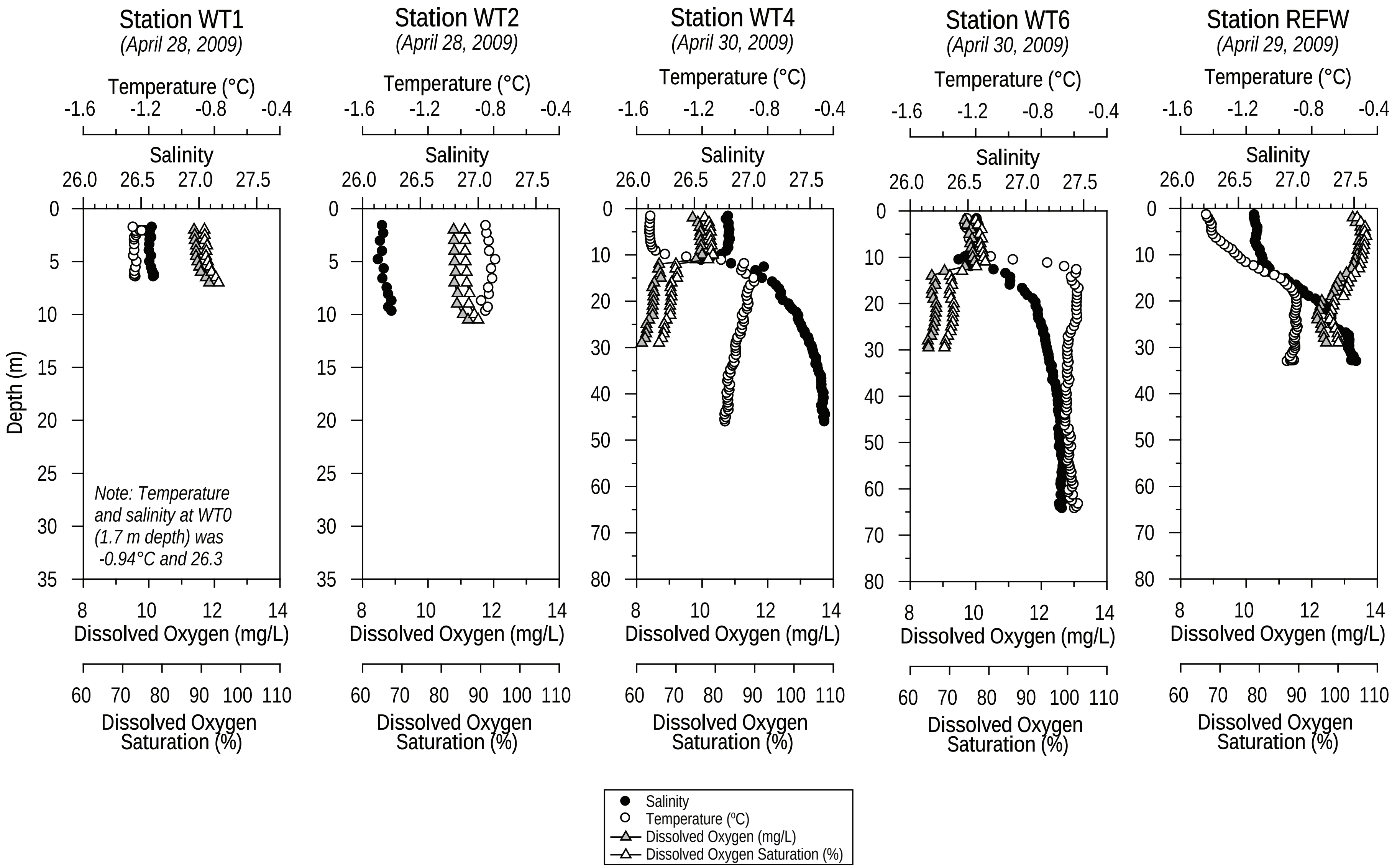

Figure 3.2-1

Temperature, Salinity, and Dissolved Oxygen Profiles in Roberts and Reference Bays, Hope Bay Belt Project, April 2009

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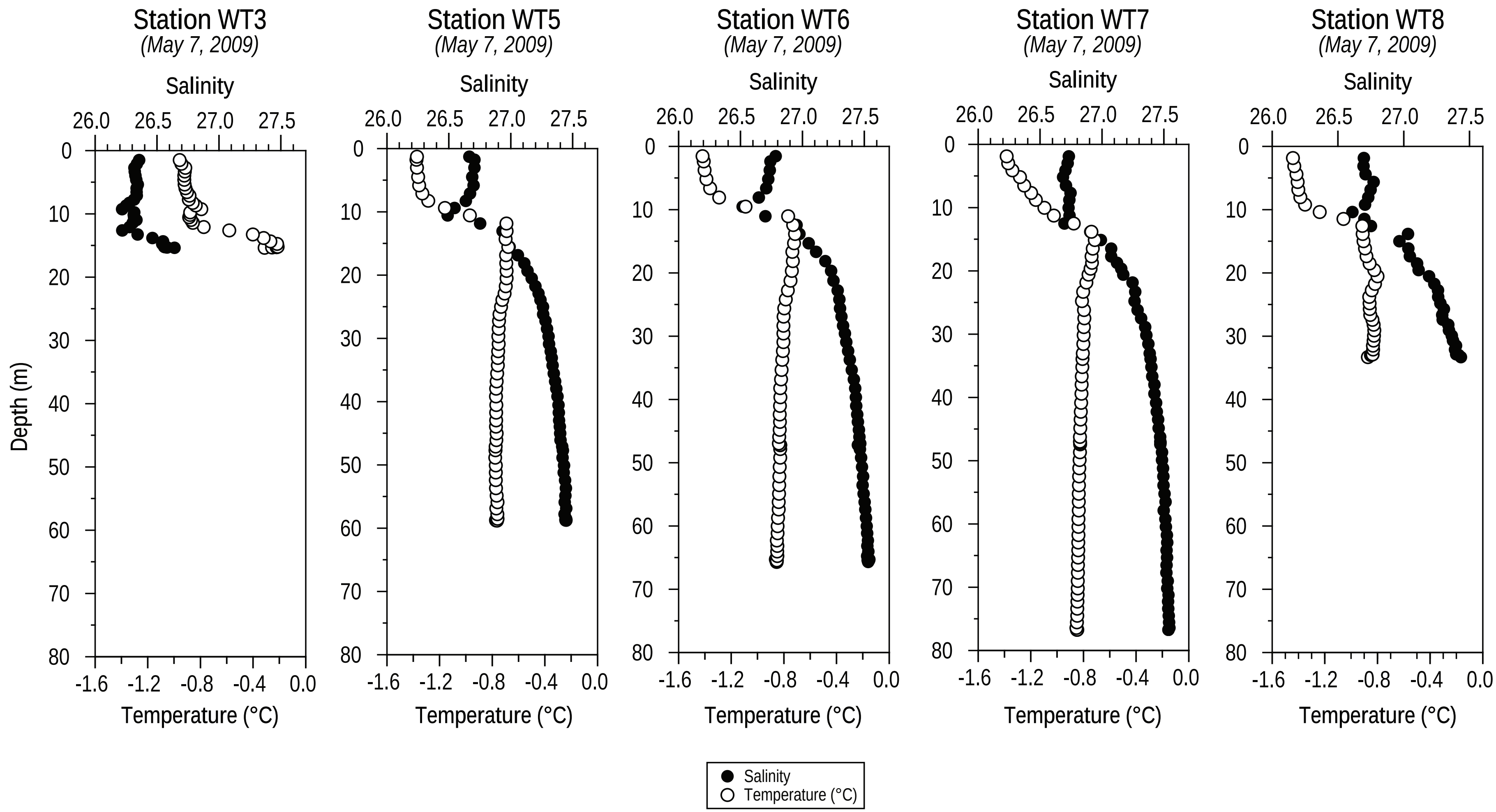

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Temperature and Salinity Profiles in Roberts Bay, Hope Bay Belt Project, May 2009

Figure 3.2-2

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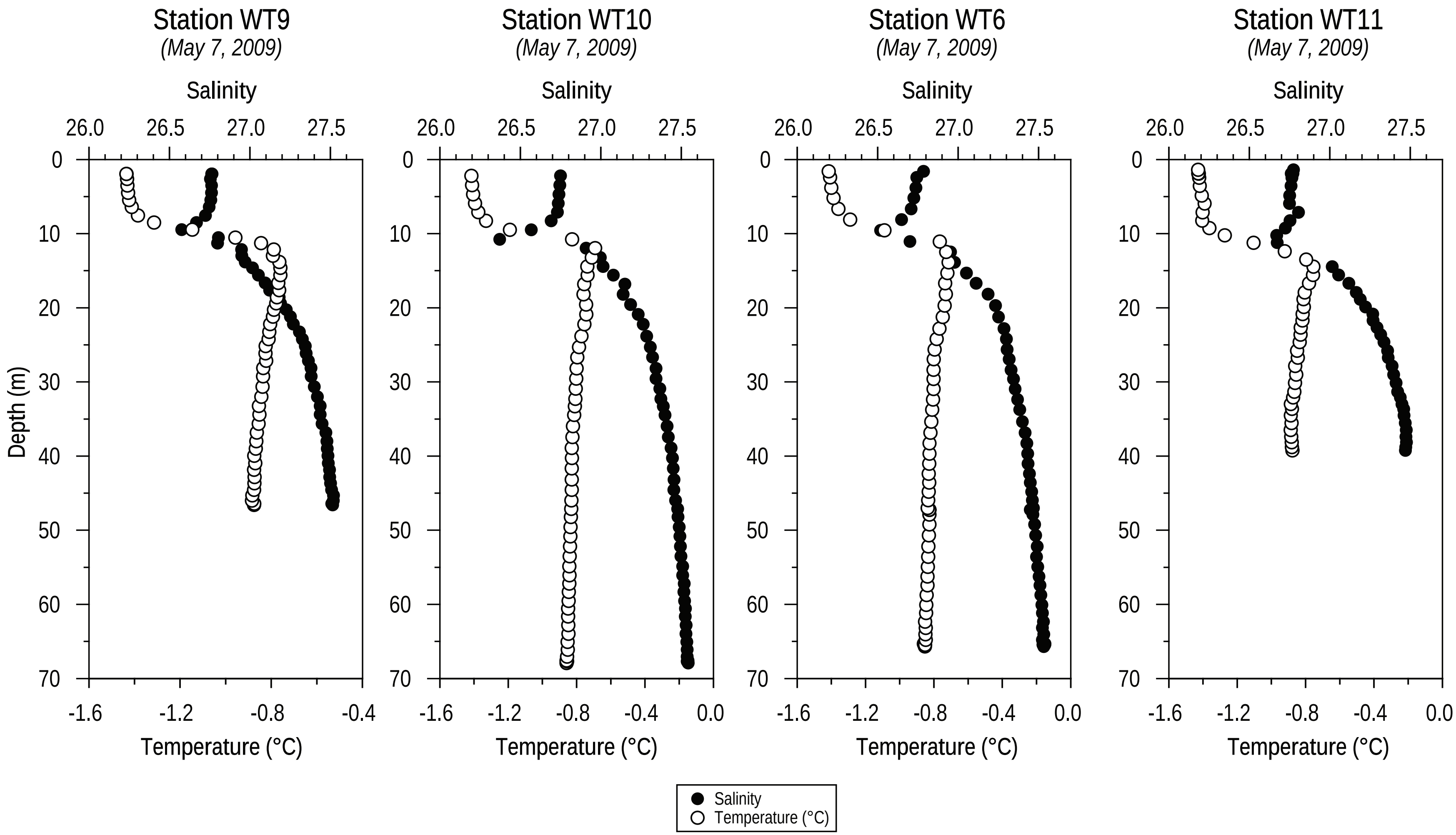

Temperature and Salinity Profiles in Roberts Bay, Hope Bay Belt Project, May 2009

Figure 3.2-3

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The higher subsurface salinity and vertical stratification at WT3 indicates that the influence of oceanic bottom water begins in this region of Roberts Bay. Overall, the surface layer was warmer and more brackish at the head of the inlet (WT3) and became progressively more saline and colder towards the sea (Figure 3.2-4). The deep water portion of the basin was characterized by warmer temperatures and much more saline water (>27.5). Notably, there is a sill at the entrance to Roberts Bay (WT8). This restricts the flow of bottom water into Roberts Bay, which leads to reduced deep water oxygen replenishment. These areas tend to be regions of enhanced metal and nutrient concentrations due the continual remineralization of sinking organic material and the lack of deep water renewal. Outside of the shallower depths, the east–west thermohaline profiles were largely similar to those along the north-south transect (Figure 3.2-3).

Tidal differences were also present under the ice. Figure 3.2-5 presents the density profiles collected at WT6 on April 30 and May 7, 2009, and clearly shows the presence of higher density water moving into Roberts Bay on May 7, 2009. This sampling date corresponded with the spring tidal cycle (April 30 was a neap tide), thus the higher density water may be evidence of increasingly oceanic water moving into Roberts Bay during a strong spring flood tide.

3.2.1.2 Hope Bay

Thermohaline data were collected at 15 sites in Hope Bay (HB1 to HB15) on May 2 and May 6, 2009. Seven sites were sampled on May 2 (Figures 3.2-6 and 3.2-7) and eight sites were sampled on May 6 (Figures 3.2-8 and 3.2-9). Figures 3.2-6 and 3.2-8 show the thermohaline profiles at the head of Hope Bay, and Figures 3.2-7 and 3.2-9 show the profiles near the mouth of the bay. The full dataset is provided in Appendix 3.2-2.

Overall, Hope Bay surface salinities (~26.6–26.8) and temperatures (~-1.4°C) were similar to Roberts Bay. The main difference between the two inlets was the less defined vertical stratification in Hope Bay. Pycnocline depths in Hope Bay were near 10 m, but isohaline (constant salinity) conditions were generally not attained until 20 m below this depth. This likely resulted from the increased mixing caused by water flowing through the network of islands and raised bathymetries present in Hope Bay. Like the seaward Roberts Bay sites, there was evidence of brining in the Hope Bay sites since surface temperatures were below -1.4°C (the freezing temperature of seawater at salinities exceeding 26). Notably, the salinity at site HB1, where the Koignuk River empties into Hope Bay, was 27.1. This indicates that no freshwater was flowing from the Koignuk into Hope Bay in early May. As well, deep water salinities were slightly lower at HB3 (27.3) than the seaward sites (27.5). Since this site is located in the narrowing section of Hope Bay, it is likely that tidal mixing is stronger here and less dense surface waters are more fully incorporated into the bottom layer.