Report for:

Decommissioning of Dock Facilities at Polaris Mine
Little Cornwallis Island, Nunavut

00282
March 2001

Westmar

COMINCO LTD.

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TABLE OF CONTENTS

Executive Summary

Figure 1 in *Appendix A* shows the location of the Polaris Mine at the southwest end of Little Cornwallis Island in the Canadian High Arctic. The mine produces lead and zinc concentrates that are shipped out during a short shipping season when bulk carriers can safely navigate the ice infested waters.

The mine is nearing the end of its life, and is to be decommissioned and returned, as close as possible, to a natural condition. Westmar was retained by Cominco Ltd. to examine concepts for decommissioning the dock and adjacent shoreline. Norman Allyn, P.Eng., Manager Coastal Engineering at Westmar, visited the site in August 2000. In September 2000, he met with the contractor that constructed the dock in 1980 and 1981.

The form and method of construction provided a cost-effective installation that was completed in a relatively short time frame, given the harsh environmental conditions. The facility included a sheet pile cell dock built from the ice in the winter, and a barge containing all of the process equipment that was set on a prepared base and incorporated into the shoreline.

This report reviews various options to decommission the dock facilities at the Polaris Mine operations. The report examines the main issues associated with each of three options considered, and recommends one of the options as the preferred method of decommissioning the dock facilities.

Prior to decommissioning, the following detailed design work will be required:

- Prepare accurate topographic and hydrographic surveys of the surrounding site.
- Incorporate the remedial excavation proposed in "Polaris Mine Decommissioning and Reclamation Plan" by Gartner Lee Ltd.
- Finalize the excavation plane through the dock to minimize the cut and fill volumes, within the ranges discussed in this report and based on the topographic survey and remedial excavation, while protecting the aquatic environment by minimizing erosion and sedimentation.
- Develop detailed procedures for the excavation process of the dock area to ensure protection of the aquatic environment during the process.

- Determine the gradations of the natural beach and fill materials to evaluate their rates of erosion.

- Assess the need to perform a thermodynamic analysis on the natural beach and fill materials, to determine the suitability of the proposed beach material to resist erosion based on the beneficial effect of permafrost.

The following three options were considered for decommissioning the dock facilities:

Option 1: Cut off the sheet piles under water and reinstate a beach profile that will minimize erosion.

Option 2: Encase the dock in rock.

Option 3: Leave the dock in place (do nothing).

Option 1 is the preferred option for the following reasons:

- It has minimal impact on the aquatic environment, as there is no work on the seabed.

- The flat slope will have minimal sedimentation rate due to the flat slope angle and the action of permafrost, both of which result in reduced erosion.

- It reestablishes a smooth shoreline similar to the original shoreline, and removes the dock as a projection of the beach into Crozier Strait.

The option will comprise the following activities:

- Excavate a trench on the back or east side of the dock, and cut-off the sheet piles at an elevation of about 1 m below lowest normal tide.

- Inspect for, and recover any refrigerant in the freezing pipes in the dock. Remove the freezing pipes.

- Spill contingency plans must be in place in case there is a spill of the refrigerant while recovering it to prevent potential contamination from reaching the ocean.

- Inspect soils for any evidence of refrigerant and excavate any contaminated soils.

- Remove the frozen fill in the interior of the cells by drilling, blasting and/or excavating. The deepest practical depth is about 3 m below lowest normal tide. The sheet piles should be left in place during excavation near the water to prevent fill from falling into the water.

- Either remove the sheet piles completely or alternatively cut them off 2 to 3 m below the lowest normal tide at the front or west face of the dock. Taper up at the sides to achieve a sloping seabed of about 17.5H:1V which approximates the original beach slope below the high waterline.

- Remove the rock fill adjacent to the sheet piles.

- Re-grade the adjacent shoreline, and the fill on the land side of the dock to achieve the design beach slope.

- About 80,000 m^3 of fill will be removed from inside the cells and in the vicinity of the dock to achieve a smooth shoreline. The near surface material that is contaminated with concentrate dusts will be removed and disposed of in the mine (refer to Polaris Mine Decommissioning and Reclamation Plan). Underlying clean materials that are excavated will be utilized as fill at other areas of the site.

- The steel beams remaining from the original temporary dock located near Section Line 800N, as shown in *Drawing No. 00282-00-101* in *Appendix D*, will be removed or cut-off at ground level (see *Photograph Nos. 21 and 22* in *Appendix B*).

To achieve a cost-effective solution, contractors should be allowed to propose alternative methods of performing the work so that the best use is made of available equipment. However, no proposal will be considered that does not meet the requirements of Cominco or fails to provide adequate protection to the aquatic environment.

Glossary

- D_{50}: The cubic dimension of the mean size rock by weight, such that 50% of the total weight of rock is comprised of pieces of rock smaller than the D_{50} size of rock.
- Fetch: The length of open water over which wind from a specific direction can generate waves.
- Peak Wave Period, T_P: The wave period of the most energetic waves in a wave train.
- Return Period: The average time period between events of a given or greater intensity.
- Significant Wave Height, H_S: The average height of the highest 33% of the waves in a wave train.
- Wave Height: The distance from trough to peak of a wave, measured vertically.
- Wave Period: The time for two successive wave crests to pass a given point.
- W_{50}: The weight of the mean size rock, such that 50% of the total weight of the rock is comprised of pieces of rock weighing less than the W_{50} weight of rock.

1 Introduction

1.1 General

Polaris Mine in the Canadian High Arctic is located at the southwest end of Little Cornwallis Island, as shown in *Figure 1* in *Appendix A*.

The lead and zinc ore is mined underground in permafrost, crushed and then transported by conveyor to the process barge, where it is processed into lead and zinc dry concentrates.

The concentrate is shipped to market during a short shipping season when bulk ore carriers can navigate to the deep sea dock through the ice infested waters. The MV Arctic, which is capable of breaking about 1.2 m thick sheet ice, is the first vessel in, and the last vessel out.

The mine is nearing the end of its life, and is to be decommissioned by returning it as close as possible to a natural condition. Westmar was retained by Cominco Ltd. to examine the decommissioning of the dock and adjacent shoreline. Norman Allyn, P.Eng., Manager Coastal Engineering at Westmar, has extensive arctic marine experience, and is the project manager for this work. Mr. Allyn travelled to the site in August 2000, and met with the dock construction contractor in Montreal in September 2000.

This report addresses options for decommissioning the dock.

1.2 Description of Dock and Shoreline

The mine was constructed over a two year period in 1980 and 1981. The construction incorporated techniques that provided a fast and cost-effective installation. These included a sheet pile cell dock built from the ice in the winter, and a barge containing all of the process equipment that was set on a prepared base and incorporated into the shoreline. The facilities are described as follows.

1.2.1 Sheet Pile Cell Dock

The berth for the export of the concentrate on bulk carriers was constructed using steel sheet pile cells. Four cells, each about 26 m in diameter, were constructed by driving sheet piles through the ice in the early winter of 1981. The four cells were tied together by three inter-connecting arcs on the front face. The cells were filled with rock and overburden excavated from the barge dry dock. The front face of the cells form a berth approximately 90 m long with a depth of about 13 m at low water.

1.2.2 Process Barge

The 31 m wide by 122 m long process barge was built in Quebec and towed to the site. A base was prepared in the dry dock, and upon arrival of the barge in mid August 1981, the dry dock was flooded by removing the closure berm.

The barge was floated into place on a high tide, and was ballasted down onto the prepared base. The entrance to the dry dock was filled in to form the shoreline adjacent to the northernmost cell of the dock. The location of the process barge is shown in *Drawing Nos. 00282-00-101 and 00282-00-103 in Appendix D*.

1.3 Construction of Dock in 1981

The dock was built by Tower Arctic Ltd. A paper on the construction is attached in *Appendix E*.

Tower Arctic adopted the following construction procedure:

- The ice was first flooded and thickened to 3 m.
- A slot was cut in the ice using a double bladed chainsaw device called a "ditch witch".
- A curved steel pile driving guide was placed on the ice on the outside of the cells.
- The sheet piles were driven through about 3 m of silt to allow a minimal penetration into the underlying fractured limestone, using a vibro-hammer.
- Three small tie arcs, with a radius of 4.5 m, were installed along the front face, to connect the four cells as shown on *Drawing No. 00282-00-101 in Appendix D*.
- The sheets were 24 m long, and were cut-off 4.6 m above water level, except for a section at the back, where they were cut-off lower to allow trucks to end dump fill into the cells.
- The ice in the interior of the cells was cut up and removed. Weak silts inside the cells were excavated from a portion of the seabed at the front of the cells, before filling.

- Fill was placed inside and along the back of the cells, using excavated material from the process barge dry dock. Mine rock was not used in the fill.

- Sheets of insulating styrofoam were placed between the fill and the sheet piles, on the front and sides of the dock where the sheets are exposed to the sun. The insulation was approximately 100 mm thick, 3 m long and 0.6 m wide.

- Work was completed in mid May 1981, when the ice started to deteriorate.

- The concrete cope beam and the bollards were installed in the summer.

- The intention was to install a refrigeration system to freeze the fill. However, using thermistors, it was determined that the natural progress of the freeze front was adequate and only part of the refrigeration system was installed. The freeze pipes are shown on Bechtel Canada Limited *Drawing No. 110-C-148, Rev. A, "Dock Freezing Arrangement"*, which contains a handwritten note "All work on this drawing is cancelled, May12, 1981". The pipes shown have an outside diameter of 150 mm, are set in the fill to an elevation of about -10 m Plant Datum (PD), and are sealed with a blind flange 150 mm below the top surface of the fill. It is known that a number of the freeze pipes were installed and that the refrigeration plant operated for a brief period of time.

The shoreline on either side of the dock consists of fill and riprap rock slope protection, which is "faired in" to the original shoreline to the north of the dock between Stations 1700N and 1800N and south of the dock at approximately Station 800N as shown in *Drawing No. 00282-00-101* in *Appendix D*.

Cross-sections of the shoreline in the vicinity of the dock are shown in *Drawing Nos. 00282-00-102 to 00282-00-106* in *Appendix D*.

2 Design Criteria

The design criteria for ice coverage, wind and waves are developed in the following subsections. Supplementary information on datums, tide elevations and currents is provided in *Appendix C*.

2.1 Ice Coverage

Ice coverage is important in determining the open water to the south of Polaris, in McDougall Sound and Barrow Strait, for calculating waves that can be generated in this area under the action of winds from the south.

Information on ice coverage was obtained from the following references:

- Annual Arctic Ice Atlas, Canadian Ice Service, Environmental Canada, 2000.
- Ice Thickness Climatology, 1961 - 1990 Normals, Ice Centre, Ice Climatology Services, Ottawa, Ontario, 1992.
- Canadian Sea Ice Atlas from Microwave Remotely Sensed Imagery: July 1987 to June 1990, E. LeDrew, D. Barber, T. Agnew and D. Dunlop, 1992.
- Ice Atlas, Canadian Arctic Waterways, W.E Markham, 1981.
- Supplement to Ice Atlas, Canadian Arctic Waterways, W.E. Markham, 1984.

From these references, the following is noted:

- The average ice thickness at the end of the ice growth period in May/June is about 2.0 m.
- The average date on which melting degree days start to accumulate is about mid June.

- The average date on which break up of the ice occurs is mid August. *Figure 2 in Appendix A* from the Ice Atlas, Canadian Arctic Waterways shows that by August 20th, the ice cover at Polaris has reduced to 8/10 or 80% ice coverage of the sea surface in a median year.

- The break up date is variable, and full open water does not occur in the average year. *Figures 3 and 4* in *Appendix A* from the Ice Atlas, Canadian Arctic Waterways, show that in the ice season with maximum ice, coverage is still 7/10 or 70% ice coverage of the sea surface at the end of August, and 10/10 or full ice coverage of the sea surface as early as September 10th.

- The average date of the beginning of the accumulation of freezing degree days is September 1st.

- The average date of the start of freeze up is mid September. *Figures 5 and 6* in *Appendix A* from the Ice Atlas, Canadian Arctic Waterways show that on September 17th, the cover is 2/10 or 20% ice coverage of the sea surface at Polaris in an average ice season, but increases to 9/10 or 90% ice coverage of the sea surface by September 24th.

- The freeze up date is variable, and can occur as late as early October. *Figure 7* in *Appendix A* from the Ice Atlas, Canadian Arctic Waterways shows open water at Polaris on October 8th.

The Ice Atlas by Markham is for 15 years of data, and indicates that in most years, the open water season is less than one month. From observations, the area does not completely clear of ice, with ice remaining in bays and along the coastline. It is considered that about once in 15 years the ice will clear to the extent that significant fetches for the generation of waves will occur, similar to the open water shown in *Figure 8* in *Appendix A*.

2.2 Wind

Wind data for Resolute was obtained from the Meteorological Service of Canada, Environment Canada, Toronto, Ontario. The wind data provided the monthly maximum wind speeds for the period of 1953 to 2000, of which there were 38 years of good data.

A Gumbel analysis of the data was performed to determine the extreme wind speed in the month of September, when open water could occur.

The design return period of 200 years was selected in consultation with Mr. Bruce Donald, P.Eng. of Cominco Ltd. For a 1 in 15 year probability of achieving open water, the corresponding return period for wind is 13 years, to achieve a combined return period of 200 years.

For a return period of 13 years, the September wind speed is calculated as 23 m/s. This compares with the wind data provided in the National Building Code of Canada (NBCC) for Resolute, which gives the 1 in 10 year wind speed for all months as 28 m/s. The reason that the 13 year return period wind speed for September is lower than the 10 year return period wind speed is as follows:

C The 13 year return period wind speed is for the month of September only, and so is for a return period of 13 months at the time of year represented by the September wind data.

C The 10 year return period wind speed is for all twelve months of the year, and so is for a return period of 120 months.

The 1 in 200 year return period design hourly average wind speed, predicted for September is about 30 m/s. This compares with the wind data provided in the NBCC for Resolute, which gives the 1 in 100 year wind speed for all months as 34 m/s. The comparisons with the NBCC indicate that the predicted wind speeds for September are of an appropriate magnitude.

2.3 Waves

Wind-generated wave heights and periods are a function of wind speed, wind duration and fetch.

Fetch, represented by open water, is determined by ice coverage. It is assumed that the wind speed is independent of ice coverage, and so a joint probability study of wind speeds and ice coverage was carried out to predict the 200 year return period wave height. The combination of return periods on open water wind speed considered are shown in *Table 1* on the following page.

TABLE 1: Combined Wind and Fetch for Design Return Period Event of 200 Years

Design Return Period for Waves	Return Period for Ice Coverage	Fetch	Return Period for Maximum Wind Speed	Maximum Hourly Average Wind Speed
200 year	15 year	100 km	13 year	23 m/s

Deep water design waves were predicted using the wave hindcasting technique in the US Army Corp of Engineers "Shore Protection Manual" (1984). The predicted design wave that will occur once in 200 years, including the effects of ice cover, shoaling and refraction is as follows:

- H_s: 3 m
- T_p: 9 sec

Where H_s is significant wave height and T_p is the peak wave period.

2.4 Rock Quality

Testing of three potential riprap materials, namely Limestone and Dolomite rock from the Little Red Dog Quarry (LRDQ), and Mine Rock, was performed by Levelton Engineering Ltd. and detailed results are attached in *Appendix F*. The results are summarized in *Table 2* on the following page, and indicate that only the Limestone rock from the Little Red Dog Quarry is suitable for use as riprap for slope protection for the following reasons:

- The Limestone rock meets the specified results for all seven tests.
- The Dolomite rock does not meet the specified Freeze-Thaw result.
- The Mine rock does not meet the specified results for LA Abrasion, Magnesium Sulphate Soundness, Petrographic Examination or Freeze-Thaw.

TABLE 2: Rock Quality Test Results

Test	Requirement	Sample		
		Limestone	Dolomite	Mine Rock
LA Abrasion, 500 revolutions (ASTM C535)	Not more than 30% loss.	17.1 %	17.3%	44.8%
Durability Index (ASTM D3744)	No index less than 35.	92	82	71
Bulk Specific Gravity (saturated surface dry, ASTM C127)	Not less than 2.65.	2.74	2.63	3.76
Absorption (ASTM C127)	Not more than 2%.	0.985%	1.56%	1.72%
Magnesium Sulphate Soundness, 5 cycles (ASTM C88)	Not more than 15% loss.	1%	0.6%	31.6%
Petrographic Examination	Absence of weakness or materials that could result in significant stone alteration and reduction in durability.	Excellent	Good	Poor
Freeze-Thaw (CIRIA Special Publication 83, A2.4)	Not more than 0.5% weight loss.	0.03%	5.2%	0.7%

2.5 Slope Protection and Natural Beach Materials

2.5.1 Riprap Rock Size

The size of riprap rock was calculated using the Hudson Formula in the US Army Corps of Engineers "Shore Protection Manual", 1984. For the 200 year return period design wave (H_s = 3 m), nominal rock sizes required for protection of the shore at varying slopes are listed in *Table 3* on the following page.

TABLE 3: Riprap Rock Size for 1 in 200 Year Design Event for Varying Slope

Slope	Nominal Rock Size D_{50} (mm)	Rock Mass W_{50} (kg)
2H:1V	1,200	4,580
3H:1V	1,000	2,650
4H:1V	920	2,070
5H:1V	850	1,630

Note: 1. D_{50} is the cubic dimension of the mean size of rock, by weight.
2. W_{50} is the weight of the mean size of rock.

A mean rock size of 300 mm has been produced from LRDQ and used for slope protection, as can be seen in *Photograph Nos. 11 and 14*. It is possible to increase the size of rock produced from LRDQ by the following means:

- Increase the drill spacing and adjust the blast pattern and the amount and type of explosives in the drill holes.

- Use a grizzly to separate out the fraction of smaller rock.

LRDQ is generally highly fractured, as can be seen in *Photograph No. 1* in *Appendix B*. The joint spacing in the quarry will limit the mean size to the range of 400 mm to 500 mm. This size of rock was achieved just south of the dock at Station 1300 N, as shown in *Photograph No. 13*.

It is apparent that the mean size of rock required, even for a slope as flat as 5H:1V, cannot be produced in any quantity on Little Cornwallis Island.

2.5.2 Effect of Permafrost on Stability of Riprap and Natural Beaches

The surface of the permafrost at the beach is subjected to freeze/thaw cycles as follows:

- During the winter months, the beaches will become completely frozen.

- During the short open water season, the surface layer of the permafrost will thaw, but this will be less in the tidal zone than in the interior of the island due to the cooling effect of the sea water, which is near the freezing point of sea water.

The freeze/thaw cycles will have a different effect on the larger riprap material than on a natural beach comprised of sands and gravels, as follows:

- The riprap rock has large voids that will thaw at break-up, as observed with the riprap at the site during the site visit by Mr. Norman Allyn on August 17 to19, 2000.

- The natural beach consists of a wide gradation of sand and gravel material. The voids between the larger fraction of gravel are filled with the finer fraction of the sands and gravels, and so will not thaw to as great an extent as a riprap slope.

The limited thawing of the natural beach material is the reason why the slopes made from the finer naturally occurring sands and gravels resist erosion and are stable under wave attack, even when set at a steep angle. Examples of this can be seen in *Photograph Nos. 23 and 24* in *Appendix B*.

The presence of permafrost allows naturally occurring sands and gravels to resist erosion much better than beaches in southern climates. This effect, combined with the short open water season, is likely the main reason that islands in the arctic have stable sand and gravel beaches that resist erosion under seemingly hostile environmental conditions.

3 Concepts for Decommissioning Shoreline and Dock

The dock will remain in service during the decommissioning of the mine to load vessels with material leaving the site. It will be one of the last structures to be decommissioned.

Several concepts were addressed and the following three options were reviewed in detail.

3.1 Option 1 - Remove Dock to 2 to 3 m Below Low Tide Leaving a Beach With a Low Slope

3.1.1 Overview

This option involves excavating the dock fill material from inside the cells and then removing/cutting off the sheet piles. The cross-section of *Option 1* is shown in *Drawing No. 00282-00-103* in *Appendix D*. The remnants of the dock would be underwater where it will not present a hazard to small local vessel traffic.

The following work would be performed to complete Option 1:

- Excavate a trench on the east or back side of the dock, and cut-off the sheet piles at an elevation of about 1 m below lowest normal tide.

- Inspect for, and recover any refrigerant in the freezing pipes in the dock. Remove the freezing pipes.

- Inspect for and excavate any soils contaminated by refrigerant. This work will be done “in the dry”.

- Spill contingency plans must be in place in case there is a spill of the refrigerant while recovering it to prevent potential contamination from reaching the ocean.

- Remove the frozen fill in the interior of the cells by drilling, blasting and/or excavating. The deepest practical depth is about 3 m below lowest normal tide. The sheet piles should be left in place during excavation near the water to prevent fill from falling into the sea.

- Either remove the sheet piles completely or alternatively cut them off 2 to 3 m below the lowest normal tide at the front or west face of the dock. Taper up at the sides to achieve a sloping seabed of about 17.5H:1V, which approximates the original beach slope below the high water line.

- Remove the soil adjacent to the sheet piles.

- Re-grade the adjacent shoreline, and the fill on the land side of the dock to achieve the design beach slope.

- About 80,000 m^3 of fill will be removed from inside the cells and in the vicinity of the dock to achieve a smooth shoreline. The near surface material that is contaminated with concentrate dusts will be removed and disposed of in the mine (refer to Polaris Mine Decommissioning and Reclamation Plan). Underlying clean materials that are excavated will be utilized as fill at other areas of the site.

- The steel beams remaining from the original temporary dock located near Section Line 800 N, as shown in *Drawing No. 00282-00-101* in *Appendix D*, will be removed or cut-off at ground level (see *Photograph Nos. 21 and 22* in *Appendix B*).

To achieve a cost-effective solution, contractors should be allowed to propose alternative methods of performing the work so that the best use is made of available equipment. However, no proposal will be considered that does not meet the requirements of Cominco or fails to provide adequate protection to the aquatic environment.

3.1.2 Effect on the Shoreline

The condition of the shoreline was documented at 100 m intervals during the site visit by Mr. Allyn in August 2000. Photographs in *Appendix B* provide a visual condition record, and the cross-sections on the drawings in *Appendix D* show the original, existing and proposed shorelines. *Table 4* on the following page summarizes the information provided in *Appendices B and D*.

TABLE 4: Details of Option 1 at 100 m Intervals Along the Shoreline

Station	Existing Shoreline and Dock	Shoreline After Decommissioning
1800 N	Natural beach gravel with a mean grain size of about 10 mm.	The natural beach will remain unchanged.
1700 N	The north end of the fill, with some pieces of rock up to 300 mm cubic size.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to high water, and then faired into the existing ground line over a total distance of about 25 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
1600 N	Near the north end of the fill. The fill is not covered by riprap at this location, and has some pieces of rock up to 300 mm cubic size.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to high water, and then faired into the existing ground line over a total distance of about 45 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
1500 N	The bank to the north of this location is not covered with riprap, while the bank between this location and the dock is covered with riprap with a mean size of about 300 mm cubic dimension.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to high water, and then faired into the existing ground line over a total distance of about 25 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
1400 N	This section passes through the sheet pile cell dock and the Process Barge.	A plane sloping upward at 17.5H:1V from about 2 m below low water at the front of the dock, intersects the surface of the fill about 60 m west of the Process Barge. Erosion and sedimentation is controlled by the flat slope and permafrost.
1300 N	The bank at this location is covered with what is likely the largest possible size of riprap from Little Red Dog Quarry and observed on the shoreline, with a mean size of 400 mm to 500 mm.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V, and faired to the existing ground line over a total distance of about 75 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
1200 N	The bank between this location and the dock has been armoured with riprap in the last two years, while the shoreline south of this location has not and the gravel fill is generally unprotected from wave attack and is eroding.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to the existing ground line over a distance of about 35 m. Erosion and sedimentation is controlled by the flat slope and permafrost.

Station	Existing Shoreline and Dock	Shoreline After Decommissioning
1100 N	The bank is exposed to wave action as much of the riprap has slipped down the bank.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to the existing ground line over a distance of about 35 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
1000 N	Similar to Station 1100 N, the bank is exposed to wave action as much of the riprap has slipped down the bank.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to high water, and then faired into the existing ground line over a total distance of about 30 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
900 N	This location is at the north end of the Temporary Dock, which was installed in 1980/81 to offload equipment at the site before the sheet pile cell dock was operational.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to high water, and then faired into the existing ground line over a total distance of about 30 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
800 N	This location is at the south end of the temporary dock. There is riprap immediately to the north of this location, and natural beach to the south of this location.	This section will have some minor trimming to fair in the shoreline. Erosion and sedimentation is controlled by the flat slope and permafrost.
700 N	Natural beach gravel with a mean grain size of about 10 mm, similar to Station 1800 N.	There is no excavation required at this location.

Note: 1. The survey data provided to Westmar by Cominco Ltd. comprises widely spaced spot elevations, and so the cross-sections developed can only be considered as preliminary. Detailed topographic and hydrographic surveys are required to finalize the cross-sections and volumes for detailed design, tendering and construction.

The benefits of Option 1 are as follows:

C There is minimal impact on the aquatic environment, as there is no work on the seabed.

C The recontoured beach will be erosion resistant through the combination of a flat slope and the action of permafrost on the foreshore area of the beach, both of which result in reduced erosion.

- A smooth shoreline is reestablished, similar to the original shoreline.

- The steel sheet pile cell dock is removed as a projection of the beach into Crozier Strait.

The disadvantages of Option 1 are as follows:

- Precautions to minimize sedimentation during the decomissioning is required.

- Work methods require removal of the freeze pipes to be completed prior to the area being flooded to eliminate the potential release of contaminants into the ocean.

- The dock structure left in place some distance below the waterline will eventually erode over an extended period of time, but due to the gradual nature of the process, will not degrade the aquatic environment.

- The forces of nature will re-shape and erode the beach, but this is anticipated to take place over a sufficiently long period of time to not cause sedimentation that would degrade the aquatic environment. The rate of erosion should not be significantly different from the original beach.

3.2 <u>Option 2 - Encase the Dock in Rock</u>

The option encases the dock in rock and extends the existing shoreline 95 m to the southwest, as shown in *Figure 9* in *Appendix A*.

This option presents the following issues:

- An area of about 50,000 sq. m of the seabed will be covered by rock, which has a significant impact on the existing aquatic environment.

- In the order of 450,000 cu. m of rock would be required.

- The size of rock required to withstand ice action and waves in the 1 in 200 year return period design storm is larger than the size of rock available in Little Red Dog Quarry. Larger rock is available from the mine, but it is of poor quality and will not stand up to the freeze/thaw cycles, as discussed in *Section 2.6*. Importing rock would be prohibitively expensive, and is not considered practical. This option would only be erosion resistant if 850 mm, durable rock were used for the slope of 5H:1V in the wave zone.

The benefits of Option 2 are as follows:

- The dock could be uncovered at some future date and reused.
- Deterioration of the dock by ice and wave action is prevented.

3.3 Option 3 - Leave the Dock in Place

The dock and some land based facilities could be donated to the Government of Canada or Nunavut, as a northern base for the icebreaker fleet or for research activities. At this time, the Government has not responded to this offer. However, the Government is in the process of divesting marine facilities, and probably would not accept responsibility to maintain the facility for the long term.

Wave action is focussed on the slope of the fill adjacent to the ends of the dock. This is due to waves reflecting off the vertical face of the cells, and combining with the waves impinging directly on the slope from deep water. As a result, the rip rap on the slope at these locations would require continued maintenance to prevent loss of land behind and adjacent to the dock, and this is confirmed by the historical requirement to frequently re-armour these slopes.

Left without maintenance, the land surrounding the dock would gradually erode, and in combination with corrosion of the steel, would eventually result in the failure of the dock structure.

The benefits of Option 3 are as follows:

- This method is the low cost solution to decommissioning the dock.
- The dock would remain available for use by others in the short term.

The disadvantages of Option 3 are as follows:

- The dock would require maintenance or would degrade over time.
- The land adjacent to the dock would require maintenance or would be eroded by wave action over time.

Without a commitment of long term care and maintenance of the dock, this is not a viable option.

4 The Impact on the Aquatic Environment

The three options that were considered have the following impacts on the aquatic environment:

Option 1: Remove Dock 2 to 3 m Below Low Tide and Regrade Beach to a Low Slope:

- The construction of Option 1 will have very little impact on the aquatic environment, as it should be possible to perform the work without spilling any significant volumes of fill onto the seabed.

- Removal of the dock eliminates concerns of long term deterioration of the dock.

- Decommissioning the dock will be sequenced so the majority of the work is done on dry land.

- Removal of refrigerants will be done to protect the environment. If there is any evidence of refrigerants contaminating the soils, they will be excavated and disposed of in an approved manner.

- Gradual erosion of the shoreline is a natural occurrence. Developing a shoreline with a beach that provides a smooth shoreline and a slope similar to the surrounding natural features will ensure that erosion rates will proceed at a rate similar to the naturally occurring beaches.

Option 2: Encase the Dock in Rock:

- The additional rock will cover a large area of the seabed and will have a significant impact on the aquatic environment.

- A large volume of rock is required for this option.

- As the riprap on the island does not meet the design requirements of size or durability for long term life expectancy, this option will ultimately result in the dock being exposed to the effects of the ocean unless rock is brought in from off the island, which would be prohibitively expensive.

Option 3: Leave the Dock in Place:

- In the short term Option 3 will have very little impact on the seabed and the aquatic environment.

- In the long term, without maintenance, the land around the dock will deteriorate and fall onto the seabed. It is anticipated that this will occur slowly and will not have a significant effect on the aquatic environment.

- Finally, without maintenance the steel cells will corrode and lose support from the surrounding fill and gradually collapse. It is anticipated that this will occur slowly and will not have a significant effect on the aquatic environment.

- The dock facility would not remain functional in the long term without ongoing maintenance.

5 The Effect of Global Warming

Global warming will cause longer periods of open water and higher water levels resulting from the melting of glacial ice. The increase in the period of open water may result in increased wave action at the site, depending on the strength, duration and direction of the winds.

The specific effects of global warming on the options considered are as follows:

- Larger rock sizes are required for any riprap options in order to maintain stability under the action of higher waves. This will further detract from options that utilize riprap as there are no quarries on the Island that could produce the required quantity of suitable rock.

- The increased water level will affect the height of the beach on the island. However, the beach has changed over time due to the rebound of the land from the last ice age, and it is not anticipated that it will have any effect on the present beach process.

From these considerations, it is not expected that global warming will have any significant impact on the preferred option presented herein, or on the conclusions of this report.

6 Recommendations

In developing the options, consideration was given to the prevailing ice, wind, waves, tides and currents, water elevations, and the availability of rock of sufficient quality and size. It is recommended that Option 1 for detailed design for decommissioning the dock, for the following reasons:

- Provides minimal impact on the aquatic environment.
- Removes all above water improvements, and provides adequate water depth for any small craft operating in the area.
- Restores the beach to a more natural slope at the waterline.
- Provides a smooth shoreline parallel to the original shoreline.

APPENDIX A

Figures

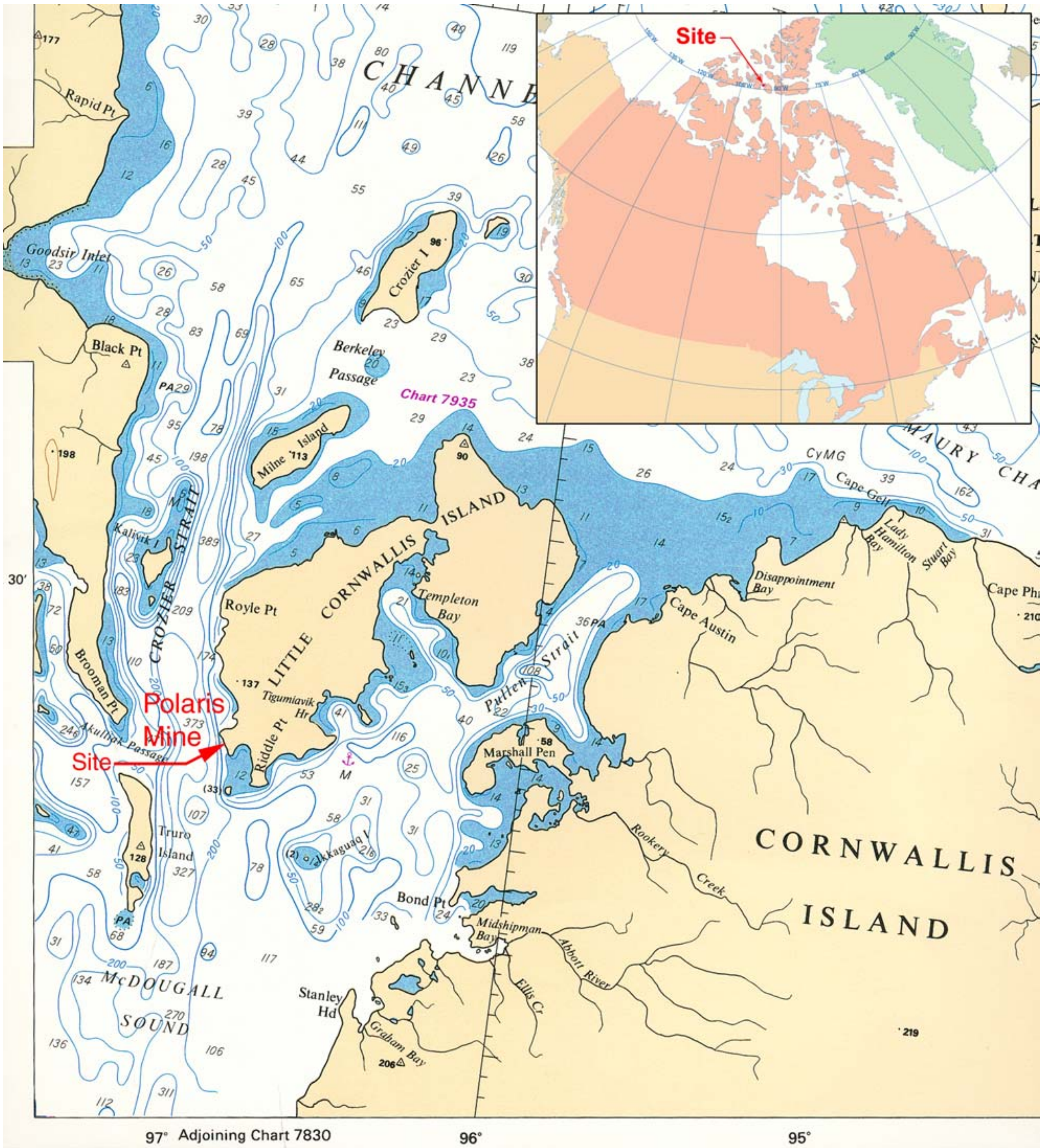


Figure 1: Site location (from Chart 7950, Canadian Hydrographic Service, 1985, depths in metres, Scale 1:500,000).

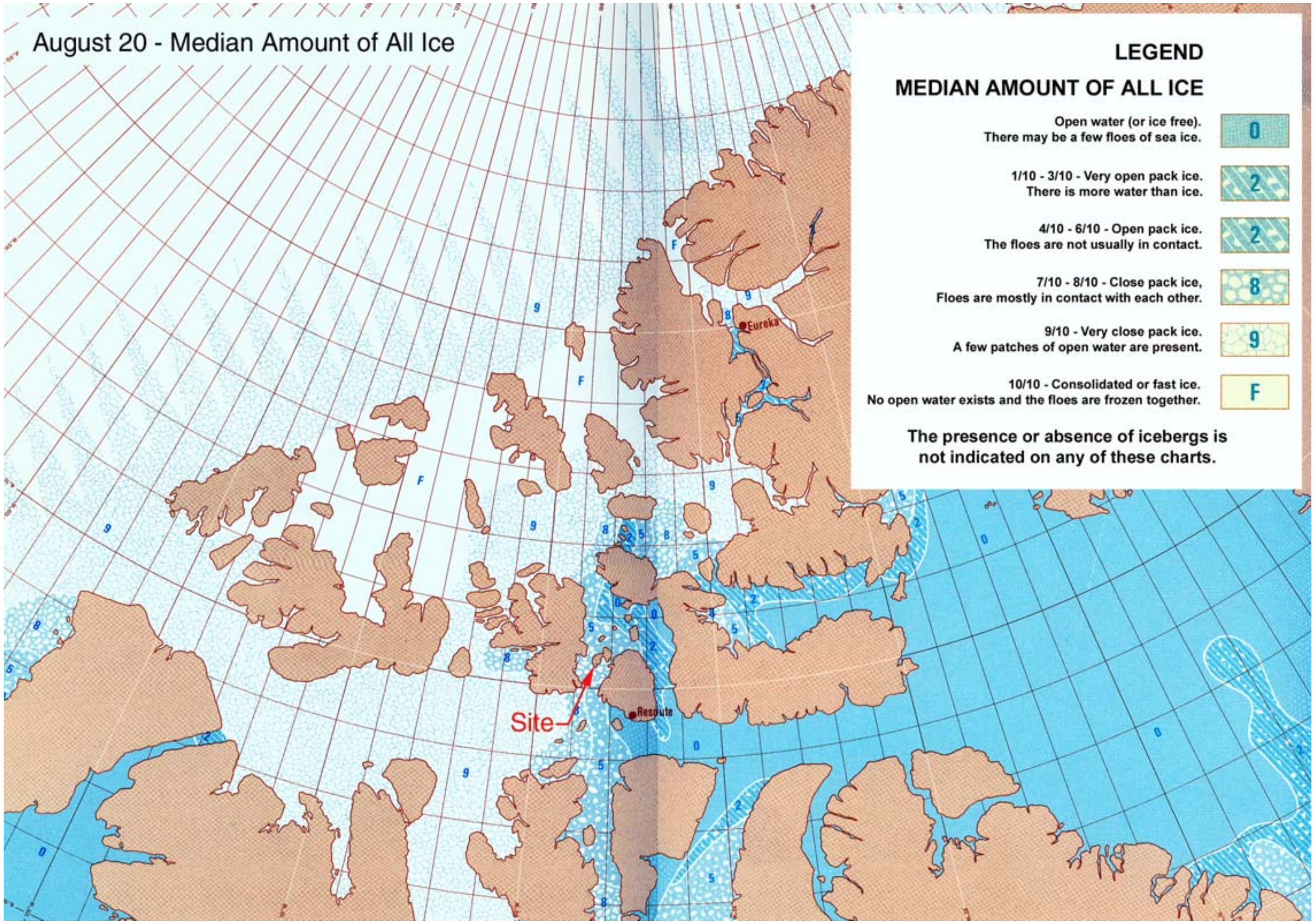


Figure 2: Median amount of all ice on August 20th, when break up of the ice occurs. The ice cover at Polaris is 8/10.

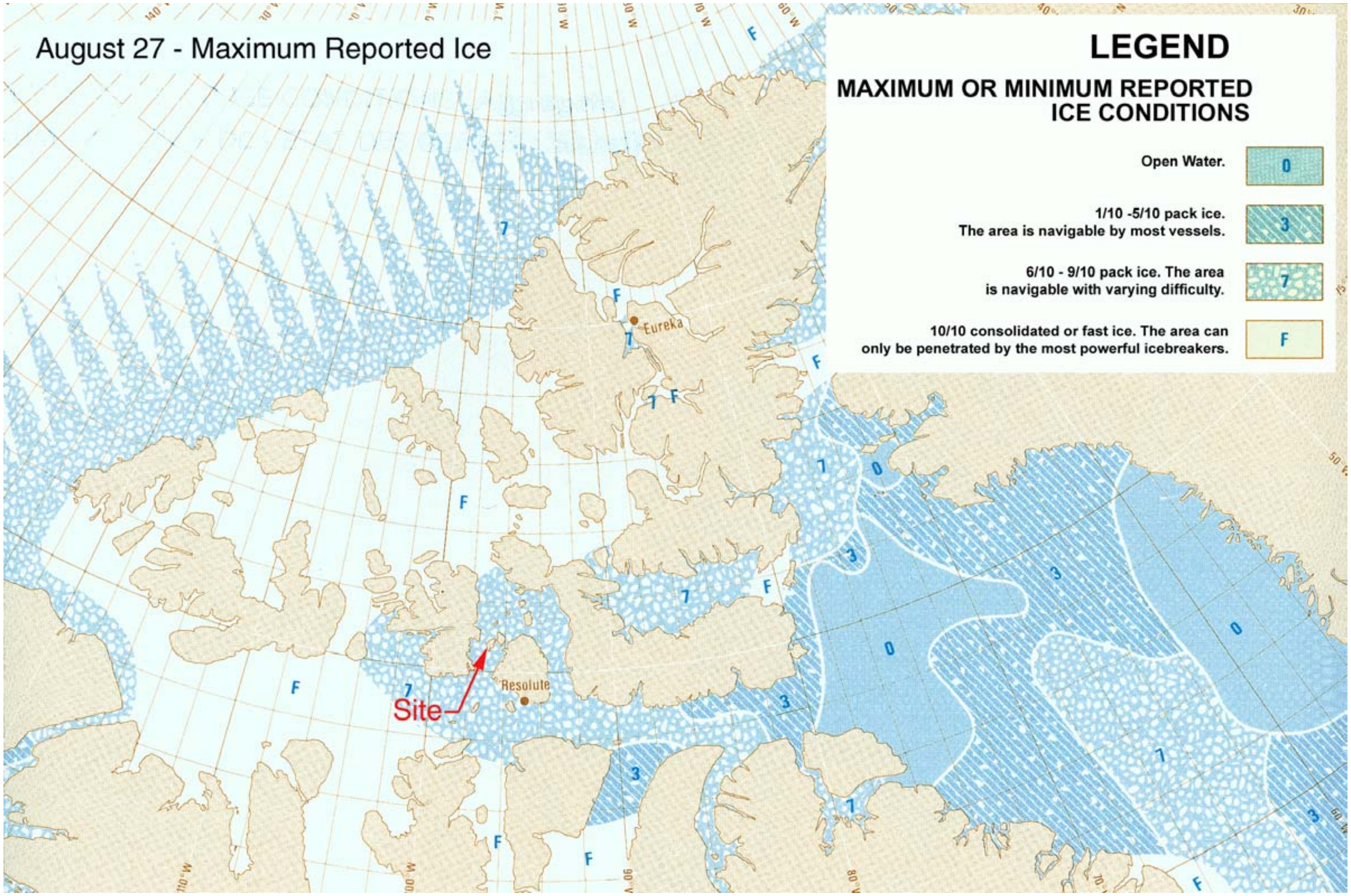


Figure 3: Maximum reported ice conditions on August 27th, when 7/10 ice cover is present at Polaris.

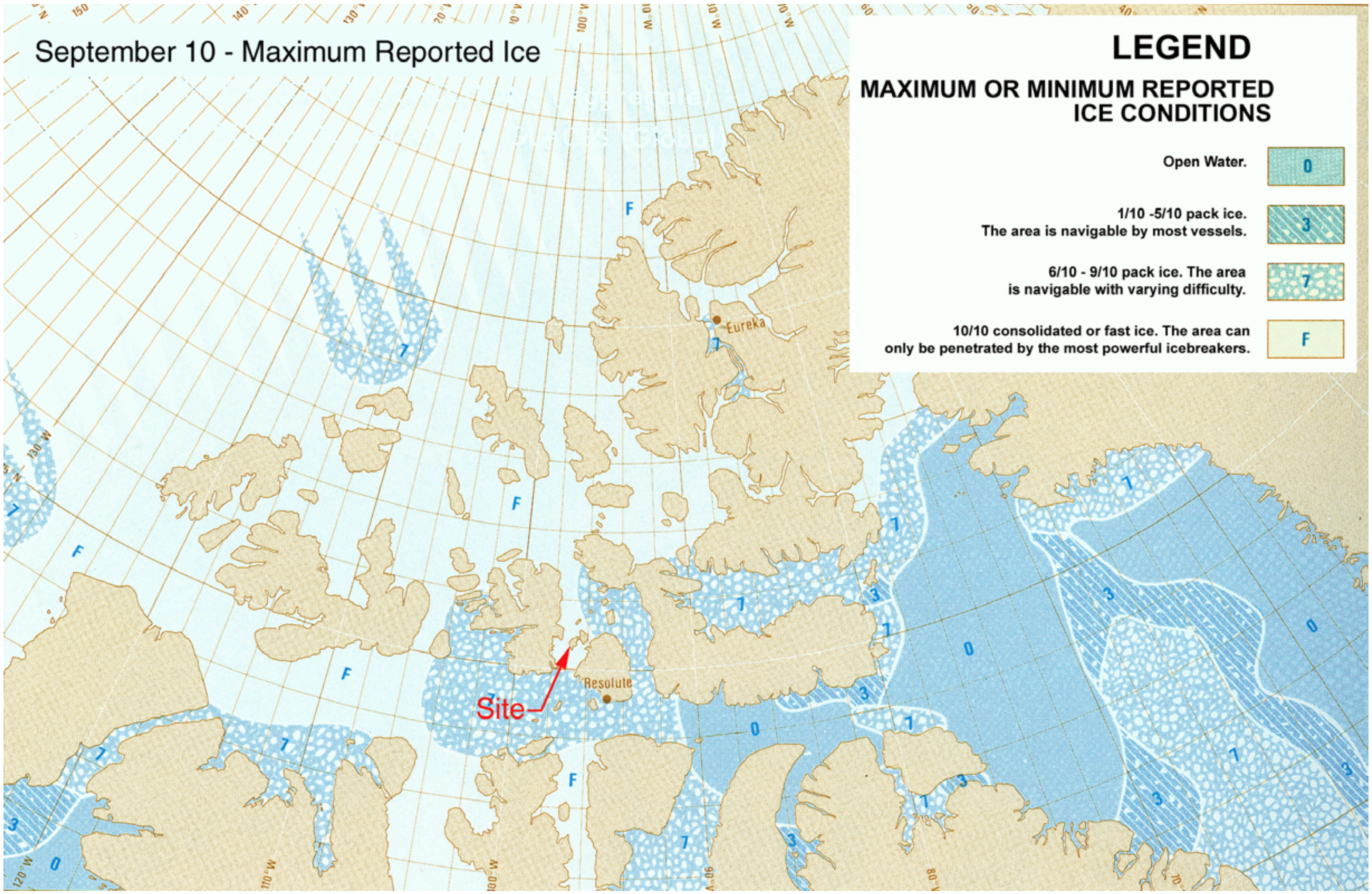


Figure 4: Maximum reported ice conditions on September 10th, when 10/10 ice coverage is present at Polaris.

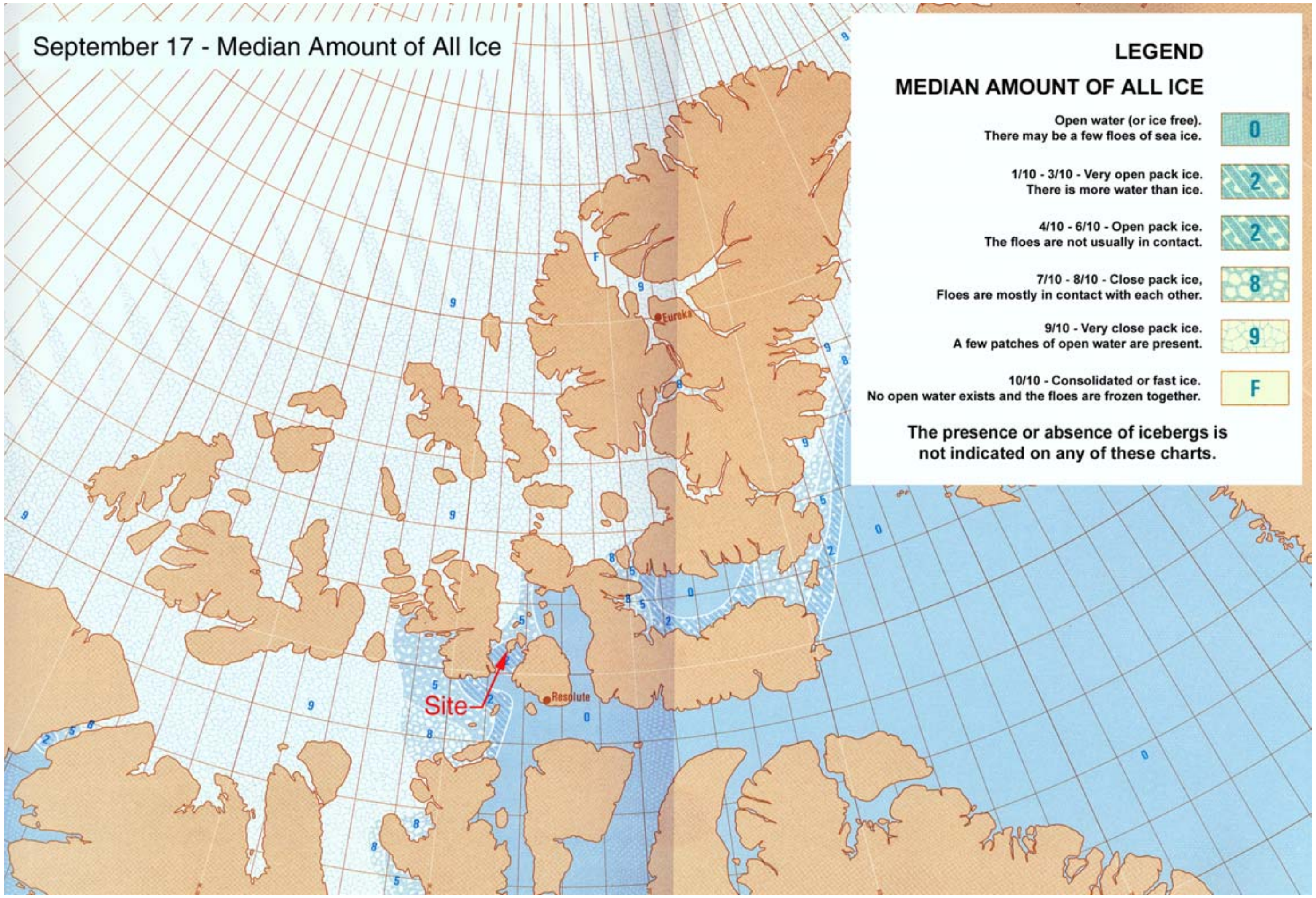


Figure 5: Median amount of all ice on September 17th, when freeze up starts. The ice cover is 2/10 at Polaris.

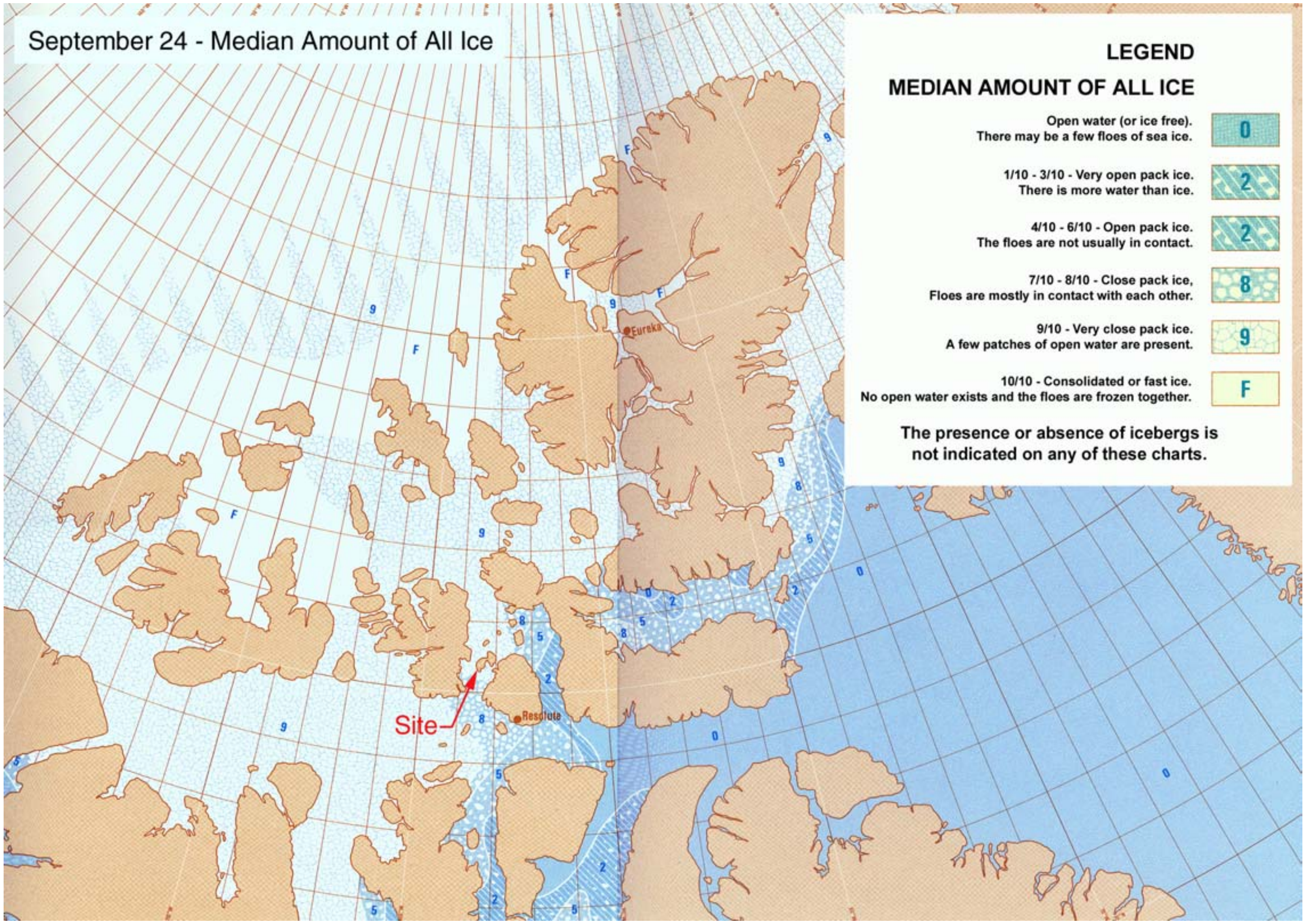


Figure 6: Median amount of all ice on September 24th. The ice cover is 9/10 at Polaris.

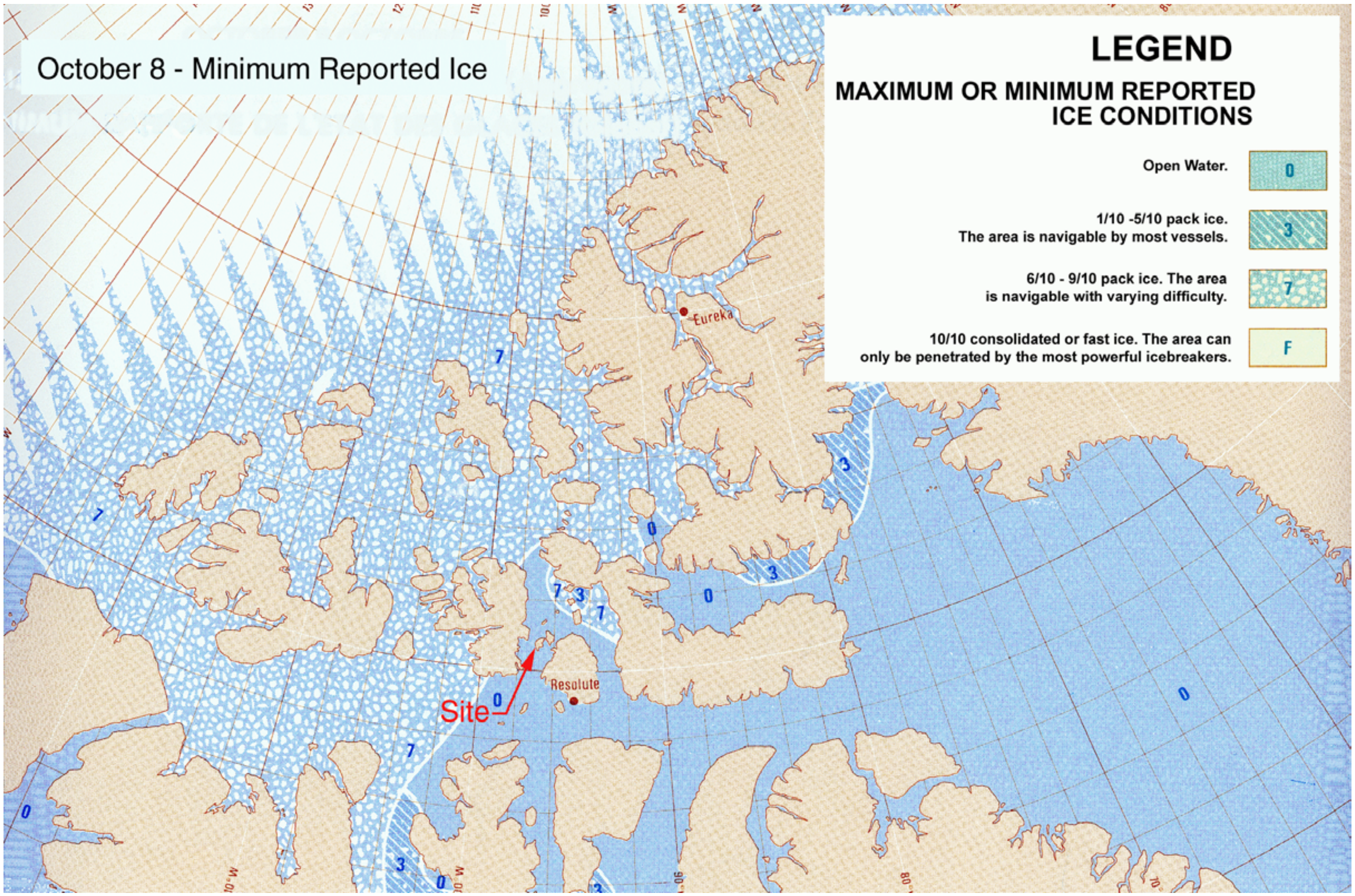


Figure 7: Minimum reported ice conditions on October 8th, when there is open water at Polaris.

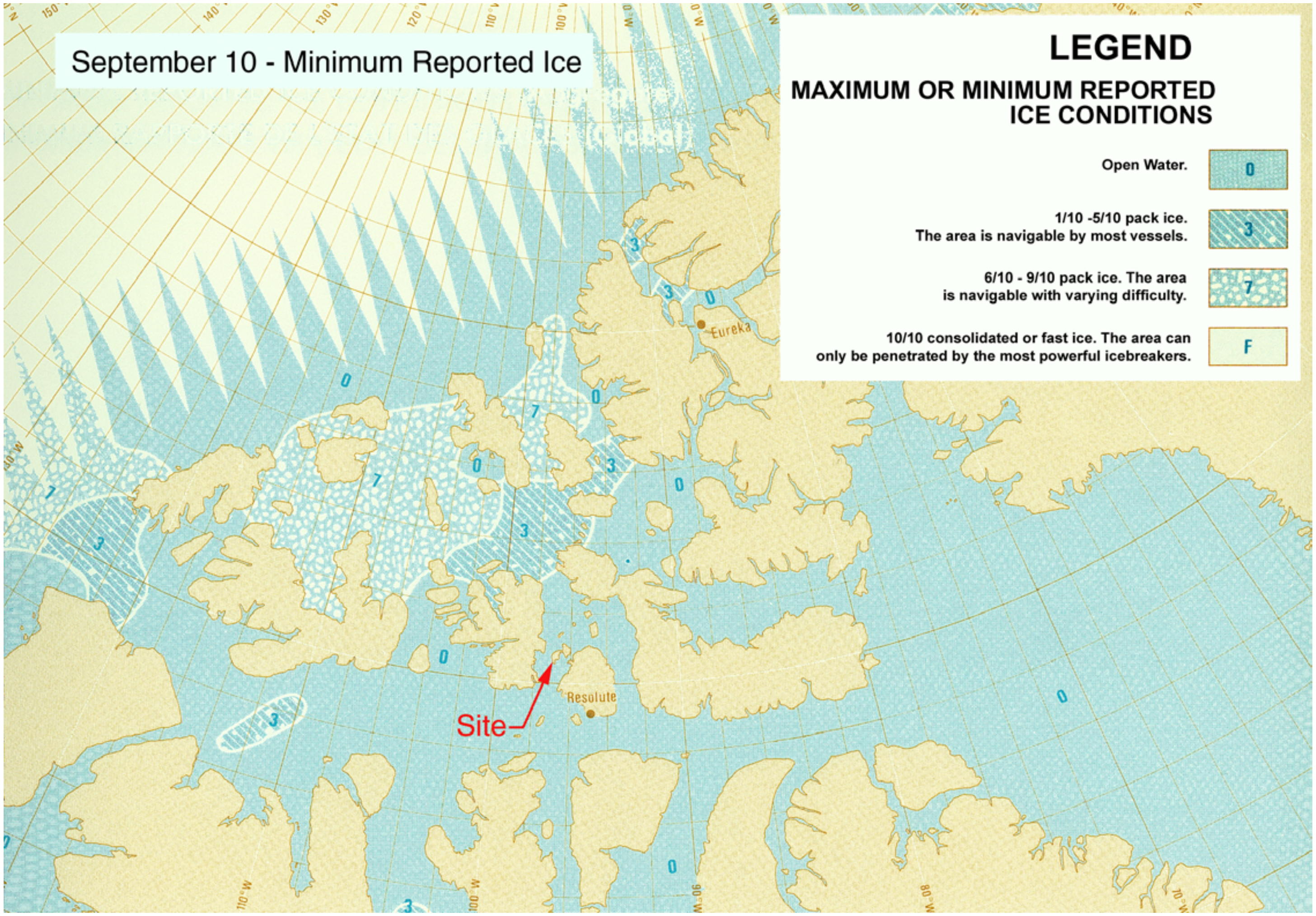


Figure 8: Minimum reported ice conditions on September 10th, when maximum open water is present.

Figure 9: Cross-section through dock at Station 1400 N

showing Option 2, to encase dock in rock (Scale 1:1,000).

APPENDIX B

Photographs

Photograph No. 1: Quarry face in Little Red Dog Quarry (August 17, 2000).

Photograph No. 2: View of shoreline to north of dock, from north end of dock (August 17, 2000).

Photograph No. 3: View of area between dock and process barge (August 18, 2000).

Photograph No. 4: View of shoreline to south of dock, from the deck of the vessel "Federal Baffin" (August 17, 2000).

Photograph No. 5: View of shoreline looking north at Station 1800 N. The beach is natural at this location, and is comprised of gravel with a mean size of about 10 mm (August 19, 2000).

Photograph No. 6: View of shoreline looking north at Station 1700 N. The fill, which is tapering out at this station, is about a 300 mm minus material. (August 19, 2000).

Photograph No. 7: View of shoreline looking south at Station 1700 N. (August 19, 2000).

Photograph No. 8: View of shoreline looking north at Station 1600 N. The fill is about a 300 mm minus material, with a mean size of 25 mm. (August 19, 2000).

Photograph No. 9: View of shoreline looking south at Station 1600 N. (August 19, 2000).

Photograph No. 10: View of shoreline looking north at Station 1500 N. The shoreline to the north of 1500 N is fill comprised of material with about 300 mm minus material. (August 19, 2000).

Photograph No. 11: View of shoreline looking south at Station 1500 N. The shoreline is covered

with rip rap to the south of Station 1500 N, with a mean size of about 300 mm (August 19, 2000).

Photograph No. 12: View of shoreline looking north at Station 1300 N.
New riprap has been placed in this area in the last 2 years. (August 19, 2000).

Photograph No. 13: View of shoreline looking south at Station 1300 N. This area has the largest size rock produced from the Little Red Dog Quarry and used as riprap, with a mean size in the range of about 400 mm to 500 mm. (August 19, 2000).

Photograph No. 14: View of shoreline looking north at Station 1200 N. New riprap has been placed between here and the dock in the last 2 years, and has a mean size of about 300 mm. (August 19, 2000).

Photograph No. 15: View of shoreline looking south at Station 1200 N. It has been more than

two years since riprap has been placed south of Station 1200 N. (August 19, 2000).

Photograph No. 16: View of shoreline looking north at Station 1100 N. (August 19, 2000).

Photograph No. 17: View of shoreline looking south at Station 1100 N. The riprap is failing and the bank behind the riprap is eroding. Some larger pieces of mine rock are in the order of 900 mm cube size, and are deteriorating rapidly due to freeze/thaw cycles. (August 19, 2000).

Photograph No. 18: View of shoreline looking north at Station 1000 N. Most of the riprap has slipped down the slope at this location. (August 19, 2000).

Photograph No. 19: View of shoreline looking south at Station 1000 N. (August 19, 2000).

Photograph No. 20: View of shoreline looking north at Station 900 N. (August 19, 2000).

Photograph No. 21: View of shoreline looking south at Station 900 N. Note the H-Piles at the berth face of the temporary dock. (August 19, 2000).

Photograph No. 22: View of shoreline looking north at Station 800 N. This is the southern extent of the riprap and is immediately south of the H-Piles at the temporary dock. (August 19, 2000).

Photograph No. 23: View of shoreline looking south at Station 800 N.

The beach is natural material south of Station 800 N. (August 19, 2000).

Photograph No. 24: View of shoreline looking north at Station 700 N. The beach is comprised of natural material at this location, with some regrading of the top of the bank to form a flat storage area. (August 19, 2000).

Photograph No. 25: View of shoreline looking south at Station 700 N. (August 19, 2000).

APPENDIX C

Datums, Tide Elevations and Currents

DATUMS, TIDE ELEVATIONS AND CURRENTS

Datums

General

A datum is a horizontal plane from which elevations are measured, positive up. Datums for the site include:

- Chart Datum (CD), which is defined as the lowest normal tide.

- Plant Datum (PD), which is approximately 2.3 m above CD.

- Mine Datum (MD), the datum used for surveying in the underground mine. This datum is 1,000 m below the PD in order to maintain positive values of elevation in the mine. MD is approximately 997.7 m below CD.

The datum used in the drawings prepared by Westmar is the present PD.

Establishing the Datum

Elevations to CD of three benchmarks at Polaris Mine were provided to Westmar by the Canadian Hydrographic Service. Based on this information and the measurements by Cominco Surveyors of elevations to PD taken on the same three benchmarks, it was determined that PD is 2.3 m above CD.

It appears that PD has changed since 1981. The top of the fill at the dock was shown as 4.57 m in the design drawings and was recently measured as 3.2 m to the current PD. The present PD is therefore about 1.37 m above the original PD.

Tide Elevations

Tide elevations to Chart Datum at Polaris Mine, are provided in the Canadian Tide and Current Tables (2000). The tide elevations to Chart, Plant and Mine Datums are given in *Table 1* on the following page.

TABLE 1: Tide Elevations to Chart, Plant and Mine Datums

Tide	Tide Elevations to Chart Datum (CD)	Tide Elevations to Plant Datum (PD)[1]	Tide Elevations to Mine Datum (MD)[2]
Higher High Water, Large Tide (HHWL)	1.7 m	-0.6 m	999.4 m
Mean Water Level (MWL)	0.9 m	-1.4 m	998.6 m
Lower Low Water, Large Tide (LLWL)	0.0 m	-2.3 m	997.7 m

Note: 1. PD is 2.3 m above CD.

2. MD is 1,000 m below PD to maintain positive values for all elevations in the underground mine.

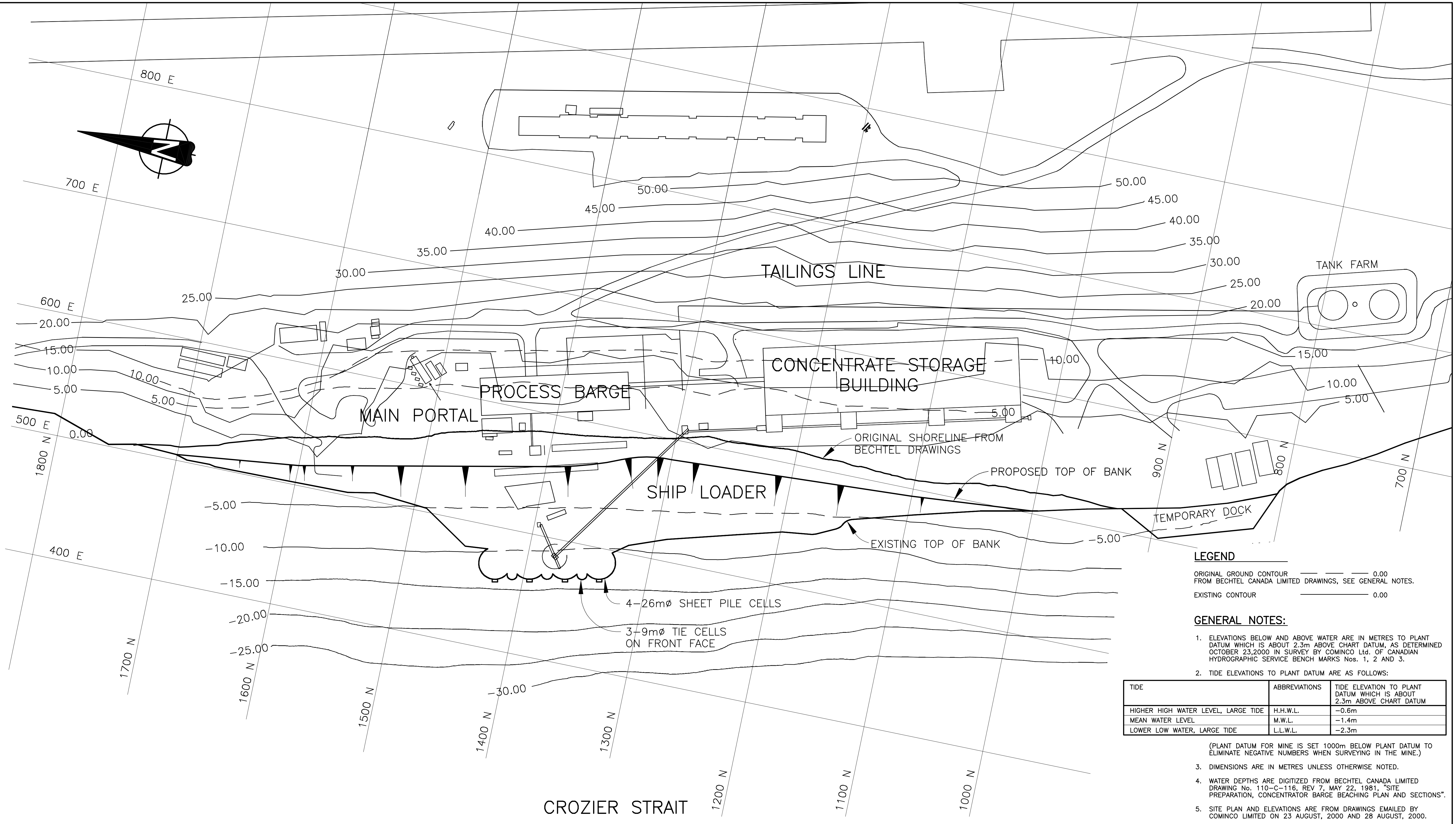
Currents

Wind and tide driven current along Crozier Strait has been observed during the open water period, but the magnitude at these currents is unknown.

During the winter months, the ice is landfast and tidal currents under the ice have been observed by divers. These currents will not affect the shoreline as the ice is landfast at the site during this period.

APPENDIX D

Drawings



PLAN
1:3000

LEGEND

ORIGINAL GROUND CONTOUR — — — 0.00
FROM BECHTEL CANADA LIMITED DRAWINGS, SEE GENERAL NOTES.

EXISTING CONTOUR ——— 0.00

GENERAL NOTES:

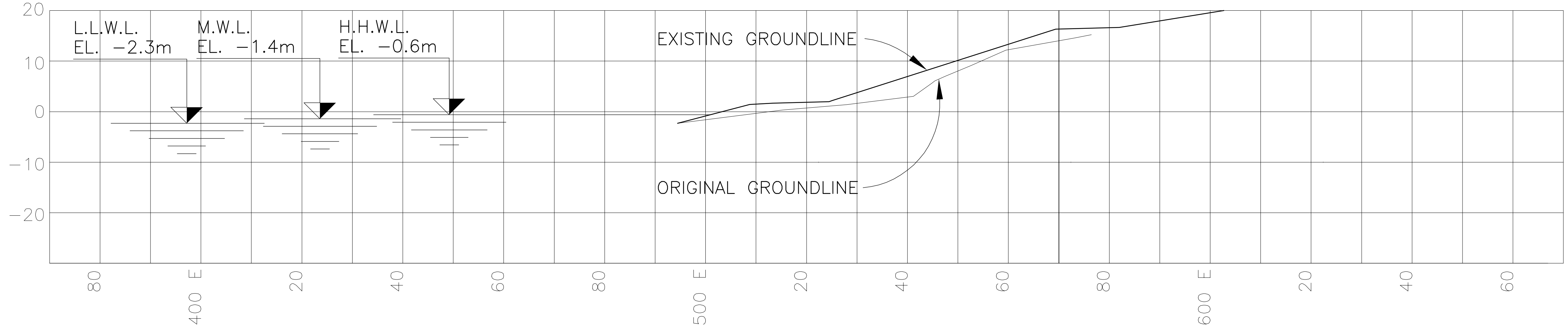
1. ELEVATIONS BELOW AND ABOVE WATER ARE IN METRES TO PLANT DATUM WHICH IS ABOUT 2.3m ABOVE CHART DATUM, AS DETERMINED OCTOBER 23,2000 IN SURVEY BY COMINCO Ltd. OF CANADIAN HYDROGRAPHIC SERVICE BENCH MARKS Nos. 1, 2 AND 3.
2. TIDE ELEVATIONS TO PLANT DATUM ARE AS FOLLOWS:

TIDE	ABBREVIATIONS	TIDE ELEVATION TO PLANT DATUM WHICH IS ABOUT 2.3m ABOVE CHART DATUM
HIGHER HIGH WATER LEVEL, LARGE TIDE	H.H.W.L.	-0.6m
MEAN WATER LEVEL	M.W.L.	-1.4m
LOWER LOW WATER, LARGE TIDE	L.L.W.L.	-2.3m

(PLANT DATUM FOR MINE IS SET 1000m BELOW PLANT DATUM TO ELIMINATE NEGATIVE NUMBERS WHEN SURVEYING IN THE MINE.)

3. DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
4. WATER DEPTHS ARE DIGITIZED FROM BECHTEL CANADA LIMITED DRAWING No. 110-C-116, REV 7, MAY 22, 1981, "SITE PREPARATION, CONCENTRATOR BARGE BEACHING PLAN AND SECTIONS".
5. SITE PLAN AND ELEVATIONS ARE FROM DRAWINGS EMAILED BY COMINCO LIMITED ON 23 AUGUST, 2000 AND 28 AUGUST, 2000.

CLIENT: COMINCO LIMITED	Westmar Maritime, Structural, Civil and Materials Handling Engineers
PROJECT: POLARIS MINE DECOMMISSIONING OF DOCK	TITLE: GENERAL ARRANGEMENT
	SCALE: SHOWN · DATE: NOV23/00 · DRAWING NUMBER: 00282-00-101



SECTION – 1700 N
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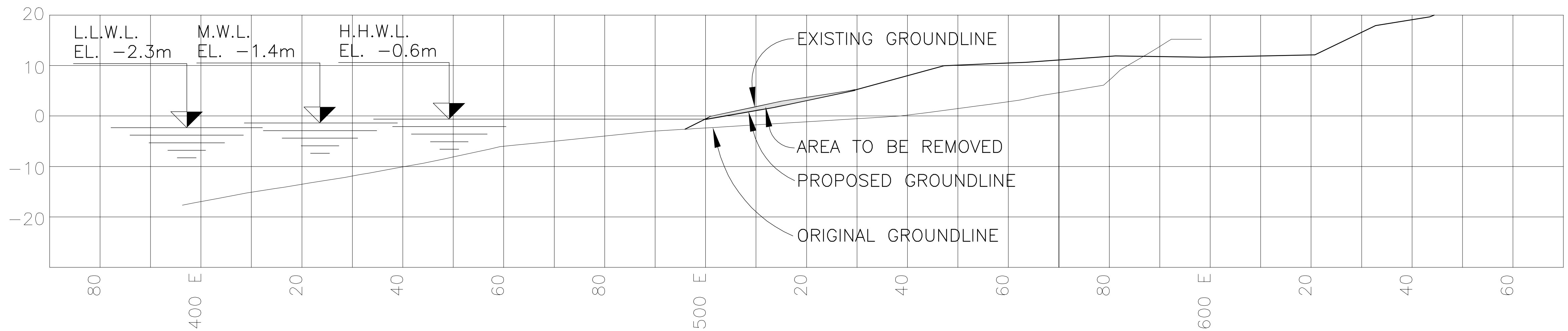

SECTION – 1600 N
1:1000

NOTES:

1. FOR GENERAL NOTES SEE DWG. −101.
2. EXISTING GROUNDLINE INTERPOLATED FROM INFORMATION PROVIDED BY COMINCO LIMITED.
3. ORIGINAL GROUNDLINE INTERPOLATED FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS.

CLIENT: COMINCO LIMITED	Westmar — Maritime, Structural, Civil and Materials Handling Engineers
PROJECT: POLARIS MINE DECOMMISSIONING OF DOCK	TITLE: SECTIONS – SHEET 1

SCALE	DATE	DRAWING NUMBER
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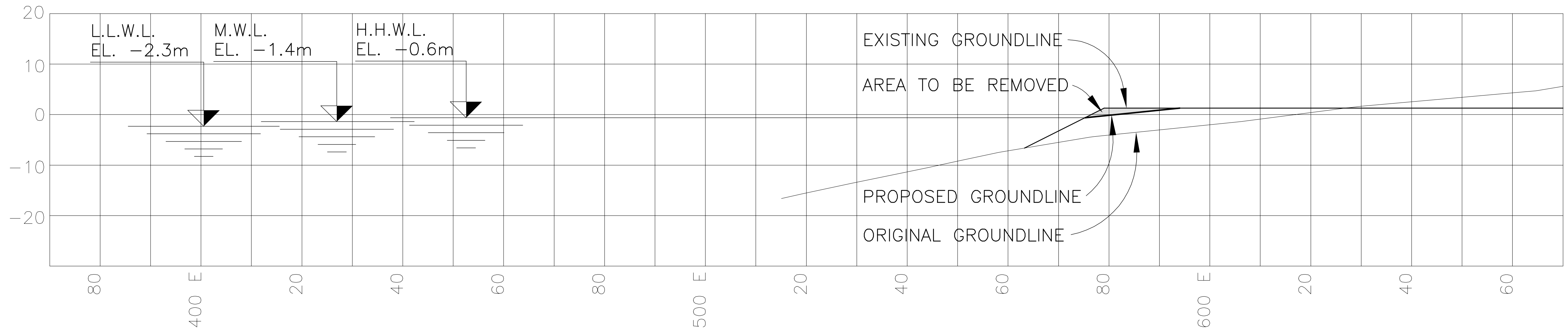
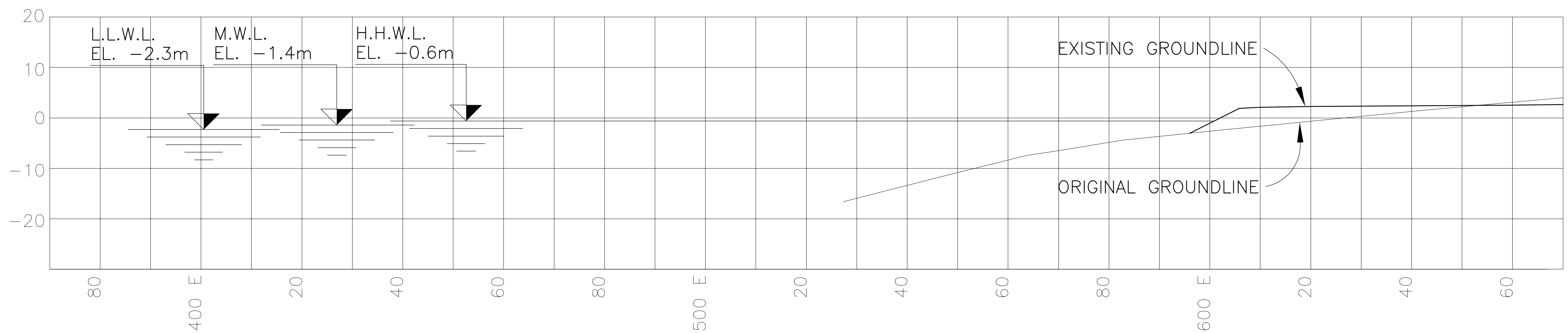


SECTION − 1100 N

1:1000



SECTION − 1000 N

1:1000

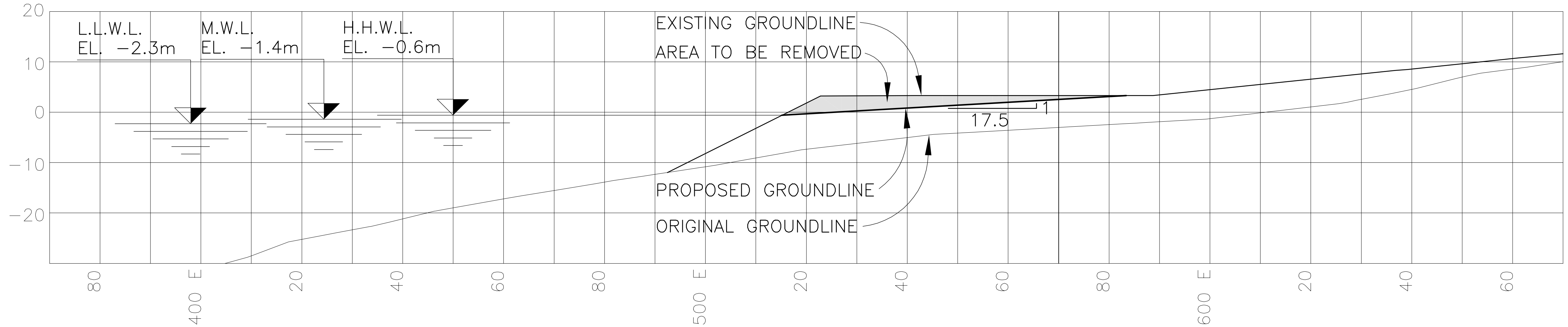
NOTES:

1. FOR GENERAL NOTES SEE DWG. −101.
2. EXISTING GROUNDLINE INTERPOLATED FROM INFORMATION PROVIDED BY COMINCO LIMITED.
3. ORIGINAL GROUNDLINE INTERPOLATED FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS.

Filename: P:\2000\00282\SURVEY\00282-00-102.DWG − Nov. 28/00 4:10pm CERICKSON

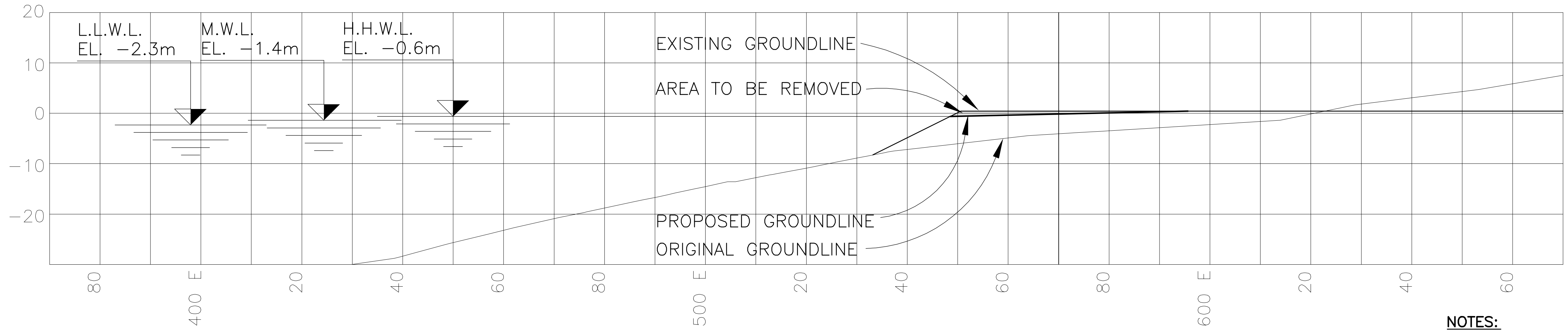
CLIENT COMINCO LIMITED	**Westmar** Maritime, Structural, Civil and Materials Handling Engineers
PROJECT POLARIS MINE DECOMMISSIONING OF DOCK	TITLE SECTIONS − SHEET 4

SCALE	DATE	DRAWING NUMBER
SHOWN	OCT24/00	00282−00−105



SECTION – 1300 N

1:1000



SECTION – 1200 N

1:1000

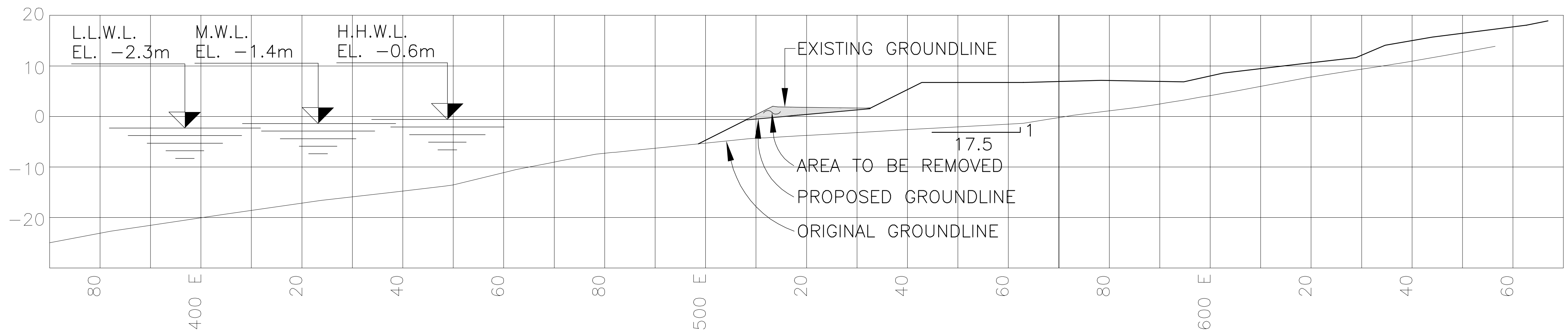
NOTES:

1. FOR GENERAL NOTES SEE DWG. −101.
2. EXISTING GROUNDLINE INTERPOLATED FROM INFORMATION PROVIDED BY COMINCO LIMITED.
3. ORIGINAL GROUNDLINE INTERPOLATED FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS.

Filename: P:\2000\00282\SURVEY\00282-00-102.DWG – Nov. 28/00 4:10pm CERICKSON

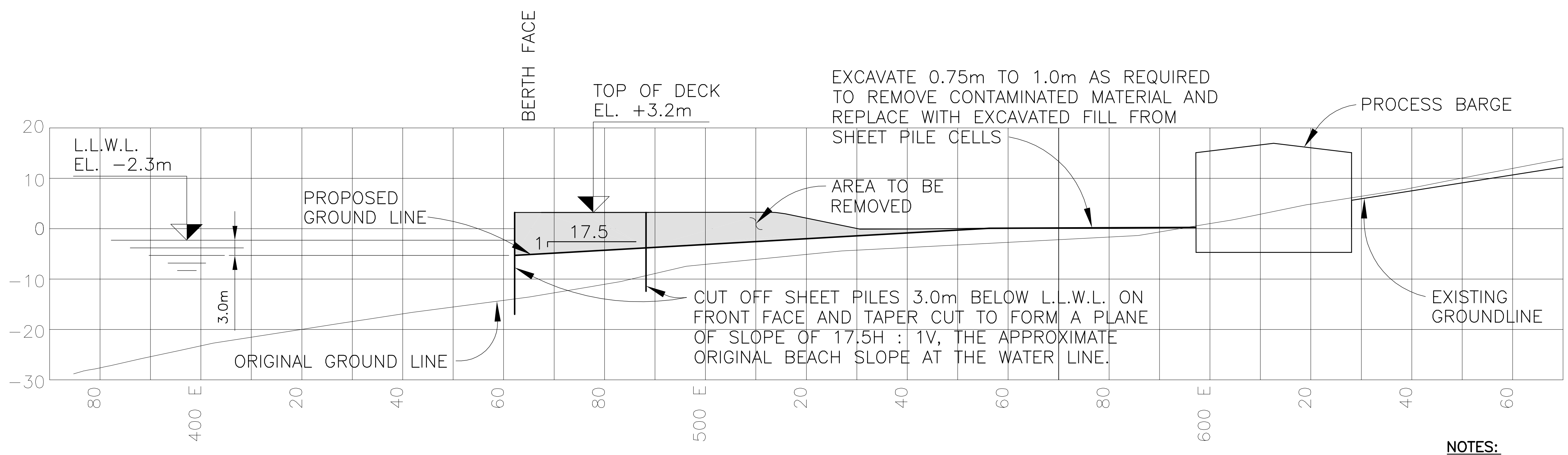
CLIENT COMINCO LIMITED	**Westmar** Maritime, Structural, Civil and Materials Handling Engineers
PROJECT POLARIS MINE DECOMMISSIONING OF DOCK	TITLE SECTIONS – SHEET 3

SCALE	DATE	DRAWING NUMBER
SHOWN	OCT24/00	00282–00–104



SECTION − 1500 N

1:1000



SECTION − 1400 N

1:1000

NOTES:

1. FOR GENERAL NOTES SEE DWG. −101.
2. EXISTING GROUNDLINE INTERPOLATED FROM INFORMATION PROVIDED BY COMINCO LIMITED.
3. ORIGINAL GROUNDLINE INTERPOLATED FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS.

Filename: P:\2000\00282\SURVEY\00282−00−102.DWG − Nov. 28/00 4:10pm CERICKSON

CLIENT	
COMINCO LIMITED	**Westmar** Maritime, Structural, Civil and Materials Handling Engineers
PROJECT	TITLE
POLARIS MINE DECOMMISSIONING OF DOCK	SECTIONS − SHEET 2

SCALE	DATE	DRAWING NUMBER
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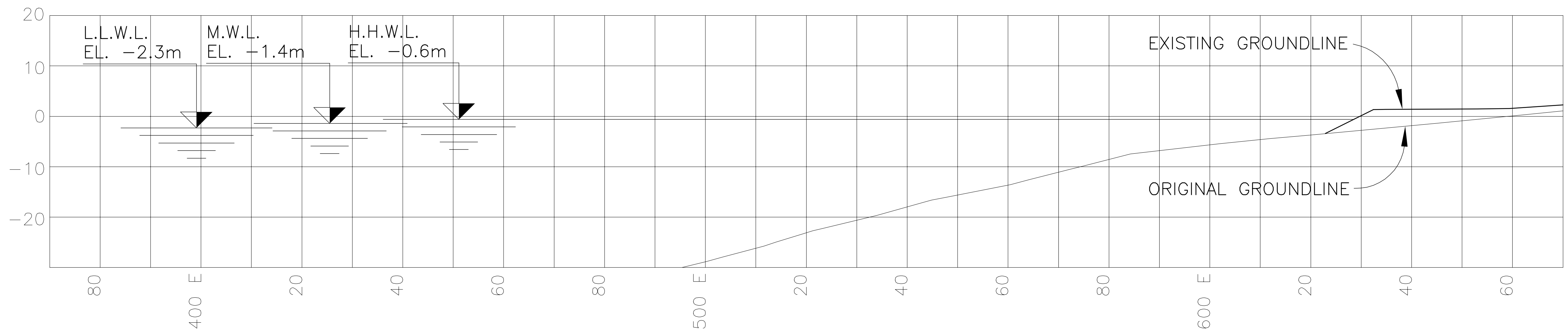

SECTION – 900 N

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NOTES:

1. FOR GENERAL NOTES SEE DWG. −101.
2. EXISTING GROUNDLINE INTERPOLATED FROM INFORMATION PROVIDED BY COMINCO LIMITED.
3. ORIGINAL GROUNDLINE INTERPOLATED FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS.

CLIENT COMINCO LIMITED	**Westmar** Maritime, Structural, Civil and Materials Handling Engineers
PROJECT POLARIS MINE DECOMMISSIONING OF DOCK	TITLE SECTIONS – SHEET 5
	SCALE: SHOWN — DATE: OCT24/00 — DRAWING NUMBER: 00282−00−106

APPENDIX E

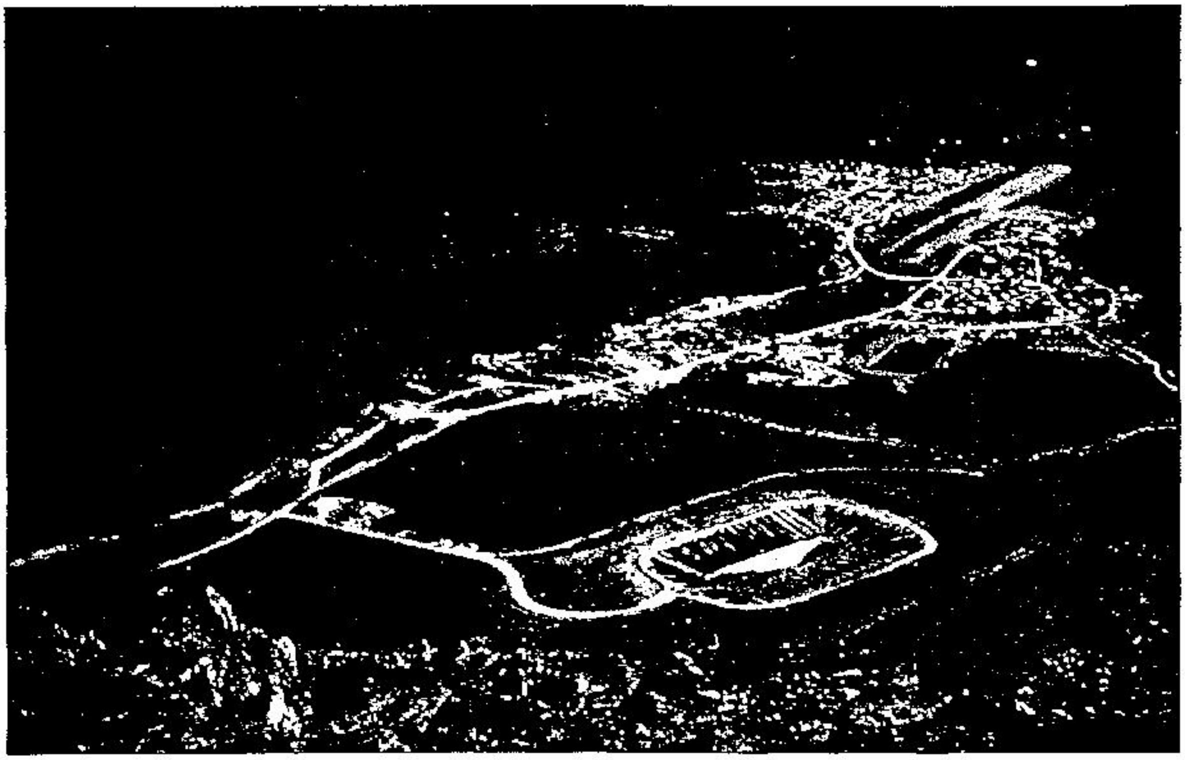
Paper on Construction of Dock

Canadian Civil Engineer

February 1997

février 1997

L'ingénieur civil canadien



CIVIL ENGINEERING IN THE HIGH ARCTIC
LE GÉNIE CIVIL EN RÉGIONS ARCTIQUES

SPECIAL 25TH CSCE ANNUAL CONFERENCE INSERT INSIDE
ENCART SPÉCIAL – 25e CONGRÈS ANNUEL DE LA SCGC

DOCK FACILITIES ON LITTLE CORNWALLIS ISLAND

by
Jean Barthe, Vice-President
Tower Arctic Ltd.

The mining operation of Cominco at Little Cornwallis Island, also named Polaris mine, consists of underground mining for lead and zinc ore. The site installation involves a concentrator, which was fabricated in southern Canada, floated and permanently grounded at the site, a huge ore storage building, an outstanding living accommodation compound and a dock to accommodate the ore handling ships during the short season of sailing through the Arctic archipelago.

The construction of the deep sea dock was awarded to Tower Arctic Ltd. in the fall of 1980. Some heavy construction equipment was already on site, other pieces of equipment were flown in by Hercules from our operation at Resolute Bay.

The dock consisted of the construction of four circular sheet-pile-cells 26 m. in diameter joined together by smaller intermediate cells in 15 m. of water.

After an underwater investigation, the first location was abandoned due to questionable soil conditions.

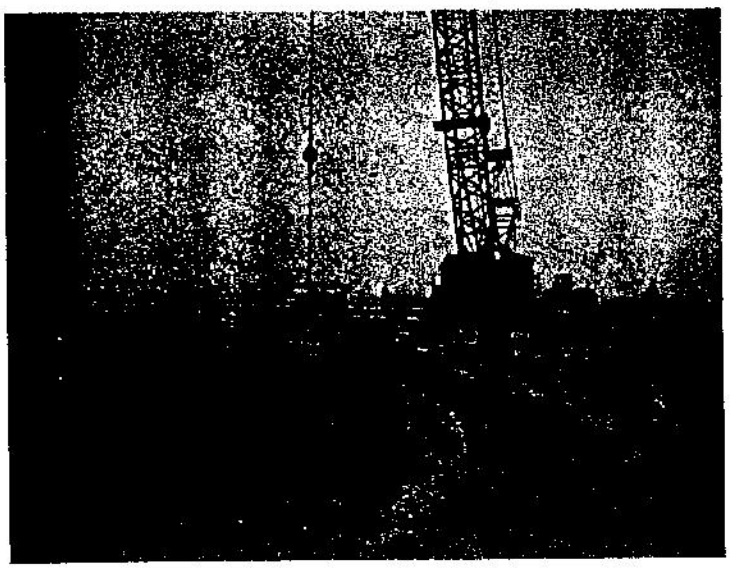
A new site was selected where the bottom of the ocean consisted of two to three meters of silt overlaying fractured limestone.

As soon as the Arctic night was over, being early March, when we could get a few hours of daylight, we started an operation of reinforcing the sea ice in order to develop a platform that would support the heavy pieces of equipment and the construction material.

In order to obtain this platform we started a flooding operation with sea water (-2°C), by pumping four to six cm of water every seven hours over the entire area, in order to develop a depth of 3 meters. An extra long auger was used to drill through the ice in order for our flooding pumps to have access to water.

This platform would allow 100 ton pieces of equipment to manoeuvre for a reasonable period of time. As a rule the heavier pieces of equipment were relocated every day so as not to develop any ice fatigue of cracking in the platform. Steel cables were also embedded in the platform ice to anchor it to shore.

Underwater inspection with divers revealed the presence of a chunk of multi-year old ice frozen into the surface ice exactly in the location of two of the cells. That multi-year old ice had to be removed, which involved a blasting and front-end loader operation. Divers from Arctic Divers Ltd., Yellowknife, were present for the duration of the job. The divers became very friendly with a seal who used to follow them underwater and breathe from their expelled air bubbles.



An exterior guide frame assembled in sections and deposited on the ice surface was our unconventional way of establishing the exact location of each piece of sheet piling. A trench was cut through the ice in order to allow each pile to be placed in the proper location.

Handling the 25 meter piles was a delicate operation. A special multi-grasp bridle was developed so that they could be picked up easily without the risk of developing kinks, as most often winds of up to 50 km/hour were present.

When a few piles were threaded in place, an electric hammer with controls for the amplitude and frequency was used to drive each pile in place through the layer of silt and a few centimetres into limestone in order to socket the bottom. The driving of each pile was carefully monitored and recorded. The closing of each cell was with a Y pile and had to be a very accurate operation so that the cell locked safely in a cylindrical shape. These rigid Y piles were also attaching the main cells to the intermediate cells.

Throughout these operations, the weather conditions would not permit the engines of the equipment to be shut off. On the other hand, the long hours of daylight allowed work in two shifts. We had a great deal of respect for our crew who worked daily in these cold temperatures and almost always under constantly windy conditions.

Due to the level of polar bear activity in the area, watch dogs were used twenty-four hours a day in order to provide warning to the crew if a bear was in the vicinity.

Once the piles of a cell were in place, they reproduced the exact contours of the solid ground below. These piles had to be cut off at an even elevation of five meters above main sea level. The layer of ice that remained inside the cell had to be removed prior to starting the infill operation. That volume of ice, estimated at fifty tons per cell, had to be broken into blocks with a trencher and clammed out of each cell.

Prior to starting any infill operation, the silt at the front of the cells had to be clammed out and replaced with proper aggregates so as not to develop extreme horizontal pressure on the piles. At the back and sides, the exterior backfill would balance any pressure from the interior. The first fill at the bottom was with coarse material, finer gravely fill completed this operation. The rejects from the mine operation became very useful material for this purpose.

Another consideration given to this dock project was the need for the interior fill to become frozen solid as soon as possible, so a system with pipes and a compressor was installed in order to help nature freeze the material throughout. A layer of styrofoam was also placed against a portion of the interior of the piles so as to retain the fill in the frozen and solid state.

The operation that started in early March was completed by mid-May, just about ten days before the ice started to show serious signs of major movement. The tide at Little Cornwallis Island is in the order of 1.2 meters which was a major consideration for our construction methods.

Also associated with this project Tower Arctic Ltd. installed the H.D.P.E tailings line, and the Ciba Geigy fibreglass water supply line for the mining facility.

This successful operation required a good knowledge of the extreme forces of nature in the Arctic which demand that very stage of construction be given the most serious attention to detail.

INSTALLATION PORTUAIRES: LITTLE CORNWALLIS ISLAND

par
Jean Barthe, Vice-président
Tower Arctic Ltd.

L'opération minière de la compagnie Cominco à Little Cornwallis, aussi appelée Mine Polaris, consiste à extraire en galerie souterraine le minerai de plomb et de zinc.

La construction du quai en eau profonde fut confiée à la compagnie Tower Arctic Ltd. à l'automne 1980. Bien que des équipements de construction étaient déjà en place, nous eurent à transporter par avion Hercules certains de nos propres équipements à partir de nos opérations de Resolute Bay.

Ce quai devait être construit en eau de 15 mètres de profondeur de façon à pouvoir accommoder les navires transporteurs de minerai.

A l'emplacement originalement désigné, des conditions de sol sous-marin inconsistants nous obligèrent à un déplacement de site.

Au nouveau site, le sol consistait en un dépôt de deux à trois mètres de limon sur calcaire fracturé, lequel servirait à fixer la base des paleplanches.

Au début de mars, là où la longue nuit arctique permet au soleil de commencer à poindre, nous débutions la mobilisation de nos premières équipes. Au grand étonnement des travailleurs qui arrivaient, le Boeing 737 se posait régulièrement sur la surface glacée du lac Garrow. Le terminus, un abri en contreplaqué, avait vite fait de ramener ces arrivants à la réalité des conditions de pionnier en territoire arctique.

Notre premier travail fut de consolider la glace de la plateforme de travail afin de pouvoir circuler et opérer avec les lourdes pièces d'équipement et le matériel de construction.

Cette opération nécessitait des arrosages trois fois par 24 heures afin de submerger de quatre à six centimètres d'eau de mer (-2° C.) à chaque arrosage l'entière surface de la plateforme. Une épaisseur de glace de trois mètres devait être atteinte. L'opération d'une tarrière à glace rallongée nous donnait accès à l'eau de mer. Des pompes de type à spirale donnait le rendement désiré.

La plateforme terminée, des pièces d'équipement lourd de 100 tonnes pouvaient maintenant opérer sécuritairement durant des periodes pratiques. Des poids de 300 tonnes étaient possible pour de courtes périodes. Les pièces d'équipement étaient relocalisées quotidiennement afin d'éviter que des failles se développent dans la glace. La

APPENDIX F

Rock Quality Test Results from Levelton Engineering Ltd.

Appendix F-1: September 21, 2000 - Materials Tests
Appendix F-2: October 4, 2000 - Materials Tests
Appendix F-3: October 4, 2000 - Petrographic Examinations and Table
Appendix F-4: October 31, 2000 - Freeze-Thaw Tests
Appendix F-5: March 13, 2001 - Summary of Rock Quality Tests

APPENDIX F-1

September 21, 2000 - Materials Tests

LEVELTON
Engineering Solutions

F_x Transmittal

Levelton Engineering Ltd.

150-12791 Clarke Place
Richmond, B.C.
Canada V6V 2H9
Tel: 604 278-1411
Fax: 604 278-1042
E-Mail: info@levelton.com

To	Norm Allyn, P. Eng. – WESTMAR	Fax number	985 - 2581
cc		Fax number	
From	Fred Shrimer, P. Geo.	Project number	100-0865
Date	September 21, 2000	Total number of pages (including cover page)	16

PROJECT: **Polaris Mine -- Rip Rap Testing**

Norm:

Accompanying this cover sheet are 15 individual test reports for five sets of tests run on the three rock types obtained from Polaris Mine.

There are:

- SG & Absorption (crushed material)
- SG & Absorption (sawn block samples)
- Los Angeles Abrasion
- Petrographic Examination (very preliminary only, at this stage)
- Durability Index

Currently, the lab is running $MgSO_4$ Soundness on both blocks and crushed material. Freeze-Thaw testing has also been initiated.

I hope to get thin-section analyses done next week.

Please call me if you have any questions.

Regards,

Fred Shrimer, P. Geo.

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TECHNICAL REPORT

LEVELTON
Engineering Solutions

September 21, 2000
Our file: 100-0865

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Los Angeles Abrasion Test (CSA A23.2-17A, ASTM C-535)**

Sample: Grey sample ("Limestone") **Sampled by:** Client

Sample	"Limestone"
Grading	'1'
Revolutions	500
No. of Spheres	12
Initial Mass (g)	10004.1
Final Mass (g)	8296.6
Percent loss	17.1

Reported by: F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

DATE: Sept 21, 2000

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September 21, 2000
Our file: 100-0865

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip-Rap Testing, Polaris Mine
SUBJECT: **Los Angeles Abrasion Test (CSA A23.2-17A, ASTM C-535)**

Sample: Beige-buff stone ("Dolomite") **Sampled by:** Client

Sample	"Dolomite"
Grading	'1'
Revolutions	500
No. of Spheres	12
Initial Mass (g)	10002.5
Final Mass (g)	8269.7
Percent loss	17.3

Reported by: F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

DATE: Sept 21 2000

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Levelton Engineering Ltd., 150 - 12791 Clarke Rd., Richmond, B.C. Canada V6V 2H9 Tel: 604-278-1411 Fax: 604-278-1042

TECHNICAL REPORT

LEVELTON
Engineering Solutions

September 21, 2000
Our file: 100-0865

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip-Rap Testing, Polaris Mine
SUBJECT: **Los Angeles Abrasion Test (CSA A23.2-17A, ASTM C-535)**

Sample: Mine Rock **Sampled by:** Client

Sample	"Mine Rock"
Grading	'2'
Revolutions	500
No. of Spheres	12
Initial Mass (g)	10014.6
Final Mass (g)	5523.5
Percent loss	44.8

Reported by: F. Shrimer, P. Geo.

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September 21, 2000
Our file: 100-0865

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing – Polaris Mine
SUBJECT: **Durability Index Test (ASTM D-3744)**

Sample: **Grey rock ("Limestone")**
Sampled by: Client

Sample	Sediment Height (mm)	Durability Index (D_c)
"Limestone"	6	92

Reported by: F. Shrimer, P. Geo.

PROFESSIONAL GEOSCIENTIST PROVINCE OF BRITISH COLUMBIA F. H. SHRIMER

DATE: Sept 21, 2000

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Levelton Engineering Ltd., 150 - 12791 Clarke Rd., Richmond, B.C. Canada V6V 2H9 Tel: 604-278-1411 Fax: 604-278-1042

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Engineering Solutions

September 21, 2000
Our file: 100-0865

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing -- Polaris Mine
SUBJECT: Durability Index Test (ASTM D-3744)

Sample: Beige rock ("Dolomite")
Sampled by: Client

Sample	Sediment Height (mm)	Durability Index (D_c)
"Dolomite"	10	82

Reported by: P. Shrimer, P. Geo.

PROFESSIONAL GEOSCIENTIST
PROVINCE OF BRITISH COLUMBIA
F. H. SHRIMER

DATE: Sept 21, 2000

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WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: **Mr. Norm Allyn, P. Eng.**

PROJECT: Rip Rap Testing – Polaris Mine
SUBJECT: **Durability Index Test (ASTM D-3744)**

Sample: **Mine rock**
Sampled by: Client

Sample	Sediment Height (mm)	Durability Index (D_c)
"Mine Rock"	31	71

Reported by: F. Shrimer, P. Geo. DATE: Sept 21, 2000

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September 21, 2000
Our file: 100-0865

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip-Rap Testing -- Polaris Mine
SUBJECT: **Specific Gravity & Absorption (ASTM C-127)**

Sample: Grey Rock ("Limestone") Sampled by: Client

Sample	Bulk G_s (Dry Basis)	Bulk G_s (SSD Basis)	Absorption (%)
"Limestone"	2.709	2.720	0.43

Note: 1. Test results given are averaged values from two separate test runs.

Reported by: F. Shrimer, P. Geo.

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DATE: Sept 21, 2000

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September 21, 2000
Our file: 100-0865

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip-Rap Testing – Polaris Mine
SUBJECT: **Specific Gravity & Absorption (ASTM C-127)**

Sample: Buff-beige Rock ("Dolomite") Sampled by: Client

Sample	Bulk G_s (Dry Basis)	Bulk G_s (SSD Basis)	Absorption (%)
"Dolomite"	2.653	2.689	1.40

Note: 1. Test results given are averaged values from two separate test runs.

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Reported by: F. Shrimer, P. Geo. DATE: Sept 21, 2000

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#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip-Rap Testing – Polaris Mine
SUBJECT: **Specific Gravity & Absorption (ASTM C-127)**

Sample: Mine Rock   Sampled by: Client

Sample	Bulk G_s (Dry Basis)	Bulk G_s (SSD Basis)	Absorption (%)
"Mine rock"	3.489	3.536	1.35

Note: 1. Test results given are averaged values from two separate test runs.

Reported by: F. Shrimer, P. Geo.

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DATE: Sept 21, 2000

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WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip-Rap Testing -- Polaris Mine
SUBJECT: **Specific Gravity & Absorption of Block Samples (ASTM C-127)**

Sample: Grey Rock ("Limestone") Sampled by: Client

Sample	Bulk G_s (Dry Basis)	Bulk G_s (SSD Basis)	Absorption (%)
"Limestone"	2.712	2.739	0.985

Note: 1. Test results given are averaged values for five sawn block samples.

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Reported by: F. Shrimer, P. Geo. DATE: Sept 21, 2000

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WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip-Rap Testing – Polaris Mine
SUBJECT: **Specific Gravity & Absorption (ASTM C-127)**

Sample: Buff-beige Rock ("Dolomite") Sampled by: Client

Sample	Bulk G_s (Dry Basis)	Bulk G_s (SSD Basis)	Absorption (%)
"Dolomite"	2.585	2.626	1.565

Note: 1. Test results given are averaged for six individual sawn block samples.

Reported by: F. Shrimer, P. Geo. DATE: Sept 21, 2000

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Levelton Engineering Ltd., #150 - 12791 Clarke Place, Richmond, B.C. Canada V6V 2H9 Tel: 604-278-1411 Fax: 604-278-1042

TECHNICAL REPORT

LEVELTON
Engineering Solutions

September 21, 2000
Our file: 100-0865

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C.
V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip-Rap Testing – Polaris Mine
SUBJECT: **Specific Gravity & Absorption (ASTM C-127)**

Sample: Mine Rock   Sampled by: Client

Sample	**Bulk G_s (Dry Basis)**	**Bulk G_s (SSD Basis)**	**Absorption (%)**
"Mine rock"	3.647	3.760	1.723

Note: 1. Test results given are averaged values for six separate block samples sawn from a larger chunk.

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Reported by: F. Shrimer, P. Geo.   DATE: Sept 21, 2000

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APPENDIX F-2

October 4, 2000 - Materials Tests

Fax Transmittal

Levelton Engineering Ltd.

150-12791 Clarke Place
Richmond, B.C.
Canada V6V 2H9
Tel: 604 278-1411
Fax: 604 278-1042
E-Mail: info@levelton.com

To	Norm Allyn, P. Eng. – WESTMAR	Fax/phone number	985-2581/985-6488
cc		Fax/phone number	
From	Fred Shrimer, P. Geo.	Project number	100-0865
Date	October 4, 2000	Total number of pages (including cover page)	7

PROJECT: Testing of Polaris Rip-Rap

Norm:

Accompanying this cover are Technical Reports which provide results of the Magnesium Sulphate Soundness tests done on the three rock types.

Review of the data provides fairly clear insight that the Mine Rock is unsuitable, while the two carbonate rocks are of much higher quality.

Please note that I have done thin-section analysis of the three rock types and have identified both the grey-brown and the buff-beige rocks as "Limestone". They appear to be mixtures of crystalline and micritic calcite limestone, with between 5% and 30% of fossil fragments. Interestingly, many trilobite remains in a couple of slides, indicating Paleozoic age for these rocks. The Mine Waste samples, of course, were comprised of variable amounts of metallic sulphides (mostly sphalerite and galena) in a matrix of dolomite and calcite. "Colloform" texture to these rocks, interesting characteristic.

The freeze-thaw test is currently underway on the three rock types. I believe it's entering about the 7th cycle or so right now.

I will review the file and see what other outstanding tests I can find and forward to you.

Please call if you have any questions.

Regards,

Fred Shrimer, P. Geo.

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TECHNICAL REPORT

Our file: 100-0865
October 4, 2000

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)

Material Tested:	"Mine Waste"

Source: Polaris Minesite   **Sampled by:** Westmar
Sample: Sawn blocks, approximately 15 cm x 3.5 cm x 10 cm

Samples	Solution		Number of Cycles
	Magnesium Sulphate		5
	Original Mass (g)	Final Mass (g)	Percent Loss
M1	2505.3	1966.9	21.5%
M5	2469.6	1012.8	59.0%
AVERAGE LOSS BY MASS (%)			40.1%

Notes: 1. Massive disintegration of samples by third cycle.

REPORTED BY: [signature] DATE: Oct 4, 2000
F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

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Notice: The test data given in this report pertain to the sample provided, and may not be applicable to samples from production other than that represented by the sample. This test report constitutes a testing service. Interpretation may be provided on request.

Levelton Engineering Ltd., #150 - 12791 Clarke Place, Richmond, B.C. V6V 2H9 Canada Tel: 604-278-1411 Fax: 604-278-1042

TECHNICAL REPORT

LEVELTON
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Our file: 100-0865
October 4, 2000

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)**

Material Tested:	"D" samples

Source: Polaris Minesite **Sampled by:** Westmar
Sample: Sawn blocks, approximately 15 cm x 3.5 cm x 10 cm

Samples	Solution			Number of Cycles
	Magnesium Sulphate			5
	Original Mass (g)	Final Mass (g)		Percent Loss
		Actual (*)	Estimated (*)	
D1a	1979.0	1981.8	1972	0.35%
D1b	1591.8	1593.8	1585	0.43%
AVERAGE LOSS BY MASS (%)				0.39%

Notes: 1. (*) The actual mass of the samples was greater at the conclusion of the test than the initial mass, even though the samples had undergone loss of material, via flaking and splitting. It is postulated that sulphate crystallization may have developed within the rock in areas of porosity. To account for the lost material which flaked or split from the samples, the residual particles were weighed. The lost mass is considered to be an estimate only.

REPORTED BY: F. Shrimer, P. Geo. DATE: Oct 4, 2000

PROFESSIONAL GEOSCIENTIST
PROVINCE OF BRITISH COLUMBIA
F. H. SHRIMER

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TECHNICAL REPORT

Our file: 100-0865
October 4, 2000

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)**

Material Tested: "L" samples

Source: Polaris Minesite **Sampled by:** Westmar
Sample: Sawn blocks, approximately 15 cm x 3.5 cm x 10 cm

Samples	Solution			Number of Cycles
	Magnesium Sulphate			5
	Original Mass (g)	Final Mass (g)		Percent Loss
		Actual (*)	Estimated (*)	
L1	3057.8	3059.9	3045	0.42%
L4	2758.5	2731.0	--	1.00%
AVERAGE LOSS BY MASS (%)				0.69%

Notes: 1. (*) The actual mass of the L1 sample was greater at the conclusion of the test than its initial mass, even though the sample had undergone loss of material, via flaking and splitting. It is postulated that sulphate crystallization may have developed within the rock in areas of porosity. To account for the lost material which flaked or split from the samples, the residual particles were weighed. The lost mass is considered to be an estimate only.

2. It is further postulated that the L4 sample may have had a net loss which was greater than indicated, due to uptake of $MgSO_4$. Thus, the loss may be underestimated.

REPORTED BY: ______________ DATE: Oct 4, 2000
F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

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Notice: The test data given in this report pertain to the sample provided, and may not be applicable to samples from production other than that represented by the sample. This test report constitutes a testing service. Interpretation may be provided on request.

Levelton Engineering Ltd., #150 - 12791 Clarke Place, Richmond, B.C. V6V 2H9 Canada Tel: 604-278-1411 Fax: 604-278-1042

TECHNICAL REPORT

Our file: 100-0865
October 4, 2000

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)**

Material Tested	"Mine Waste"

Source: Polaris Minesite
Sample: Crushed gravel

Sampled by: Westmar

Sample	Solution				Number of Cycles		
50 x 5 mm crush	Magnesium Sulphate				5		
Loss per Sieve Fraction							
Sieve Fraction	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm
Loss (%)	38.6	23.8	28.6	39.6	35.1	35.1	35.1
Original Grading (%)	17.4	28.5	20.9	10.8	9.7	4.7	8.0
Weighted Loss (%)	6.717	6.796	5.984	4.275	3.401	1.648	2.805
Total Weighted Loss (%)							31.6%

Notes: 1. Extensive disintegration of samples by end of second cycle.

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F. H. SHRIMER
BRITISH COLUMBIA
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REPORTED BY: F. Shrimer, P. Geo. DATE: Oct 4, 2000

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TECHNICAL REPORT

Our file: 100-0865
October 4, 2000

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)**

Material Tested: "L" sample

Source: Polaris Minesite
Sample: Crushed gravel

Sampled by: Westmar

Sample		Solution			Number of Cycles		
50 x 5 mm crush		Magnesium Sulphate			5		
Loss per Sieve Fraction							
Sieve Fraction	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm
Loss (%)	0.115	1.081	0.743	0.781	3.699	3.699	3.699
Original Grading (%)	32.3	26.2	20.1	7.6	6.7	2.8	4.3
Weighted Loss (%)	0.037	0.283	0.149	0.059	0.248	0.104	0.159
Total Weighted Loss (%)							1.00%

Notes: 1. Some widening of cracks, some edges flaking.

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BRITISH COLUMBIA
GEOSCIENTIST

REPORTED BY: F. Shrimer, P. Geo. DATE: Oct 4, 2000

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Levelton Engineering Ltd., #150 - 12791 Clarke Place, Richmond, B.C. V6V 2H9 Canada Tel: 604-278-1411 Fax: 604-278-1042

TECHNICAL REPORT

Our file: 100-0865
October 4, 2000

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)**

Material Tested:	"D" sample

Source: Polaris Minesite
Sample: Crushed gravel

Sampled by: Westmar

Sample	Solution				Number of Cycles		
50 x 5 mm crush	Magnesium Sulphate				5		
Loss per Sieve Fraction							
Sieve Fraction	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm
Loss (%)	0.209	0.450	1.451	1.451	1.451	1.451	1.451
Original Grading (%)	49.9	24.3	13.8	4.2	3.8	1.6	2.4
Weighted Loss (%)	0.104	0.109	0.200	0.061	0.055	0.023	0.035
Total Weighted Loss (%)							0.60%

Notes: 1. Some minor disintegration.
2. Cracks have widened after test completed.

REPORTED BY: F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

DATE: Oct 4, 2000

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Levelton Engineering Ltd., #150 - 12791 Clarke Place, Richmond, B.C. V6V 2H9 Canada Tel: 604-278-1411 Fax: 604-278-1042

APPENDIX F-3

October 4, 2000 - Petrographic Examinations and Table

LEVELTON
Engineering Solutions

Fax Transmittal

Levelton Engineering Ltd.

150-12791 Clarke Place
Richmond, B.C.
Canada V6V 2H9
Tel: 604 278-1411
Fax: 604 278-1042
E-Mail: info@levelton.com

To	Norm Allyn, P. Eng. – WESTMAR	Fax/phone number	985-2581/985-6488
cc		Fax/phone number	
From	Fred Shrimer, P. Geo.	Project number	100-0865
Date	October 4, 2000	Total number of pages (including cover page)	5

PROJECT: Testing of Polaris Rip-Rap

Norm:

Accompanying this cover are Technical Reports for the Petrographic Examinations.

I have also included, for reference, a comparative table which provides all the data in a single page.

My review of the project file indicates that all tests have been completed and reported, with the exception of the Freeze-Thaw test.

I cannot find any reference in my file indicating that you wanted any assessment of the Acid Rock Drainage characteristics of the materials – primarily the Mine Waste rock. Please advise.

Please call if you have any questions.

Regards,

Fred Shrimer, P. Geo.

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Please call 604-278-1411 if any pages are missing.

TECHNICAL REPORT

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

LEVELTON
Engineering Solutions

ATTENTION: Mr. Norm Allyn, P. Eng.

Our file: 100-0865
September 21, 2000

PROJECT: Rip Rap Testing – Polaris Mine
SUBJECT: **Petrographic Examination (ASTM C-295)**

Sample: Mottled Mine Waste Rock ("M" samples)

PETROGRAPHIC DESCRIPTION

Mineralized limestone -- altered fine-grained micritic and crystalline limestone, mineralization throughout consists of lead-zinc-iron sulphides, and possible oxides. Concentration of metals variable between the three chunk samples provided. Numerous common voids/vugs in the rock are preferential zones of weakness. The rock is generally of moderate strength, but some zones are crumbly and weak. Occasional zones are almost of good strength.

In thin-section, samples comprised of colliform texture of metallic sulphides, mostly galena and sphalerite. Groundmass is calcite and/or dolomite. Some dendritic galena. Dolomite is the primary carbonate, and occurs mostly as well-defined crystals, although there is some calcite as crystals also.

COMMENTS

The rock is not very competent, due to the presence of crystalline galena, sphalerite, pyrite and other metallic minerals, and also because of vugs, voids and fissures in the rock material.

QUALITY

The mineralized mine waste rock is generally not suitable for construction applications, other than for use as fill, due to its low strength, high porosity, and high metals content. Although the host material is carbonate, the rock may well contribute to acid-rock drainage under certain circumstances. Regulations governing the use of potentially acid-drainage-producing rock should be reviewed to determine whether ARD tests may be needed, if the rock were used as fill in environmentally-sensitive areas.

Petrographic Number of the sample was '191', which is equivalent to an overall rating of "Poor" for physical-mechanical quality.

SUMMARY

The mine waste rock is not considered suitable for construction applications, with the possible exception of "fill".

PETROGRAPHER: F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

DATE: Oct 4, 2000

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Notice: The test data given in this report pertain to the sample provided, and may not be applicable to material other than that represented by the sample. This test report constitutes a testing service. Interpretation may be provided on request.

TECHNICAL REPORT

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

LEVELTON
Engineering Solutions

ATTENTION: Mr. Norm Allyn, P. Eng.

Our file: 100-0865
September 21, 2000

PROJECT: Rip Rap Testing -- Polaris Mine
SUBJECT: **Petrographic Examination (ASTM C-295)**

Sample: Grey Rock -- "L" samples

PETROGRAPHIC DESCRIPTION

Limestone -- very fine-grained micritic limestone, dense, very strong.

In thin-section, these rocks are limestone composed of a mixture of finely crystalline and micritic calcite. Dense-textured. A little bit of porosity, evidenced in vuggy cavities, with coarser material in them. Fairly pure calcite, no discernible extraneous sediments detected. One section would be termed "organo-clastic limestone", reflecting considerable amount of shell fragments (up to 30%) in the section (e.g., L-2). Organic-derived material includes brachiopod and gastropod shell fragments. Parts of the rock are recrystallized.

COMMENTS

The limestone was quite strong. A few calcite-filled veins cut the rock.

QUALITY

The limestone was judged to be of good physical quality.

"Good" quality material was 96.6% by mass, while "Fair" quality material was 3.4%, giving a Petrographic Number of "107". For aggregate sizes, this equates with an overall quality rating of "Excellent".

SUMMARY

The grey limestone samples were judged to be of overall satisfactory quality for engineering construction applications.

PETROGRAPHER: F. Shrimer, P. Geo.

PROFESSIONAL GEOSCIENTIST
PROVINCE OF BRITISH COLUMBIA
F. H. SHRIMER

DATE: Oct 4, 2000

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TECHNICAL REPORT

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

LEVELTON
Engineering Solutions

ATTENTION: Mr. Norm Allyn, P. Eng.

Our file: 100-0865
September 21, 2000

PROJECT: Rip Rap Testing – Polaris Mine
SUBJECT: **Petrographic Examination (ASTM C-295)**

Sample: Buff-Beige Rock -- "D" samples

PETROGRAPHIC DESCRIPTION

Limestone -- fine-grained micritic limestone, dense, very strong.

In thin-section, these rocks are limestone composed of a mixture of finely crystalline and micritic calcite. Dense-textured. Minor porosity. Patchy appearance. Some vuggy zones, and small amount of shell and other organic fragments. Many trilobite fragments in one section, some brachiopod and ostracods, algae.

COMMENTS

The material was quite strong.

QUALITY

The buff-beige limestone was strong and judged to be of good physical quality. Petrographic Number analysis determined a PN of '111', which rates the aggregate as being of "Good" physical-mechanical quality, when compared with other aggregates. "Good" quality material comprised 94.7% by mass of the sample, while "Fair" quality material accounted for 5.3% of the sample, by mass.

SUMMARY

The buff-beige limestone was judged to be of overall satisfactory quality for engineering construction applications.

PETROGRAPHER: [signature] F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

DATE: Oct 4, 2000

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TECHNICAL REPORT

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

October 4, 2000
Our file: 100-0865

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: Comparison of Test Results

TEST	CRUSHED GRAVEL SAMPLES			SAWN ROCK SAMPLES		
	"MW"	"L"	"D"	"MW"	"L"	"D"
Los Angeles Abrasion loss (%)	44.8	17.1	17.3	--	--	--
Durability Index	71	92	82	--	--	--
Specific Gravity	3.536	2.720	2.689	3.760	2.739	2.626
Absorption (%)	1.35	0.43	1.40	1.723	0.985	1.565
Sulphate Soundness loss (%)	31.6	1.00	0.60	40.1	0.69	0.39
Petrographic Number	191	107	111	--	--	--
Petrographic Quality	Poor	Excellent	Good	--	--	--

Reported by:
F. Shrimer, P. Geo.

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Notice: The test data given herein pertain to the sample provided, and may not be applicable to material from earlier or subsequent production, or from other zones. Reporting of these data constitutes a testing service. Interpretation may be provided upon request.

APPENDIX F-4

October 31, 2000 - Freeze-Thaw Tests

LEVELTON
Engineering Solutions

F_x Transmittal

Levelton Engineering Ltd.

150-12791 Clarke Place
Richmond, B.C.
Canada V6V 2H9
Tel: 604 278-1411
Fax: 604 278-1042
E-Mail: info@levelton.com

To	Norm Allyn, P. Eng. – WESTMAR	Fax/phone number	985-2581/985-6488
cc		Fax/phone number	
From	Fred Shrimer, P. Geo.	Project number	100-0865
Date	October 31, 2000	Total number of pages (including cover page)	4

PROJECT: Testing of Polaris Rip-Rap

Norm:

Accompanying this cover are Technical Reports for the Freeze-Thaw test (CIRIA method).

The method given in the CIRIA volume is somewhat vague in terms of determination of loss, and other procedural details. At any rate, the results are provided on the test report forms. The observational data are of some significance, and would indicate that the "limestone" samples were the materials which performed the best in these tests.

I have taken photographs of the samples at the beginning of as well as at the conclusion of the test, which I will forward to you, once the film's been developed.

My reading of the test method suggests that their limit is 0.5% maximum loss (?).

The test method says that the "stone must have no cracks in it", which simply was not possible to do. Two of the rocks (the ones that failed) had joints in them. My thought is that the test has now enabled an assessment as to the structural (e.g., rock mechanics) implications of those joints. (Some joints are acceptable, while others may not be.)

I trust that this is the information you need. Please call to discuss, or if you have any questions.

Regards,

Fred Shrimer, P. Geo.

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Please call 604-278-1411 if any pages are missing. FILE 00282

TECHNICAL REPORT

LEVELTON
Engineering Solutions

Our file: 100-0865
October 31, 2000

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Freeze-Thaw Test of Rock Specimens (CIRIA Spec. Pub. 83, A2.4)**

Material Tested: "Mine Waste"

Source: Polaris Minesite
Sample: Mine rock

Sampled by: Westmar

PARAMETER	RESULT
Absorption (%)	1.72
Weight loss (%)	0.7
Duration of test (# cycles)	25 (21 Sept - 26 Oct, 2000)
Crack propagation	Sample 'X' has developed minor cracks, extending from previously-existing voids in the rock. Sample 'Z' has developed a number of extensive open cracks, which have extended nearly 70% through the rock.

Notes: 1. Two specimens prepared from the sample.

REPORTED BY: F. Shrimer, P. Geo.

PROFESSIONAL GEOSCIENTIST — PROVINCE OF BRITISH COLUMBIA — F. H. SHRIMER

DATE: Oct 31, 2000

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Notice: The test data given in this report pertain to the sample provided, and may not be applicable to samples from production other than that represented by the sample. This test report constitutes a testing service. Interpretation may be provided on request.

TECHNICAL REPORT

LEVELTON
Engineering Solutions

Our file: 100-0865
October 31, 2000

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Freeze-Thaw Test of Rock Specimens (CIRIA Spec. Pub. 83, A2.4)**

Material Tested: [illegible] "Dolomite"

Source: Polaris Minesite
Sample: "Dolomite" (buff-beige rock)

Sampled by: Westmar

PARAMETER	RESULT
Absorption (%)	1.57
Weight loss (%)	Sa. A: 10.0 ; Sa. B: 0.3 Average: 5.2
Duration of test (# cycles)	25 (21 Sept - 26 Oct, 2000)
Crack propagation	Sample 'A' has been fragmented by several major open cracks, breaking into two larger parts and numerous smaller chips and pieces. Fractures have developed both along pre-existing joints as well as through the rock fabric itself. Sample 'B' has developed one significant crack which has nearly extended through the rock (75% complete), and the specimen is in danger of being broken imminently.

Notes: 1. Two specimens prepared from the sample.

PROFESSIONAL
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F. H. SHRIMER
BRITISH COLUMBIA
GEOSCIENTIST

REPORTED BY: F. Shrimer, P. Geo. DATE: Oct 31, 2000

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Levelton Engineering Ltd., #150 - 12791 Clarke Place, Richmond, B.C. V6V 2H9 Canada Tel: 604-278-1411 Fax: 604-278-1042

TECHNICAL REPORT

LEVELTON
Engineering Solutions

Our file: 100-0865
October 31, 2000

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Freeze-Thaw Test of Rock Specimens (CIRIA Spec. Pub. 83, A2.4)**

Material Tested: "Limestone"

Source: Polaris Minesite
Sample: "Limestone" (brown-grey rock)

Sampled by: Westmar

PARAMETER	RESULT
Absorption (%)	0.99
Weight loss (%)	0.03
Duration of test (# cycles)	25 (21 Sept - 26 Oct, 2000)
Crack propagation	No noticeable development of cracks in Sample 'C'. A few flakes have been removed at the conclusion of the test from edges. Sample 'D' was noted to have a very slight initiation of a crack in the specimen, and both completed as well as incipient flaking failures along edges of the specimen.

Notes: 1. Two samples prepared from the sample.

REPORTED BY: F. Shrimer, P. Geo.

PROFESSIONAL
PROVINCE OF
F. H. SHRIMER
BRITISH COLUMBIA
GEOSCIENTIST

DATE: Oct 31, 2000

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APPENDIX F-5

March 13, 2001 - Summary of Rock Quality Tests

Fax Transmittal

Levelton Engineering Ltd.

150-12791 Clarke Place
Richmond, B.C.
Canada V6V 2H9
Tel: 604 278-1411
Fax: 604 278-1042
E-Mail: info@levelton.com

LEVELTON
Engineering Solutions

To	Gang Yang, EIT. – WESTMAR	Fax/phone number	985-2581/985-6488
cc		Fax/phone number	
From	Fred Shrimer, P. Geo.	Project number	100-0865
Date	March 13, 2001	Total number of pages (including cover page)	2

PROJECT: Testing of Polaris Rip-Rap

Gang:

Accompanying is the revised table listing the test data from the testing of the Polaris rock samples.

hope our discussion this afternoon was of help in interpreting the results. Please call me if you have any further questions.

Regards,

GY
NFA
GY

Fred Shrimer, P. Geo.

00282

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Please call 604-278-1411 if any pages are missing.

TECHNICAL REPORT

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

March 13, 2001
Our file: 100-0865

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Comparison of Test Results**

TEST	CRUSHED GRAVEL SAMPLES			SAWN ROCK SAMPLES		
	"MW"	"L"	"D"	"MW"	"L"	"D"
Los Angeles Abrasion loss (%)	44.8	17.1	17.3	--	--	--
Durability Index	71	92	82	--	--	--
Specific Gravity	3.536	2.720	2.689	3.760	2.739	2.626
Absorption (%)	1.35	0.43	1.40	1.723	0.985	1.565
Freeze-Thaw Test loss (%)	--	--	--	0.7	0.03	5.2
Sulphate Soundness loss (%)	31.6	1.00	0.60	40.1	0.69	0.39
Petrographic Number	191	107	111	--	--	--
Petrographic Quality	Poor	Excellent	Good	--	--	--

Reported by: F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

March 13, 2001.

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Notice: The test data given herein pertain to the sample provided, and may not be applicable to material from earlier or subsequent production, or from other zones. Reporting of these data constitutes a testing service. Interpretation may be provided upon request.

Levelton Engineering Ltd., 150 - 12791 Clarke Rd., Richmond, B.C. Canada V6V 2H9 Tel: 604-278-1411 Fax: 604-278-1042

APPENDIX G

CIRIA Freeze-Thaw Test Specifications

CIRIA
CONSTRUCTION INDUSTRY RESEARCH
AND INFORMATION ASSOCIATION

CENTRE FOR CIVIL ENGINEERING
RESEARCH AND CODES
CUR

Manual on the use of rock in coastal and shoreline engineering

CIRIA SPECIAL PUBLICATION 83

CUR REPORT 154

$$C_{w3} = \frac{W_3}{W_t} \cdot 100$$

Calculate the number per cent of stones with length-to-thickness ratio greater than 3 and 2 using the formula:

$$C_{n3} = \frac{n_3}{n} \cdot 100$$

$$C_{n2} = \frac{n_2}{n} \cdot 100$$

A2.3.5 REPORT

The report must provide the following data:

1. The measured weight per cent of stones with length-to-thickness ratio greater than 3;
2. The measured number percent of stones with length-to-thickness ratio greater than 3, and greater than 2;
3. A reference to this standard;
4. A description of the sample, including the weight and the number of stones;
5. The source of the sample;
6. The date of the test.

Note: Box 35 in Section 3.6 of the main text gives practical guidance on taking length and thickness measurements.

A2.4 Determination of Resistance to Freeze/Thaw Cycles

Note: This standard is based on Draft NEN 5184 and B5812.

A2.4.1 SUBJECT AND AREA OF APPLICATION

This standard gives the method to determine the resistance against freeze/thaw cycles of a stone of a grading class with a nominal size greater than the 31.5 mm sieve size.

A2.4.2 SAMPLE FOR ANALYSIS

The stone must be taken at random from the largest fraction of stone material set by the requirements for gradings. If the stone is heavier than 20 kg, the test will have to be carried out on a representative part of at least 10 kg. The stone must have no cracks in it.

A2.4.3 EQUIPMENT AND OTHER AIDS

A2.4.3.1 Drying oven or other appropriate apparatus, capable of adjustable temperature of (110 ± 5)°C;
A2.4.3.2 Weighing equipment, accurate up to 0.01% of the weight of the stone;
A2.4.3.3 Freezer-box with air circulation in which the stone can be exposed to the temperature described in Section A2.4.4.2;
A2.4.3.4 Vessel with a volume at least six times the volume of the stone;
A2.4.3.5 Saw for use in case the stone has a volume in excess of 150 ml;

A2.4.3.6 Plas film, brush.

A2.4.4 METHOD OF OPERATION

A2.4.4.1 Water absorption at atmospheric pressure

Cut from the stone a representative piece, using the saw, if the stone has a volume in excess of 150 ml. The representative part of the stone should have a volume of at least 50 ml and, at most, 150 ml. Determine the water absorption, in accordance with Section A2.7, of the stone or part of the stone.

End the test if the water absorption does not exceed 0.5%, as in that case the stone is considered to be (satisfactorily) resistant to freeze/thaw cycles. Carry out freeze test in accordance with A2.4.4.2 below if the water absorption exceeds 0.5%

A2.4.4.2 Execution of the freeze test

Let the stone absorb water in accordance with Section A2.7. Wrap the stone in plastic film and place it in the freezer-box. Adjust the temperature control in such a way that the temperature in the stone reaches a level of −15°C or lower in a time of about 5 hours. Maintain that temperature for at least 2 hours. Remove the plastic film and immerse the stone directly in the water in the vessel, which contains drinking water with at least five times the volume of the stone at a temperature of 15–20°C.

Leave the stone submerged for at least 2 hours. Repeat the freeze–thaw cycle 25 times. At the end of these tests, dry the stone in the oven at a temperature of (110 ± 5)°C until the stone reaches a stage when its weight remains constant.

Determine the weight loss of the stone and check to see if any cracks have developed.

A2.4.5 REPORT

1. Water absorption;
2. Weight loss in per cent and rounded to 0.1%;
3. The development of any cracks during the test;
4. Resistance against freeze/thaw cycles (weight loss less than 0.5% and no crack development);
5. Reference to this standard;
6. Description of the stone, including the weight loss;
7. Source of stone;
8. Duration of the tests.

A2.5 Determination of Dynamic Crushing Strength

Note: This standard is based on Draft NEN 5185.

A2.5.1 SUBJECT AND AREA OF APPLICATION

This standard provides the method for the determination of the dynamic crushing strength of natural stone and of other types of stone and stone-type materials. The dynamic crushing strength is determined as the average test result from a duplicated test.