



**WorleyParsons**  
resources & energy



# IQALUIT PORT DEVELOPMENT



Prepared in association with The Mariport Group, Ltd.



Photo courtesy City of Iqaluit



### TRANSMITTAL

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**ACKNOWLEDGE  
RECEIPT TO**

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**ORIGINATOR** Harald Kullmann

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**PROJECT 09120 - IQALUIT PORT DEVELOPMENT**

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## **1. EXECUTIVE SUMMARY**

Iqaluit is a major northern community and suffers from the same deficiencies in transportation infrastructure as the other smaller northern communities, a lack of adequate marine infrastructure. The vast majority of resupply materials arrive in Iqaluit by annual sealift during the summer open-water season. Iqaluit's problems are further compounded by its very large tidal range, one of the largest in North America. This creates a setting where the cost of infrastructure, which for the north is already in the order of four to five times higher than for southern developed centres, is even higher.

Annual sealift cargo is lightered from ships anchored in an exposed location into a beach using small tugs and barges with forklift trucks meeting the barges somewhere in shallow water. The existing landing beach is expected to reach capacity by about 2018. Fuel for local consumption and power generation is brought in by tanker and offloaded at the manifold at Innuvit Head using floating hoses, another common practice for northern communities.

Small craft facilities are equally deficient, with only an all-tide boat launching ramp at the Old Causeway and a boat basin with fixed dock at the Municipal Breakwater. The facilities at the Municipal Breakwater are useable only at high tide.

Four locations have been assessed for deep sea port facilities to handle both resupply cargo and fuel. All four locations are located on the western shoreline of Koojesse Inlet from Innuvit Head, the location of past port development studies, to the Old Causeway. The preferred location is adjacent the south end of Polaris Reef, referred to as Option 4, just north of the original Innuvit Head site. This site avoids the issues of spanning the channel between the mainland and Innuvit Head, it has a shorter access road for better integration between storage laydown and it has the lowest capital cost. The estimated cost for the deep-sea port facility at South Polaris Reef is \$67,800,000. This includes a primary laydown area behind wharf of 1.2 ha, with a secondary storage yard and parking of 3 ha adjacent to the Old Causeway. The port costs include for lighting, security, office space and fire protection. A fuel manifold would be located behind the wharf to handle all fuel and an auxiliary landing ramp is provided adjacent to the laydown area to allow a second cargo vessel at anchor to lighter cargo when the wharf is occupied.

Option 6 is presented to allow for a staged construction for the South Polaris Reef facility. If full funding for the deep-sea port is not available a configuration has been developed that allows the majority of the facility to be built but without the wharf. The configuration allows the wharf and its associated foundation preparation to be constructed in the future. The cost of Option 6 is \$29,500,000. Existing fuel receiving operations would continue with floating hoses at Innuvit Head, but an additional \$330,000 would provide much needed mooring improvements to the tanker berth.



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Three options for small craft harbours have been developed, including two options of full-tide accessible floating harbour. One option is an expansion to the Municipal Breakwater into deeper water and one at the Old Causeway; both include a very large breakwater structure over 14 m tall. A third option, Option C, is an upgrade of existing facilities at the Municipal Breakwater and has been identified at the public open house and in discussions with the City of Iqaluit as the preferred option as it has a modest capital cost, it retains public access for boating on the Iqaluit side of Koojesse Inlet maintaining the opposite side for industrial activities and cargo receiving, and it addresses many of the needs for the community residents. Option C is estimated at \$4,500,000 when combined with either Option 4 or 6. The improvements include approximately 1 ha of upland boat storage and parking where there currently is little or no space available, a deeper boat basin with launching ramp allowing improved tidal access, three 5 m by 10 m floats at the shoreline, and other miscellaneous items to improve access and safety associated with boating activities.

It is expected that cost of the infrastructure will not produce a rate of return that supports the economics of the installation. This is not unexpected as even in southern developed centres where only dedicated transshipment terminals with very high throughput can sustain their infrastructure through handling charges alone. The rest must absorb the costs through the profits of other operations or external funding. Iqaluit, with a comparatively low volume of cargo, will not produce a positive rate of return and the cost must be covered through funding from other sources. The question then becomes "What is the minimum acceptable level of service for community like Iqaluit?". Lost cargo or delayed cargo is not unheard of for Iqaluit. The Iqaluit Port Development project is a four-year planning and construction project, with two years of planning and permitting and two years of construction. The landing beach will run out of capacity by approximately 2018 and by then something will need to be done.



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## **2. INTRODUCTION**

### **2.1 Background**

The past fifteen years has seen many changes in the usage of marine infrastructure in the eastern Arctic. In particular, the need has become more and more apparent for improved marine facilities to meet the diverse needs of many users. This is particularly the case in Iqaluit. Resupply needs patterns have changed, and volumes have increased significantly with exceptional increases in Iqaluit following creation of Nunavut. In addition local boat owners are gradually moving to larger vessels, and therefore have increased requirements for launch ramps, sheltered moorage and berthage; commercial enterprises such as fishing, research, and tourism outfitters are increasing the scope of their marine involvement and require safe and accessible loading/offloading points; cruise ships visiting the city prefer some form of berth that is accessible at most states of the tide for passenger transfer. The City of Iqaluit, with funding from the Department of Economic Development & Transportation, completed a *Strategic Plan for the Iqaluit Deepwater Port Project in 2005*.

### **2.2 Scope of Study**

The following is the scope of the work as presented in the Request for Proposal:

- Provide conceptual design of multi-purpose marine facility including cargo laydown area, public areas and access roads, which will increase the efficiency of the Iqaluit harbour facilities and will use the most innovative and economical solution for the design and construction of these new marine facilities;
- Provide listing of approvals required under Nunavut legislation, including identifying measures required to obtain approvals;
- Provide list of engineering studies and investigations required to advance design from conceptual to tender ready stage;
- Provide Class D cost estimates for all approvals, engineering investigations and studies, design work, and construction;
- Provide projected timeline for completion of approvals, engineering investigations and studies, detailed design, and construction.

As a result of the kick-off meeting on August 11 to 13, 2009 and follow-up meetings on December 7, 2009 and May 6, 2010, a decision was made to present several options for both small craft harbour improvements and deep-sea wharf options, along with an interim staged cargo handling improvement option.



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## **2.3 Concurrent Work**

During the course of the work for this study, the Government of Nunavut (GN) undertook the following additional studies in support of the eventual execution of the port development. These additional tasks were contracted direct with GN, but, with the exception of the habitat assessment, were scoped, managed and coordinated by WorleyParsons.

- A marine habitat assessment for some of the potential locations for port improvement works;
- A topographic survey of the tidal zone covering the potential locations for improvements. This work extended from approximately the high watermark to approximately mean low water, providing the data that was missed between the upland topographic data available from Natural Resources Canada and the offshore bathymetry obtained from Canadian Hydrographic Services (CHS). The topographic data has been incorporated into the site plans presented in Appendix D;
- A geophysical survey of the offshore potential sites. The intent of this survey is to provide a fast and economical approach to providing insight into subsurface conditions at the potential sites. Foundation preparation is generally a major factor in assessing the cost and time to construct marine infrastructure especially the deep foundations associated with a wharf. This data would serve to estimate if the ground conditions are likely to be more favourable at one site over another. Once a preferred site(s) has been selected, the more costly geotechnical drilling program can be minimized. This survey work is presented in Appendix C;
- A desktop geotechnical assessment of the various components and conceptual assessment of foundation preparation requirements and development of a field program and cost estimate to advance the geotechnical engineering to a preliminary engineering level. This desktop study is presented in Appendix C.

## **2.4 Past Studies**

The following previous studies were available in support of this study:

- “General Cargo Marine Terminal Frobisher Bay, NWT,” by Public Works, July 1980.
- “2001 Nunavut Transportation Strategy”, by LPS Avia, FSC, The Mariport Group, Innuvik Support Services Inc.
- “Strategic Plan for the Iqaluit Deepwater Port Project,” by Aarluk Consulting, August 2005.
- “A Stripping and Seasonal Warehouse Facility for Iqaluit,” by The Mariport Group Ltd., January 2008.
- “Community Access and Zero Date System”, The Mariport Group Ltd., December 2009.

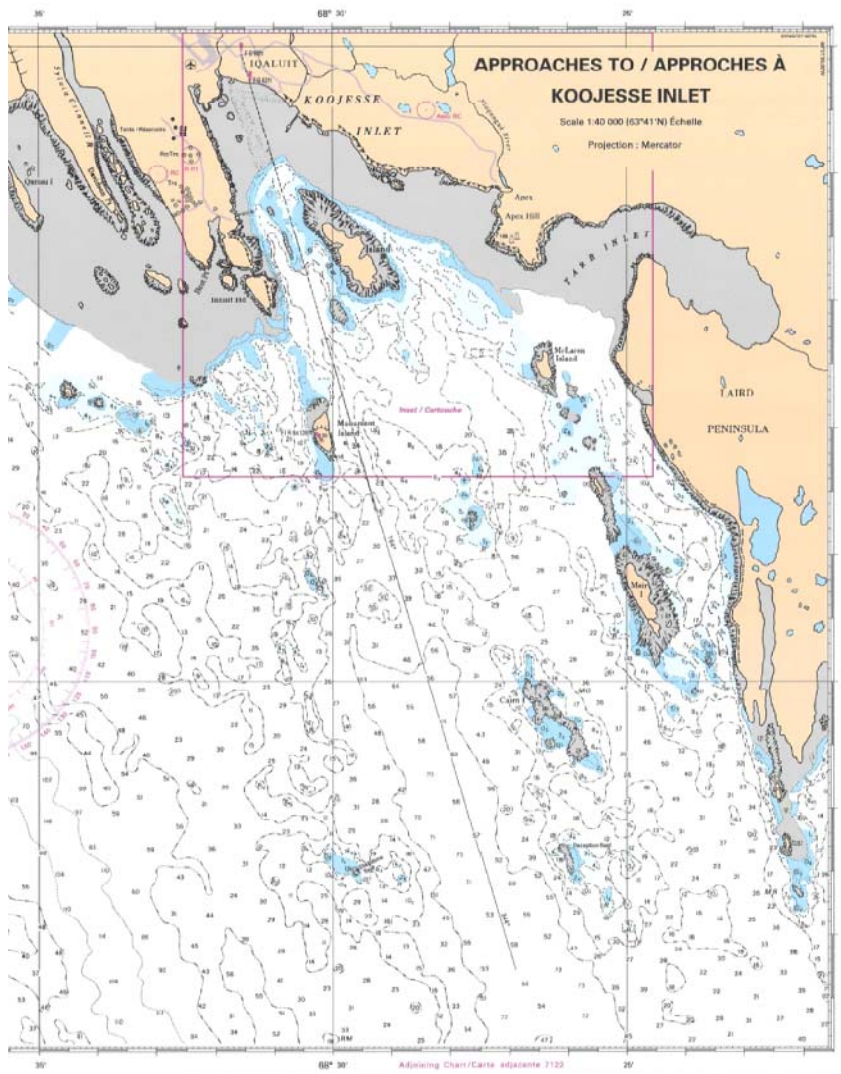


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**3. SITE CONDITIONS**

**3.1 Site Location**

Iqaluit is situated in Koojesse Inlet at the head of the 250 km long Frobisher Bay on Baffin Island. The site is located well within the limits defined as the Arctic (average annual temperature below -10 deg. C). Figure A shows the site location.



**Figure A Upper Frobisher Bay, excerpt of CHS Chart 7127, reproduced with permission from CHS.**



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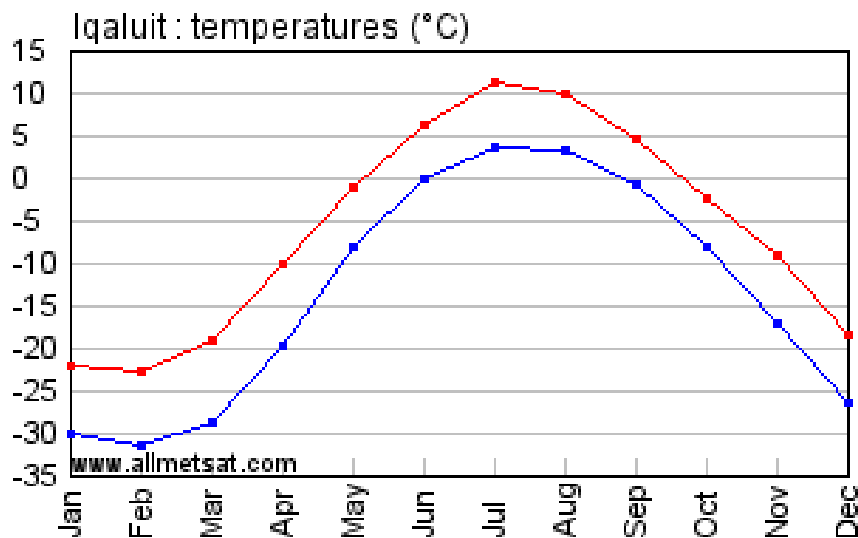
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### 3.2 Temperature

The following temperature data was obtained from Climate Services Canada for Iqaluit. These are not extreme temperatures, but are used in establishing temperature related issues:

- January Design Temperature (2.5%): -40 deg. C
- July Design Temperature (2.5% dry): 16 deg. C
- Degree-Days below 18 deg. C: 10,050

Figure B below show the average daily minimum and maximum temperatures, by month.



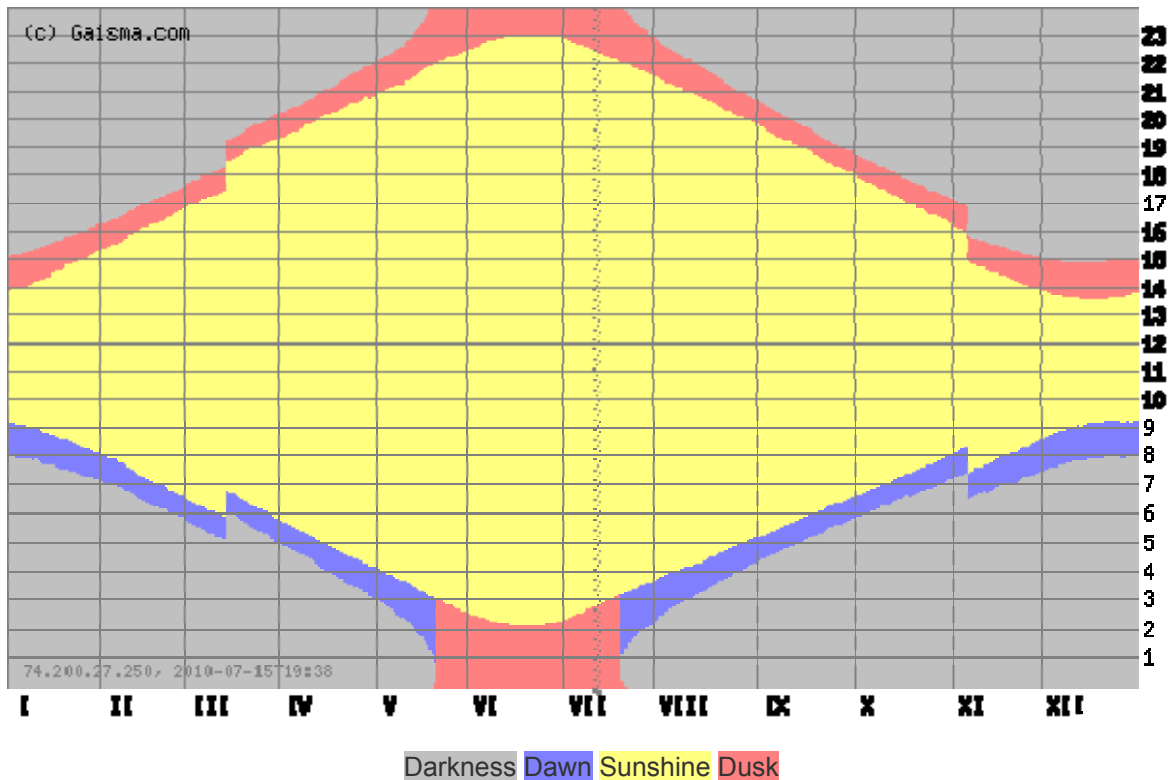
**Figure B Daily maximum and minimum temperatures (source: Eldorado Weather).**



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### 3.3 Daylight Hours

The daylight and darkness hours for Iqaluit are shown in Figure C by month.



**Figure C Daylight hours for Iqaluit (source: www.Gaisma.com).**

### 3.4 Rainfall

The following rainfall data was obtained from Climate Services Canada for Iqaluit:

- 15 Minutes Rainfall (1 in 10 year): 5 mm
- One Day Rainfall (1 in 50 year): 58 mm
- Annual Rainfall (average): 200 mm
- Annual Total Precipitation (average): 433 mm



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### 3.5 Snow

The following snow load data was obtained from Climate Services Canada for Iqaluit:

- Ground Snow Load (1 in 50 year):  $S_g = 2.9 \text{ kPa}$ ,  $S_r = 0.2 \text{ kPa}$

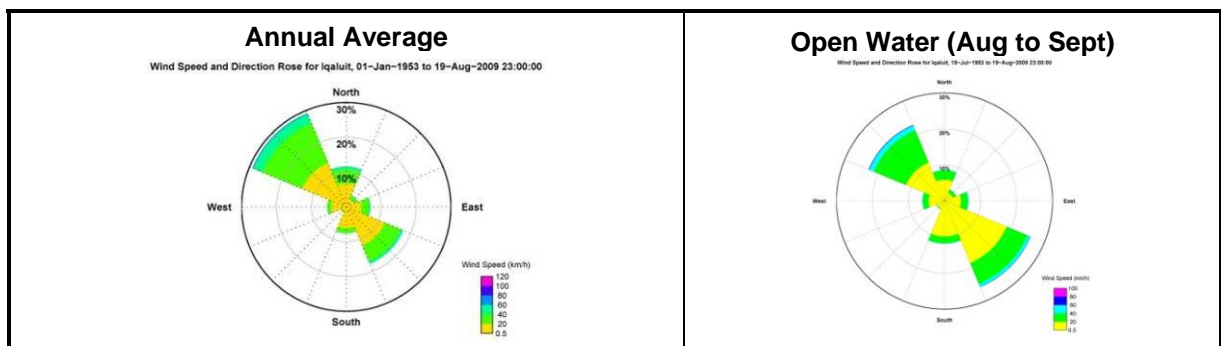
### 3.6 Wind

#### 3.6.1 Statistics

The wind record at Iqaluit airport (approximately 3.0 km northwest of the site) was acquired from Environment Canada. The data is considered to be directly applicable to the sites of interest because of proximity and the prevailing winds are consistent with the local topography at the sites. The wind record consists of approximately 57 years of hourly wind data from 1953 to 2009. The wind speeds and directions were recorded at an average of one or two minute intervals, taken every hour. The wind speeds in this record are treated as hourly average wind speeds.

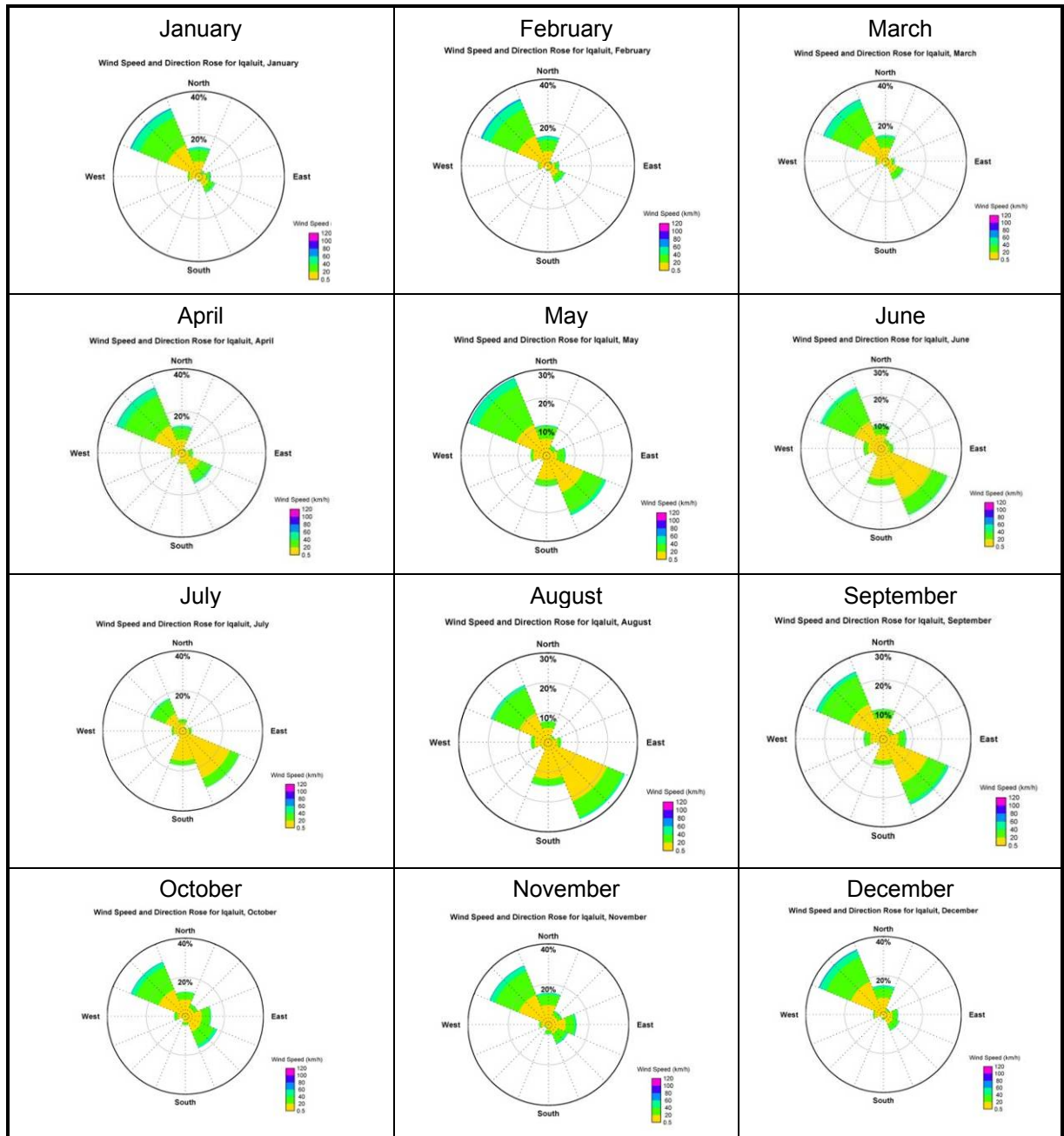
A statistical analysis was conducted based on the wind record. Annual average percentage occurrences of various wind speeds and direction intervals were calculated for the open water period (mid-July to mid-October), and the results are presented in Table B. Annual average, monthly statistical analysis and open water periods, with their corresponding wind roses can be found in Appendix A.

The corresponding annual average, monthly and open water wind roses, are shown in Figure D. It is anticipated that the harbour will be utilized and operational only during the open water period.





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**Figure D Wind roses at Iqaluit.**

**3.6.2 Increase in Storm Frequency and Intensity**

Storm frequency due to climate change was also investigated. Table A summarizes the top 20 recorded wind speeds at Iqaluit airport.

**Table A Top 20 Wind Speeds (Hourly Average) Recorded at Iqaluit Airport**

Year	Month	Day	Hour	Wind Speed (kph)	Wind Direction
1963	9	16	14	84	290
1959	9	11	12	85	290
1961	8	23	0	85	320
1961	10	9	0	85	320
1963	9	16	18	85	290
1997	10	14	17	85	140
1997	10	14	14	87	140
1961	9	19	10	89	320
1961	9	19	12	89	320
1961	9	19	16	89	320
1961	9	20	8	89	320
1986	10	11	23	89	320
1986	10	12	1	89	320
1961	8	23	1	90	320
1986	10	12	0	91	320
1960	9	22	13	92	140
1961	9	20	10	92	320
1986	10	12	3	94	320
1960	9	22	11	97	140
1986	10	12	2	104	320

As it is seen, there is no clear pattern in the increase of storm events over the period of records. Table A supports this conclusion. The Intergovernmental Panel on Climate Change (IPCC) reports “There is no evidence of systematic increases in intense storms in the Arctic” (2007).



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**Table B Percentage Occurrences of Winds for Various Speeds and Directions, mid-July to mid-October**

Percent	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0 - 0.5																	<b>12.00**</b>
0.5 - 10	1.40	0.54	0.56	0.47	1.08	1.71	6.21	5.30	2.27	0.81	0.83	0.68	1.21	1.74	2.65	1.40	<b>28.88</b>
10 - 20	1.30	0.47	0.96	0.88	1.22	1.68	5.86	5.01	1.08	0.32	0.45	0.48	0.88	1.52	5.18	3.27	<b>30.58</b>
20 - 30	0.48	0.21	0.45	0.46	0.68	0.81	3.08	2.00	0.25	0.07	0.10	0.13	0.47	0.92	4.50	2.60	<b>17.21</b>
30 - 40	0.12	0.07	0.19	0.22	0.21	0.29	1.41	0.77	0.09	0.02	0.03	0.03	0.18	0.51	2.63	1.09	<b>7.84</b>
40 - 50	0.03	0.01	0.05	0.08	0.07	0.09	0.54	0.17	0.02	*	0.01	*	0.04	0.13	0.93	0.32	<b>2.40</b>
50 - 60	*	*	0.03	0.04	0.02	0.02	0.16	0.05	*			*	*	0.04	0.24	0.05	<b>0.66</b>
60 - 70	*	*	0.01	*	0.02	*	0.06	*	*	*	*			0.02	0.08	*	<b>0.23</b>
70 - 80				*	*	*	0.02	*						0.01	0.05		<b>0.08</b>
80 - 90							*							*	*		<b>0.01</b>
90 - 100							*								*		*
>100															*		*
<b>Subtotal</b>	<b>3.33</b>	<b>1.29</b>	<b>2.24</b>	<b>2.15</b>	<b>3.30</b>	<b>4.62</b>	<b>17.34</b>	<b>13.32</b>	<b>3.71</b>	<b>1.23</b>	<b>1.42</b>	<b>1.33</b>	<b>2.79</b>	<b>4.90</b>	<b>16.28</b>	<b>8.74</b>	
<b>Total</b>	<b>4.08</b>	<b>2.04</b>	<b>2.99</b>	<b>2.9</b>	<b>4.05</b>	<b>5.37</b>	<b>18.09</b>	<b>14.07</b>	<b>4.46</b>	<b>1.98</b>	<b>2.17</b>	<b>2.09</b>	<b>3.54</b>	<b>5.65</b>	<b>17.03</b>	<b>9.49</b>	
Cumulative Probability	4.08	6.12	9.11	12.01	16.06	21.43	39.52	53.59	58.05	60.03	62.2	64.29	67.83	73.48	90.51	100	
Exceedance	95.92	93.88	90.89	87.99	83.94	78.57	60.48	46.41	41.95	39.97	37.8	35.71	32.17	26.52	9.49	0	

\* Denotes values less than 0.01%.

\*\* Calm (<0.5 kph): 12.0%



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As shown in Table B winds are most frequent from the east-southeast through to the south-southeast sectors, clockwise (30.7% of the time) during the open water season, followed by winds from the northwest and north-northwest (25.0% of the time). The more severe storms ( $\geq 60$  kph) come from both the northwest and southeast. The area is calm ( $<10$  kph) 40.9% of the time, during the open water season. The maximum recorded wind speed during the mid-July to mid-October season was 104.0 kph from the northwest.

**3.6.3 Extreme Probability Analysis**

The historical storm events with wind speeds exceeding 55 kph (29.7 knots), for the open water period were extracted from the wind record from Iqaluit Airport, and the peak storm wind speeds were identified. The site is located on the very northern end of Frobisher Bay; therefore waves from the southeast represent the main impact to the sites. There is a small fetch from the northeast, during higher water events. Therefore only the southeast and northeast winds were investigated.

An extreme probability analysis was conducted based on these storm records.

The design wind speeds for varying return periods were determined, and the results are presented in Table C.

**Table C Design Wind Speeds**

Return Period or Exceedance Percentage Occurrences	ESE-SSE (Clockwise)		Northeast	
	kph	knots	kph	knots
10 Years	76.8	41.5	64.0	34.6
25 Years	83.4	45.0	69.3	37.4
50 Years	88.3	47.7	70.3	39.4
100 Years	93.2	50.3	76.6	41.3

It is noted that wind speeds published by the National Building Code of Canada (NBCC 2005) for Iqaluit are as follows:

- 10 Year Return Period: 88.6 kph (47.9 knots)
- 50 Year Return Period: 112.76 kph (66.3 knots)

These wind speeds are published for building design purposes and should not be used to create wind generated waves. These wind speeds represent all year events. The wind speeds reported in Table B are for the open water season only, when wind generated waves can be produced.



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### **3.7 Seismic**

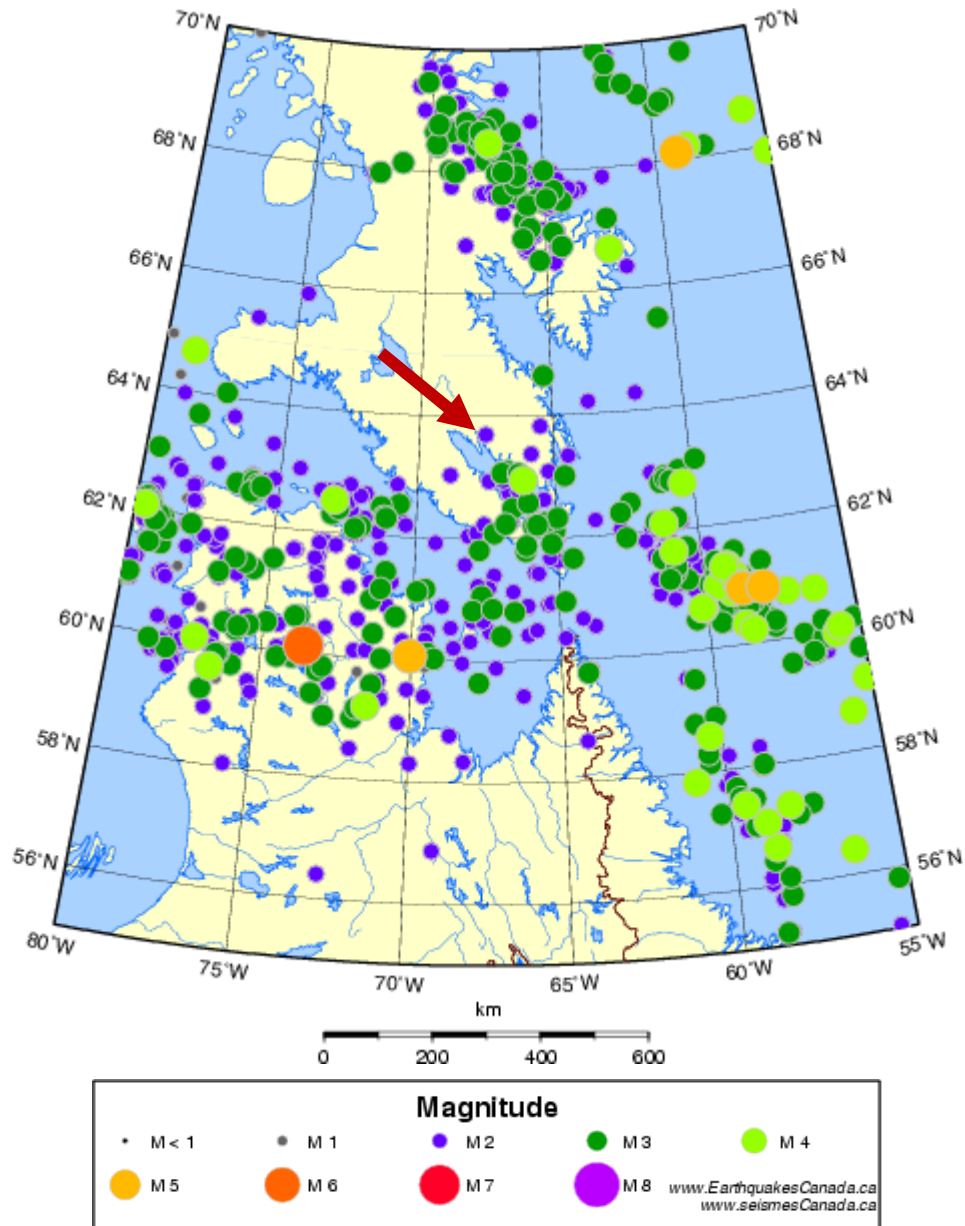
The site is located in an area of low seismicity. The NBCC specifies the following Peak Ground Acceleration values that have a 2% probability of being exceeded in 50 years (1 in 2475 years) for Iqaluit:

- Peak Ground Acceleration, PGA                      0.059 g

Figure E shows recent earthquakes (1985 to 2009) within the region. Most earthquakes shown are between Magnitude 2 and 3 with a generally low concentration in close proximity to Iqaluit. This is representative of a site with low seismicity which will not be a governing factor in the design of the port facilities. Therefore, for the purpose of this study, seismic effects have been ignored.



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**Figure E** Recent earthquakes recorded in the Southern Baffin and Nunavik region (1985 to 2009).



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**3.8 Tides**

Tidal information at Iqaluit, published by Canadian Hydrographic Service (CHS) in Canadian Tide and Current Tables, Volume 4 (Arctic and Hudson Bay), 2009 Edition, Department of Fisheries and Oceans (2009) was adopted as the design water levels. These design water levels, referenced to Chart Datum, are presented in Table D.

**Table D Design Water Levels**

Description	Abbreviation	Elevation (m)
Extreme Higher High Water Level	EHHWL	12.3
Higher High Water Level, Large Tide	HHWL	11.6
Higher High Water Level, Mean Tide	MHWL	9.8
Mean Sea Level	MSL	5.9
Lower Low Water Level, Mean Tide	MLWL	2.0
Lower Low Water Level, Large Tide	LLWL	0.5
Extreme Lower Low Water Level	ELLWL	-0.3

It is noted that CHS has expressed an interest to install a tide gauge in Iqaluit should a significant marine infrastructure plan be executed. A tide gauge would most suitably be installed near the deep-sea wharf structure.

Due to climate change concerns, sea level rise should be considered in any coastal design. The IPCC has published several papers on climate change issues and sea level rise. Following discussions with the IPCC, two documents were used to determine the rate of sea level rise within the Arctic region:

- Climate Change 2007: Physical Science Basis (Chapter 5); and,
- Climate Change 2007: Impacts, Adaptation and Vulnerability (Chapter 15).

Although there are no published rates of sea level rise for Iqaluit in these documents, the observed sea level rise in the North Atlantic is 1.85 mm/yr. Over a 50 year service life for structures in Iqaluit, this would equate to approximately 100 mm, which is considered relatively insignificant. However, there are a number of factors that could affect the Arctic region, including rebound of land (from past ice age(s)) and changes to water density. Further research would be necessary if this is to be considered in more detail.

**GOVERNMENT OF NUNAVUT  
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It is anticipated that the harbour will be utilized during the open water time frame (mid-July to mid-November). Wind generated wave events were isolated during this time frame, as it is the only time at which wind generated waves are able to develop.

The wind-generated waves are evaluated based on the wind-wave forecasting technique using the computer program Automated Coastal Engineering System (ACES), developed by the US Army Corps of Engineers (USACE). The design wind speeds shown in Table C are adjusted to include effects due to duration, overland-over water, sea-air temperature difference and elevations of the recording instrument before using in ACES.

As stated in Section 2.5, deep water wind-generated waves from the southeast and northeast directions were considered in this study. Straight line fetches of 77 km for the southeast and 1.9 km for the northeast were used in determining the wave characteristics. These directions are noted as southern and northern respectively throughout this report.

Table E and F summarize the design deep water wind-generated waves. Wind speeds corresponding to the return period events are described in Table C.

**Table E Wind-Generated Waves for Various Return Periods**

Return Period (Years)	Southern		Northern	
	H <sub>mo</sub> (m)	T <sub>p</sub> (sec)	H <sub>mo</sub> (m)	T <sub>p</sub> (sec)
10	2.36	5.8	0.42	2.1
30	2.77	6.3	0.47	2.1
50	2.98	6.5	0.47	2.1

**Table F Southern Wind-Generated Waves for Various Wind Speeds**

ESE-SSE (clockwise)	Percentage Occurrence	Cumulative Probability	H <sub>mo</sub> (m)	T <sub>p</sub> (sec)
10 kph	13.2	25.2*	0.14	2.0
20 kph	12.6	37.8	0.44	2.9
30 kph	5.9	43.7	0.62	3.2
40 kph	8.4	52.1	0.92	3.8
50 kph	0.8	52.9	1.18	4.2
60 kph	0.2	53.1	1.59	4.9

\*Including calm winds (<0.5 kph).



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$H_{m0}$  is an energy based significant wave height, where the wave height is the vertical distance from the trough to the crest of the wave. The peak wave period ( $T_p$ ) is defined as the period of the most energetic waves in the sea state. The wave period is defined as the time between successive wave crests at a stationary point.

**3.10 Storm Surge**

There are several factors that influence storm surge: wave run-up, wave set-up, wind set-up and pressure set-up. The amount of storm surge is dependent on the wind speed, wave characteristics, water level and structure characteristics.

These components were estimated using the methods described in “The Rock Manual, The Use of Rock in Hydraulic Engineering, 2<sup>nd</sup> edition, 2007”. The results for storm surge for various wind speeds and return periods are in Table G. As a southern exposure for the site will govern only the southern storm surge was investigated.

**Table G Southern Storm Surge for Various Wind Speeds and Return Periods**

Wind Speed or Return Period	Storm Surge (m) Associated with HHWL	Elevation Above CD (m)
20 kph	0.7	12.3
30 kph	1.1	12.7
40 kph	1.7	13.3
50 kph	2.2	13.8
60 kph	2.9	14.5
10 yr	4.4	16.0
30 yr	5.2	16.8

**3.11 Overtopping**

A rubble-mound breakwater will likely be considered for some options. A target crest elevation of 14 m (Chart Datum) for a rubble-mound breakwater was investigated using various return periods. The methods described in the Coastal Engineering Manual were utilized in determining the overtopping discharge rates and safety.



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**Table H Overtopping Rates and Safety**

Return Period	Overtopping Rate (m <sup>3</sup> /s)	Safety of Traffic		Structural Safety (Embankment Seawalls)
		Vehicles	Pedestrians	
1	3.14 x 10 <sup>-4</sup>	Unsafe parking on horizontal component of breakwater	Dangerous on horizontal component of breakwater	No damage
2	2.22 x 10 <sup>-3</sup>	Unsafe at any speed	Very Dangerous	Damage if crest not protected
5	8.87 x 10 <sup>-3</sup>	Unsafe at any speed	Very Dangerous	Damage if crest not protected
10	1.86 x 10 <sup>-2</sup>	Unsafe at any speed	Very Dangerous	Damage if back slope not protected
30	4.81 x 10 <sup>-2</sup>	Unsafe at any speed	Very Dangerous	Damage even if fully protected

As shown in Table H, the rubble-mound structure would be overtopped during the annual open water wave event. The rate of water overtopping the structure is unsafe for parking and pedestrians. However, the overtopping does not damage the structure. Damage may occur at the crest during the two year event.

**3.12 Currents**

Tidal currents in the vicinity of the proposed facilities are not known. However, Koojesse Inlet is a relatively small enclosed embayment and as such currents are not expected to be large. Currents were discussed with Woodward, the marine carrier supplying fuel oil to Iqaluit, as they have experience at the tanker berth off Innuvit Head. In general, the currents are not known but the vessel captains have stated that ship-handling as a result of currents is not a problem.

For the purpose of this study, it is assumed that tidal current at the sites will peak at approximately 1 knot.

Further work will be required to assess currents at the site. It is anticipated that numerical modeling of conditions at the site will be suitable for predicting currents, rather than installing current measuring equipment at the site. For the purposes of this study, it has been assumed that currents will not impact construction procedures or the cost of mooring equipment.



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### **3.13 Sea Ice**

Information on ice conditions in Koojesse Inlet has been obtained from the following sources:

- Ice thickness data provided in “Ice Thickness Climatology, 1961-1990 Normals”, by Ice Climatology Services.
- Canadian Hydrographic Service, Sailing Directions, Arctic Canada Volume II, Fourth Ed., 1985.

There are three distinct cyclical icing conditions in the year: iced, breakup and ice-free. The ocean surrounding the area is frozen for the majority of the year. The ice-free period for Iqaluit was published in the Sailing Direction by CHS and by the GN, in the Nunavut Transportation Strategy (2001) and is noted as being from mid-July to mid-October. However, work by The Mariport Group Ltd. for GN, “Community Access and the Zone Date System” has shown that Frobisher Bay exhibits different characteristics to the broader Zone C (ASPPR Zone 15). Typical freeze-up is not until end of November, although practical re-supply access would be until end of October.

Based on the information from Sailing Directions and other sources, the ice conditions at the Iqaluit site are summarized and estimated as follows:

- On average freeze-up starts in the second or third week of October and is usually complete in November.
- On average break-up starts at the end of June. It is anticipated that this is largely triggered by the first major north-westerly storm that will generally flush the ice out of the upper reaches of Frobisher Bay.
- The maximum first year level ice thickness is 1.6 m in the average year and 2.0 m in the more extreme years.
- Multi-year (MY) ice has been observed in Frobisher Bay.
- Frobisher Bay is generally free of icebergs.
- Based on data and the theories developed from observations at Nanisivik, the dock at Iqaluit will generate an ice bustle that could exceed 10 m in width and 5 m in thickness.

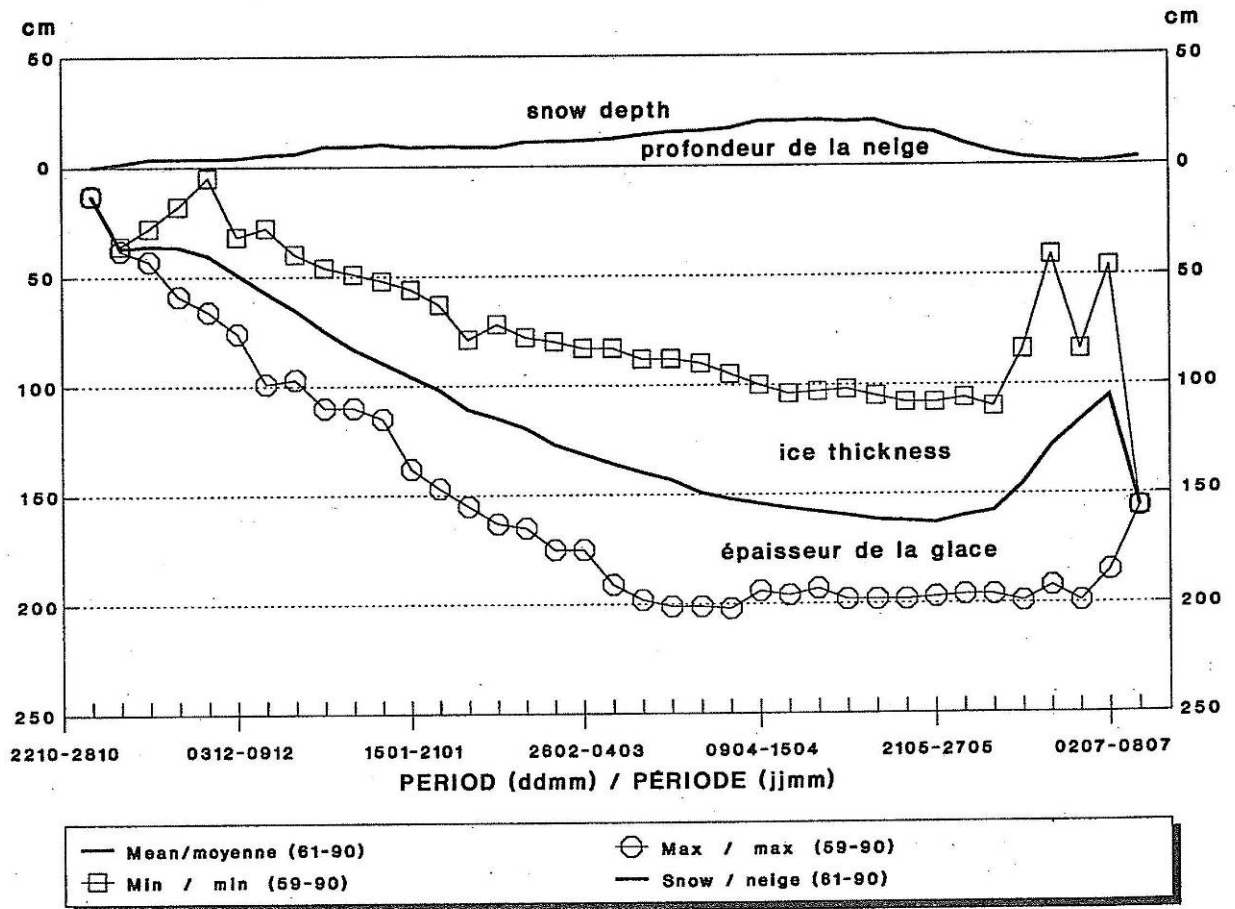
Data from The Mariport Group indicates that the trend is to a longer open-water season.

Figure F shows the ice thickness data for Iqaluit. The thickness measurements cover 31 years, from 1959 to 1990.



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**IQALUIT, N.W.T. / T.N.-0.**  
Koojessee Inlet / goulet Koojessee



**Figure F** Iqaluit ice thickness data, excerpt from Ice Thickness Climatology 1961 to 1990 normals.



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During the preliminary design phase of this project, the following supplemental sea ice and iceberg information will be established:

- a) Determine Statistical Evaluation of Break-up Dates
  - This will be performed by analyzing Canadian Ice Service historical ice charts and MODIS satellite imagery.
- b) Determine Statistical Evaluation of Freeze-up Dates
  - This will be performed by analyzing Canadian Ice Service historical ice charts and MODIS satellite imagery.
- c) Determine Design Ice Floe Sizes
  - This task will be performed by analyzing the ice charts and publicly available satellite imagery such as MODIS, RADARSAT, etc.
  - Ice thicknesses will be calculated by analyzing temperature data obtained from Environment Canada.
- d) Determine Iceberg Size Distribution (if any)
  - This will be based on the observations by the carriers navigating Frobisher Bay and iceberg size populations outside of the bay.
- e) Calculate Ice Forces
  - Ice forces will be calculated for the following scenarios:
    - ▶ Thermal action during the winter months.
    - ▶ Impacts by individual floes after break-up when the ice has deteriorated in thickness and strength.
    - ▶ Forces generated by icebreaking vessels manoeuvring at the berth before break-up.

### **3.14 Bathymetry**

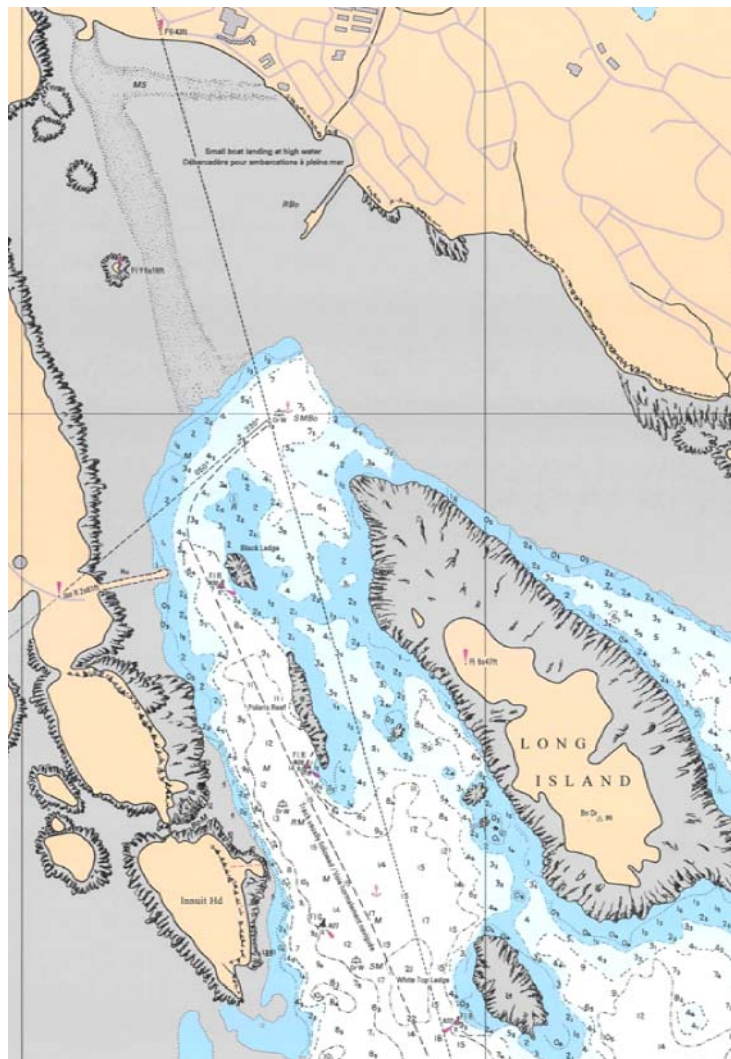
The marine navigation charts for the Koojesse Inlet area are based on sounding surveys completed in the 1950s. Recent bathymetric surveys were completed by CHS between 2000 and 2004 for the same area; however the navigation charts have not yet been updated.



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Figure G is an excerpt of CHS Chart 7127. CHS has provided the authors with permission to reproduce the charts or portions of the charts in support of this project. The data on this chart was compared at a high level with the more recent surveys and found to be in good agreement. Based on this information, the seabed of Koojesse Inlet does not appear to be substantially changing suggesting that sediments, at least subtidal, are generally stable. This is consistent with expectations.



**Figure G** Koojesse Inlet, excerpt of CHS Chart 7127, reproduced with permission from CHS.



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### **3.15 Geotechnical Data**

Geotechnical data within Koojesse Inlet is somewhat limited. Marine navigation charts depict shallow sloping tidal flats at the head of the inlet where present cargo lightering operations are conducted at the landing beach. The upper tidal is generally sandy and supports fork lift truck traffic associated with barge offloading. Historic photos of beached cargo vessels show extensive vehicular activities in the upper tidal zone. There is limited bottom sampling shown on the CHS charts, except that the southwest shoreline from the old causeway to Inuit Head is generally rocky. Adjacent to this shoreline are two rock reefs, Black Ledge and Polaris Reef. These reefs dry at approximately mean water level.

Prior to the start of this study, geotechnical data was limited to site investigation completed by Geocon Ltd., of Montreal, QC, for the St. Lawrence Seaway Authority (SLSA), dated June 30, 1975. This site investigation was in support of a port study conducted by the SLSA in the late 1970s. This same site investigation was the basis of the study conducted by Public Works Canada (Western Region) in 1980. The site investigation was limited to a specific site at Inuit Head.

The Geocon report is, appended in Appendix C. Subsurface conditions in the vicinity of Inuit Head are summarized as follows:

- Loose to very loose and/or soft to very soft sandy silts or silty sands, with some gravel and clay, overlying;
- Dense to very dense sand and gravel, overlying;
- Granite bedrock.

No other data has been obtained. While the old US Army causeway was constructed in the late 1940s there is no data available in support of that construction.

While there is no available information, subsea permafrost is not expected at this location. Other sites, such as Deception Bay which is located within 350 km of Iqaluit, had no evidence of offshore permafrost based on several site investigations. However, any drilling program should consider the potential for such issues.

Permanent dredge slopes, especially slopes where ice will ground repeatedly during tidal cycles, have been based on 6 Horizontal : 1 Vertical for the purpose of calculating quantities. Deep dredge slopes may be able to be cut steeper, but should be reviewed in more detailed at the preliminary design stage. Temporary slopes are based on 2H:1V slopes.



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**2009 Site Visit**

General observations were made during the kick-off meeting in Iqaluit for this project in August 2009. The following was noted while inspecting the shoreline:

- The shallow tidal beach between the Municipal Breakwater and the Coast Guard landing beach is strewn with boulders, with many around 300 mm diameter, but an abundance over 1 m.
- The upper beach is sandy, with increasing fineness toward mean tide. The beach area is understood to be “drivable” to about mean water, below which the soft mud makes driving impossible.
- The shoreline from the Old Causeway to Innuite Head is entirely exposed bedrock above high water. Below high tide, localized bedrock outcroppings are mixed with boulders, cobbles and gravel.
- There are no beach formations in the small embayments on the southwest shoreline, suggesting that littoral drift in this area is essentially nonexistent.

**2009 Geophysical Survey**

During the kick-off meeting, the merits of a geophysical, sub-bottom profiling, survey were discussed. The GN was particularly interested in a deep-sea wharf located at the head of the Old Causeway. However, there was no offshore geotechnical data available in this area and the site is located at a transition between beach and steep rocky shoreline. If the conditions at Innuite Head are assumed to be the same at all other sites, this could lead to low cost and short schedule estimates.

It was considered that there was still sufficient time to conduct a geophysical survey prior to freeze-up as geophysical techniques are better suited to over water for speed of data acquisition and the data would potentially assist with short-listing and preferred sites.

The geophysical survey was conducted in October 2009 by Fugro Jacques Geosurveys Ltd. of St. John's, NL under contract to GN, and summarized in their report dated March 19, 2010. This report is appended to the geotechnical desktop study in Appendix C, along with the Geocon report.

The Fugro report covered the entire south-western shoreline of Koojesse Inlet and the deeper tidal portions of the beach area at the Municipal Breakwater. The geophysical data contains some accuracy limitations that must be taken into consideration when using the data. However, the data shows that the seabed conditions are generally in agreement with the Geocon report. At the Old Causeway, subsurface conditions are interpreted to be substantially different with over twice the thickness of overburden. This information could have a significant impact on the foundation preparation requirements at that location.

The absence of return signals at the Municipal Breakwater rendered the data at that location inconclusive.



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**2010 Desktop Geotechnical Study**

In support of this study, GN retained Stantec to assist with assessing the initial parameters for the foundation preparation requirements of a deep-sea wharf and proposed new breakwater structures. This desktop study relied on both the Geocon and Fugro reports and therefore there are limitations within the interpretation.

Stantec also provided a cost estimate for conducting a geotechnical drilling program to support preliminary engineering design of the proposed structures. The letter summarizing the cost of a field program is also presented in Appendix C.



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## **4. EXISTING FACILITIES AND OPERATIONS**

### **4.1 Cargo Handling**

Cargo receiving in Iqaluit is generally conducted by barge lightering operations from ships anchored offshore in the upper reaches of Frobisher Bay, south of Koojesse Inlet. The ships generally provide their own barges and tugs to support lightering. However, some shipping lines leave one or two barges in Iqaluit for the duration of the shipping season. Cargo barges are landed at the landing beach adjacent to the airport runway where shipping companies offload cargo at the high watermark. A local contractor is responsible for storing the cargo within the beach laydown area and distributing the cargo within the townsite. The Canadian Coast Guard's Superintendent of Arctic Field Operations (Beachmaster) is responsible for coordination of the activities at the landing beach and laydown yard.

In past years, when some of the ships hauling cargo from southern ports were smaller, the vessels would also offload at low tide while beached, see Figure H.



**Figure H Arctic Viking being offloaded while aground on the Beach in Iqaluit (note the bouldery beach adjacent to the landing area which is kept cleared of boulders).**



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The landing beach consists of approximately 1 hectare of open storage space and a 1 hectare secured (fenced) compound. Coast Guard reported that the laydown area is presently utilized to its limit and if significant cargo cannot be delivered to the end user, for whatever reason, the laydown area will quickly overflow with the next significant cargo volume.

It is relevant to note that generally vessels supplying cargo to Iqaluit will also travel to other communities within the Arctic for three primary reasons:

1. Iqaluit requires a significant volume of cargo in comparison with other communities;
2. Iqaluit is reasonably well situated near the shipping route to all other Arctic regions, including Nunavik, Kivalliq, and the rest of the Eastern and Central Arctic, and;
3. Iqaluit has a reasonably long open water seasons, especially as compared to communities further north. This results in Iqaluit receiving significantly more voyages, many with only modest cargo volumes. Appendix B shows the ship calls into Iqaluit from 2000 to 2008 (Source: NORDREG). Iqaluit usually receives approximately 20 cargo vessel calls each year, while the cargo could often be accommodated with only three fully loaded vessels.

Cargo is generally in the form of crated break-bulk with some containers. Table I shows the cargo handled between 2000 and 2006.

**Table I Dry Cargo Landed and Shipped From Iqaluit<sup>1</sup>**

Year	Tonnes	m <sup>3</sup> at 3.5 m <sup>3</sup> /tonne	Retrograde Tonnes
2000	26,821	93,874	1,901
2001	10,536	36,876	2,567
2002	13,609	47,632	1,175
2003 <sup>2</sup>	(8,950)	(31,325)	1,541
2004	12,320	43,120	2,585
2005	14,208	49,728	2,212
2006	15,388	53,858	1,228

2003 was a poor data collection year; see lack of petroleum product information.

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<sup>1</sup> Source: Statistics Canada. Does not include lateral cargo.

<sup>2</sup> 2003 was a poor data collection year; see lack of petroleum product information.



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The very soft mud that exists in the shallower tidal flats means that barge offloading can only be completed during approximately a 4 hour period at high tide. Also, the very shallow beach slope, approximately 1%, requires fork lift trucks to offload in the water. Figure I shows the typical cargo handling operations at the Iqaluit landing beach.



**Figure I Cargo lightering at the Iqaluit landing beach.**

At the start of each sealift season, the tidal portion of the beach must be cleared of boulders and cobbles deposited by the shifting ice floes during the breakup period.

It is noted that at the end of the 2008 shipping season, one vessel was turned back while on route through Frobisher Bay. The beach was reportedly severely choked with ice with the consequence that the barge lightering operation could not be undertaken. The cargo was not delivered until the following year.

In 2009, a structural steel beam was reported to have accidentally been dropped into the sea during a lightering operation. This caused a delay in construction of a building in Iqaluit until the following year, when the component could be replaced.

## **4.2 Fuel Resupply**

The existing marine facilities associated with tanker offloading include a spread mooring arrangement comprised of two shore bollards and two offshore moorings. The shore bollards and conventional cast steel bollards, secured to bedrock with rock bolts. The two offshore moorings are comprised of a mooring buoy with 100 mm stud-link chain and twin concrete anchor blocks, the first being 15 tonnes (33,000 lbs) and the second being 6.4 tonnes (14,000 lbs). The details of the shore bollards, steel casting or rock bolts, are not known.



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The offshore moorings have been reported to have capacities of 54 tonnes and 136 tonnes, though this may be optimistic. Woodward reported that the offshore moorings have been dragged in storm conditions on more than one occasion. Woodward advised that the mooring arrangement as currently configured results in the tanker moored broadside to the prevailing winds which is not desirable.

Fuel is supplied by coastal tanker under contract to Woodward Oil. Which transfer cargo by ship supplied floating hoses deployed by ship’s crew after the ship has been secured and weather conditions are favourable.

Fuel volumes by year are presented in Table J.

**Table J Petroleum Products <sup>3</sup>**

Year	Fuel Volumes (tonnes)	
	Inbound	Outbound
2000	67,540	0
2001	47,047	360
2002	50,981	5,059 <sup>4</sup> net 45,922
2003	No data	0
2004	47,025	0
2005	45,501	0
2006	43,192	0

Appendix B shows the shipping statics for tankers. Generally between 2000 and 2008, approximately six calls per year were made by tankers.

**4.3 Small Craft Facilities**

Iqaluit has modest facilities for the support of small craft activities. These include use of the Old Causeway and the Municipal Breakwater.

<sup>3</sup> Source: Statistics Canada.

<sup>4</sup> There was a problem with gasoline shipped to Nunavut in 2001. While the problem is still before the courts, it is believed to have been caused by a specification issue for olefin content. There were further problems although not as severe, in 2005. Gasoline was back-shipped to the USA in 2002.



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**Old Causeway**

The Old Causeway was constructed in the 1940s by the US Army Corps of Engineers. Details of the original construction are not available. The causeway is approximately 250 m in length with a sloping crest of approximately 3% to 4%. The causeway slopes down to the offshore end which has an elevation of approximately 4 m above local Chart Datum. There are the remnants of four vertical corrugated culvert pipes and steel wire lashing. It is understood that there was a wharfhead at the end of the causeway, but no details or photos of the original construction are available. Figures H and I show the Old Causeway.



**Figure J** View from the Old Causeway looking northeast. Note boats being launched and resupplied at the end of the launching ramp. Tide at the time is estimated to be 2 m.



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**Figure K View from the bottom end of the Old Causeway toward shore. West side launching ramp is in the foreground. Tide at the time is estimated to be 2 m.**

The inshore section of the causeway (approximately 190 m) is maintained for boat launching. At the end of the driving surface, there is steep ramp with approximately 12% grade that extends down to low tide. The driving surface is a coarse rock, of approximately 100 mm to 150 mm rock. Due to ice action and exposure to storm waves in the open water season, the causeway surface requires regrading and compaction at least twice a year.

### **Municipal Breakwater**

The Municipal Breakwater was constructed between 1996 and 1999. It is approximately 300 m in length with a fixed tidal dock at the offshore end and approximately 5 m wide driving surface along the crest. The fixed dock dries at approximately mean water level. There is a boat basin on the west side of the breakwater which was dredged (excavated) to approximately elevation 4.5 m CD.

Two small boat launching ramps were recently constructed at the inshore end of the breakwater to facilitated launching boats at high tide.

The fixed dock is a two-level structure, with the lower level subject to flooding at mean high water level. The structure is a steel frame crib with timber planks retaining the rock fill. Early problems with ice action at the dock lead to the installation of steel panels over the timber facing to stop ice jacking of the timbers. The fixed dock was fitted with a small manual jib crane. Figures J to L show the Municipal Breakwater.



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**Figure L** Fixed Dock at the Municipal Breakwater at low tide.



**Figure M** Shore end of Municipal Breakwater, showing the boat basin on the west side. Note the bouldery beach adjacent.



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**Figure N Municipal Breakwater during an extreme high water event, showing the approach and adjacent road flooded. The upper fixed dock can be seen at the end of the breakwater, with the lower fixed dock flooded.**

Access to boats is frequently a scramble down the riprap slope with cargo and/or gasoline jerry cans at either the Municipal Breakwater or the Old Causeway.



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## **5. DESIGN CRITERIA**

### **5.1 Design Life**

Marine facilities would generally be designed on the basis of a 50 year service life. Considering the remoteness of Iqaluit and the cost associated with maintenance and replacement, a longer service life may be appropriate. This could be achieved through special provisions in materials, maintenance, and replacement of sacrificial components.

It is important to note that service life does not imply that maintenance on the structures will not be required during that period. Due to the harsh conditions in the Arctic and the lack of experience with facilities and structures with an age approaching 50 years, considerable variability in the amount of maintenance required should be expected. For example, maintenance may include the following:

- Regular comprehensive inspections, both above and below water;
- Replacement of anodes for corrosion resistance;
- Addition of wear plates to small craft floats;
- Patching of concrete spalls within tidal zone of fixed structures;
- Regular regrading of gravel driving surfaces, including the wharf surfacing, laydown area and approach roads;
- Occasional repair of riprap slopes from ice action;
- Annual repair of landing / launching ramp surfaces;
- Clearing of boulders on ramps and/or tidal beaches;
- Partial replacement of fender system approximately every 25 years;
- Sounding surveys and/or sweeping to check for boulders where vessel underkeel clearance can be an issue at low tide;

### **5.2 Operability**

Cargo and fuel handling are anticipated to continue to operate during the open water season only. The length of the season will be longer for a deep-sea wharf option than for an option relying on landing ramps. However, the design and/or installation of the dock structure would not preclude shipping operations during the winter months with icebreaker assistance or icebreaking capable cargo vessels, such as those operated by Fednav Ltd. in other Arctic ports. Such provisions in the design may not govern the facility components, except that the scouring effects of icebreaking activities at the dock and the alignment of the dock for vessel approach will both require careful consideration.



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Small craft harbour floats will require removal from the water during the winter months. The operating season for small craft facilities will be dictated by essentially zero ice conditions allowing deployment and recovery activities at a nearby landing beach facility.

**5.2.1 Cargo Resupply Vessels**

Cargo resupply to Iqaluit is generally provided by Nunavut Eastern Arctic Shipping Ltd. (NEAS) and Nunavut Sealink Supply Inc. (NSSI), using ships provided by Groupe Degagnés. The following cargo resupply vessels and principal dimensions are to be considered.

**Table K Design Cargo Resupply Vessels**

Name	LOA (m)	Breadth (m)	Draft (m)	Freeboard (m)
<b>NSSI (Operated by Degagnés)</b>				
Rosaire A. Degagnés	138.1	21.0	8.0	---
Anna Degagnés	173.5	23.1	10.0	3.7
Camilla Degagnés	133.0	20.6	6.9	---
Sedna Degagnés	139.0	21.0	8.0	---
Zelada Degagnés	139.0	21.0	8.0	---
<b>NEAS</b>				
Aivik	109.9	19.4	5.9	---
Avataq	113.2	18.9	8.5	---
Qamutik	137.2	18.9	8.5	---
Umiavut	113.2	18.9	8.5	---

Barges for lightering operations have typical hull dimensions of 8 m wide by 17 m long by 1.5 m deep. There is some variation with both larger and smaller barges. The assist tugs typically draw 1.5 m, with some as much as 2.4 m.

In Iqaluit, NSSI typically operates two cranes and three barges.

**5.2.2 Fuel Resupply Tankers**

The fleets of Petro-Nav, owned by Groupe Degagnés, and Coastal Shipping Ltd., owned by Woodward Group of Goose Bay, Labrador, are considered. Presently, only Coastal Shipping provides fuel resupply to Iqaluit and the rest of the Qikiqtaaluk region.

**GOVERNMENT OF NUNAVUT  
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Name	LOA (m)	Breadth (m)	Draft (m)	Freeboard (m)
<b>Woodward</b>				
Tuvaq	164.2	22.2	9.5	2.5
Dorsch	130.7	18.5	8.3	-
Mokami	97.4	14.2	6.5	-
Nanny	116.6	19.0	7.8	2.3
<b>Petro-Nav (Degagnés)</b>				
Thalassa Degagnés	134.5	17.20	7.9	2.1
Petrolia Degagnés	134.5	17.20	7.9	2.1
Vega Degagnés	140.8	21.20	7.3	3.4
Maria Degagnés	120.0	21.00	9.0	-
Jana Degagnés	123.7	17.70	8.4	2.2
Esta Degagnés	123.7	17.70	8.4	2.2
Dara Degagnés	123.7	17.70	8.4	2.2

**5.2.3 Other Vessels**

Northern Transportation Company Limited (NTCL), based in Hay River, NWT, provides resupply services to the Western Arctic, the Kivalliq region of Nunavut, and Alaska, loading cargo in Hay River NWT, Richmond, BC, Churchill, MB and Montreal, QC. NTCL owns and operates a fleet of tugs and barges in support of such resupply services. The NTCL vessels are relatively small in comparison to the NEAS, NSSI and Woodward vessels, but they could have an impact to some wharf components such as fenders and the structure configuration. Thus, their barges with a loaded freeboard in the order of 1 m may need to be considered.

Coast Guard vessels to consider are listed in Table M. While these vessels do not strictly require access to a deep-sea wharf, they may do so if the berth is vacant or to provide icebreaking assistance into the berth, should it be necessary in the future. Such vessels are not expected to govern the configuration of a dock, but could influence scour protection and structure strength requirements.

**GOVERNMENT OF NUNAVUT  
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Name	LOA (m)	Breadth (m)	Draft (m)	Freeboard (m)
John G. Diefenbaker (preliminary)	135.0	28.0	10.0	-
Louis S. St-Laurent	119.5	24.4	9.9	6.4
Terry Fox	88.0	17.8	8.3	0.8
Des Groseilliers	98.2	19.8	7.2	3.4

Naval vessels to be considered are listed in Table N. As with the Coast Guard vessels, the naval vessels will have no specific need to berth at a dock in Iqaluit. It is not expected that these vessels will govern the design the facilities.

**Table N Design Naval Vessels**

Name	LOA (m)	Breadth (m)	Draft (m)	Freeboard (m)
Arctic/Offshore Patrol Ship (AOPS) (preliminary)	115.0	18.0	8	-
AOR 510	172.5	23.2	10.1 (Deep) 5.1 (Docking)	2.2 (Deep Departure) 7.3 (Docking Light)
Iroquois-Class Destroyer (DDH)	129.8	15.2	5.0 (Operational Light) 4.376 (Light in Sea)	4.0 (Operational Light) 4.6 (Light in Sea)
Canadian Patrol Frigate (CPF)	135.5	16.4	5. (Deep Departure) 4.6 (Operational Light)	6.1 (Deep Departure) 6.5 (Operational Light)
Joint Support Ship (JSS) (preliminary)	210.0	32.2	8.8 (Deep Departure) 7.1 (Docking Light)	12.5 (Deep Departure) 15.5 (Docking Light)
Maritime Coastal Defence Vessels (MCDV)	55.3	11.3	3.4	6.5/6.8



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## **5.3 Wharf Configuration**

### **5.3.1 General**

The general approach to the design of a wharf in a remote Arctic site is to minimize the infrastructure that is normally provided for in southern developed ports. Specifically, the dock length is usually significantly shorter than the vessel length and shore-based moorings supplement vessel mooring to compensate for the shorter dock length. Examples of such installations include all the Arctic deep-sea structures in Canada, Deception Bay, Nanisivik, Polaris and Voisey's Bay.

While the driving surface of most wharf structures in the south is either asphalt or concrete paving, the wharf for Iqaluit is proposed to be a gravel surface.

### **5.3.2 Wharf Length**

The minimum breasting face of a wharf is generally stated in most literature and some standards as 40% of vessel overall length (LOA). Termpol recommends a minimum of 35% of vessel LOA. The maximum spacing of fenders under Termpol is less than 50% of LOA for the smallest vessel. Additional moorings are provided fore and aft to suit the vessel length for stability. Vessel overhang past the end fenders is generally limited to a maximum of 30% of LOA.

Based on the above, a dock length of 60 m should provide satisfactory vessel stability at the dock for most cargo and fuel resupply vessels, provided that sufficient moorings for head and stern lines are in place. The hatch length of most cargo vessels at Iqaluit is approximately 100 m. Thus, a 100 m long dock and working surface is recommended which provides reasonable working space for vehicles receiving cargo while able to serve all ship's cranes and avoids warping the ship.

For comparison, Polaris and Voisey's Bay mine docks are approximately 105 m in length, while Nanisivik and Deception Bay are 96 m. The recent Deception Bay dock replacement was fixed at 93 m.

### **5.3.3 Depth Alongside**

The maximum vessel draft for each vessel type is approximately 10 m, including the MT Tuvaq, MV Anna Degagnés, CCG Heavy Icebreaker, and AOR/JSS naval class. Typically, a 10% underkeel clearance is allowed. This suggests that a depth of 11 m will be appropriate for this facility, though a reduced clearance could be considered given the large tide range in Iqaluit. Dry cargo re-supply vessels arriving in Iqaluit will not be loaded to their marks because Arctic cargo is volumetric, not weight limited. Typically, vessels will be well under 10 m draft, unless ballasted.

If icebreaking is to be considered in Iqaluit for depth alongside, then vessel squat could become a contributing factor. It has been assumed that vessel motions under storm conditions will not adversely impact the depth requirement. However, detailed vessel motion analyses are required to confirm such effects.



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For the purpose of this study, it is assumed that the base of a caisson structure will be built to -11.0 m CD, with an allowance to build up a thin scour protection system consisting of concrete mats that could reduce this depth to -10.5 m CD. This provides a depth alongside of 11.0 m at LLWL.

### **5.3.4 Deck Elevation**

The elevation of the proposed deck should consider the following criteria:

- Cargo handling limitations at loaded condition, low tide. The ship's crew may find it difficult to clear the edge of the deck with cargo if the ship's gear is used for offloading;
- Wave exposure and acceptable overtopping criteria;
- Base pressures on the foundation. Iqaluit with significant tide range will result in very high foundation pressures during low tides.

Degagnés advised that they do not anticipate problems with handling cargo using ship's gear for a dock height above low water as high as 15 m.

A wharf deck elevation of 13 m CD would provide similar overtopping criteria as was estimated for Voisey's Bay based on green water overtopping during a 1 in 1 year storm event. Vale Inco have reported no concerns over the first 4 years of operations on the dock. This should be viewed as the practical lower limit.

A desktop study conducted by Stantec in support of this study identified that stability problems with the structure may develop with a deck elevation of 14 m. However, considering the lack of geotechnical data available, a deck elevation of 14 m CD, 2.4 m above high water, is chosen for a conservative basis for quantity assessment. The final design deck elevation is left to the preliminary engineering phase when the geotechnical assessment will be finalized.

## **5.4 Wharf Structural Loads**

### **5.4.1 Deck Loads**

The design deck loads for the wharf are as follows:

- Mobile equipment and storage:
  - Uniformly distributed surcharge storage load: 24 kPa (500 psf), this will need to be confirmed at preliminary design stage, as geotechnical issues may not allow a storage load this high.
  - Crawler or Mobile Crane: 200 tonne to 300 tonne capacity
  - Container handler: 100 tonne drive axle



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It is anticipated that the need for cranes or container handlers will be future equipment, as cargo will likely be offloaded using ship's gear, at least in the short term, and containers will only be loaded to their normal maximum for present operations (10 to 12 tonnes), which can be handled by conventional front lift truck equipment. If containers become loaded to capacity, normally 30.5 tonnes, then container handlers will be required. Containers are light loaded partly because of the nature of the cargo, but mainly because of limitations at the beach

**5.4.2 Wharf Lateral Loads**

The following lateral loads will be calculated, as appropriate, and the wharf structure will be designed to resist these loads:

- Mooring loads based on worst case combination of static wind, dynamic motion, and current.
- Ice loads, including:
  - Thermal loads
  - Ice floe impact
  - Icebreaking
- Berthing loads based on design reaction from selected fender.
- Storm wave loads.



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## **6. DEEP-SEA BERTH FACILITIES**

### **6.1 Site Selection**

The south western shoreline is considered the most practical for a deep-sea wharf site in support of sealift operations for the following reasons:

- There is sufficiently deep water close to shore;
- The primary residential districts of Iqaluit are on the opposite side of Koojesse Inlet, well removed from this area;
- This area is already serviced by Akilliq Road through the industrial and commercial lands on the western side of Iqaluit, including the airport, tank farm, garbage dump, and several commercial enterprises along Akilliq Road, to the Old Causeway;
- There is an historic quarry adjacent to the Old Causeway, likely the source of rock for the causeway, that can also provide a suitable source for aggregates for all development requirements;
- Ship approach to the potential sites is feasible and the alignment of any berth structures is likely to be very close to the alignment of the prevailing winds;
- The existing fuel line and manifold are already in this area.

All other sites away from the southwestern shoreline exhibit one or more of the following disadvantages:

- Require a relatively long road to access existing roads;
- Deep water is generally further offshore requiring a long approach causeway;
- The dock structure will most likely be founded over thick soft sediments that require significantly greater preparation efforts;
- Greater navigation hazards for ship approach;
- Access on the eastern shores of Koojesse Inlet will conflict with primarily residential neighbourhoods.

On the basis of the assessment above, it is clear that the south western shoreline of Koojesse Inlet is the preferred location for a deep-sea cargo terminal development.

The GN has requested that potential dock sites include the previously proposed site at Innuvit Head and at the end of the Old Causeway.



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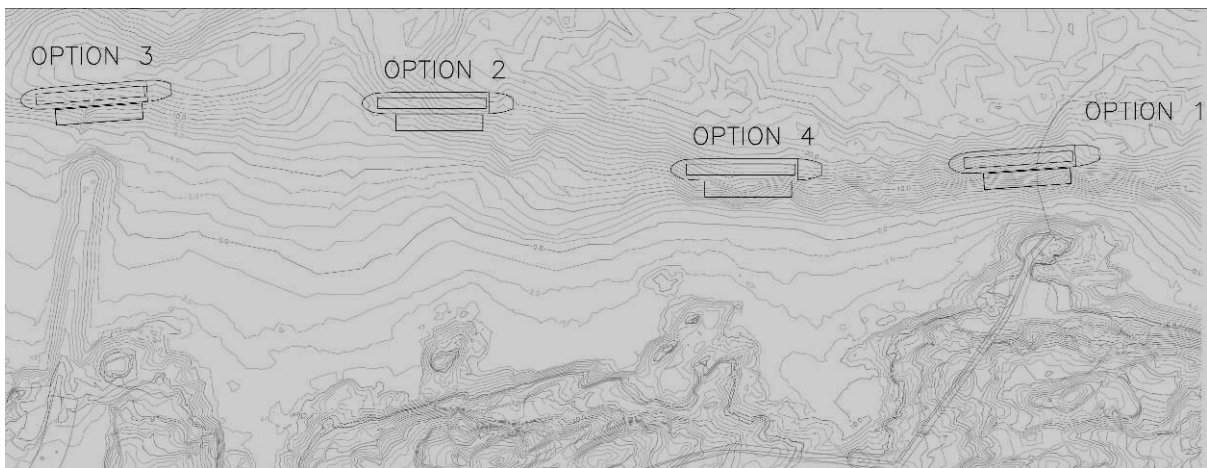
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**6.1.1 Option Locations**

Four locations on the south western shoreline of Koojesse Inlet were assessed as potential sites for a deep-sea wharf. These include the following and are shown in the attached Figure 5A:

- Option 1: Innuite Head
- Option 2: North Polaris Reef
- Option 3: Old Causeway
- Option 4: South Polaris Reef
- Option 5: Twin Ramps at Old Causeway (same location as Option 3)
- Option 6: South Polaris Reef (Stage 1 Only)

It is important to note that NEAS has deck cranes generally on the starboard side and will favour a starboard side-to approach to the structure. It is may not be feasible to conduct such a manoeuvre, as it will effectively require the vessel to approach from the north. Degagnés has deck cranes generally on the port side and is more ideally suited to approaching the proposed sites.



**Figure O Option Nos. 1 to 4.**



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### **6.1.2 Option Description**

#### **Option 1 - Innuit Head (Drawing No. 09120-SK-101)**

This option is consistent with the site assumed in all past studies, including the SLSA, Public Works and Aarluk studies. The site is located at the existing fuel receiving manifold on Innuit Head. The following advantages and disadvantages are noted in relation to the other options:

- Advantages
  - Ship access to the berth is the best, without significant reefs to contend with.
  - Distance from ship-side to the primary laydown area is shortest.
  - The seabed conditions are largely known, with a drilling program having been conducted in the 1970s, though some additional field investigation work is anticipated to be required.
- Disadvantages
  - During construction, the fuel receiving berth and its associated spread mooring system will need to be temporarily relocated.
  - The travel distance between the primary laydown area and the secondary storage area and the city is greatest.
  - Access to Innuit Head requires crossing the high tide channel adjacent to Innuit Head. This requires either a bridge structure or a filled causeway.

Some differences between the present arrangement and those of past studies include the following:

- The access road was originally shown along the west side of the peninsula forming Innuit Head. Considering that there are Iqaluit residents with summer camps west of the proposed site, it was deemed preferable to construct the road along the east side to minimize their exposure to noise.
- The crossing between the mainland and Innuit Head was originally based on a bridge. Consideration should be given to allowing crane access and heavy container handler access to Innuit Head. This would mean that the bridge would be very substantial. While a filled causeway will restrict small boat traffic from transiting the channel at high water, this is deemed to be the lesser of the two impacts. Considering the environmental impact associated with the road and wharf structure, the impact from the causeway is expected to be of minor consequence.
- The foundation for the wharf structure is based on blasting a bench into the bedrock. This is an extremely costly and time consuming undertaking with potentially significant environmental



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issues. This study is based on the assumption that it is feasible to construct on a rock-filled mattress as is most often the approach for this type of structure.

**Option 2 - North Polaris Reef (Drawing No. 09120-SK-102)**

This option is adjacent to the north end of Polaris Reef. The clear distance between the dock face and Polaris Reef is approximately 200 m. This site was selected since it was situated close to the end of Akilliq Road, there is an outcropping of bedrock in the tidal zone that suggests the foundation conditions are favourable, and the navigation clearance to the reef is better than for Option 3. The following advantages and disadvantages are noted in relation to the other options:

- Advantages
  - No temporary fuel receiving berth is required during construction.
  - The upland laydown/storage areas are fully integrated.
  - The distance to the city centre is low.
- Disadvantages
  - The length of the approach causeway between land and the wharf is over 250 m. This makes cargo offloading more inefficient and mooring arrangements more problematic.
  - Navigation clearance to the adjacent Polaris Reef, while better than Option 3, may not receive favourable review from the shipping companies.
  - Geophysical assessment revealed that the subsurface conditions at this location are not as favourable as the shallow tidal observations would suggest. This is expected to lead to significantly more foundation preparation over other options.

**Option 3 - Old Causeway (Drawing No. 09120-SK-103)**

This option was requested by GN as one of the primary options to focus efforts on, as the existing causeway provides the basis for the approach to the dock. There could be a benefit to utilizing existing infrastructure from a permitting perspective and the facility had previously been used for cargo receiving in the 1950s. The site has also been occasionally used to transfer cargo in recent years, especially when the beach is choked with ice. The following advantages and disadvantages are noted in relation to the other options:

- Advantages
  - Part of the approach causeway has already been constructed, albeit the contribution of the existing causeway to the new breakwater is small.



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- No temporary fuel receiving berth is required during construction.
- The upland laydown/storage areas are fully integrated.
- The distance to the city centre is reasonable.
- The permitting process is likely to be less demanding due to the reuse of the causeway structure.
- Disadvantages
  - The navigation clearance to Black Ledge less than 100 m.
  - Significant clearance dredging is required forward (north) of the berth.
  - The length of approach causeway between land and the wharf is over 200 m. This makes cargo offloading more inefficient and mooring arrangements more problematic.
  - Geophysical assessment revealed that the subsurface conditions at this location are not as favourable as the shallow tidal observations would suggest. This is expected to lead to significant foundation preparation over other options.

**Option 4 - South Polaris Reef (Drawing No. 09120-SK-104)**

This option was developed as a compromise between Option Nos. 1 and 2. The clear distance between the dock face and the southern end of Polaris Reef is approximately 250 m. The following advantages and disadvantages are noted in relation to the other options:

- Advantages
  - Ship access to the berth is good, without significant reefs to contend with.
  - Distance from ship-side to the primary laydown area is acceptable at 100 m.
  - The geophysical assessment suggests that the foundation conditions at this site are similar to Option 1, except that the seabed slopes more gently, suggesting that wharf stability will be better than Option 1.
  - A temporary fuel receiving berth will not be required.
  - A road will not be required to cross the channel to Inuit Head.
- Disadvantages
  - The travel distance between the primary laydown area and the secondary storage area is 400 m, which is significantly greater than Options 2 and 3, but significantly less than Option 1.
  - The stern mooring line will cross the channel to Inuit Head, affecting small craft access at high tide.



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**Option 5 - Twin Ramps at Old Causeway (Drawing No. 09120-SK-105)**

This option was developed as an interim option, should sufficient funding for a deep-sea wharf not be available. This option presents the twin ramps preferred by the sealift companies, in recognition that ice choking the landing beach (or ramp) can preclude lightering. The ramps are situated on either side of a full breakwater structure over the old causeway. The following advantages and disadvantages are noted in relation to the other options:

- Advantages
  - The cost is less than half that of a facility with a deep-sea wharf.
  - It may be desirable to combine a small craft mooring facility with the breakwater at a nominal increased cost. However, this presents the problem of combining public access and boating activities with cargo handling operations. This will be difficult to manage safely.
  - The upland laydown/storage areas are fully integrated.
  - The distance to the city centre is low.
  - The permitting process is likely to be less demanding due to the reuse of the causeway structure.
- Disadvantages
  - The location is not favourable for the addition of a deep-sea wharf at the end of the breakwater in the future. Thus, a second site would be required to develop a deep-sea wharf.
  - This option does not improve the fuel handling. However, this option could be combined with improvements to the spread mooring system at the tanker berth.
  - Geophysical assessment revealed that the subsurface conditions at this location are not as favourable as the shallow tidal observations would suggest. This is expected to lead to a significant increase in foundation preparation over other options.

**Option 6 - South Polaris Reef - Stage 1 Only (Drawing No. 09120-SK-112)**

This option was developed as an interim option, should sufficient funding for a deep-sea wharf not be available. This option provides a staged approach with a provision to add the deep-sea wharf in the future. The following advantages and disadvantages are noted in relation to the other options:

- Advantages
  - The cost is less than half that of a facility with a deep-sea wharf.
  - This option provides a significant initial stage toward constructing a deep-sea wharf.



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- Disadvantages
  - The landing ramp is not well protected from southerly storm waves near low tide. However, lightering operations may need to be suspended due to seastate before problems develop at the landing ramp.
  - This option does not improve the fuel handling. However, this option could be combined with improvements to the spread mooring system at the tanker berth.
  - Geophysical assessment revealed that the subsurface conditions at this location are not as favourable as the shallow tidal observations would suggest. This is expected to lead to a significant increase in foundation preparation over other options.

## **6.2 Structure Alternatives**

Several structure types were considered in the Public Works assessment of the structure options. These included a single large concrete caisson, sheet pile tied bulkhead (two options), a combination timber crib and tied-back bulkhead, steel sheet pile cellular structure, a Delong-type structure (jack-up platform with drilled shaft support piles), and a floating structure. The Aarluk report made note of some of these options but provided no particular comments.

The options considered by Public Works are very typical of other studied sites in the Arctic, including the Nanisivik wharf in Strathcona Sound and a 1970s study for an LNG terminal on Melville Island. While it is generally agreed with the conclusions stated within the Public Works report, there are some comments worth presenting here in regards to sheet pile cells and concrete caissons.

### *Sheet Pile Cellular Construction*

Sheet pile cells represent the vast majority of Arctic deep-sea wharves, including:

- The original Deception Bay wharf in Nunavik, Quebec
- Nanisivik Mine on northern Baffin Island, Nunavut
- Polaris Mine on Little Cornwallis Island, Nunavut
- Voisey's Bay Mine in Labrador
- Red Dog mine in Alaska on the Chukchi Sea
- Several structures in the Russian Arctic, Svalbard, and Greenland

These structures have generally been built since the 1970s, but there is little in the way of literature on the conditions of these structures. It is known that the wharf in Deception Bay suffered from very high corrosion rates, unexpected in an Arctic environment. The Deception Bay wharf was replaced with a concrete caisson structure after 36 years.



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The Public Works report states that the structure would be constructed in the winter from the ice, similar to the Nanisivik wharf and Polaris wharf, but that due to the length of the sheet piles, difficulties in threading piles will be experienced. It is expected that construction from the ice will not be practical due to the size of the equipment required to deal with the large tidal variation. As such, construction would be most practical in the summer open-water season from a large floating spud barge or jack-up rig.

A concept for the sheet pile structure is shown on Drawing No. 09120-SK-107. Conceptual level calculations suggest that the structure will be at the limit for internal stresses (hoop tension and vertical shear). With cells at 20 m in diameter, five cells with interconnecting arcs would be required to construct a wharf of approximately 100 m effective length. It is expected that a five-cell wharf would be difficult to thread, drive and fill in one open water season, even assuming that the equipment over-winters during both the season before and after.

The geotechnical desktop study presented in Appendix C expects that structure stability (overturning, sliding and global stability) can be achieved with this structure with 5 m penetration into a prepared foundation fill. Stantec confirmed that dredging would be required for the foundation, resulting in a minimum two-year construction duration for the wharf structure alone. Based on experience with such assessments, the sheet pile wharf will result in a higher capital cost if construction is at least one year longer than other options.

*Concrete Caissons*

A single concrete caisson was proposed by the SLSA and carried forward by Public Works and Aarluk. The only known examples of such a structure used as a deep-sea wharf in an Arctic region are:

- Deception Bay wharf replacement in Nunavik, Quebec, and
- Tarsiut Island caissons in the Canadian Beaufort.

The Aarluk report references the Tarsiut caissons as an option in combination with an upper bulkhead wall. The Tarsiut caissons remain beached at Herschel Island in the Beaufort Sea, owned by Conoco-Phillips. Conoco-Phillips remains interested in a third party taking possession of the caissons at no cost. It is possible, with Iqaluit's tidal range, to "stack" the caissons, arranging in a two-by-two pattern to achieve a height of 22 m and length of 70 m. However, these caissons are not considered practical for the following reasons:

- The transportation through the Northwest Passage is feasible but costly, estimated to be in the order of \$15 million.
- The caissons are known to have deterioration in the upper zone, including one with a breach in the side wall. Repairs would be required.



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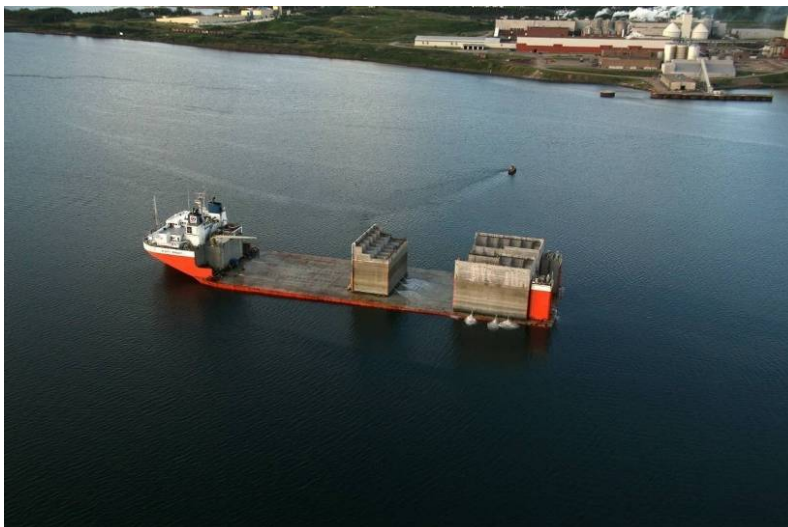
- The caissons likely do not have sufficient width to maintain stability without some form of tie-back system.
- The caisson base slab and walls will likely not be able to accommodate the internal soil pressures from stacking, without some form of strengthening.

Based on the above, the Tarsiut caissons are not expected to be a practical option. If Conoco is interested in sharing the cost of transportation, the Tarsiut caissons could be an option for a small craft wharf and/or breakwater structure. However, in past discussions, they have not specifically identified a willingness to contribute to such costs.

The Deception Bay wharf replacement, completed in 2007, is of similar size to the proposed Iqaluit structure and warrants a more detailed assessment as it most closely represents a viable option.

It is noted all past studies for Iqaluit were on the basis of constructing a single caisson and wet-towing from the fabrication facility in the south to Iqaluit. It is expected that wet-towing (towing while floating) is not practical for the exposure in the North Atlantic, as the towing time would be in excess of 30 days and there would be problems experienced in obtaining the necessary insurance. Also, a single caisson of such size would need to be constructed at special facilities, increasing costs over the conventionally fabricated caissons with known costs.

The Deception Bay caissons were transported on a semi-submersible (refer to Figure P).



**Figure P Deception Bay caissons loaded onto Dockwise's Mighty Servant 1 in the Strait of Canso, ready for transportation to site (2007).**



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Based on the comments above, this study is based on a wharf structure using concrete caissons similar to Deception Bay.

### **6.2.1 Structure Configuration**

The structure layout is shown on Drawing No. 09120-SK-106. Three concrete caissons are used for the berth structure, similar to Deception Bay.

It is important to note that the Deception Bay caissons pushed the limits of the transport vessel in several respects. Thus, for Iqaluit where the caissons will be wider and taller, a conceptual evaluation of the caisson weight, stability and draft was undertaken, as the number of vessels that could transport these caissons is extremely limited.

The concrete caissons have been conceptually assessed with the following parameters:

- Width: 19 m
- Length: 33 m
- Overall height: 25 m (assumes deck at +14 m)
- Weight (dry): 6,700 tonnes
- Ballast water for transportation: 1,300 tonnes
- Floating draft (with ballast water): 13.4 m
- GM (with ballast water): 0.3 m

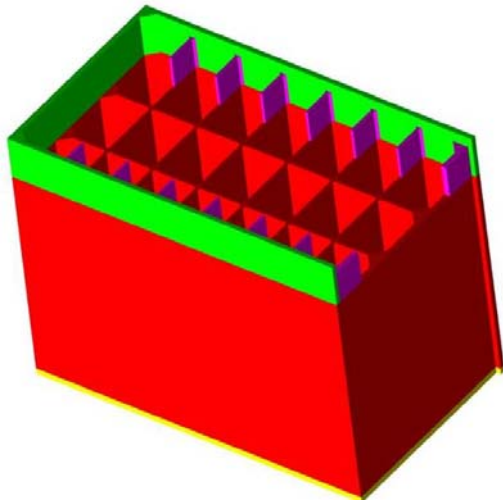
Caissons of this size have been confirmed to be capable of being fabricated at an East Coast site using existing facilities. If during preliminary design it is determined that the weight of the caisson cannot satisfy the requirements of the available semi-submersible vessel, then it is possible to construct the caissons with a shorter height and construct the remaining height using precast concrete structural retaining wall elements. Alternatively, the large tide range could allow a smaller caisson to be sunk onto the main, lower caisson.

For the purpose of this study, it has been assumed that the caissons can be sized to fit the semi-submersible. *Blue Marlin*, owned by Dockwise Shipping BV and that this ship is available for the target year of the installation.



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**Figure Q Typical caisson configuration.**

The caisson size is generally selected on the basis of an aspect ratio in the order of 1 to 1.25 for initial configuration. However, the following are key criteria that must be considered and will also affect aspect ratio:

- Draft while floating, which is important for considering the available transportation vessels;
- Floating stability during local towing;
- Base pressure under design lateral loads.

The caisson will be fully ballasted with rock-fill for stability and finished with a gravel road base. The concept by Public Works was based on a concrete deck surface. However, since there are no particular plans to pave the upland storage areas at this time, a concrete deck would seem to be unnecessary. It is assumed that regrading of the surface will be required from time to time.

*Caisson Transportation*

With a floating draft in excess of 13 m, there is only one vessel in the world that could transport these caissons, *Blue Marlin*. It will be essential to secure the vessel at an early stage as the vessel will be in high demand. It should be expected to secure the vessel at least a year in advance. This vessel has no ice-class rating and thus it will be necessary to make the transportation in summer, ideally in August, prior to the fall storm season.

It is relevant to note that the vessel is foreign flagged and will require a waiver to allow it to operate between two Canadian locations, namely the fabricating site and the installation site. This can be a problematic process, though the waiver was received within reasonable time for Deception Bay.



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### **6.2.2 Foundation Preparation**

Preparation of the foundation for the caissons is consistent with typical caisson construction methods in the south. This includes dredging of the soft seabed sediments to bedrock or dense till-like layer. A coarse rock-fill mattress is placed on the dredged surface and finished with a lighter levelling course which is screeded to receive the caissons.

The geotechnical desktop study confirmed that it is not required to dredge down to bedrock, if the underlying granular layer is sufficiently dense. This is based on the assumption that an interpreted layer below the soft sediments is sufficiently dense as depicted in the old drill holes at Innuvit Head. The study was able to establish a suitable factor of safety on stability and bearing capacity based on a deck elevation of 13 m above Chart Datum. In order to achieve a suitable factor of safety with an elevation of 14 m, the foundation preparation requirements are based on a 7 m wide mattress berm in front of the caissons, with a dredge limit of 30 m in front of the caissons. Detailed drilling, sampling and analyses will be required to confirm the deck elevation and foundation preparation requirements.

### **6.2.3 Causeway Construction**

The approach causeway from the laydown area to the dock will be constructed of coarse rock fill, with a roadway width of 9 m, plus a 4 m wide utility and pipeline corridor. Side slopes have been conceptually set at 2H:1V and faced with riprap. The backup area immediately behind the wharf can be widened to approximately 35 m, allowing greater manoeuvrability of cargo handling vehicles.

The geotechnical desktop study suggested that the soft surface sediments should be removed if the thickness is greater than 2 m.

## **6.3 Auxiliary Landing Ramp**

It is recognized that the two sealift companies that service Iqaluit frequently conduct voyages at the same time, in particular at the start and end of the shipping season. The frequency of coincident arrivals will increase as volume increases. Thus, it is necessary to consider offloading two vessels at the same time. The first vessel would have berthing priority while the second vessel would need to anchor offshore and lighter the cargo into an auxiliary all-tide landing ramp located adjacent to the primary laydown area.

If a tanker vessel is also in port, it may be necessary to offload two sealift vessels at the same time. The auxiliary ramp has been set at 30 m wide to allow for two barges to be handled at the same time.



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## **6.4 Yard**

The existing Coast Guard laydown area is approximately 1 hectare of open storage, including all corridors, and 1 hectare of secure compound.

The various options generally provide between 3 and 4 hectares of storage space between the primary laydown and the secondary storage yard. Considering that cargo will be offloaded faster than the existing beach landing operation and the distance to the city receivers will result in slower removal of cargo, a modestly greater area for storage will be required. The available space will provide allowance for future growth.

## **6.5 Shoreline Protection**

Shoreline protection is based on riprap produced from the local quarry. It is anticipated that some amount of maintenance will be required to the riprap slopes from time to time.

## **6.6 Scour Protection**

Protection to the foundation mattress will be required, regardless of whether or not icebreaking activities need be accommodated. Under normal conditions, the base of the caissons would be buried in a suitably sized riprap that is resistant to scour from the propeller wash. Such propeller washing is expected to be greater for icebreaking vessels than for conventional cargo vessels with normal power. For Iqaluit however, the total height of the caissons needs to be minimized since the floating draft is pushing the limits for the largest vessel of its kind in the world. This requires that the scour protection system needs to be thin, yet heavy.

For this study, a system of flexible concrete mats of approximately 300 mm to 400 mm thickness similar to that developed for Deception Bay is proposed. The mats are connected directly to the toe of the caissons with chains and shackles and all joints are sealed with a tremie concrete. The installation is simple and rapid, and it does not require that the mattress follows a precise profile. In addition, the mats allow the constructed height of the caissons to be reduced by over 1 m. Flexible concrete mats have been allowed for as the basis of the estimate. Figure R shows the proposed system.



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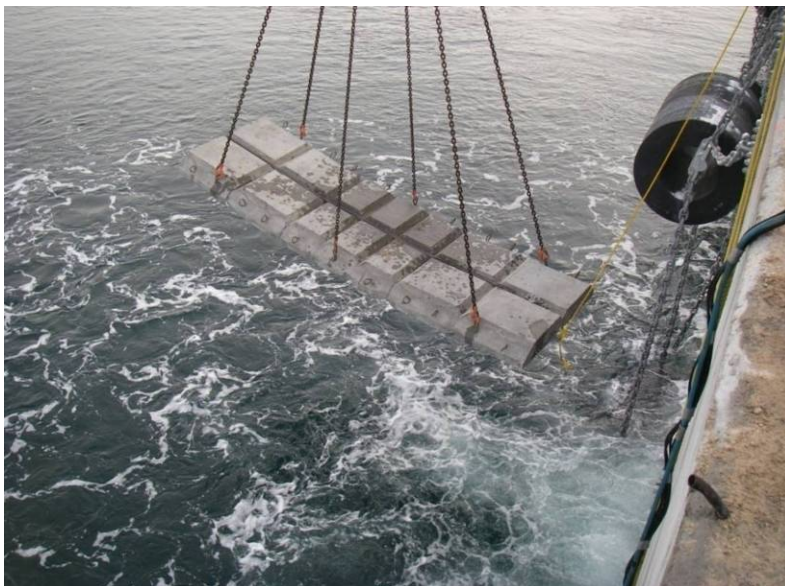
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**Figure R Scour protection mats.**

The mats are highly resistant to impacts from ice blocks, should ice be driven below the vessel. They allow a suitable location to anchor ice management diffusers should this be desirable at some time in the future.

Figure S shows the concrete mats that were installed at Deception Bay in 2007.



**Figure S Scour protection mats for caisson foundation mattress.**



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## **6.7 Ice Management**

No form of ice management is planned for the Iqaluit port. The operational requirements at this time do not warrant providing access outside of the open water season.

## **6.8 Wharf Hardware**

### **Fenders**

Foam-filled floating fenders are proposed for use on the wharf. Due to the extreme tidal range at the site, fixed fenders are not deemed to be practical and the ice action associated with winter tides will be exacerbated by appendages on the wharf. It is therefore proposed to support the fenders on chains secured to pad eyes above high water. At the closure of the summer shipping season, the fenders would be removed from the wharf using crane assistance.

### **Moorings**

Ship mooring will be provided with two shore-based mooring bollards, one for forward lines and one for aft lines. Standing lines of suitable length to reach from the shore bollards to the wharf will be provided and deployed prior to arrival of the vessel. Electric capstans will be provided on the wharf to assist with handling of the ship's lines.

Six bollards will be provided on the wharf structure to secure spring lines and additional fore and aft lines.

### **Bullrails and Handrails**

Galvanized 250 mm diameter steel pipe bullrails will be provided around the perimeter of the wharf. The bullrails will be supplied with sockets to accommodate removable chain-type handrails. The handrails are intended to remain in place in the absence of a vessel to improve safety, considering the height of the structure above low tide and the presence of ice in the winter.

### **Safety Ladders**

Four galvanized heavy chain-type safety ladders will be provided on the wharf, two on the front face and one on either end. The ladders will be removed at the close of each shipping season.



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## **Navigation Aids**

Some changes to the navigation aids will be required and these will generally fall under the guidelines set under International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). Two new range day beacons, similar to the day beacons within the city limits, will be required west of the airport runway. These day beacons will be on a range line that offset from the wharf face that the ships will use to approach the berth.

The port-hand buoy (green) adjacent to Innuvit Head will most likely need to be redeployed to immediately offshore of the old fuel manifold, but outside of the approach path to the wharf.

Lighting on the wharf will provide sufficient identification to allow an approaching vessel to orient itself with the wharf face.

A windsock may be valuable for assisting the captain of an approaching vessel. However, the prevailing winds are generally parallel to the wharf alignment and thus a windsock is not likely necessary.

## **6.9 Lighting**

Allowance is made for lighting on the wharf, in the primary laydown area, in the secondary storage area and on the road between the two laydown areas. Poles are medium height and can be hinged-type that allows the luminaire to be lowered and accessed without the need for a crane or manlift.

## **6.10 Wharf Electrical**

Power will be provided at the wharf for the following:

- Area lighting;
- Port superintendent's office, and if required a dock-side shelter for line crews and riggers;
- Instrumentation associated with fuel receiving;
- General power outlets, usually located along the fuel line, at the manifold, and at each light pole;
- Electric capstans.

## **6.11 Fuel Handling**

Fuelling receiving equipment will be provided adjacent to the wharf. Fuel transfer is proposed to be using hoses from the ship's manifold to a manifold at the rear of the dock.



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The Aarluk report proposed using a marine loading arm fixed to the wharf structure. However, such devices are generally large, particularly for Iqaluit that needs to accommodate a very large tidal range. The loading arm, if fixed to the structure, will limit the ability to maintain clear access for cargo handling when a cargo vessel is berthed at the facility.

Spill equipment, including a containment boom for the vessel, has been allowed for. In support of boom deployment, it is assumed that a local contractor will provide such service rather than providing a dedicated boat and operator.

### 6.12 Security and Fire Protection

Allowance has been made to provide security fencing on the primary laydown area only.

A cash allowance is made for provision of fire protection at the yard and dock.

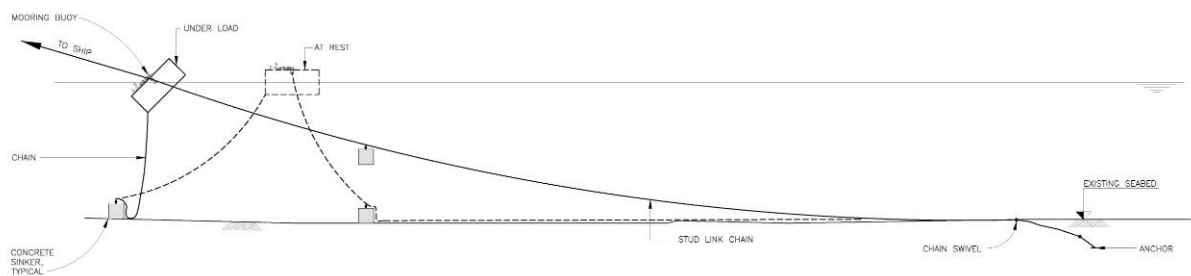
### 6.13 Other Improvements

#### 6.13.1 Fuel Berth Spread Mooring

It is not surprising that the anchors have, on occasion, been dragged by the tanker in storm conditions. Gravity anchors (concrete blocks) are not anticipated to develop any significant capacity unless they sink into the seabed mud, the extent of which is unknown.

To reduce the demand on the anchor system, it is recommended that the system is reconfigured, with the addition of two offshore anchors, fitted with self-burying, fluke-type anchors and locating sinkers. The reconfiguration would allow the vessel to orient into the prevailing winds. The vessel would back into the spread mooring, while paying out its anchor line.

The existing offshore moorings are located in relatively close quarters. Ice breakup is expected to result in only small ice floes developing and not likely to result in dragging of the anchors during breakup. Figure T shows a typical mooring component used in spread mooring arrangements.



**Figure T Proposed new mooring for spread mooring.**



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NEAS requested that a mooring buoy is provided as a secure offshore mooring for cargo vessels. While generally the ship's anchor(s) would serve for temporary offshore mooring, a single point mooring (SPM) could be provided. Such a system would be located in the same area as is currently used for anchorage by cargo vessels with sufficient swinging room.

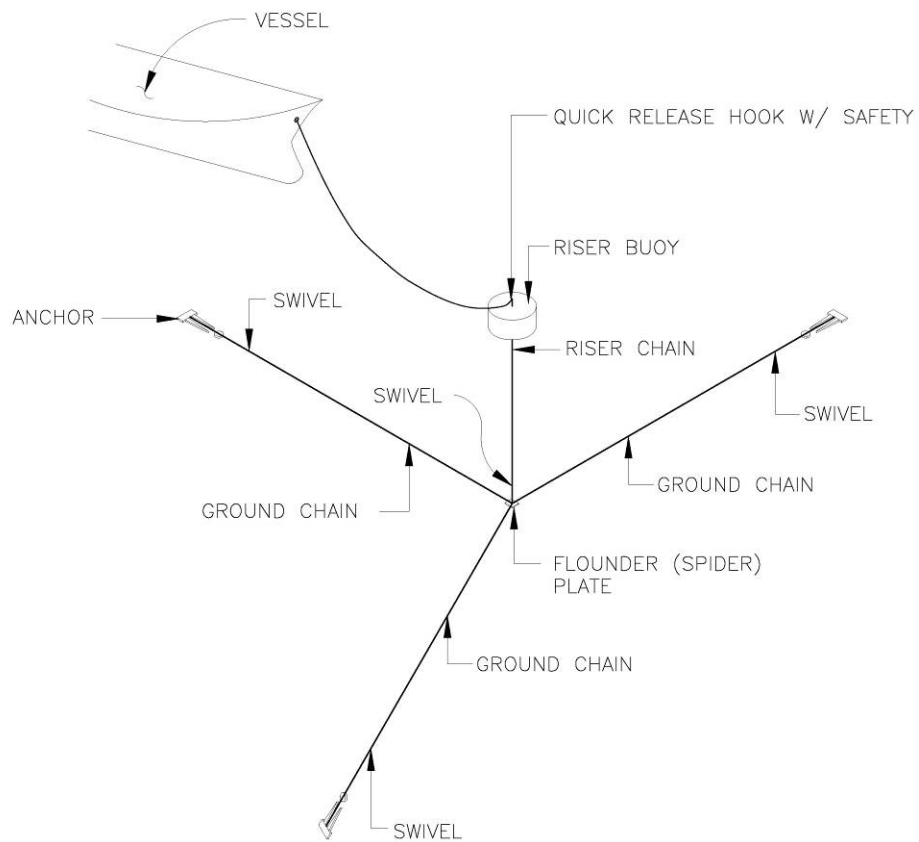
An SPM would be comprised of three self-burying, fluke-type anchors connected to a flounder plate which is connected to the mooring buoy. Each anchor is sized to develop the design line pull. In laying out SPMs, it is important to consider swinging room of the moored vessel and the anchor system. Figure 102 shows a typical SPM.

It is noted that it may be difficult to ensure that the SPM does not drift and break loose during breakup. The proposed anchorage is relatively exposed and the resultant ice breakup could result in very large ice floes mobilizing and causing the anchors to drag. Due to the size of the system, it is not feasible to remove and redeploy each season. Although an ice study is required to assess the risks, an SPM is not considered feasible for dry cargo vessels.



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**Figure U Typical single point mooring.**



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## **7. SMALL CRAFT HARBOUR FACILITIES**

### **7.1 General**

It is desired to improve the facilities for small boats. This may include the following:

- Local small fish boats
- Commercial offshore fishing boats
- Cruise ship tenders
- Tour boats and other commercial ventures

The primary small craft facilities that are lacking in Iqaluit are protected all-tide boat moorage and protected all-tide boat launching. The Municipal Breakwater provides protection, but neither moorage nor all-tide launching. The Old Causeway provides launching near all-tide, but it is not protected from storm conditions.

#### **7.1.1 Improvement Options**

Three options have been considered to address the deficiencies at Iqaluit:

##### **Option A: Old Causeway (Drawing No. 09120-SK-108)**

This option involves raising the Old Causeway to a full height breakwater and constructing a small craft mooring facility on the protected north side. A boat launching ramp would be constructed on the north side adjacent to the mooring facility. The following advantages and disadvantages are noted in relation to the other options:

- Advantages
  - There is an ample amount of upland space that could be available for boat storage and/or vehicle and trailer parking.
  - Makes use of the existing causeway structure.
- Disadvantages
  - There will be a greater amount of public access required to the western shoreline of Koojesse Inlet, which over the long-term is anticipated to be developed into industrial lands.



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- The geophysical survey indicated that the Old Causeway site is underlain by thick soft sediments. The geotechnical desktop study indicated that construction of a tall breakwater at this site may be problematic. As an order of magnitude, the breakwater would require construction in 1 m to 2 m lifts, with an uncertain amount of time required to allow for pore water pressure to dissipate. This will require a more detailed assessment of actual sediment properties.
- The location is not ideal for cruise ship tenders, as the nearby developed areas are industrial.

**Option B: Municipal Breakwater Expansion (Drawing No. 09120-SK-109)**

This option involves extending the Municipal Breakwater into deeper water and dredging an access channel. An all-tide mooring facility and launching ramp would be constructed on the north side of the breakwater. At the time that the Municipal Breakwater was constructed, a future extension to the breakwater was contemplated, though it was not clear if additional dredging and mooring facilities was a part of the expansion. The following advantages and disadvantages are noted in relation to the other options:

- Advantages
  - The Municipal Breakwater is removed from industrial activities associated with the proposed cargo and fuel handling operations on the western side of Koojesse Inlet.
  - Small craft operations can be consolidated in one location.
  - Better for cruise ship passengers to be dropped off, as the location is close to shops and reasonably close to restaurants.
- Disadvantages
  - There is limited parking/storage space at the Municipal Breakwater; however, this is alleviated by the proposed filling.
  - Significant dredging is required to achieve a boat basin with ample space and all-tide moorage and launching.
  - The distance from the shoreline to the end of the breakwater is over 700 m.
  - The geophysical assessment was inconclusive in this area, as no signal reflections were obtained. Thus, it is uncertain whether a breakwater of the height required is feasible.



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**Option C: Municipal Breakwater Upgrades (Drawing No. 09120-SK-111)**

This option involves the construction of modest improvements to the Municipal Breakwater. In recognition that Options A and/or B may suffer from problems associated with foundation preparation, resulting in cost increases, the following improvements are proposed:

- Excavate a deeper boat basin on the protected side of the breakwater, allowing for a longer period of tidal accessibility.
- Provide a series of 5 m by 10 m floats, accessible from shore within the boat basin, but which would ground out at lower tides.
- Fill the shoreline to provide an additional 1 hectare of storage and/or parking.
- Concrete access stairs for access to boats not moored to floats.
- Equipment improvements on the wharf, including two larger hydraulic or electric davits and ladders.
- Launching ramps on either side of the breakwater.

The following advantages and disadvantages are noted in relation to the other options:

- Advantages
  - The cost will be relatively low in comparison with the other options.
  - Small craft operations can be consolidated into one location.
  - Significant improvement in the amount of storage area, both during the summer and for the winter layup period.
- Disadvantages
  - All-tide access is not provided.
  - The ability to dredge with land based equipment and re-use the material as fill have not been verified. If the material is too soft, the costs will increase.

**7.2 Breakwater**

Generally, small craft installations require a protected harbour in which to moor, launch and retrieve boats. Koojessé Inlet is relatively exposed requiring a breakwater to protect any new installations. The breakwater crest elevation is generally chosen based on the level of exposure to overtopping waves permitted under storm conditions. A crest elevation of 14 m CD is chosen. This elevation can be expected to see in a 1 in 1 year storm event overtopping ( $3.14 \times 10^{-4} \text{ m}^3/\text{s}$  as noted in Section 2) that is considered to be unsafe for parking on the crest and dangerous for pedestrians on the crest. Under such events, the facility would need to be closed for safety reasons. Alternatively, the crest could be raised at increased cost of construction.



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The geotechnical desktop study has identified that the breakwater or approach to the deep-sea wharf is likely to require some amount of staged filling for construction. Stantec has assessed a nominal thickness increment of 1 m to 2 m. Between lifts, there will need to be a halt to construction while fine grained sediments dissipate pore water pressure. The time required to dissipate pore water pressures is unknown but could be days or even weeks between each lift. If pore pressures are allowed to rise too high, slope failure will occur during construction. A detailed geotechnical field investigation is required to fully define the seabed conditions at the location under consideration.

### **7.3 Small Craft Floats**

Small craft floats associated with southern fishing harbours are usually pile anchored or chain anchored systems. Pile anchored arrangements are usually used where the seabed sediments allow for easy installation of the mooring piles and the depth is not too great (less than 15 m). Chain anchored arrangements are usually used for deeper water, or where the thickness of sediments is too thin for to provide any support for piled systems or where the float arrangement is relatively simple (such as linear float strings).

In the case of Iqaluit, the tidal range and ice conditions will preclude allowing the floats to remain in place during the winter months. Mooring piles will likely be subjected to lateral ice pressures that are difficult to predict and potentially leading to overstressing of the steel or ground fixity. Also, ice jacking could be problematic for this installation. Chain anchored arrangements are also expected to be problematic, as chains need to either be dropped to the seabed and recovered the following year or risk freezing in, potentially jacking out the anchor block at a high tide.

An alternative system is based on using spuds. Groupe Océan, a marine industry firm from Quebec, has been constructing large sectional floats / barges with integral spuds for several years now. This system is largely self-contained, combining the mooring system and floats into a single unit that can be removed with relative ease for winter layup. This system is particular well suited for Iqaluit, where the ice conditions and tidal range create significant problems. The system installed at Mingan, QC, is shown in Figure V.



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**Figure V Small Craft Facility at Mingan, QC, showing a three-piece spudded float system that is completely removed during winter months. Photo courtesy Groupe Océan.**

Groupe Océan was consulted on Iqaluit to develop a float system comprising a 15 m by 50 m sectional barge and three 4 m by 50 m finger floats. The barge would be used for landing the gangway that would be required to accommodate the full tidal range and as a work platform for provisioning or offloading large fishing boats or accommodating cruise ship tenders. The finger floats would allow rafting of smaller boats. The 4 m wide finger floats would allow ATV access alongside, while still maintaining adequate stability. The through-truss gangway will be approximately 60 m long. Deploying and recovering the gangway is proposed to be conducted using the barge itself by pushing the barge under the gangway and allowing high tide to lift the shore end off its abutment and then secured it to the barge. The spuds would be retracted either by winching or using several grounding cycles. Ultimately, the floats, barge, spuds and gangway would be beached at a suitable location such as the existing landing beach.

The standard Groupe Océan pontoon design would be improved for beaching procedures, including thickening the bottom plate, fitting with fore and aft rakes and other heavy duty hardware to assist with towing and dragging.

In discussions with Stantec during the desktop study, they believe that the ground conditions at either Option A or B locations will be suitable for a spudded system to develop adequate semi-permanent lateral resistance to storm wind and current pressures on the system.



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For the Option C three small mooring floats have been included, a more conventional tube steel pontoon system as has been proposed and/or supplied for other Nunavut communities. Such system would be chain anchored to concrete blocks buried in the seabed. The pontoon would be removed for the winter, with the connecting chains left on the seabed. Since the seabed dries at low tides, the chains can be easily recovered for the redeployment and reattachment of the pontoon floats. The floats would be robust to allow for grounding on the daily tide cycles. Boats moored to the floats need to be carefully moored to the floats with sufficient slack to allow differential movements of the float and boats during settling onto the seabed. A 20 m aluminum gangway is fixed to a shore abutment and the float. A small crane would be required to deploy and recover the gangways for the season.



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**8. CONSTRUCTION COSTS**

Table O presents that summary of costs for the deep-sea wharf/cargo handling options. A detailed breakdown of the costs is presented in Appendix E. The costs have been updated based on interpretations of the geotechnical desktop study for each site.

**Table O Cost Estimate Summary - Cargo Handling Options**

Description	Estimated Cost
Option 1 - Innuvit Head	\$69,900,000
Option 2 - North Polaris Reef	\$77,300,000
Option 3 - Old Causeway	\$73,200,000
Option 4 - South Polaris Reef	\$67,800,000
Option 5 - Twin Ramps Only at Old Causeway	\$27,000,000
Option 6 - South Polaris Reef - Stage 1 Only	\$29,500,000

Table P presents that summary of costs for the small craft harbour options as an added cost to the deep-sea wharf costs. A detailed breakdown of the costs is presented in Appendix E.

**Table P Cost Estimate Summary - Small Craft Harbour and Miscellaneous Options**

Description of Added Cost	Estimated Cost
Option A - Old Causeway	\$14,700,000
Option B - Municipal Breakwater Expansion	\$20,900,000
Option C - Municipal Breakwater Upgrades	\$4,500,000
Tanker Berth Spread Mooring Improvements	\$330,000
Offshore Single Point Mooring	\$1,100,000

In reviewing the estimated costs, it is important to note the following:

- The cost estimates are based on in-house experience from construction of similar projects in similar environments and from budget price quotations from suppliers and contractors. The detailed cost breakdown provides information on the source of some of the cost data, when it has been obtained from external sources.
- The costs are roughly estimated to be to a Class D level, with an accuracy of approximately 40%. It is important to note that projects of this type have a significant risk associated with their execution and tender pricing and bid qualifications are expected to vary significantly.



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- A contingency amount has been included to cover undefined items in the scope of work that has not been specifically allowed for but will be required as part of the work.
- The costs associated with the small craft harbour developments are based on combining with one of the deep-sea wharf / cargo options. If it is intended to proceed with small craft harbour developments only, the cost of mobilization for some equipment will need to be added to the small craft harbour costs.
- It is assumed that sediment dredging is conducted with conventional clamshell equipment and no special provisions and that dredged sediment can be ocean disposed of in deep water near the site.
- There is no specific allowance for marine habitat compensation associated with site filling or dredge disposal.
- No allowance is made for the container stripping warehouse.
- No allowance is made for port related mobile equipment, such as truck / trailer units, front lift trucks.
- No allowance is made for construction camps. It is assumed that there is sufficient accommodation in Iqaluit.



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**9. EXECUTION PLAN**

The following schedule is developed in support of an accelerated execution plan. Should significant delays be required between some stages of the work, the project could expect a one-year delay to completion.

- Additional Engineering Studies: Q3 - Q4 2010
- Environmental Studies: Q3 2010
- Preliminary Engineering: Q3 - Q4 2010
  - Preliminary engineering (based on environmental and engineering studies)
  - Project Execution Plan
  - Project Cost Estimating
- Project Budget Established: Q1 2011\*
- Project Approval: Q1 2011
- Permitting/Approvals: Q1 - Q2 2011
- Geotechnical Field Drilling: Q2 2011
- Detailed Engineering: Q1 - Q2 2011
- Tendering: Q3 2011
- Mobilization: Q3 2011
- Construction: Q2 2012 - Q3 2013
- Facilities operational: start of 2014 season

\*Note: project budget is established before geotechnical drilling completed. A more costly over-water program could be undertaken in Q3 2010 to provide greater cost accuracy before project approval.



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**10. CARGO OPERATIONS**

**10.1 Iqaluit Beach Accessibility**

Research by The Mariport Group Ltd. on behalf of GN has shown that Iqaluit is accessible as follows for a Type B<sup>5</sup> vessel:

**Table Q Iqaluit Access for a Type B Vessel**

<b>Zone 15</b>	<b>Mean Date VOD<sup>6</sup> Route</b>	<b>Earliest VOD Route</b>	<b>Latest VOD Route</b>	<b>Average Access Days Per Season</b>
1978 to 1988	30 July	17 July	17 August	98
1989 to 1998	23 July	10 July	09 August	112
1999 to 2008	19 July	02 July	13 August	126
<b>Mean</b>	<b>24 July</b>	---	---	<b>112</b>
	<b>Mean Closing Date</b>	<b>Earliest Closing</b>	<b>Latest Closing</b>	
1978 to 1988	06 November	27 October	23 November	---
1989 to 1998	13 November	27 October	05 December	---
1999 to 2008	23 November	07 November	08 December	---
<b>Mean</b>	<b>13 November</b>	---	---	---

It should be noted that these dates are different from Zone 15 because of the nature of Frobisher Bay as well as winds during the ice break up period in late June/early July.

Climate change has indicated a definite trend for the mean opening of a very open drift route into Iqaluit with consistent seasonal variability of about two weeks between mean and earliest opening. There has also been a trend to a later closing of the season although the variability between mean and latest closing has not been as consistent as season opening. Note that these dates are for the ability of a Type B vessel to safely navigate through Frobisher Bay to an anchorage location; they do not give dates when the beach may be safely used and in some years ice blocks on the beach have prevented discharge for over one week. Also, flash freezes are not unknown in Iqaluit; one occurring at the end of the 2008 shipping season preventing discharge. On this occasion, the ship sailed back to Montreal with cargo.

<sup>5</sup> Type B is equivalent to Baltic 1A ice class, and dry cargo ships for Arctic service are typically of this class.

<sup>6</sup> VOD = Very Open Drift.



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**10.2 Approximate Temperature and Daylight Hours<sup>7</sup>**

Daylight hours are shown in Figure C in Section 2.

Weather also becomes stormier as the season progresses and winds over 30 km/hr create considerable problems for safe lighterage of cargo from ships at anchor and operations are usually halted above this wind speed.

**% days with Winds Over 30 km/h**

July	7%
August	9%
September	13%
October	18%
November	19%

The sealift beach is only accessible approximately two hours before and two hours after high water. Thus in July and August, with reasonable temperatures and 16 to 20 hours daylight, there is a high probability that both high tides can be used. However, as the season progresses, temperatures decline and hours of daylight are materially reduced and by November the likelihood of being able to safely use even a single tide is low.

The following data has been used as a basis for estimating the number of days needed to service Iqaluit:

2009 population	7,400
Dry cargo demand per person <sup>8</sup>	8 m <sup>3</sup>
Population growth	2.5% pa
Productivity <sup>7</sup>	830 m <sup>3</sup> /day
2009 beach days needed	71
2015 beach days needed	83
2020 beach days needed	94
2025 beach days needed	106
2030 beach days needed	120

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<sup>7</sup> Web sources.

<sup>8</sup> Based on Mariport estimates from cargo shipped in 2006, days used by each carrier to move their shipped cargo. Productivity averaged between both carriers.



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Days available and potential utilization:

**Table R Iqaluit Season Days and Availability**

Month	Actual Days	High Wind Days	Net Days	Tides <sup>9</sup> Available
July	13	1	12	24
August	31	3	28	38
September	30	4	26	31
October	31	6	25	26
November	23	6	17	8
<b>Total</b>	<b>127</b>	<b>20</b>	<b>107</b>	<b>127</b>

Based on estimated tidal availability within daylight hours to transfer cargo and excluding days with winds in excess of 30 km/h, the season of 126 days is effectively reduced to the equivalent of 64 days.

The split in cargo carried between the two carriers serving Iqaluit is approximately 70/30<sup>10</sup>. With two carriers moving cargo, and assuming both can discharge simultaneously at the high watermark, the beach will be fully occupied for every available day by about 2018 at current average productivity levels.

Thus cargo delivery will become a problem in the coming years unless some form of all tide accessibility is provided, or a means of improving vessel productivity for cargo transfer is found.

Advice from Mr. Luc Beland, CCG Superintendent Arctic Field Operations, and long time beach master at Iqaluit, is that the beach can currently manage up to three barges at once, but becomes congested with four. Typically, NEAS will operate with one or two barges but NSSI may deploy up to three units, one of which may be their large barge<sup>11</sup>. He has also stated that extreme congesting develops if cargo is not cleared promptly.

This means that as demand increases in Iqaluit and operators need to call more frequently and stay longer at anchor to shift cargo, there will be many more occasions when two ships will need to discharge simultaneously. This will lead to congestion on the landing beach and the potential for unsafe operations moving onto and off the beach for tugs and barges given the narrow operating window.

<sup>9</sup> Based on when high tides occur relative to daylight hours. Assumed that one hour before and one hour after sunrise / sunset is workable for beach arrival.

<sup>10</sup> This is evidenced by cargo shipped in 2006.

<sup>11</sup> Comments by Mr. Luc Beland with regard to discharge crew sizes supports Mariport's estimates of vessel productivity.



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**Figure W Graphic overlay showing location of proposed new runway approach lighting.<sup>12</sup> Red outline identifies landing beach.**

A major issue regarding beach access is the proposed runway approach lighting for Iqaluit airport (see previous graphic). The supports for the light arrays will cut off access to the beach and in order to maintain safe access, a new approach would need to be cleared to the east<sup>13</sup>. This will result in a greater distance from the high water mark to the laydown area.

The proposed approach lighting provides increased accessibility. It is understood that the airport has been operating under a waiver from Transport Canada, but this waiver (which creates some limitations on traffic due to increased thresholds for aircraft operations) is unlikely to continue indefinitely. Also, the existing lighting is substandard and old so a compliant lighting system will likely be needed in the medium term. If medium term is interpreted as next 5 to 10 years (2015 to 2020), then this will coincide with beach access issues due to increased traffic and require Iqaluit to introduce a landing system for dry cargo that permits operations at any state of the tide.

<sup>12</sup> Image, and comments regarding airport lighting, provided by LPS Avia.

<sup>13</sup> Any such work in the beach area, which would involve boulder removal and levelling, may meet with significant permitting issues.



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### **10.3 Economic Benefit of either 24 Hour Lighterage at the Old Causeway, or Access to a Deep-Sea Wharf**

In determining the economic benefit there is a need to establish current handling rates for dry cargo and petroleum products, compare them with improved productivity at either the old causeway or at a dock, and then assign a value. The following provides the approach taken.

#### **10.3.1 Beach and Anchorage Productivity**

The most recent year for which traffic data is available for Iqaluit is 2006<sup>14</sup>. This shows that:

- 4,934 tonnes of dry cargo were shipped from Valleyfield (NEAS)
- 10,454 tonnes of dry cargo were shipped from Ste. Catherine (NSSI)

Dry cargo for the Arctic is high volume relative to weight and ships tend to be cube limited rather than DWT limited. Based on historic data, the probable volumes were most likely in the order of 17,300 m<sup>3</sup> and 36,500 m<sup>3</sup> respectively, for a total of 53,800 m<sup>3</sup>.

Petroleum Products Division of CGS has provided data for product import from 2004 to 2009, although NPC imports for 2004 were not available. We have been able to use the data to provide base year quantities for 2009:

- P50 Diesel      30,867 m<sup>3</sup>
- Jet A1            23,473 m<sup>3</sup>
- Mogas            4,987 m<sup>3</sup>

Growth rates for P50 have been strong, at 4.2% per annum over the period from 2005, while Mogas has grown at 2.3% per annum over the period since 2004, roughly equivalent to annual population increase. Jet A1, interestingly, has shown mixed results over the period, and 2009 levels are below the six year average demand of 26,170 m<sup>3</sup>. It would seem that Jet was overstocked in 2006 and 2007 and 2009 lower levels may be an effort to correct inventory; we have used 0.5% per annum growth rate from 2009.

Ship days handling dry cargo and petroleum products are given in Table S and indicate an average dry productivity of 830 m<sup>3</sup>/day for beach operation and 3,300 m<sup>3</sup>/day for petroleum products at the mooring at Innuite Head.

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<sup>14</sup> Statistics Canada port data is, typically, four years behind the current year.

**GOVERNMENT OF NUNAVUT  
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Description	Ship	Dates <sup>15</sup>	Days	
<b>NEAS</b>	Umiavut	24-29/09	6	
		03-10/07	8	
		06-09	---	
	Aivik	28-29/07	2	
		18-21/08	4	
		05-08/09	4	
		18-19/09	2	
		07-10/10	4	
		15/11	-	
	Total Days			30
Productivity		17,300 m <sup>3</sup>	577 m <sup>3</sup> /Port Day	
<b>NSSI</b>	Anna Desgagnes	07-13/07	7	
		13, 14-/09	2	
		01-05/10	5	
		06,07/10	2	
	Camilla Desgagnes	05/08	---	
		22, 23/08	2	
		05-08/10	4	
	Cecilia Desgagnes	05/08	---	
		23,24/08	2	
		27,28/08	2	
	Mathilde Desgagnes	02-04/08	3	
		06-09/10	4	
		24, 25/10	2	
	Total Days			35
	Productivity		36,500 m <sup>3</sup>	1,043 m <sup>3</sup> /Port Day
Average all calls		53,800 m <sup>3</sup>	828 m <sup>3</sup> /Port Day	

<sup>15</sup> From NORDREG reports.



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Description	Ship	Dates <sup>15</sup>	Days	
Petroleum Products	Tuvaq	11-13/07	3	
		25-26/07	2	
		20-23/10	4	
		04-06/11	3	
	Jade Star	17-20/08	4	
	Total days			16
	Productivity		53,000 m <sup>3</sup>	3,313 m <sup>3</sup> /Port Day

**10.3.2 Cargo Handling Productivity**

**Causeway**

Using the causeway only benefits dry cargo for improved productivity. Although capital costs include better spread moorings off Inuit Head, these will not measurably improve tanker productivity while the tankers continue to use small diameter floater hose<sup>16</sup>.

For dry cargo, the causeway would offer two ramps with 24-hour access, 2 miles to 3 miles from the anchorage area. This compares with current beach access of ±2 hours around high water, and 3 miles to 4 miles from the anchorage. Assuming that the ships can now work 16 hours per day, compared with a maximum of 8 hours in 25 hours around the tide onto the beach, the causeway would at least double productivity. 1,660 m<sup>3</sup>/day average capability is assumed.

**Deep-Sea Wharf**

Dry cargo productivity would improve further with a deep-sea wharf, although using ship-based cranes to access the dock at the bottom of the tide may reduce handling rates. Also, there would be some congestion due to competing use and occasional ship calls might need to use the auxiliary ramp rather than wait for a ship to clear the dock.

Based on loading rates in Ste. Catherine and Valleyfield, ships typically take 7 to 10 days for a full northbound cargo. This time includes offloading retrograde cargo and returned containers as well as additional time needed for cargo stowage. NEAS vessels are typically 16,500 m<sup>3</sup> capacity, while NSSI vessels are 20,000 m<sup>3</sup>, including deck cargo. Loading rates would therefore range about 2,800 m<sup>3</sup> at the high end to 1,600 m<sup>3</sup> per day at the low end. We have assumed that an average discharge rate for dry cargo of 2,500 m<sup>3</sup>/port day is achievable at a dock considering all factors above.

<sup>16</sup> A shore floater hose could be provided at a larger diameter as part of the upgrade package. This would require larger equipment for deployment and increased deployment time, but could materially improve discharge rates.

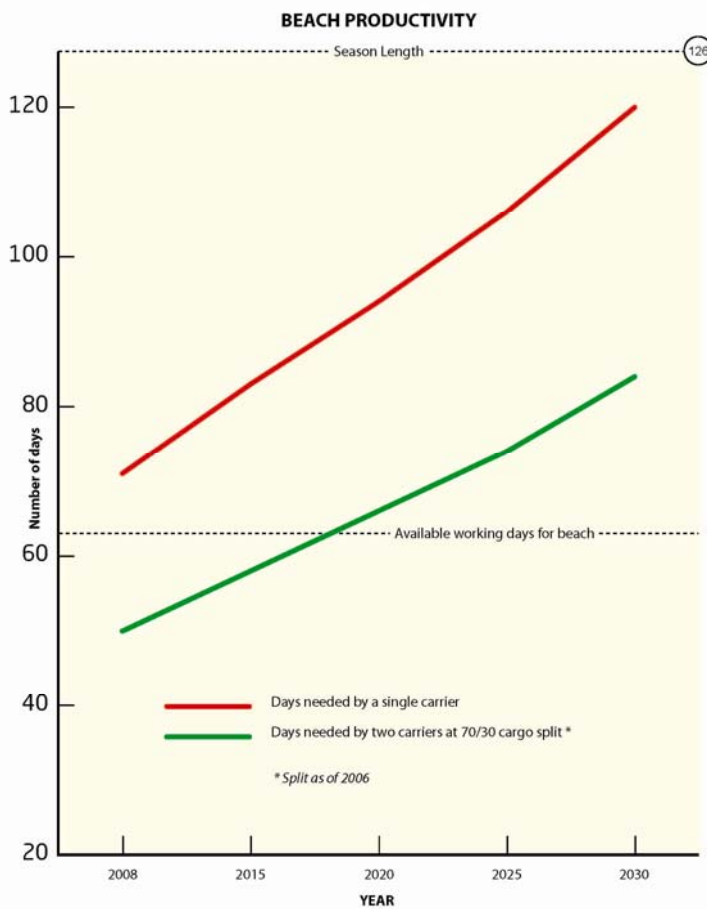


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For tanker operation, and assuming current discharge is via a 100 mm floater hose to an 200 mm shore manifold, discharge rates four times current<sup>17</sup> should be achievable with the ship directly connected to the shore manifold without reducers. 10,000 m<sup>3</sup> per day is assumed.

Figure X shows the productivity estimates for beach, ramp and dock access for 2008 through to 2030. The figure shows that beach productivity will reach capacity by 2018, ignoring any impacts from the proposed runway lighting upgrades.

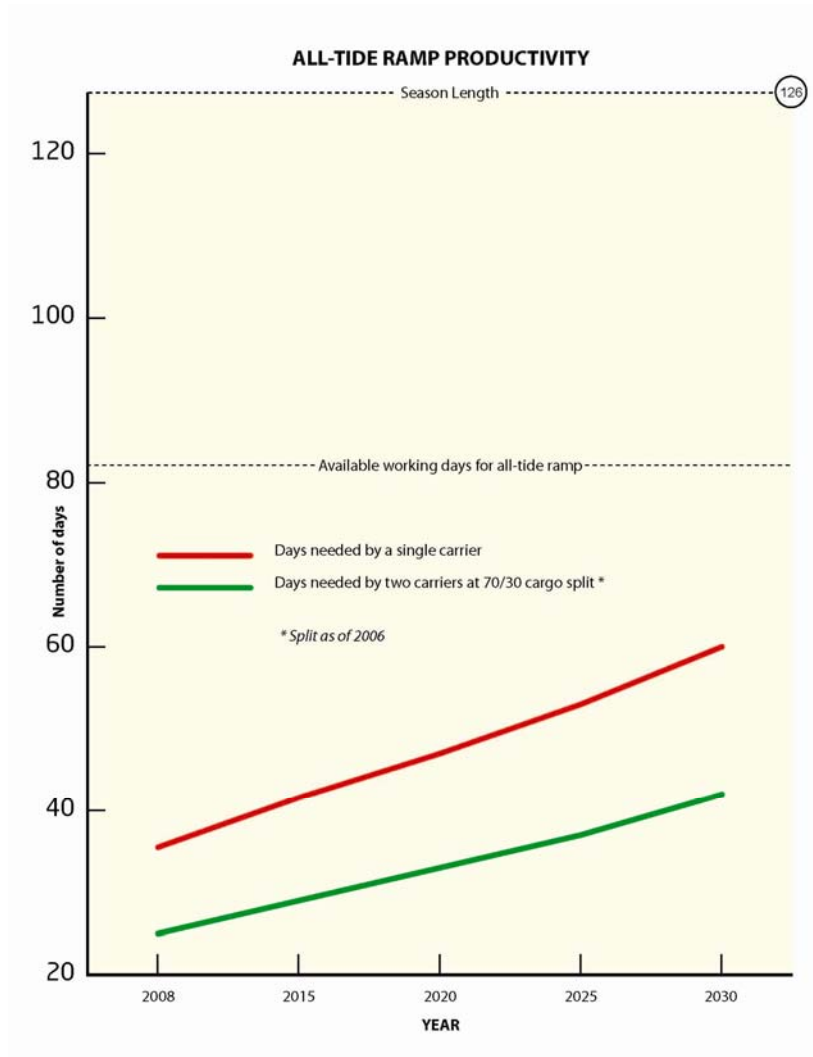


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<sup>17</sup> Based on cross-sectional area of the pipeline.

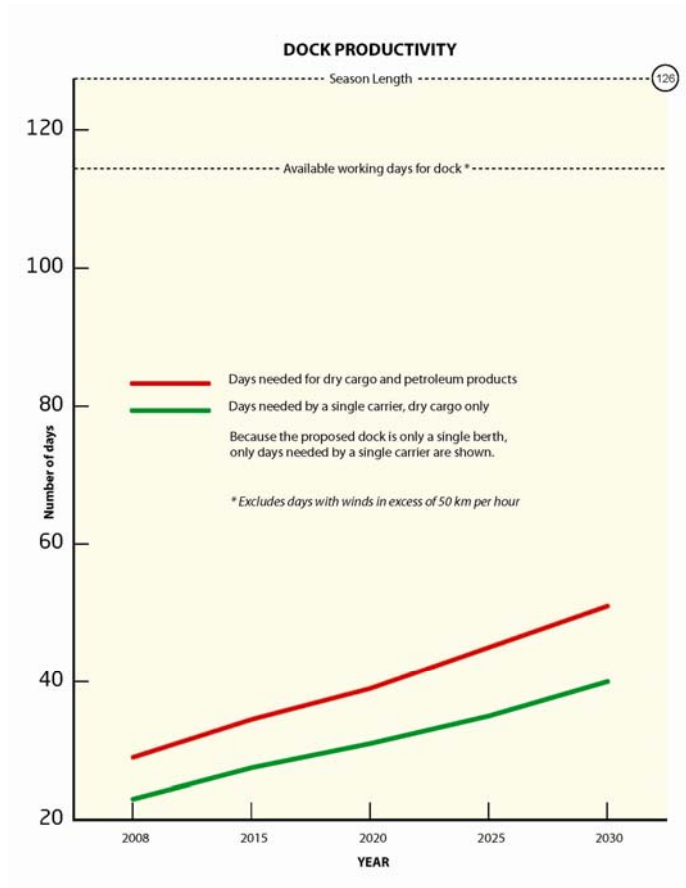


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**Figure X Beach, ramp and dock productivity.**

**10.3.3 Cost and Benefit**

Capital and operating costs are based on Options 4 and 5. Operating, repair and maintenance and other costs associated with the new dock have been estimated.

Ship costs at anchor are taken from a recent Mariport report<sup>18</sup> for the GN on Sealift, as are the estimated costs for lighterage per port day. This report was targeted at dry cargo, and ship costs for tankers were not estimated. The economic analysis assumes the same daily cost in port or at anchor for tankers as for dry cargo ships.

<sup>18</sup> *Considerations Regarding an Open Market for Sealift*. The Mariport Group Ltd. for Government of Nunavut, December 2009.



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Note that dry cargo lighterage equipment costs per port day in the Arctic are based on a sampling of voyages that shows approximately 50% to 60% of season days are spent in Arctic ports.

With regard to use of a deep-sea wharf, we have maintained lighterage equipment costs, even though it is not being used (unless necessary due to another ship on the dock) because the ships call Iqaluit only as part of extensive port rotations where the equipment is still needed. Thus the carriers are still incurring costs, even though the equipment is not being used.

The benefit for dry cargo is taken as the difference in cost between operations at the sealift beach, versus the alternative. For petroleum products there is no benefit with the spread mooring, but there is with the deep-sea wharf.

An example of savings based on ship and lighterage values estimated and assuming 50,000 m<sup>3</sup> of dry cargo and 50,000 m<sup>3</sup> of POL is shown in Table T.

**Table T Exemplary cost savings for a causeway and dock relative to the current beach operation.**

Description	Beach	Causeway	Dock
Dry cargo days	60.2	30.1	20.0
Tanker days	15.2	15.2	5.0
Dry cargo ship cost savings	---	\$552,750	\$1,105,500
Lighterage cost savings	---	116,580	159,500
Tanker cost savings	---	0	280,500
<b>Total</b>	---	<b>\$669,330</b>	<b>\$1,545,500</b>

**Trucking Costs**

Moving operations from the existing beach area, which involves relatively short trucking distances for delivery, to the proposed laydown area, will incur additional costs. The GN has advised that the current shore cartage contract is \$42/revenue ton<sup>19</sup>. The contractor has advised that the new location would double these costs. This seems high considering the additional travel time is low compared to loading and unloading associated with local delivery.

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<sup>19</sup> A revenue ton is 2.5 m<sup>3</sup> or a metric tonne.



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### **Congestion Delays**

Assuming that ship arrivals in Iqaluit are essentially random (they are actually somewhat semi-random due to a similar number of sailings into the Arctic), then with a single berth there are likely to be delays because of a ship arriving when another is already on the dock. The delay risk and length of delay increases with more arrivals and longer dock service times, i.e., time the dock is committed to a single vessel from approach through departure.

On the basis of the number of days projected for dock use at the example used above, berth occupancy is 20% on a 126-day season.

Dry cargo ships always discharge a part load and in 2006 there were 18 ship events of two days or more. There were another four ship calls of one day or less which have been excluded from the analysis. There were five tanker arrivals.

Based on this level of activity and using queuing theory, the average delay factor would be 0.21 days / ship. This would be mitigated for dry cargo operators as they could elect to use the ramp rather than wait. Queuing is very dependent on the number of ship arrivals and 50,000 m<sup>3</sup> of dry cargo could actually be carried in only three shiploads if fully loaded and on a dedicated run. Tanker arrivals are dependent on size of the vessel and could not be reduced below three arrivals with the current fleet.

### **Economics Model**

The economics model looks solely at direct benefits; no multipliers for indirect or direct benefits are assumed.

The Data Table includes the capital cost for each of the two options being analysed and the percentage of estimated cost that is actually spent in Nunavut and thus benefits the region. Because the causeway option is primarily rock and blasting, this has a high remaining value. The dock, which would require construction of the cells in the south and movement by a chartered heavy lift vessel, shows the lowest remaining percentage of value.

Broad estimates of annual operation, maintenance and repair are provided. These are \$305,000 per annum for the deep-sea dock, of which the largest single component is security<sup>20</sup> and the harbourmaster position. The causeway and ramp option has an estimated annual cost of \$123,000. Because there are two ramps, a harbourmaster is not considered necessary, but annual regrading of the ramps to provide a working surface after ice events during the winter and normal wear and tear during the open water season are expected to be fairly high.

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<sup>20</sup> Transport Canada Marine Security have advised that because the dock handles petroleum products, it would be considered in a higher risk category, and would need a security system to be developed.



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Iqaluit's population is expected to grow vigorously over the planning period and dry cargo demand will remain higher, on a per capita basis, than other communities due to the city's role as Nunavut's capital, and the high level of visitors. Dry cargo demand is calculated in the forecast based on the assumed annual  $m^3$ /person level<sup>21</sup>, population growth rate and base year population.

Cargo handling rates are described in the section above on cargo handling productivity.

**Internal Rate of Return (IRR)**

The Internal rate of return for a project demonstrates its economic viability, with a higher figure indicating a greater need.

The base case is as described in the data page and shows that the IRR for Option 5<sup>22</sup> is 41%, but -3% for the deep-sea wharf. However, neither of these cases takes into account additional trucking costs. If the full additional trucking costs are included then an IRR cannot be calculated for either the dock or the causeway as additional costs always exceed benefits.

In terms of looking at sensitivity, it could be argued that while the new tanker moorings are part of the overall causeway project, their cost should not be assigned to what is, essentially, a dry cargo solution. However, the cost of upgrading moorings is less than \$0.6 million and removing this from the capital cost and annual maintenance still prevents an IRR being calculated with additional trucking costs at \$42.00 / revenue ton. If the additional trucking costs are reduced in order to achieve the World Bank target of a minimum of 10% IRR, they cannot exceed \$30.00/revenue tonne more than the current rates from the Sealift beach.

If internal trucking costs are maintained, but annual maintenance costs for the causeway ramps and lay down area were halved and the costs of the tanker mooring excluded, then the IRR "improves" to -2%.

Thus containing additional trucking costs is critical to an economic viability of the project.

Sensitivity analysis for the deep-sea wharf, shows that if the \$30/revenue tonne incremental trucking cost at which the causeway option generates a 10% IRR is assumed, the deep-sea wharf only "improves" to -6%. In order to achieve a positive IRR, capital costs would have to be reduced to \$30 million, which is not feasible. However, this is the estimated cost of Option 6, the interim version of Option 4, where the wharf structure is excluded and only a ramp is included.

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<sup>21</sup> The level of  $8 m^3$  / annum is based on historic data.

<sup>22</sup> The capital cost used excludes the cost of the small craft facilities.



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The primary problem is lack of volume relative to investment costs needed. For example, if the base population for 2009 is doubled to 15,000 persons and the increase in trucking costs is kept at 42%, then the deep-sea wharf generates an IRR of 3%, while the causeway achieves 6% IRR. With the same population assumptions and a \$30/revenue tonne increase in the trucking costs, the IRR's improves to 0% and 30%.



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## **11. PUBLIC OPEN-HOUSE**

A public open-house was held in Iqaluit on Monday, June 21, 2010, at the Parish Hall. The open-house was supported by representatives from of GN Department of Economic Development and Transportation, WorleyParsons, and The Mariport Group.

A total of 31 people signed in at the open house and were represented by a broad stakeholders and residents of Iqaluit and including:

- City of Iqaluit
- Nunavut Tunngavik Inc.
- Hunters and Trappers Association
- Nunavut Tourism
- Nunavut Eastern Arctic Shipping
- Canadian Northern Economic Development Agency
- Nunavut Teacher Education Program / Native Access Program
- Arctic College
- Nunavut Arts and Crafts Association
- Other GN Departments
- Canadian Coast Guard
- Environment Canada
- Representatives of Various Media

Visitors to the open house were provided with eight display boards (refer to Appendix G) and a 51-slide slide-show. The boards and slide-show were presented in Inuktitut and English. The slide show was an updated version of a presentation made to the City of Iqaluit by GN in January 2010. It is noted that the costs presented in this report are updated from the costs presented on the display boards as the geotechnical desktop study provided additional input that has been incorporated into this report.

In general, discussions at the open house were largely based on providing information and explaining the basis of the options presented. However, there was clear support for the Iqaluit Port Development project. Option 4 was consistently favoured over other sites for the deep-sea wharf. Option C was also consistently favoured for small craft harbour improvements.

Concerns over the environmental implications on local fishing were raised and in particular the effects of offshore blasting. As offshore blasting is no longer expected, this issue is no longer a factor. The impacts to local fish for the proposed work are presented in the report by Nunami Jacques Whitford, which, at the time of publication of this report, is in draft form.



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## **12. ADDITIONAL STUDIES**

The following additional studies are required in support of the preliminary and detailed design phases of this project:

- Field topographic survey at the Municipal Breakwater
- Current modeling study to determine currents at the sites
- Ice Study
  - Ice thickness measurements (esp. grounded ice, shoreline and dock)
  - Ice analysis, including statistical break-up and freeze-up, ice floe size
  - Ice load assessment, including impact loads and ice growth
  - Shoreline ice growth assessment
- Detailed Geotechnical Study
  - Drilling program at preferred location(s)
  - Quarry assessment
  - Design recommendations for various structures (breakwater, causeway, deep-sea structure)
- Environmental impact assessment
  - Field studies at preferred site(s), as necessary, and ocean disposal site(s)
  - Develop habitat compensation plan and associated costs



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**13. REGULATORY AGENCIES**

The following permits and approvals will be required for the Iqaluit Port Development project:

- Land Use Plan from the Nunavut Planning Commission (NPC)
- Project Certificate from the Nunavut Impact Review Board (NIRB)
- Certificate of Authorization from the Canadian Environmental Assessment. This is likely to be waived as the NIRB review will cover the same impacts. Fisheries Act Authorization by the Department of Fisheries and Oceans (DFO)
- Ocean Dumping Permit from Environment Canada (EC)
- Navigable Waters Protection Act approval from Transport Canada
- Quarry Permit from Indian and Northern Affairs Canada (INAC)
- The project is understood to be located entirely within the boundary of the City of Iqaluit, a municipal permit will be required.



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## **14. CONCLUSIONS AND RECOMMENDATIONS**

### **Cargo Handling**

Past port development studies have all focused on Innuvit Head, Option 1 location for this study. This study has considered other potential sites, focusing on the other factors that can affect site selection, such as connectivity to the existing roads and services and geotechnical foundation conditions.

The study has assessed that the deep sea wharf facility, Option 4, located adjacent the south end of Polaris Reef is preferred. This option has similar ship accessibility as Option 1, the original site of past port development studies, but a shorter road access and improved integration with the secondary storage area at the Old Causeway. This option has been interpreted to have slightly better ground conditions than Option 1 and, being located away from Innuvit, Head, avoids the need for a temporary relocation of the tanker berth. Some of the other notable changes that have been incorporated in the concept include:

- The preferred main structure would be concrete caissons as other studies have assumed, but the structure would need to be constructed using existing facilities in the south, requiring three smaller caissons rather than one large caisson. The caissons would be shipped to site on a large semi-submersible ship, as the caissons, large or small, do not have sufficient stability and the towing speed too low for in-water towing from the south.
- The foundation would be a rock mattress constructed over top of bedrock, rather than the previously assumed blasted bench within the bedrock. This has been reviewed with a geotechnical engineer to confirm feasibility. This has the benefit of time and cost saved and avoids the environmental impact and associated protracted permitting process.
- The surfacing on the wharf would be gravel, rather than a more costly suspended concrete deck.
- Fuel handling would be by hoses over the dock to a shore manifold, rather than using a loading arm that would conflict with cargo handling operations.
- An auxiliary landing ramp is provided adjacent to the primary laydown area to allow offloading of two resupply ships at the same time, while incurring the cost of only one wharf.
- The access road to the port would be constructed on the east side of the peninsula serviced by Akilliq Road, avoiding the more sensitive west side that is used for summer camps.
- There are two laydown / storage areas proposed, allowing for some amount of isolation of the sites from public access. This improves security and safety to the public.
- The yard space is substantial at over 4 hectares allowing for future volume increase and an ability to allow longer term storage for some cargo.



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The cost of the preferred facility is significantly greater than previous estimates, at \$67,800,000. This estimate is considered more realistic than past estimates, as it is generally consistent with the cost of other similar facilities recently constructed in the remote north.

Feedback from the open house in June 2010 confirmed a preference for Option 4. There was no negative feedback received that suggested that changes to the concept should be made at this time.

This study also presented a phased approach to construction of Option 4, should funding be limited. Option 6 presents the upland infrastructure only associated with Option 4, deleting the costly deep sea wharf structure. This option is estimated to be \$29,500,000. Option 6 precludes any changes to fuel receiving operations. However, it is recommended that upgrades to the tanker berth are carried out to improve the alignment of the ship with respect to the prevailing winds. These improvements at the tanker berth are estimated to be an additional \$330,000.

It is expected that cost of the infrastructure will not produce a rate of return that supports the economics of the installation. This is not unexpected as even in southern developed centre where only dedicated transshipment terminals with very high throughput can sustain their infrastructure through handling charges alone, the rest must absorb the costs through profits from other operations or external funding. Iqaluit, with a comparatively low volume of cargo, will not produce a positive rate of return and the cost must be covered through funding from other sources.

The Iqaluit Port Development project is a four-year planning and construction project, with two years of planning and permitting and two years of construction. The landing beach will run out of capacity by approximately 2018 and by then something will need to be done.

### **Small Craft Facilities**

Three options for small craft harbours have been developed, including two options of full-tide accessible floating harbour. One option is an expansion to the Municipal Breakwater into deeper water and one at the Old Causeway; both include a very large breakwater structure over 14 m tall. These options are estimated to be in the range of \$15,000,000 to \$20,000,000, when added to the main deep sea wharf scope of work.

A third option, Option C, is an upgrade of existing facilities at the Municipal Breakwater and has been identified at the public open house and in discussions with the City of Iqaluit as the preferred option as it has a modest capital cost, it retains public access for boating on the Iqaluit side of Koojesse Inlet maintaining the opposite side for industrial activities and cargo receiving, and it addresses many of the needs for the community residents. Option C is estimated at \$4,500,000 when combined with either Option 4 or 6. The improvements include approximately 1 hectare of upland boat storage and parking where there currently is little or no space available, a deeper boat basin with launching ramp allowing improved tidal access, three 5 m by 10 m floats at the shoreline, and other miscellaneous items to improve access and safety associated with boating activities.



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The Iqaluit Port Development project is a four-year planning and construction project, with two years of planning and permitting and two years of construction. The landing beach will run out of capacity by approximately 2018 and by then something will need to be done.

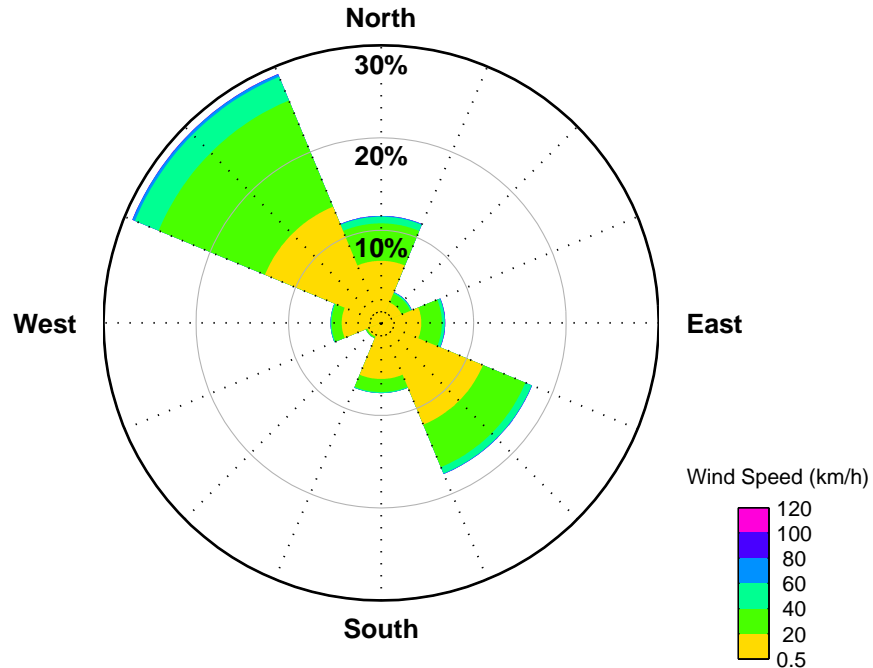


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IQALUIT PORT DEVELOPMENT

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## Appendix A Wind Data

## Wind Speed and Direction Rose for Iqaluit, 01-Jan-1953 to 19-Aug-2009 23:00:00



### JFT (%) of Wind Speed against Direction for the entire period 01-Jan-1953 to 19-Aug-2009

N=496440	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0-0.5 (Calm)</b>	-	-	-	-	-	-	-	-	16.24	100.00
<b>0.5-10</b>	3.30	1.06	1.91	5.84	3.60	1.04	2.68	5.48	24.90	83.76
<b>10-20</b>	3.41	1.32	2.44	6.08	2.47	0.55	1.59	8.12	25.98	58.86
<b>20-30</b>	2.61	0.73	1.56	3.31	1.02	0.15	0.75	7.50	17.63	32.88
<b>30-40</b>	1.44	0.30	0.66	1.65	0.39	0.03	0.33	4.93	9.74	15.25
<b>40-50</b>	0.56	0.10	0.22	0.59	0.08	*	0.09	2.15	3.81	5.50
<b>50-60</b>	0.16	0.05	0.08	0.15	0.02	*	0.02	0.63	1.12	1.70
<b>60-70</b>	0.06	0.03	0.03	0.04	*	*	*	0.22	0.41	0.58
<b>70-80</b>	0.02	*	0.01	0.01	*	-	*	0.07	0.12	0.17
<b>80-90</b>	*	*	*	*	-	-	*	0.02	0.03	0.05
<b>90-100</b>	*	*	*	*	-	-	-	*	0.01	0.02
<b>100-110</b>	*	*	*	-	-	-	-	*	*	*
<b>110-120</b>	-	*	-	-	-	-	-	*	*	*
<b>120-130</b>	-	-	-	-	-	-	-	*	*	*
<b>&gt;130</b>	-	-	-	-	-	-	-	-	-	-
<b>subTot.</b>	11.57	3.60	6.93	17.68	7.59	1.79	5.47	29.13		
<b>Total **</b>	13.60	5.63	8.96	19.71	9.62	3.82	7.50	31.16		
<b>Cumul.</b>	13.60	19.23	28.19	47.91	57.52	61.34	68.84	100.00		

\* denotes values less than 0.01% – denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

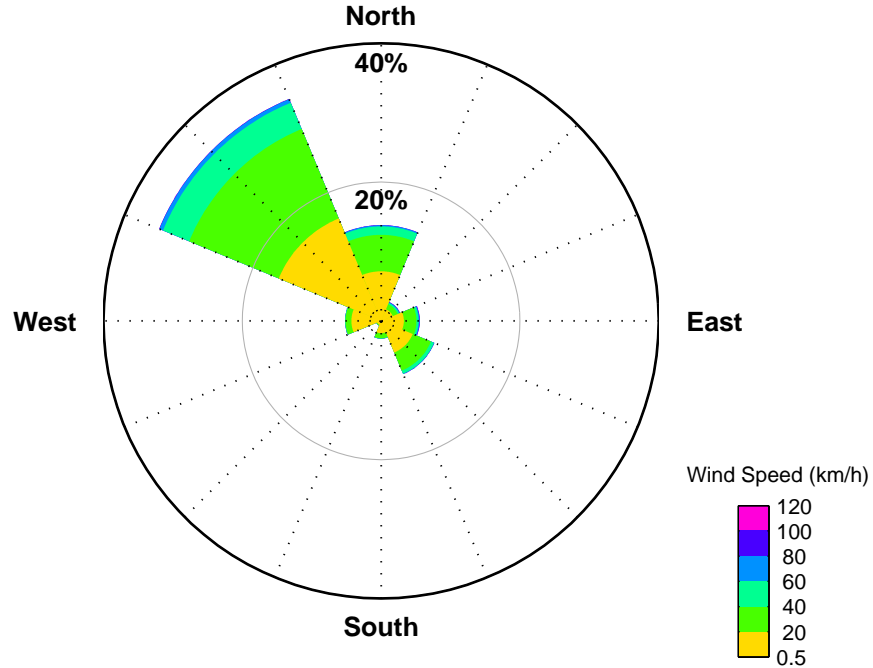
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: All data (01-Jan-1953 to 19-Aug-2009)  
 Data source: Environment Canada  
 Data summary: All Records  
 Number of Records: 496440  
 Calm (% < 0.5km/h): 16.24

#### Key Statistics:

Maximum Wind Speed: 129.00 km/h  
 Mean Wind Speed: 16.08 km/h  
 Std. Dev. Wind Speed: 13.61 km/h

## Wind Speed and Direction Rose for Iqaluit, January



### JFT (%) of Wind Speed against Direction for the month of Jan (1953 to 2009)

N=42408	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0-0.5 (Calm)</b>	-	-	-	-	-	-	-	-	26.20	100.00
<b>0.5-10</b>	4.09	1.12	1.54	2.23	1.13	0.39	2.82	7.45	20.77	73.80
<b>10-20</b>	3.06	0.70	1.74	2.71	0.65	0.21	1.47	8.53	19.06	53.04
<b>20-30</b>	3.06	0.52	1.22	1.78	0.49	0.11	0.60	8.29	16.07	33.97
<b>30-40</b>	2.19	0.24	0.59	1.05	0.24	0.02	0.25	5.69	10.28	17.90
<b>40-50</b>	0.93	0.15	0.20	0.38	0.04	*	0.04	2.99	4.74	7.63
<b>50-60</b>	0.28	0.09	0.10	0.09	0.01	-	0.02	1.10	1.69	2.89
<b>60-70</b>	0.13	0.07	0.06	0.05	*	*	-	0.40	0.72	1.20
<b>70-80</b>	0.04	0.03	0.06	0.01	-	-	-	0.17	0.31	0.48
<b>80-90</b>	0.02	0.02	0.03	-	-	-	-	0.03	0.10	0.17
<b>90-100</b>	*	0.02	0.03	-	-	-	-	*	0.06	0.07
<b>100-110</b>	-	*	*	-	-	-	-	-	*	*
<b>110-120</b>	-	-	-	-	-	-	-	-	-	-
<b>120-130</b>	-	-	-	-	-	-	-	-	-	-
<b>&gt;130</b>	-	-	-	-	-	-	-	-	-	-
<b>subTot.</b>	13.81	2.95	5.59	8.31	2.56	0.74	5.19	34.65		
<b>Total **</b>	17.09	6.23	8.86	11.58	5.83	4.01	8.47	37.93		
<b>Cumul.</b>	17.09	23.32	32.18	43.76	49.59	53.61	62.07	100.00		

\* denotes values less than 0.01% - denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

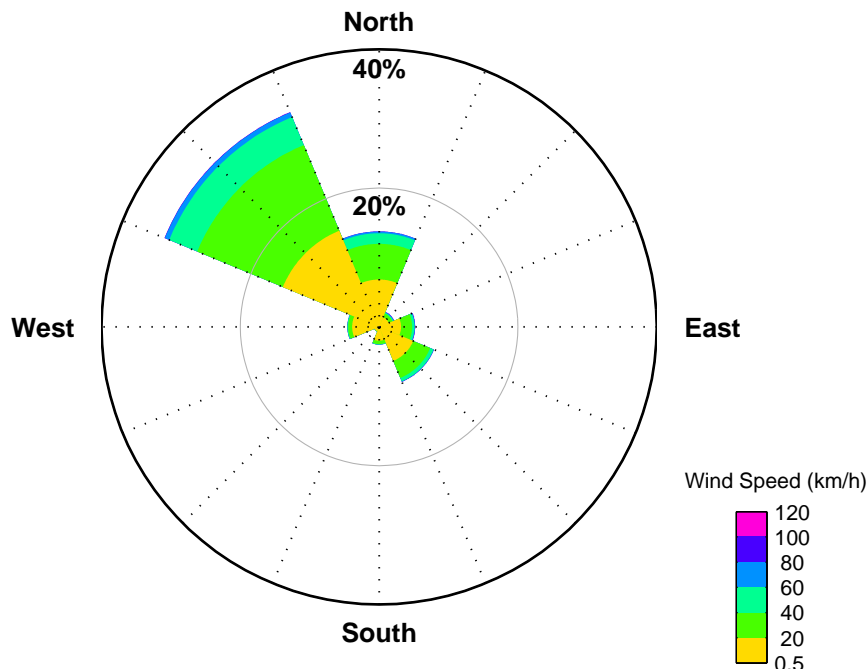
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Jan (01-Jan-1953 to 31-Jan-2009)  
 Data source: Environment Canada  
 Data summary: January  
 Number of Records: 42408  
 Calm (% < 0.5km/h): 26.20

#### Key Statistics:

Maximum Wind Speed: 108.00 km/h  
 Mean Wind Speed: 15.74 km/h  
 Std. Dev. Wind Speed: 15.69 km/h

## Wind Speed and Direction Rose for Iqaluit, February



### JFT (%) of Wind Speed against Direction for the month of Feb (1953 to 2009)

N=38640	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0–0.5 (Calm)</b>	–	–	–	–	–	–	–	–	28.79	100.00
<b>0.5–10</b>	3.70	0.90	1.56	2.78	1.34	0.48	2.70	6.82	20.27	71.21
<b>10–20</b>	3.13	0.60	1.60	2.53	0.66	0.20	1.19	8.19	18.10	50.94
<b>20–30</b>	3.02	0.39	1.19	1.70	0.33	0.05	0.40	7.75	14.82	32.84
<b>30–40</b>	2.12	0.19	0.41	0.97	0.14	0.01	0.16	5.61	9.61	18.02
<b>40–50</b>	1.18	0.09	0.21	0.37	0.05	–	0.10	3.19	5.19	8.41
<b>50–60</b>	0.35	0.05	0.12	0.14	0.04	–	0.02	1.18	1.90	3.22
<b>60–70</b>	0.17	0.05	0.07	0.05	*	–	*	0.58	0.93	1.32
<b>70–80</b>	0.08	0.03	0.02	0.03	–	–	*	0.12	0.29	0.39
<b>80–90</b>	*	0.01	0.02	*	–	–	–	0.04	0.08	0.11
<b>90–100</b>	–	0.02	*	–	–	–	–	–	0.02	0.03
<b>100–110</b>	–	*	–	–	–	–	–	–	*	*
<b>110–120</b>	–	*	–	–	–	–	–	–	*	*
<b>120–130</b>	–	–	–	–	–	–	–	–	–	–
<b>&gt;130</b>	–	–	–	–	–	–	–	–	–	–
<b>subTot.</b>	13.75	2.34	5.20	8.56	2.56	0.74	4.57	33.49		
<b>Total **</b>	17.35	5.94	8.80	12.16	6.15	4.33	8.17	37.09		
<b>Cumul.</b>	17.35	23.29	32.09	44.25	50.40	54.74	62.91	100.00		

\* denotes values less than 0.01% – denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

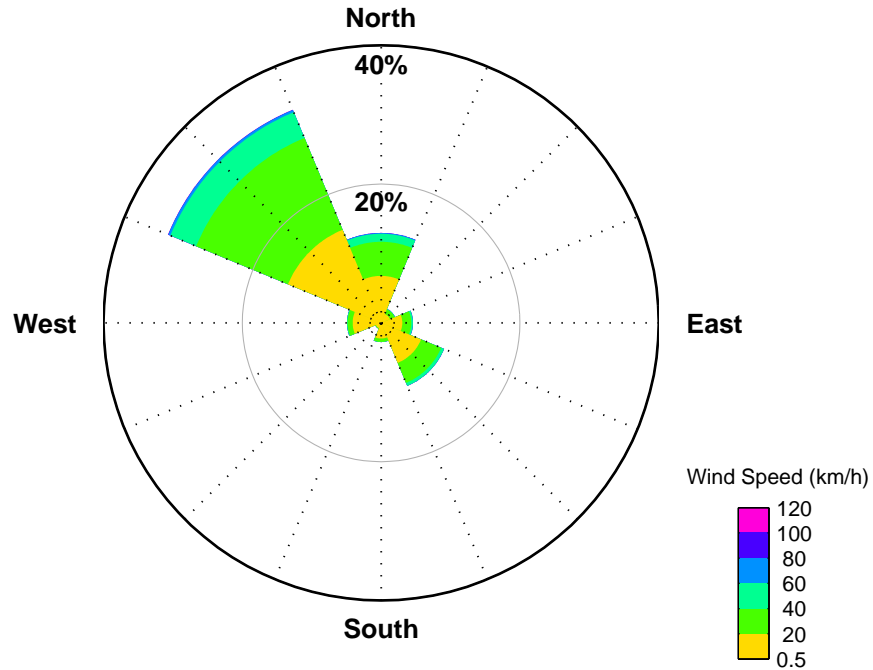
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Feb (01–Feb–1953 to 28–Feb–2009)  
 Data source: Environment Canada  
 Data summary: February  
 Number of Records: 38640  
 Calm (% < 0.5km/h): 28.79

#### Key Statistics:

Maximum Wind Speed: 120.00 km/h  
 Mean Wind Speed: 15.38 km/h  
 Std. Dev. Wind Speed: 16.02 km/h

## Wind Speed and Direction Rose for Iqaluit, March



### JFT (%) of Wind Speed against Direction for the month of Mar (1953 to 2009)

N=42408	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0–0.5 (Calm)</b>	–	–	–	–	–	–	–	–	28.57	100.00
<b>0.5–10</b>	3.70	0.80	1.49	3.24	1.66	0.62	3.01	6.52	21.05	71.43
<b>10–20</b>	3.07	0.59	1.57	3.01	0.59	0.18	1.09	8.01	18.10	50.38
<b>20–30</b>	3.00	0.51	0.84	2.03	0.36	0.08	0.46	8.26	15.54	32.28
<b>30–40</b>	1.92	0.20	0.43	1.09	0.13	0.03	0.27	6.07	10.15	16.74
<b>40–50</b>	0.87	0.06	0.17	0.39	0.03	–	0.07	3.08	4.68	6.59
<b>50–60</b>	0.28	*	0.08	0.05	–	–	0.02	0.93	1.37	1.91
<b>60–70</b>	0.10	*	*	0.01	–	–	*	0.24	0.37	0.54
<b>70–80</b>	0.01	–	*	–	–	–	–	0.10	0.12	0.17
<b>80–90</b>	*	–	*	–	–	–	–	0.02	0.03	0.05
<b>90–100</b>	–	–	*	–	–	–	–	*	0.01	0.03
<b>100–110</b>	–	–	–	–	–	–	–	*	*	0.01
<b>110–120</b>	–	–	–	–	–	–	–	*	*	0.01
<b>120–130</b>	–	–	–	–	–	–	–	*	*	*
<b>&gt;130</b>	–	–	–	–	–	–	–	–	–	–
<b>subTot.</b>	12.96	2.17	4.60	9.83	2.77	0.90	4.92	33.26		
<b>Total **</b>	16.54	5.74	8.17	13.40	6.34	4.47	8.50	36.84		
<b>Cumul.</b>	16.54	22.28	30.45	43.85	50.19	54.67	63.16	100.00		

\* denotes values less than 0.01% – denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

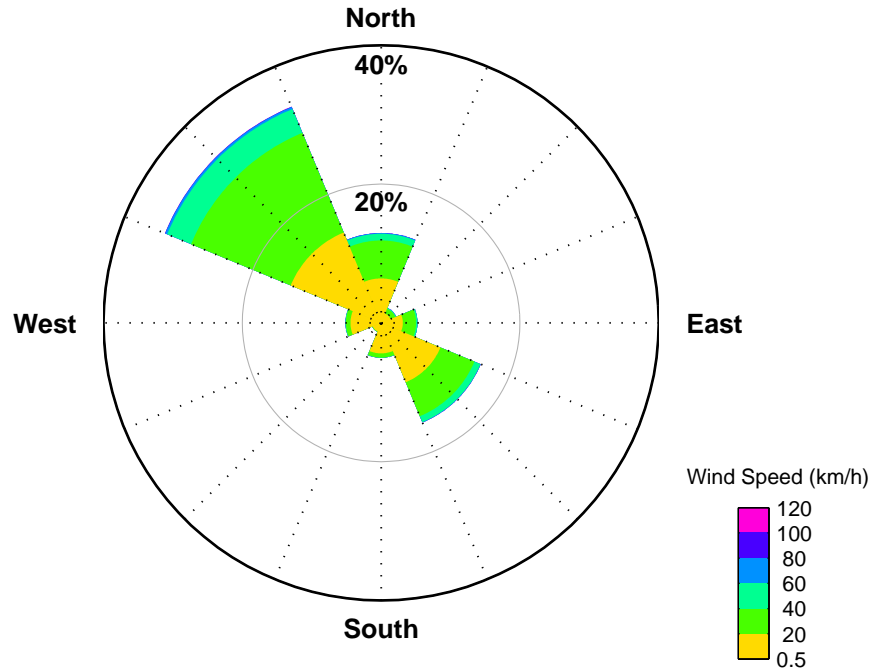
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Mar (01–Mar–1953 to 31–Mar–2009)  
 Data source: Environment Canada  
 Data summary: March  
 Number of Records: 42408  
 Calm (% < 0.5km/h): 28.57

#### Key Statistics:

Maximum Wind Speed: 129.00 km/h  
 Mean Wind Speed: 14.73 km/h  
 Std. Dev. Wind Speed: 14.94 km/h

## Wind Speed and Direction Rose for Iqaluit, April



### JFT (%) of Wind Speed against Direction for the month of Apr (1953 to 2009)

N=41040	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0-0.5 (Calm)</b>	-	-	-	-	-	-	-	-	18.60	100.00
<b>0.5-10</b>	2.94	0.74	1.41	4.60	3.33	1.11	3.19	5.48	22.80	81.40
<b>10-20</b>	3.46	0.71	1.72	4.66	1.06	0.20	1.23	8.63	21.67	58.60
<b>20-30</b>	3.44	0.50	1.26	3.40	0.42	0.05	0.40	9.08	18.55	36.92
<b>30-40</b>	2.04	0.25	0.64	1.90	0.19	0.02	0.25	6.47	11.75	18.38
<b>40-50</b>	0.78	0.10	0.19	0.75	0.03	*	0.06	3.01	4.93	6.63
<b>50-60</b>	0.18	0.02	0.03	0.19	*	-	0.01	0.71	1.14	1.69
<b>60-70</b>	0.08	0.01	-	0.04	-	-	*	0.24	0.38	0.55
<b>70-80</b>	0.03	-	*	0.02	-	-	-	0.07	0.12	0.18
<b>80-90</b>	*	*	-	-	-	-	*	0.03	0.04	0.05
<b>90-100</b>	-	-	-	-	-	-	-	*	*	0.02
<b>100-110</b>	-	-	-	-	-	-	-	*	*	*
<b>110-120</b>	-	-	-	-	-	-	-	*	*	*
<b>120-130</b>	-	-	-	-	-	-	-	-	-	-
<b>&gt;130</b>	-	-	-	-	-	-	-	-	-	-
<b>subTot.</b>	12.96	2.34	5.25	15.55	5.03	1.39	5.15	33.74		
<b>Total **</b>	15.28	4.66	7.57	17.88	7.35	3.71	7.48	36.06		
<b>Cumul.</b>	15.28	19.95	27.52	45.40	52.75	56.46	63.94	100.00		

\* denotes values less than 0.01% - denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

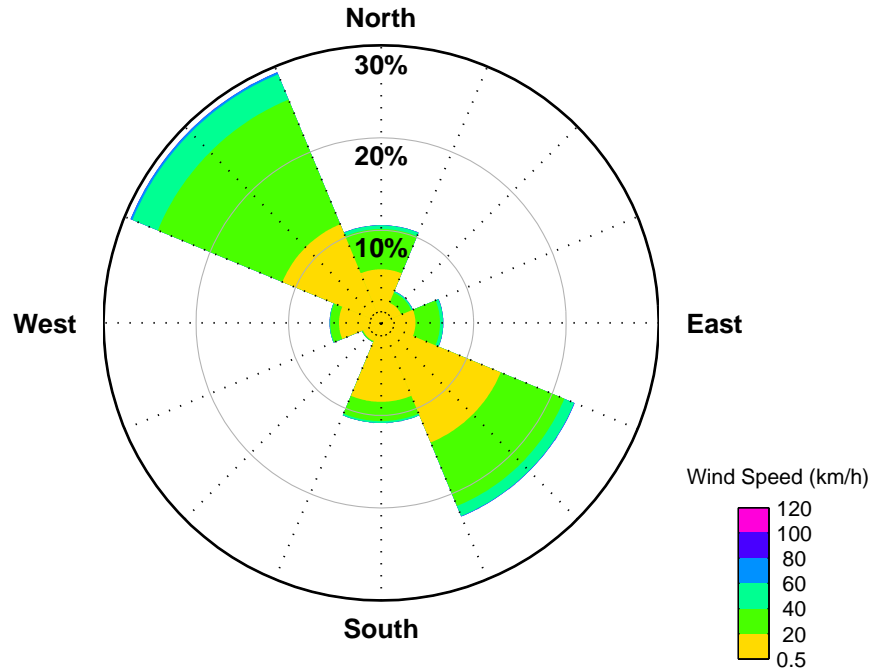
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Apr (01-Apr-1953 to 30-Apr-2009)  
 Data source: Environment Canada  
 Data summary: April  
 Number of Records: 41040  
 Calm (% < 0.5km/h): 18.60

#### Key Statistics:

Maximum Wind Speed: 116.00 km/h  
 Mean Wind Speed: 16.74 km/h  
 Std. Dev. Wind Speed: 14.38 km/h

## Wind Speed and Direction Rose for Iqaluit, May



### JFT (%) of Wind Speed against Direction for the month of May (1953 to 2009)

N=42408	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0-0.5 (Calm)</b>	-	-	-	-	-	-	-	-	8.40	100.00
<b>0.5-10</b>	2.08	0.78	1.42	6.28	4.91	1.54	2.76	3.46	23.23	91.60
<b>10-20</b>	3.72	1.57	2.29	7.72	3.62	0.57	1.78	8.09	29.37	68.38
<b>20-30</b>	2.87	0.87	1.80	4.82	1.52	0.11	0.74	8.83	21.58	39.01
<b>30-40</b>	1.48	0.31	0.85	2.62	0.56	*	0.20	5.76	11.78	17.43
<b>40-50</b>	0.34	0.10	0.26	0.95	0.17	0.01	0.05	2.27	4.17	5.65
<b>50-60</b>	0.06	0.06	0.08	0.21	0.03	*	0.02	0.69	1.14	1.48
<b>60-70</b>	0.02	0.02	0.02	0.05	-	-	*	0.17	0.28	0.34
<b>70-80</b>	-	*	-	*	-	-	-	0.05	0.06	0.06
<b>80-90</b>	-	-	-	-	-	-	-	*	*	*
<b>90-100</b>	-	-	-	-	-	-	-	-	-	-
<b>100-110</b>	-	-	-	-	-	-	-	-	-	-
<b>110-120</b>	-	-	-	-	-	-	-	-	-	-
<b>120-130</b>	-	-	-	-	-	-	-	-	-	-
<b>&gt;130</b>	-	-	-	-	-	-	-	-	-	-
<b>subTot.</b>	10.56	3.71	6.72	22.65	10.82	2.25	5.56	29.33		
<b>Total **</b>	11.61	4.76	7.77	23.70	11.87	3.30	6.61	30.37		
<b>Cumul.</b>	11.61	16.37	24.15	47.85	59.72	63.01	69.63	100.00		

\* denotes values less than 0.01% - denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

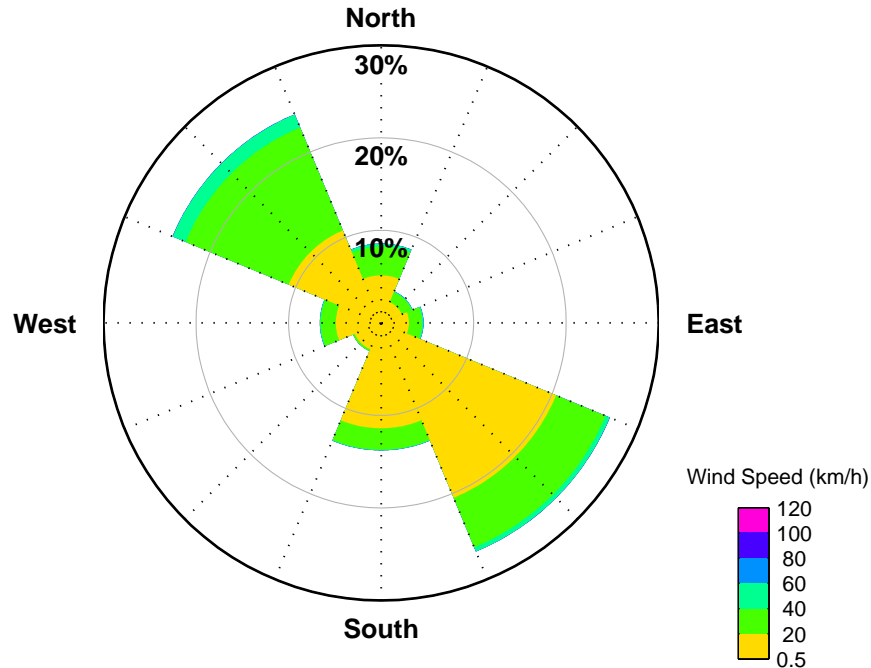
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled May (01-May-1953 to 31-May-2009)  
 Data source: Environment Canada  
 Data summary: May  
 Number of Records: 42408  
 Calm (% < 0.5km/h): 8.40

#### Key Statistics:

Maximum Wind Speed: 85.00 km/h  
 Mean Wind Speed: 18.29 km/h  
 Std. Dev. Wind Speed: 12.78 km/h

## Wind Speed and Direction Rose for Iqaluit, June



### JFT (%) of Wind Speed against Direction for the month of Jun (1953 to 2009)

N=41040	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0-0.5 (Calm)</b>	-	-	-	-	-	-	-	-	8.28	100.00
<b>0.5-10</b>	1.79	0.75	1.31	10.09	6.56	1.92	2.59	3.10	28.10	91.72
<b>10-20</b>	3.35	1.67	1.71	10.39	4.84	1.16	2.30	7.72	33.14	63.61
<b>20-30</b>	2.18	0.82	1.06	4.24	1.77	0.17	1.16	7.66	19.06	30.48
<b>30-40</b>	0.92	0.34	0.35	1.54	0.54	0.03	0.46	4.41	8.60	11.42
<b>40-50</b>	0.26	0.07	0.10	0.42	0.06	*	0.08	1.31	2.31	2.82
<b>50-60</b>	0.05	0.02	0.05	0.07	0.02	-	0.02	0.20	0.44	0.51
<b>60-70</b>	0.01	*	0.01	0.01	-	-	*	0.02	0.07	0.07
<b>70-80</b>	*	-	*	-	-	-	-	-	*	*
<b>80-90</b>	-	-	-	-	-	-	-	-	-	-
<b>90-100</b>	-	-	-	-	-	-	-	-	-	-
<b>100-110</b>	-	-	-	-	-	-	-	-	-	-
<b>110-120</b>	-	-	-	-	-	-	-	-	-	-
<b>120-130</b>	-	-	-	-	-	-	-	-	-	-
<b>&gt;130</b>	-	-	-	-	-	-	-	-	-	-
<b>subTot.</b>	8.58	3.68	4.59	26.77	13.79	3.28	6.62	24.41		
<b>Total **</b>	9.61	4.72	5.62	27.81	14.82	4.32	7.65	25.45		
<b>Cumul.</b>	9.61	14.33	19.95	47.76	62.58	66.90	74.55	100.00		

\* denotes values less than 0.01% - denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

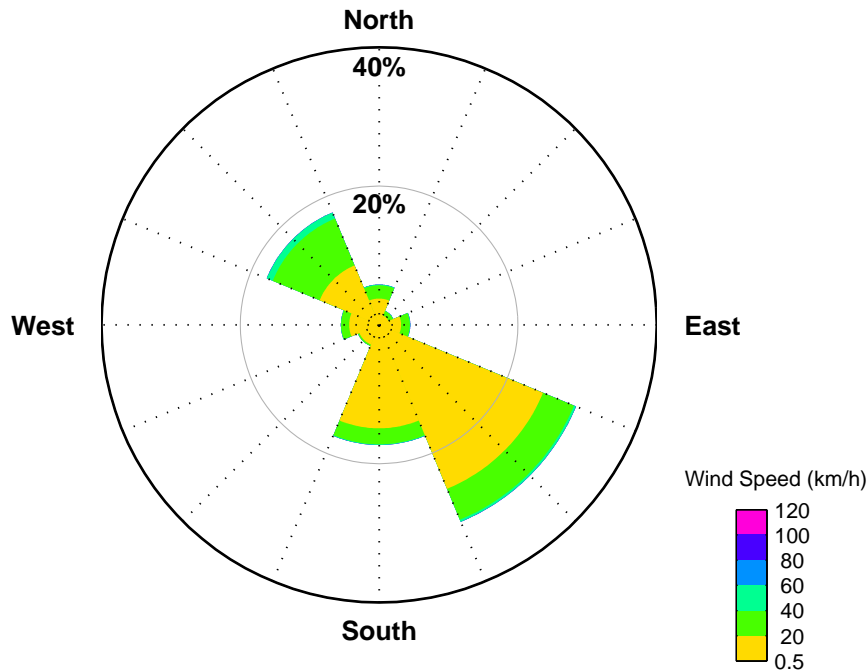
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Jun (01-Jun-1953 to 30-Jun-2009)  
 Data source: Environment Canada  
 Data summary: June  
 Number of Records: 41040  
 Calm (% < 0.5km/h): 8.28

#### Key Statistics:

Maximum Wind Speed: 72.00 km/h  
 Mean Wind Speed: 15.97 km/h  
 Std. Dev. Wind Speed: 11.19 km/h

## Wind Speed and Direction Rose for Iqaluit, July



### JFT (%) of Wind Speed against Direction for the month of Jul (1953 to 2009)

N=42408	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0-0.5 (Calm)</b>	–	–	–	–	–	–	–	–	13.13	100.00
<b>0.5-10</b>	1.49	0.52	1.60	13.83	8.86	2.00	2.76	3.23	34.29	86.87
<b>10-20</b>	2.30	0.94	1.56	11.75	6.05	1.07	1.56	6.04	31.27	52.58
<b>20-30</b>	1.45	0.49	0.93	3.66	1.74	0.20	0.83	4.89	14.19	21.31
<b>30-40</b>	0.45	0.21	0.33	1.16	0.56	0.01	0.32	2.44	5.48	7.12
<b>40-50</b>	0.11	0.04	0.06	0.26	0.07	*	0.04	0.78	1.35	1.64
<b>50-60</b>	*	*	*	0.04	0.03	–	*	0.15	0.25	0.29
<b>60-70</b>	–	–	*	0.01	*	–	–	0.01	0.03	0.05
<b>70-80</b>	–	–	–	*	*	–	–	–	0.01	0.01
<b>80-90</b>	–	–	–	–	–	–	–	–	–	–
<b>90-100</b>	–	–	–	–	–	–	–	–	–	–
<b>100-110</b>	–	–	–	–	–	–	–	–	–	–
<b>110-120</b>	–	–	–	–	–	–	–	–	–	–
<b>120-130</b>	–	–	–	–	–	–	–	–	–	–
<b>&gt;130</b>	–	–	–	–	–	–	–	–	–	–
<b>subTot.</b>	5.81	2.20	4.49	30.73	17.31	3.28	5.51	17.54		
<b>Total **</b>	7.45	3.84	6.13	32.37	18.95	4.92	7.15	19.18		
<b>Cumul.</b>	7.45	11.29	17.42	49.79	68.74	73.67	80.82	100.00		

\* denotes values less than 0.01% – denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

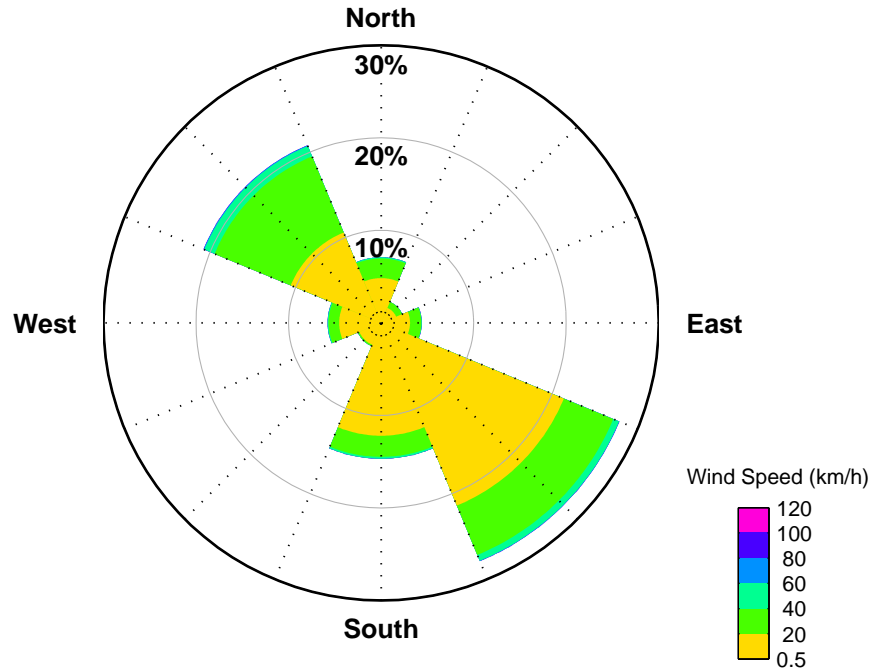
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Jul (01-Jul-1953 to 31-Jul-2009)  
 Data source: Environment Canada  
 Data summary: July  
 Number of Records: 42408  
 Calm (% < 0.5km/h): 13.13

#### Key Statistics:

Maximum Wind Speed: 80.00 km/h  
 Mean Wind Speed: 13.07 km/h  
 Std. Dev. Wind Speed: 10.41 km/h

## Wind Speed and Direction Rose for Iqaluit, August



### JFT (%) of Wind Speed against Direction for the month of Aug (1953 to 2009)

N=42120	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0-0.5 (Calm)</b>	-	-	-	-	-	-	-	-	14.15	100.00
<b>0.5-10</b>	2.03	0.65	1.66	11.76	7.42	1.65	2.75	3.76	31.68	85.85
<b>10-20</b>	2.82	1.10	1.47	9.63	4.79	0.89	1.78	6.83	29.31	54.16
<b>20-30</b>	1.61	0.56	0.93	4.17	1.74	0.13	0.83	5.78	15.74	24.85
<b>30-40</b>	0.51	0.14	0.29	1.62	0.55	0.03	0.32	3.13	6.59	9.11
<b>40-50</b>	0.11	0.01	0.04	0.54	0.14	*	0.08	1.04	1.98	2.52
<b>50-60</b>	0.02	-	*	0.14	0.05	-	0.02	0.17	0.40	0.54
<b>60-70</b>	*	-	*	0.03	*	-	*	0.07	0.12	0.14
<b>70-80</b>	-	-	-	*	-	-	-	0.01	0.02	0.02
<b>80-90</b>	-	-	-	-	-	-	-	*	*	*
<b>90-100</b>	-	-	-	-	-	-	-	-	-	-
<b>100-110</b>	-	-	-	-	-	-	-	-	-	-
<b>110-120</b>	-	-	-	-	-	-	-	-	-	-
<b>120-130</b>	-	-	-	-	-	-	-	-	-	-
<b>&gt;130</b>	-	-	-	-	-	-	-	-	-	-
<b>subTot.</b>	7.10	2.46	4.40	27.90	14.69	2.71	5.79	20.80		
<b>Total **</b>	8.87	4.23	6.17	29.67	16.46	4.48	7.56	22.57		
<b>Cumul.</b>	8.87	13.10	19.27	48.94	65.40	69.88	77.43	100.00		

\* denotes values less than 0.01% - denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

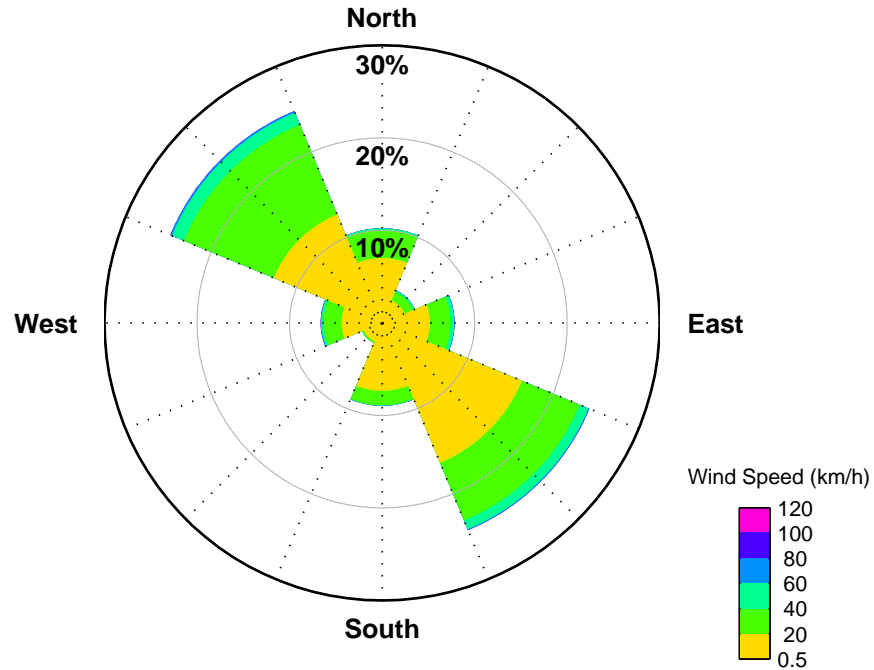
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Aug (01-Aug-1953 to 19-Aug-2009)  
 Data source: Environment Canada  
 Data summary: August  
 Number of Records: 42120  
 Calm (% < 0.5km/h): 14.15

#### Key Statistics:

Maximum Wind Speed: 90.00 km/h  
 Mean Wind Speed: 13.86 km/h  
 Std. Dev. Wind Speed: 11.32 km/h

## Wind Speed and Direction Rose for Iqaluit, September



### JFT (%) of Wind Speed against Direction for the month of Sep (1953 to 2008)

N=40320	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0-0.5 (Calm)</b>	-	-	-	-	-	-	-	-	11.16	100.00
<b>0.5-10</b>	2.97	1.09	2.32	7.76	4.25	1.40	2.30	4.23	26.32	88.84
<b>10-20</b>	4.04	1.52	2.87	8.60	3.09	0.72	2.08	8.45	31.37	62.51
<b>20-30</b>	2.36	0.69	1.56	4.57	1.13	0.15	1.28	6.81	18.54	31.15
<b>30-40</b>	0.69	0.32	0.66	2.18	0.43	0.04	0.67	3.71	8.70	12.61
<b>40-50</b>	0.15	0.10	0.27	0.82	0.05	*	0.20	1.07	2.67	3.91
<b>50-60</b>	0.02	0.08	0.11	0.22	0.01	-	0.05	0.32	0.81	1.24
<b>60-70</b>	*	0.01	0.04	0.07	*	-	0.03	0.10	0.27	0.42
<b>70-80</b>	-	-	*	0.02	-	-	0.02	0.07	0.12	0.15
<b>80-90</b>	-	-	-	-	-	-	*	0.01	0.02	0.03
<b>90-100</b>	-	-	-	*	-	-	-	*	*	*
<b>100-110</b>	-	-	-	-	-	-	-	-	-	-
<b>110-120</b>	-	-	-	-	-	-	-	-	-	-
<b>120-130</b>	-	-	-	-	-	-	-	-	-	-
<b>&gt;130</b>	-	-	-	-	-	-	-	-	-	-
<b>subTot.</b>	10.23	3.81	7.83	24.25	8.96	2.32	6.64	24.79		
<b>Total **</b>	11.63	5.21	9.22	25.65	10.35	3.72	8.04	26.19		
<b>Cumul.</b>	11.63	16.83	26.05	51.70	62.06	65.77	73.81	100.00		

\* denotes values less than 0.01% - denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

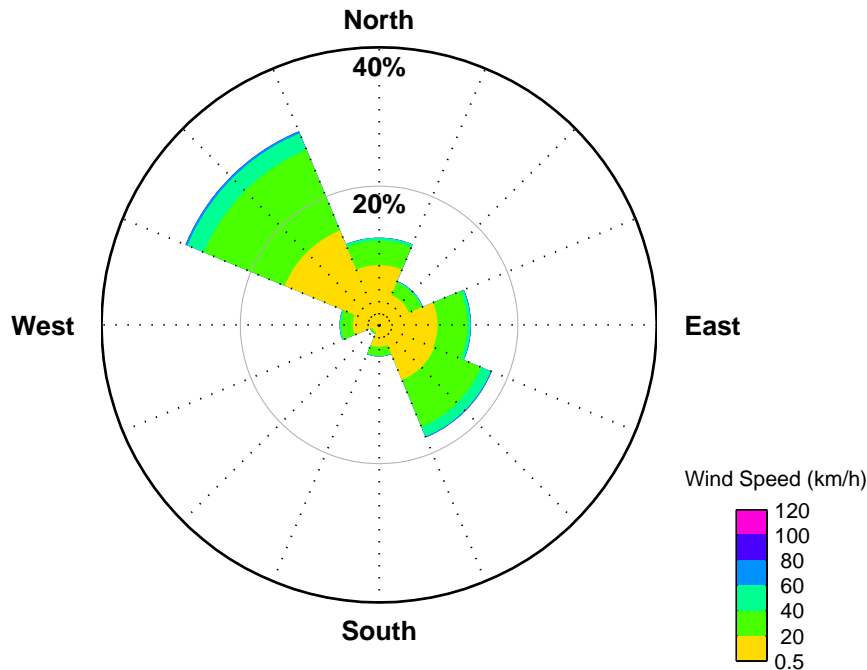
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Sep (01-Sep-1953 to 30-Sep-2008)  
 Data source: Environment Canada  
 Data summary: September  
 Number of Records: 40320  
 Calm (% < 0.5km/h): 11.16

#### Key Statistics:

Maximum Wind Speed: 97.00 km/h  
 Mean Wind Speed: 16.07 km/h  
 Std. Dev. Wind Speed: 12.30 km/h

## Wind Speed and Direction Rose for Iqaluit, October



### JFT (%) of Wind Speed against Direction for the month of Oct (1953 to 2008)

N=41664	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0–0.5 (Calm)</b>	–	–	–	–	–	–	–	–	7.91	100.00
<b>0.5–10</b>	4.42	1.82	3.17	3.10	1.57	0.54	1.95	5.63	22.20	92.09
<b>10–20</b>	4.20	2.83	5.24	5.50	1.58	0.54	1.84	9.12	30.84	69.89
<b>20–30</b>	2.51	1.37	3.08	4.48	0.86	0.23	1.10	7.45	21.07	39.05
<b>30–40</b>	1.01	0.57	1.25	2.84	0.43	0.07	0.58	5.12	11.87	17.98
<b>40–50</b>	0.31	0.14	0.33	1.20	0.09	0.02	0.17	1.95	4.22	6.11
<b>50–60</b>	0.10	0.06	0.11	0.31	0.02	*	0.04	0.64	1.28	1.89
<b>60–70</b>	0.02	0.04	0.05	0.11	0.01	*	0.01	0.22	0.46	0.61
<b>70–80</b>	–	–	0.02	0.02	–	–	*	0.08	0.12	0.14
<b>80–90</b>	–	–	–	*	–	–	–	*	0.01	0.02
<b>90–100</b>	–	–	–	–	–	–	–	*	*	*
<b>100–110</b>	–	–	–	–	–	–	–	*	*	*
<b>110–120</b>	–	–	–	–	–	–	–	–	–	–
<b>120–130</b>	–	–	–	–	–	–	–	–	–	–
<b>&gt;130</b>	–	–	–	–	–	–	–	–	–	–
<b>subTot.</b>	12.57	6.83	13.24	17.56	4.56	1.42	5.70	30.22		
<b>Total **</b>	13.56	7.82	14.23	18.55	5.55	2.41	6.68	31.21		
<b>Cumul.</b>	13.56	21.37	35.60	54.15	59.70	62.11	68.79	100.00		

\* denotes values less than 0.01% – denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

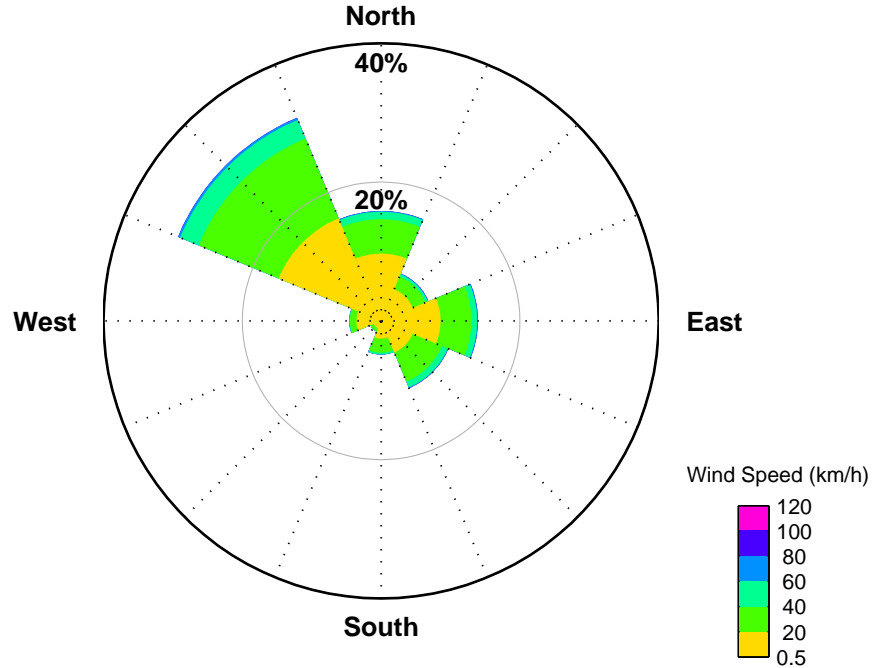
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Oct (01–Oct–1953 to 31–Oct–2008)  
 Data source: Environment Canada  
 Data summary: October  
 Number of Records: 41664  
 Calm (% < 0.5km/h): 7.91

#### Key Statistics:

Maximum Wind Speed: 104.00 km/h  
 Mean Wind Speed: 18.63 km/h  
 Std. Dev. Wind Speed: 13.04 km/h

## Wind Speed and Direction Rose for Iqaluit, November



### JFT (%) of Wind Speed against Direction for the month of Nov (1953 to 2008)

N=40320	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0-0.5 (Calm)</b>	-	-	-	-	-	-	-	-	9.52	100.00
<b>0.5-10</b>	5.39	2.20	3.24	1.73	0.91	0.47	2.16	7.03	23.13	90.48
<b>10-20</b>	4.30	2.73	5.32	3.18	1.66	0.68	1.40	8.96	28.24	67.35
<b>20-30</b>	2.94	1.46	3.18	2.75	1.35	0.36	0.61	7.32	19.99	39.11
<b>30-40</b>	2.02	0.52	1.28	1.80	0.66	0.11	0.32	5.15	11.87	19.12
<b>40-50</b>	0.80	0.26	0.58	0.69	0.21	0.04	0.09	2.28	4.96	7.25
<b>50-60</b>	0.27	0.11	0.24	0.21	0.05	*	0.02	0.61	1.51	2.29
<b>60-70</b>	0.10	0.08	0.10	0.08	*	-	*	0.25	0.64	0.78
<b>70-80</b>	0.02	*	0.02	0.01	*	-	-	0.07	0.13	0.15
<b>80-90</b>	-	*	-	-	-	-	-	*	0.01	0.01
<b>90-100</b>	-	-	*	-	-	-	-	-	*	*
<b>100-110</b>	-	-	-	-	-	-	-	-	-	-
<b>110-120</b>	-	-	-	-	-	-	-	-	-	-
<b>120-130</b>	-	-	-	-	-	-	-	-	-	-
<b>&gt;130</b>	-	-	-	-	-	-	-	-	-	-
<b>subTot.</b>	15.84	7.39	13.96	10.48	4.86	1.67	4.61	31.68		
<b>Total **</b>	17.03	8.58	15.15	11.67	6.05	2.86	5.80	32.87		
<b>Cumul.</b>	17.03	25.61	40.75	52.42	58.47	61.33	67.13	100.00		

\* denotes values less than 0.01% - denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

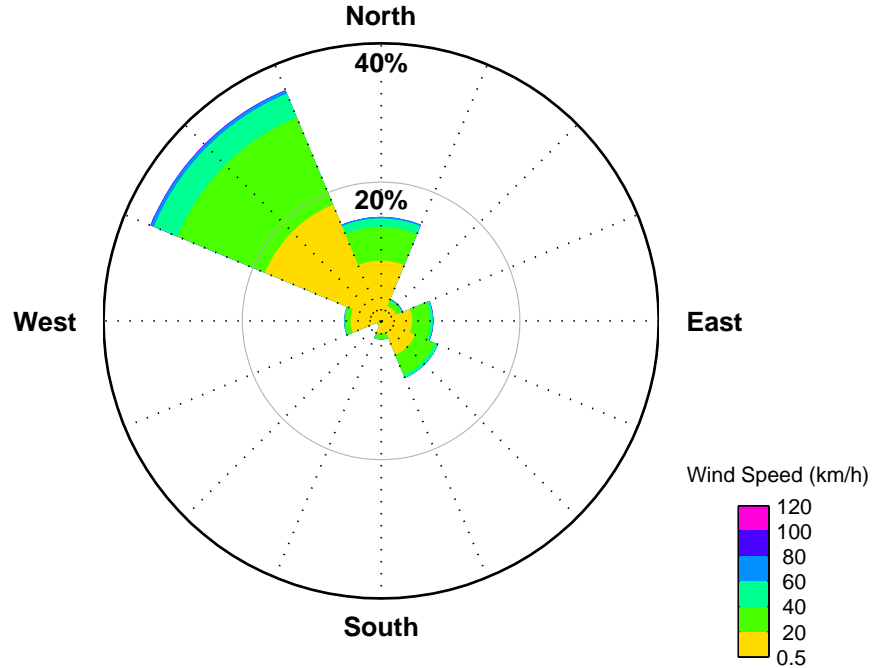
#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Nov (01-Nov-1953 to 30-Nov-2008)  
 Data source: Environment Canada  
 Data summary: November  
 Number of Records: 40320  
 Calm (% < 0.5km/h): 9.52

#### Key Statistics:

Maximum Wind Speed: 97.00 km/h  
 Mean Wind Speed: 18.58 km/h  
 Std. Dev. Wind Speed: 13.72 km/h

## Wind Speed and Direction Rose for Iqaluit, December



### JFT (%) of Wind Speed against Direction for the month of Dec (1953 to 2008)

N=41664	N	NE	E	SE	S	SW	W	NW	Total	Cumul.
<b>0-0.5 (Calm)</b>	-	-	-	-	-	-	-	-	20.45	100.00
<b>0.5-10</b>	5.09	1.36	2.22	2.28	1.03	0.34	3.11	9.14	24.57	79.55
<b>10-20</b>	3.60	0.94	2.24	3.01	0.82	0.20	1.30	8.99	21.10	54.98
<b>20-30</b>	2.89	0.54	1.75	2.08	0.50	0.12	0.54	7.97	16.39	33.88
<b>30-40</b>	1.97	0.30	0.88	1.06	0.22	0.02	0.22	5.67	10.35	17.49
<b>40-50</b>	0.86	0.10	0.27	0.37	0.05	*	0.11	2.86	4.64	7.14
<b>50-60</b>	0.37	0.06	0.10	0.08	0.04	*	0.02	0.83	1.51	2.50
<b>60-70</b>	0.14	0.05	0.04	0.02	*	-	0.01	0.42	0.68	0.99
<b>70-80</b>	0.06	0.03	0.02	*	-	-	*	0.07	0.19	0.31
<b>80-90</b>	*	0.02	0.02	-	-	-	-	0.04	0.09	0.12
<b>90-100</b>	-	-	-	-	-	-	-	0.01	0.01	0.03
<b>100-110</b>	*	-	-	-	-	-	-	*	*	0.01
<b>110-120</b>	-	-	-	-	-	-	-	*	*	*
<b>120-130</b>	-	-	-	-	-	-	-	-	-	-
<b>&gt;130</b>	-	-	-	-	-	-	-	-	-	-
<b>subTot.</b>	14.99	3.41	7.54	8.89	2.67	0.69	5.32	36.02		
<b>Total **</b>	17.55	5.97	10.10	11.45	5.23	3.25	7.88	38.58		
<b>Cumul.</b>	17.55	23.52	33.62	45.07	50.30	53.54	61.42	100.00		

\* denotes values less than 0.01% – denotes no records in bin

\*\* includes the calm winds which are evenly distributed amongst the directional bins

#### Metadata:

Project: 09120  
 Location: Iqaluit [68deg 33'W , 63deg 45'N]  
 Data period: Compiled Dec (01-Dec-1953 to 31-Dec-2008)  
 Data source: Environment Canada  
 Data summary: December  
 Number of Records: 41664  
 Calm (% < 0.5km/h): 20.45

#### Key Statistics:

Maximum Wind Speed: 111.00 km/h  
 Mean Wind Speed: 16.08 km/h  
 Std. Dev. Wind Speed: 14.98 km/h



GOVERNMENT OF NUNAVUT  
IQALUIT PORT DEVELOPMENT

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## Appendix B Iqaluit Port Calls

## Iqaluit Sailings - 2000 to 2008

Iqaluit - 2000  
63.45N 68.31W

			Group 1	Group 2	Group 3	Group 4	Group 5		
	Radio Yellowknife	1-Jan	8-Aug					Tug	Canada
	Des Groseilliers (CCGS)	13-Jul	16-Jul				3	CCG Icebreaker	Canada
	Anna Desgagnés	13-Jul	17-Jul	4				General cargo	Canada
	Umiavut	13-Jul	19-Jul	6				General cargo	Canada
	Havelstern	17-Jul	20-Jul		3			Tanker	Great Britain
	Arctic Viking	18-Jul	21-Jul	3				General cargo	Canada
	Lady Franklin	19-Jul	21-Jul	2				General cargo	Canada
	Pierre Radisson (CCGS)	20-Jul	23-Jul				3	CCG Icebreaker	Canada
	Aivik	22-Jul	23-Jul	1				General cargo	Canada
	Mokami	22-Jul	23-Jul		1			Tanker	Canada
	Shearwater	30-Jul	30-Jul			0.5		Passengers ship	Bahamas
	Travestern	1-Aug	5-Aug		4			Tanker	Great Britain
	Aivik	10-Aug	16-Aug	6				General cargo	Canada
	Weichselstern	11-Aug	15-Aug		4			Tanker	Great Britain
	Arctic Viking	13-Aug	15-Aug	2				General cargo	Canada
	Anna Desgagnés	15-Aug	22-Aug	7				General cargo	Canada
	Des Groseilliers (CCGS)	16-Aug	16-Aug				0.5	CCG Icebreaker	Canada
	Amélia Desgagnés	16-Aug	22-Aug	6				General cargo	Canada
	Havelstern	18-Aug	18-Aug		0.5			Tanker	Great Britain
	Lady Franklin	18-Aug	27-Aug	9				General cargo	Canada
	Cécilia Desgagnés	20-Aug	21-Aug	1				General cargo	Canada
	Le Levant	1-Sep	3-Sep			2		Passengers ship	France
	Nadon	9-Sep	11-Sep	2				Pleasure craft	Canada
	Simon Fraser (CCGS)	9-Sep	11-Sep				2	CCG Icebreaker	Canada
	Aivik	12-Sep	13-Sep	1				General cargo	Canada
	Umiavut	12-Sep	16-Sep	4				General cargo	Canada
	Arctic Viking	13-Sep	15-Sep	2				General cargo	Canada
	Des Groseilliers (CCGS)	25-Sep	30-Sep				5	CCG Icebreaker	Canada
	Cécilia Desgagnés	28-Sep	30-Sep	2				General cargo	Canada
	Aivik	1-Oct	7-Oct	6				General cargo	Canada
	Pierre Radisson (CCGS)	3-Oct	10-Oct				7	CCG Icebreaker	Canada
	Mokami	4-Oct	5-Oct		1			Tanker	Canada
	Henry Larsen (CCGS)	14-Oct	25-Oct				11	CCG Icebreaker	Canada
	Cécilia Desgagnés	16-Oct	24-Oct	8				General cargo	Canada
	Number of calls			1	17	6	2	7	
	Total days in port			2.00	70.00	13.50	2.50	31.50	
	Average days in port per vessel call			2.00	4.12	2.25	1.25	4.50	

Iqaluit - 2001  
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Pierre Radisson (CCGS)	3-Jul	7-Jul				4	CCG Icebreaker	Canada
Umiavut	3-Jul	7-Jul					General cargo	Canada
Pierre Radisson (CCGS)	9-Jul	12-Jul					CCG Icebreaker	Canada
Des Groseilliers (CCGS)	14-Jul	16-Jul					CCG Icebreaker	Canada
Anna Desgagnés	15-Jul	18-Jul				3	General cargo	Canada
Lady Franklin	20-Jul	22-Jul				2	General cargo	Canada
Des Groseilliers (CCGS)	21-Jul	23-Jul					CCG Icebreaker	Canada
Aivik	22-Jul	24-Jul				2	General cargo	Canada
Pierre Radisson (CCGS)	24-Jul	27-Jul					CCG Icebreaker	Canada
Sichem America	27-Jul	29-Jul				2	Tanker	Singapore
Mokami	27-Jul	30-Jul				3	Tanker	Canada
Pierre Radisson (CCGS)	31-Jul	31-Jul					CCG Icebreaker	Canada
Anna Desgagnés	1-Aug	2-Aug				1	General cargo	Canada
Kihu	5-Aug	9-Aug				4	Tanker	Finaldn
Aivik	14-Aug	15-Aug				1	General cargo	Canada
Sichem Asia	15-Aug	16-Aug				1	Tanker	Singapore
Kihu	16-Aug	19-Aug				3	Tanker	Finaldn
Lady Franklin	18-Aug	19-Aug				1	General cargo	Canada
Atlantic Birch	19-Aug	21-Aug	2				Tug	Canada
Anna Desgagnés	20-Aug	25-Aug				5	General cargo	Canada
Aivik	2-Sep	6-Sep				4	General cargo	Canada
Pierre Radisson (CCGS)	5-Sep	5-Sep					CCG Icebreaker	Canada
Sichem Asia	8-Sep	9-Sep				1	Tanker	Singapore
Des Groseilliers (CCGS)	24-Sep	29-Sep					CCG Icebreaker	Canada
Anna Desgagnés	25-Sep	26-Sep				1	General cargo	Canada
Jacques Desgagnés	25-Sep	27-Sep				2	General cargo	Canada
Terry Fox (CCGS)	29-Sep	5-Oct					CCG Icebreaker	Canada
Aivik	30-Sep	1-Oct				1	General cargo	Canada
Mathilda Desgagnés	3-Oct	5-Oct				2	General cargo	Canada
Henry Larsen (CCGS)	7-Oct	22-Oct					CCG Icebreaker	Canada
Mokami	11-Oct	12-Oct				1	Tanker	Canada
Anna Desgagnés	12-Oct	21-Oct				9	General cargo	Canada
Aivik	18-Oct	23-Oct				5	General cargo	Canada
		Number of calls	1	15	7	0	10	
		Total days in port	2.00	43.00	15.00	0.00	41.00	
		Average days in port per vessel call	2.00	2.87	2.14	#DIV/0!	4.10	

Iqaluit - 2002  
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Pierre Radisson (CCGS)	3-Jul	4-Jul				1	CCG Icebreaker	Canada
Mokami	9-Jul	10-Jul		1			Tanker	Canada
Pierre Radisson (CCGS)	9-Jul	10-Jul				1	CCG Icebreaker	Canada
Anna Desgagnés	9-Jul	13-Jul	4				General cargo	Canada
Terry Fox (CCGS)	11-Jul	13-Jul				2	CCG Icebreaker	Canada
Umiavut	11-Jul	13-Jul	2				General cargo	Canada
Lady Franklin	14-Jul	18-Jul	4				General cargo	Canada
Henry Larasen (CCGS)	15-Jul	17-Jul				2	CCG Icebreaker	Canada
Des Groseilliers (CCGS)	16-Jul	18-Jul				2	CCG Icebreaker	Canada
Mathilda Desgagnés	28-Jul	28-Jul	0.5				General cargo	Canada
Umiavut	31-Jul	1-Aug	1				General cargo	Canada
Goose Bay (HMCS)	1-Aug	3-Aug				2	Navy vessel	Canada
Golova	5-Aug	9-Aug		4			Tanker	Turkey
Torill Knutsen	7-Aug	10-Aug		3			Tanker	Norway
Aivik	8-Aug	9-Aug	1				General cargo	Canada
Henry Larasen (CCGS)	12-Aug	15-Aug				3	CCG Icebreaker	Canada
Des Groseilliers (CCGS)	13-Aug	15-Aug				2	CCG Icebreaker	Canada
Mathilda Desgagnés	15-Aug	18-Aug	3				General cargo	Canada
Ellen Knutsen	16-Aug	19-Aug		3			Tanker	Canada
Lady Franklin	22-Aug	23-Aug	1				General cargo	Canada
Umiavut	26-Aug	26-Aug	0.5				General cargo	Canada
Aivik	27-Aug	30-Aug	3				General cargo	Canada
Golova	27-Aug	30-Aug		3			Tanker	Turkey
Jacques Desgagnés	30-Aug	1-Sep	2				General cargo	Canada
Cécilia Desgagnés	4-Sep	6-Sep	2				General cargo	Canada
Umiavut	17-Sep	21-Sep	4				General cargo	Canada
Mathilda Desgagnés	21-Sep	26-Sep	5				General cargo	Canada
Mokami	22-Sep	26-Sep		4			Tanker	Canada
Henry Larasen (CCGS)	23-Sep	28-Sep				5	CCG Icebreaker	Canada
Aivik	1-Oct	1-Oct	0.5				General cargo	Canada
Terry Fox (CCGS)	3-Oct	3-Oct				0.5	CCG Icebreaker	Canada
Anna Desgagnés	13-Oct	18-Oct	5				General cargo	Canada
Aivik	20-Oct	25-Oct	5				General cargo	Canada
Umiavut	21-Oct	24-Oct	3				General cargo	Canada
Henry Larasen (CCGS)	25-Oct	26-Oct				1	CCG Icebreaker	Canada
			Number of calls	0	18	6	0	11
			Total days in port	0.00	46.50	18.00	0.00	21.50
			Average days in port per vessel call	#DIV/0!	2.58	3.00	#DIV/0!	1.95

Iqaluit - 2003  
63.45N 68.31W

Tuvaq	26-Jun	30-Jun			4		Tanker	Canada
Umiavut	30-Jun	8-Jul	8				General cargo	Canada
Des Groseilliers (CCGS)	2-Jul	5-Jul				3	CCG Icebreaker	Canada
Anna Desgagnés	7-Jul	11-Jul	4				General cargo	Canada
Des Groseilliers (CCGS)	12-Jul	12-Jul				0.5	CCG Icebreaker	Canada
Henry Larsen (CCGS)	12-Jul	15-Jul				3	CCG Icebreaker	Canada
Tuvaq	12-Jul	15-Jul			3		Tanker	Canada
Des Groseilliers (CCGS)	15-Jul	16-Jul				1	CCG Icebreaker	Canada
Cécilia Desgagnés	21-Jul	21-Jul	0.5				General cargo	Canada
Le Levant	22-Jul	22-Jul			0.5		Passengers ship	France
Louis S. St. Laurent (CCGS)	23-Jul	31-Jul				8	CCG Icebreaker	Canada
Atlantic Patroller	27-Jul	27-Jul	0.5				General cargo	Cyprus
Terry Fox (CCGS)	31-Jul	3-Aug				3	CCG Icebreaker	Canada
Aivik	6-Aug	7-Aug	1				General cargo	Canada
Henry Larsen (CCGS)	10-Aug	17-Aug				7	CCG Icebreaker	Canada
Cécilia Desgagnés	12-Aug	14-Aug	2				General cargo	Canada
Tuvaq	13-Aug	14-Aug			1		Tanker	Canada
Anna Desgagnés	19-Aug	22-Aug	3				General cargo	Canada
Des Groseilliers (CCGS)	22-Aug	28-Aug				6	CCG Icebreaker	Canada
Jacques Desgagnés	25-Aug	27-Aug	2				General cargo	Canada
Aivik	26-Aug	29-Aug	3				General cargo	Canada
Des Groseilliers (CCGS)	30-Aug	31-Aug				1	CCG Icebreaker	Canada
Jacques Desgagnés	30-Aug	5-Sep	6				General cargo	Canada
Akademik Ioffe	3-Sep	4-Sep			1		Passengers ship	Russia
Atlantic Teak	3-Sep	8-Sep	5				Tug	Canada
Anna Desgagnés	18-Sep	19-Sep	1				General cargo	Canada
Henry Larsen (CCGS)	22-Sep	23-Sep				1	CCG Icebreaker	Canada
Amélia Desgagnés	22-Sep	26-Sep	4				General cargo	Canada
Aivik	30-Sep	1-Oct	1				General cargo	Canada
Pierre Radisson (CCGS)	1-Oct	14-Oct				13	CCG Icebreaker	Canada
Captain Hatteras	1-Oct	17-Nov	47				Pleasure craft	Unknown
Henry Larsen (CCGS)	5-Oct	6-Oct				1	CCG Icebreaker	Canada
Anna Desgagnés	6-Oct	10-Oct	4				General cargo	Canada
Terry Fox (CCGS)	7-Oct	25-Oct				18	CCG Icebreaker	Canada
Umiavut	9-Oct	22-Oct	13				General cargo	Canada
Amélia Desgagnés	10-Oct	12-Oct	2				General cargo	Canada
Reliance	15-Oct	21-Oct	6				Tug	Canada
Aivik	24-Oct	28-Oct	4				General cargo	Canada
Louis S. St. Laurent (CCGS)	27-Oct	28-Oct				1	CCG Icebreaker	Canada
Tuvaq	29-Oct	31-Oct			2		Tanker	Canada
Cécilia Desgagnés	7-Nov	8-Nov	1				General cargo	Canada
Tuvaq	13-Nov	15-Nov			2		Tanker	Canada
Aivik	16-Nov	17-Nov	1				General cargo	Canada
		Number of calls	3	19	5	2	14	
		Total days in port	58.00	61.00	12.00	1.50	66.50	
		Average days in port per vessel call	19.33	3.21	2.40	0.75	4.75	

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Pierre Radisson (CCGS)	28-Jun	29-Jun				1	CCG Icebreaker	Canada
Umiavut	4-Jul	11-Jul	7				General cargo	Canada
Tuvaq	6-Jul	8-Jul		2			Tanker	Canada
Anna Desgagnés	7-Jul	11-Jul	4				General cargo	Canada
Henry Larsen (CCGS)	8-Jul	9-Jul				1	CCG Icebreaker	Canada
Kaliutik	12-Jul	12-Jul	0.5				Tug	Canada
Pierre Radisson (CCGS)	15-Jul	18-Jul				3	CCG Icebreaker	Canada
Adakemik Ioffe	20-Jul	20-Jul			0.5		Passengers ship	Russia
Mathilda Desgagnés	20-Jul	22-Jul	2				General cargo	Canada
Pierre Radisson (CCGS)	20-Jul	22-Jul				2	CCG Icebreaker	Canada
Tuvaq	31-Jul	2-Aug		2			Tanker	Canada
Aivik	2-Aug	3-Aug	1				General cargo	Canada
Le Levant	4-Aug	5-Aug			1		Passengers ship	France
Henry Larsen (CCGS)	10-Aug	15-Aug				5	CCG Icebreaker	Canada
Anna Desgagnés	18-Aug	22-Aug	4				General cargo	Canada
Assent	24-Aug	24-Aug			0.5		Passengers ship	Great Britain
Clipper Adventurer	24-Aug	24-Aug			0.5		Passengers ship	Bahamas
Aivik	24-Aug	25-Aug	1				General cargo	Canada
Akademik Ioffe	12-Sep	12-Sep			0.5		Passengers ship	Russia
Cécilia Desgagnés	13-Sep	15-Sep	2				General cargo	Canada
Anna Desgagnés	15-Sep	16-Sep	1				General cargo	Canada
Henry Larsen (CCGS)	19-Sep	25-Sep				6	CCG Icebreaker	Canada
Aivik	20-Sep	20-Sep	0.5				General cargo	Canada
Umiavut	26-Sep	5-Oct	9				General cargo	Canada
Aivik	6-Oct	10-Oct	4				General cargo	Canada
Anna Desgagnés	10-Oct	21-Oct	11				General cargo	Canada
Henry Larsen (CCGS)	19-Oct	21-Oct				2	CCG Icebreaker	Canada
Arctic	21-Nov	2-Dec		11			Bulk carrier	Canada
Tuvaq	23-Nov	1-Dec		8			Tanker	Canada
		Number of calls	1	12	4	5	7	
		Total days in port	0.50	46.50	23.00	3.00	20.00	
		Average days in port per vessel call	0.50	3.88	5.75	0.60	2.86	

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Tuvaq	29-Jun	30-Jun			1	Tanker	Canada	
Terry Fox (CCGS)	2-Jul	13-Jul				11	CCG Icebreaker	Canada
Umiavut	3-Jul	8-Jul	5				General cargo	Canada
Dorsch	6-Jul	7-Jul			1		Tanker	Canada
Anna Desgagnés	6-Jul	14-Jul	8				General cargo	Canada
Des Groseilliers (CCGS)	7-Jul	12-Jul				5	CCG Icebreaker	Canada
Aivik	9-Jul	12-Jul	3				General cargo	Canada
Henry Larsen (CCGS)	10-Jul	10-Jul				0.5	CCG Icebreaker	Canada
Pierre Radisson (CCGS)	10-Jul	12-Jul				2	CCG Icebreaker	Canada
Tuvaq	11-Jul	15-Jul			4		Tanker	Canada
Mathilda Desgagnés	13-Jul	14-Jul	1				General cargo	Canada
Hudson Bay Explorer	15-Jul	16-Jul	1				Tug	Canada
Akademik Ioffe	21-Jul	23-Jul				2	Passengers ship	Russia
Camilla Desgagnés	24-Jul	26-Jul	2				General cargo	Canada
Mathilda Desgagnés	26-Jul	26-Jul	0.5				General cargo	Canada
Terry Fox (CCGS)	26-Jul	3-Aug				8	CCG Icebreaker	Canada
Cécilia Desgagnés	31-Jul	31-Jul	0.5				General cargo	Canada
Tuvaq	31-Jul	2-Aug			2		Tanker	Canada
Pierre Radisson (CCGS)	31-Jul	3-Aug				3	CCG Icebreaker	Canada
Anna Desgagnés	2-Aug	3-Aug	1				General cargo	Canada
Explorer	5-Aug	5-Aug				0.5	Passengers ship	Liberia
Henry Larsen (CCGS)	7-Aug	14-Aug				7	CCG Icebreaker	Canada
Anna Desgagnés	18-Aug	23-Aug	5				General cargo	Canada
Aivik	26-Aug	30-Aug	4				General cargo	Canada
Clipper Adventurer	8-Sep	8-Sep				0.5	Passengers ship	Bahamas
Umiavut	11-Sep	12-Sep	1				General cargo	Canada
Anna Desgagnés	13-Sep	13-Sep	0.5				General cargo	Canada
Polar Star	15-Sep	15-Sep				0.5	Passengers ship	Barbados
Henry Larsen (CCGS)	19-Sep	14-Oct				25	CCG Icebreaker	Canada
Aivik	20-Sep	21-Sep	1				General cargo	Canada
Anna Desgagnés	29-Sep	8-Oct	9				General cargo	Canada
Umiavut	30-Sep	9-Oct	9				General cargo	Canada
Oujukoaq	2-Oct	2-Oct	0.5				Fishing vessel	Canada
Pierre Radisson (CCGS)	2-Oct	5-Oct				3	CCG Icebreaker	Canada
Terry Fox (CCGS)	3-Oct	15-Oct				12	CCG Icebreaker	Canada
Aivik	8-Oct	9-Oct	1				General cargo	Canada
Cécilia Desgagnés	8-Oct	10-Oct	2				General cargo	Canada
Tuvaq	13-Oct	16-Oct			3		Tanker	Canada
Louis S. St. Laurent (CCGS)	18-Oct	21-Oct				3	CCG Icebreaker	Canada
Anna Desgagnés	21-Oct	22-Oct	1				General cargo	Canada
Louis S. St. Laurent (CCGS)	24-Oct	24-Oct				0.5	CCG Icebreaker	Canada
Tuvaq	28-Oct	30-Oct			2		Tanker	Canada
Louis S. St. Laurent (CCGS)	1-Nov	12-Nov				11	CCG Icebreaker	Canada
Tuvaq	12-Nov	12-Nov			0.5		Tanker	Canada
		Number of calls	2	18	7	4	13	
		Total days in port	1.50	54.50	13.50	3.50	91.00	
		Average days in port per vessel call	0.75	3.03	1.93	0.88	7.00	

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Terry Fox (CCGS)	1-Jul	5-Jul				4	CCG Icebreaker	Canada
Umiavut	3-Jul	10-Jul	7				General cargo	Canada
Pierre Radisson (CCGS)	4-Jul	9-Jul				5	CCG Icebreaker	Canada
Anna Desgagnés	7-Jul	13-Jul	6				General cargo	Canada
Terry Fox (CCGS)	9-Jul	12-Jul				3	CCG Icebreaker	Canada
Tuvaq	11-Jul	13-Jul		2			Tanker	Canada
Dorsch	14-Jul	16-Jul		2			Tanker	Canada
Henry Larsen (CCGS)	14-Jul	18-Jul				4	CCG Icebreaker	Canada
Akademik Ioffe	21-Jul	22-Jul			1		Passengers ship	Russia
Saint-Oran	21-Jul	23-Jul	2				General cargo	Canada
Tuvaq	25-Jul	26-Jul		1			Tanker	Canada
Clipper Adventurer	26-Jul	26-Jul			0.5		Passengers ship	Bahamas
Terry Fox (CCGS)	27-Jul	28-Jul				1	CCG Icebreaker	Canada
Aivik	28-Jul	29-Jul	1				General cargo	Canada
Pierre Radisson (CCGS)	31-Jul	2-Aug				2	CCG Icebreaker	Canada
Mathilda Desgagnés	2-Aug	4-Aug	2				General cargo	Canada
Camilla Desgagnés	5-Aug	5-Aug	0.5				General cargo	Canada
Cécilia Desgagnés	5-Aug	5-Aug	0.5				General cargo	Canada
Lyubov Orlova	12-Aug	13-Aug			1		Passengers ship	Malta
Jade Star	17-Aug	20-Aug		3			Tanker	Canada
Aivik	18-Aug	21-Aug	3				General cargo	Canada
Camilla Desgagnés	22-Aug	23-Aug	1				General cargo	Canada
Cécilia Desgagnés	23-Aug	24-Aug	1				General cargo	Canada
Aivik	5-Sep	8-Sep	3				General cargo	Canada
Umiavut	6-Sep	6-Sep	0.5				General cargo	Canada
Explorer	9-Sep	9-Sep			0.5		Passengers ship	Monrovia
Polar Star	9-Sep	9-Sep			0.5		Passengers ship	Barbados
Anna Desgagnés	13-Sep	14-Sep	1				General cargo	Canada
Akademik Ioffe	18-Sep	19-Sep			1		Passengers ship	Russia
Aivik	18-Sep	19-Sep	1				General cargo	Canada
Henry Larsen (CCGS)	19-Sep	4-Oct				15	CCG Icebreaker	Canada
Umiavut	24-Sep	29-Sep	5				General cargo	Canada
Kaliutik	30-Sep	8-Oct	8				Tug	Canada
Anna Desgagnés	1-Oct	5-Oct	4				General cargo	Canada
Terry Fox (CCGS)	3-Oct	7-Oct				4	CCG Icebreaker	Canada
Amundsen (CCGS)	4-Oct	11-Oct				7	CCG Icebreaker	Canada
Camilla Desgagnés	5-Oct	8-Oct	3				General cargo	Canada
Ocean Foxtrop	5-Oct	8-Oct	3				Tug	Canada
Mathilda Desgagnés	6-Oct	9-Oct	3				General cargo	Canada
Aivik	7-Oct	10-Oct	3				General cargo	Canada
Louis S. St. Laurent (CCGS)	18-Oct	10-Nov				23	CCG Icebreaker	Canada
Tuvaq	20-Oct	23-Oct		3			Tanker	Canada
Cécilia Desgagnés	21-Oct	21-Oct	0.5				General cargo	Canada
Mathilda Desgagnés	24-Oct	25-Oct	1				General cargo	Canada
Cécilia Desgagnés	27-Oct	28-Oct	1				General cargo	Canada
Amundsen (CCGS)	29-Oct	30-Oct				1	CCG Icebreaker	Canada
Tuvaq	4-Nov	6-Nov		2			Tanker	Canada
Anna Desgagnés	6-Nov	7-Nov	1				General cargo	Canada
Aivik	15-Nov	15-Nov	0.5				General cargo	Canada
		Number of calls	2	24	6	6	11	
		Total days in port	11.00	51.50	13.00	4.50	69.00	
		Average days in port per vessel call	5.50	2.15	2.17	0.75	6.27	

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Aurora Magnetica	1-Oct	25-Jul						Research vessel	Scotland
Des Groseilliers (CCGS)	3-Jul	6-Jul					3	CCG Icebreaker	Canada
Dorsch	4-Jul	7-Jul			3			Tanker	Canada
Anna Desgagnés	4-Jul	18-Jul	14					General cargo	Canada
Umiavut	5-Jul	19-Jul	14					General cargo	Canada
Terry Fox (CCGS)	8-Jul	8-Jul					0.5	CCG Icebreaker	Canada
Tuvaq	10-Jul	12-Jul			2			Tanker	Canada
Henry Larsen (CCGS)	10-Jul	13-Jul					3	CCG Icebreaker	Canada
Des Groseilliers (CCGS)	13-Jul	15-Jul					2	CCG Icebreaker	Canada
Henry Larsen (CCGS)	16-Jul	16-Jul					0.5	CCG Icebreaker	Canada
Lyubov Orlova	18-Jul	18-Jul				0.5		Passengers ship	Malta
Martha L. Black (CCGS)	24-Jul	27-Jul					3	CCG Icebreaker	Canada
Terry Fox (CCGS)	25-Jul	27-Jul					2	CCG Icebreaker	Canada
Camilla Desgagnés	28-Jul	28-Jul	0.5					General cargo	Canada
Beluga Efficiency	30-Jul	3-Aug	4					General cargo	Antigua and Barb
Tuvaq	31-Jul	2-Aug			2			Tanker	Canada
Anna Desgagnés	2-Aug	2-Aug	0.5					General cargo	Canada
Saint-Oran	2-Aug	5-Aug	3					General cargo	Canada
Aivik	6-Aug	7-Aug	1					General cargo	Canada
Terry Fox (CCGS)	8-Aug	8-Aug					0.5	CCG Icebreaker	Canada
Martha L. Black (CCGS)	10-Aug	11-Aug					1	CCG Icebreaker	Canada
Lyubov Orlova	15-Aug	16-Aug				1		Passengers ship	Malta
Camilla Desgagnés	16-Aug	19-Aug	3					General cargo	Canada
Martha L. Black (CCGS)	16-Aug	24-Aug					8	CCG Icebreaker	Canada
Aivik	27-Aug	31-Aug	4					General cargo	Canada
Cécilia Desgagnés	2-Sep	3-Sep	1					General cargo	Canada
Acadia	7-Sep	7-Sep	0.5					Pleasure craft (yacht)	Cayman Islands
Amundsen (CCGS)	9-Sep	11-Sep					2	CCG Icebreaker	Canada
Explorer	12-Sep	12-Sep				0.5		Passengers ship	Liberia
Avataq	16-Sep	17-Sep	1					General cargo	Canada
Anna Desgagnés	16-Sep	18-Sep	2					General cargo	Canada
Henry Larsen (CCGS)	16-Sep	3-Oct					17	CCG Icebreaker	Canada
Akademik Ioffe	17-Sep	17-Sep				0.5		Passengers ship	Russia
Ocean Nova	17-Sep	17-Sep				0.5		Passengers ship	Bahamas
Dorsch	21-Sep	22-Sep			1			Tanker	Canada
Cécilia Desgagnés	23-Sep	24-Sep	1					General cargo	Canada
Aivik	26-Sep	28-Sep	2					General cargo	Canada
Terry Fox (CCGS)	29-Sep	5-Oct					6	CCG Icebreaker	Canada
Kaliutik	29-Sep	15-Oct	16					Tug	Canada
Avataq	4-Oct	9-Oct	5					General cargo	Canada
Des Groseilliers (CCGS)	7-Oct	12-Oct					5	CCG Icebreaker	Canada
Anna Desgagnés	7-Oct	15-Oct	8					General cargo	Canada
Cécilia Desgagnés	13-Oct	15-Oct	2					General cargo	Canada
Aivik	21-Oct	26-Oct	5					General cargo	Canada
Louis S. St. Laurent (CCGS)	24-Oct	9-Nov					16	CCG Icebreaker	Canada
Anna Desgagnés	26-Oct	29-Oct	3					General cargo	Canada
Avataq	30-Oct	1-Nov	2					General cargo	Canada
Tuvaq	1-Nov	3-Nov			2			Tanker	Canada
Dorsch	20-Nov	22-Nov			2			Tanker	Canada
		Number of calls	2	20	6	5	15		
		Total days in port	16.50	76.00	12.00	3.00	69.50		
		Average days in port per vessel call	8.25	3.80	2.00	0.60	4.63		

Iqaluit - 2008  
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Aurora Magnetica	1-Oct-07	25-Jul				Research vessel	Scotland
Tuvaq	30-Jun	7-Jul		7		Tanker	Canada
Rosaire A. Desgagnés	6-Jul	19-Jul	13			General cargo	Canada
Mokami	9-Jul	10-Jul		1		Tanker	Canada
Pierre Radisson (CCGS)	9-Jul	12-Jul			3	CCG Icebreaker	Canada
Umiavut	9-Jul	13-Jul	4			General cargo	Canada
Umiavut	9-Oct	14-Oct	5			General cargo	Canada
Terry Fox (CCGS)	9-Jul	24-Jul			15	CCG Icebreaker	Canada
Henry Larsen (CCGS)	14-Jul	18-Jul			4	CCG Icebreaker	Canada
Tuvaq	20-Jul	21-Jul		1		Tanker	Canada
Akademik Ioffe	21-Jul	23-Jul			2	Passengers ship	Russia
Qamutik	25-Jul	4-Aug	10			General cargo	Canada
Pierre Radisson (CCGS)	29-Jul	31-Jul			2	CCG Icebreaker	Canada
Geraldine	29-Jul	1-Aug	3			Pleasure craft (yacht)	U.S.A.
Dorsch	30-Jul	30-Jul		0.5		Tanker	Canada
Alexander Von Humboldt	31-Jul	1-Aug			1	Passengers ship	Bahamas
Camilla Desgagnés	1-Aug	1-Aug	0.5			General cargo	Canada
Bremen	2-Aug	3-Aug			1	Passengers ship	Bahamas
Lyubov Orlova	4-Aug	4-Aug			0.5	Passengers ship	Malta
Prince Albert II	7-Aug	7-Aug			0.5	Passengers ship	Bahamas
Aivik	8-Aug	10-Aug	2			General cargo	Canada
Beluga Enterprise	8-Aug	11-Aug	3			General cargo	Antigua and Barb
Dutch Runner	11-Aug	15-Aug	4			General cargo	Canada
Kapitan Khlebnikov	12-Aug	12-Aug			0.5	Passengers ship	Russia
Lyubov Orlova	16-Aug	16-Aug			0.5	Passengers ship	Malta
Pierre Radisson (CCGS)	16-Aug	30-Aug			14	CCG Icebreaker	Canada
Toronto (HMCS)	18-Aug	25-Aug			7	Navy vessel	Canada
Camilla Desgagnés	18-Aug	20-Aug	2			General cargo	Canada
Shawinnigan (HMCS)	19-Aug	25-Aug			6	Navy vessel	Canada
National Geographic Explorer	30-Aug	31-Aug			1	Passengers ship	Bahamas
Aivik	5-Sep	8-Sep	3			General cargo	Canada
Pierre Radisson (CCGS)	6-Sep	11-Sep			5	CCG Icebreaker	Canada
Kapitan Khlebnikov	10-Sep	10-Sep			0.5	Passengers ship	Russia
Anna Desgagnés	13-Sep	16-Sep	3			General cargo	Canada
Beluga Enterprise	15-Sep	15-Sep	0.5			General cargo	Antigua and Barb
Qamutik	15-Sep	26-Sep	11			General cargo	Canada
Umiavut	17-Sep	17-Sep	0.5			General cargo	Canada
Ocean Nova	18-Sep	18-Sep			0.5	Passengers ship	Bahamas
Polar Star	19-Sep	19-Sep			0.5	Passengers ship	Barbados
Akademik Shokalskiy	20-Sep	20-Sep			0.5	Passengers ship	Russia
Pierre Radisson (CCGS)	21-Sep	23-Sep			2	CCG Icebreaker	Canada
Kaliutik	23-Sep	11-Oct	18			Tug	Canada
Lyubov Orlova	24-Sep	24-Sep			0.5	Passengers ship	Malta
Umiavut	28-Sep	6-Oct	8			General cargo	Canada
Akademik Ioffe	30-Sep	30-Sep			0.5	Passengers ship	Russia
Avataq	1-Oct	7-Oct	6			General cargo	Canada
Amundsen (CCGS)	3-Oct	3-Oct			0.5	CCG Icebreaker	Canada
Anna Desgagnés	5-Oct	11-Oct	6			General cargo	Canada
Des Groseilliers (CCGS)	10-Oct	10-Oct			0.5	CCG Icebreaker	Canada
Camilla Desgagnés	26-Oct	28-Oct	2			General cargo	Canada
Tuvaq	27-Oct	29-Oct		2		Tanker	Canada
Louis S. St. Laurent (CCGS)	2-Nov	5-Nov			3	CCG Icebreaker	Canada
Louis S. St. Laurent (CCGS)	11-Nov	14-Nov			3	CCG Icebreaker	Canada
Tuvaq	12-Nov	15-Nov		3		Tanker	Canada
Dorsch	15-Nov	17-Nov		2		Tanker	Canada
			2	18	7		
	Number of calls						
	Total days in port	21.00	83.50	16.50	10.00	65.00	
	Average days in port per vessel call	10.50	4.64	2.36	0.71	5.00	



GOVERNMENT OF NUNAVUT  
IQALUIT PORT DEVELOPMENT

---

## Appendix C Geotechnical Desktop Study



**Stantec**

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**GEOTECHNICAL DESK STUDY  
Proposed Marine Development  
Iqaluit**

Standing Offer for the Arctic Region  
Environmental Geophysical and  
Geotechnical Services

Report Prepared for:  
Department of Economic  
Development and Transportation  
Government of Nunavut  
Gjoa Haven, NU

File: 121611767

May 26, 2010

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- Appendix B Final Report Iqaluit Survey FJGI Doc. No. 9083SMN-001-RPT-002 Rev.0 Fugro Jacques Geosurveys Inc. March 19, 2010
- Appendix C Worley Parsons Westmar Preliminary Drawings Iqaluit Port Development. Drawing Numbers 100P1, 101P2, 101AP2, 102P2, 102AP2, 103P2, 103AP2, 104P2, 104AP, 105P2, 105AP1, 106P2, 107P2, 108P1, 108AP1, 109P1, 110P1, 111P1
- Appendix D Photographs of the Breakwater Site Option 3

## 1.0 Introduction

---

In response to your approval to proceed, Nunami Jacques Whitford Limited has carried out a geotechnical desk study of the proposed marine port docking facility for Iqaluit, Nunavut. The work was performed in accordance with the existing agreement between Nunami Jacques Whitford Limited and the Government of Nunavut.

The scope of work consisted of a review of previous investigations to infer geotechnical properties for use in foundation and stability analysis of the proposed deep sea and small craft harbor wharf structures. Our findings and recommendations are presented in this report.

Worley Parsons (WP) has considered five options for the proposed port development. These options are detailed on conceptual drawings in Appendix C. Four sites have been considered for deep sea wharf structures as shown on Worley Parsons Drawing SK100. The deep sea wharfs would consist of either sheet pile cells or concrete caissons as illustrated on Worley Parsons Drawings SK106 and SK107. A fifth option would consist of a small craft dock at Site 3 (WP) SK108 where there is an existing causeway which becomes submerged at high tide.

At present, Options 4 and 5, illustrated on (WP) Drawings SK104 and SK108 respectively, are preferred.

## 2.0 Review of Existing Information

---

The initial phase of the work included a review of existing technical reports, photos and drawings of 4 sites for 5 design options. This information was provided to us by Worley Parsons and included the following documents:

- (1) Report to The St. Lawrence Seaway Authority on Subsurface Investigation Frobisher Bay Dock Study Geocon Ltd. June 30, 1975 (Appendix A).
- (2) Final Report Iqaluit Survey FJGI Doc. No. 9083SMN-001-RPT-002 Rev.0 Fugro Jacques Geosurveys Inc. March 19, 2010 (Appendix B).
- (3) Worley Parsons Westmar Preliminary Drawings Iqaluit Port Development. Drawing Numbers 100P1, 101P2, 101AP2, 102P2, 102AP2, 103P2, 103AP2, 104P2, 104AP, 105P2, 105AP1, 106P2, 107P2 108P1, 108AP1, 109P1, 110P1, 111P1 (Appendix C).
- (4) Photographs of the Breakwater Site Option 3 (Appendix D).

The following is a summary of pertinent bathymetric and geotechnical data that we have deduced from the supplied information in order to perform slope stability and bearing capacity analyses of proposed wharf structures. We also used our own experience and judgment to select geotechnical parameters for the analysis.

### 3.0 Wharf and Shoreline Geometry

---

#### Deep Sea Wharf Configuration

The deep sea wharf would consist of 5, 19 metre diameter, rock filled steel sheet pile cells or 3, 19 by 33 metre concrete caissons constructed on the sloping harbour bottom. The cell sheets would be driven into a rockfill mattress or competent natural soils. The concrete caissons would be founded at elevation -11 with a total height of 24 or 25 metres. Extreme tides at the site range from low at -0.3 m to high of 12.3 m. Bathymetric data indicates that the harbour bottom at each of the sites slopes at approximately 3 horizontal to 1 vertical, to 6 horizontal to 1 vertical as tabulated below.

<u>Site Option</u>	<u>Approximate Ground Slope at Wharf Location</u>
1	2.7 H:1 V
2	5 H:1 V
3	6 H:1 V
4	3.5 H:1 V

The wharf locations were selected by Worley Parsons based on navigational considerations and to provide 11 metres of draft at low tide. Initially it was intended to locate the wharf deck at el.14 m. However based on preliminary stability calculations and through discussions with Worley Parsons we have assumed the wharf deck elevation will be el. 13 m for our analysis. The existing harbour bottom slope at each site option was determined from bathymetry provided to us on the Worley Parsons drawings.

#### Small Craft Harbour

Option 5 proposed by Worley Parsons consists of a small craft harbour located at Site Option 3. At present there is a rock fill causeway extending perpendicular from the shore approximately 200 metres in length. The causeway is built to approximately elevation 7 m with variable side slopes approximately 4 horizontal to 1 vertical. The present causeway becomes submerged at high tide. Worley Parson's Option 5 would consist of raising the existing causeway to elevation 14 metres and dredging an area to the north for a floating dock (Drawings SK-105 and SK-105A Appendix C). The floating dock would comprise of a spud barge that would be removed in winter.

## **4.0 Soil Parameters**

---

A geotechnical investigation was completed at site Option 1 by Geocon Limited in 1975. The findings of this investigation are attached in Appendix A. The soil strata encountered are summarized as follows:

### **4.1 LOOSE/SOFT SEA BOTTOM SEDIMENTS**

Geocon encountered two sediment layers at the sea bed described as very loose to loose or very soft to soft. These sediment layers are classified as 1) Very Loose to Loose Grey Organic Sandy Silt and Silty Sand with Occasional Gravel, 2) Very Soft to Soft Grey Organic Sandy/Clayey Silt. The borehole nearest to the shore also encountered a compact organic sediment about 1.5 metres thick classified as Compact Grey/Black Organic Sand with Occasional Gravel. For the purposes of this preliminary desk study we must rely on a geophysical survey to identify strata at all sites other than Site Option 1. The geophysics methods are unable to distinguish among these loose/soft sediments. Therefore, for analysis we have considered them as one unit with the following properties.

#### **Soil Properties Soft/Loose Sediments**

Total Unit Weight  $\gamma = 17.5 \text{ kN/m}^3$   
Buoyant Unit Weight  $\gamma' = 8.2 \text{ kN/m}^3$   
Effective Angle of Internal Friction  $\Phi = 30^\circ$   
Effective Cohesion  $c' = 0$   
Undrained Shear Strength  $C_u = 14 \text{ kPa}$

### **4.2 DENSE GRANULAR DEPOSITS**

Geocon reported Dense to Very Dense Grey/Brown Sand and Gravel below the loose/soft sediments in all locations at Option 1 location and inferred it to be continuous. This layer was found to overlie the bedrock and for analysis we have assigned the following geotechnical properties.

#### **Soil Properties Dense Sand and Gravel**

Total Unit Weight  $\gamma = 21.0 \text{ kN/m}^3$   
Buoyant Unit Weight  $\gamma' = 11.2 \text{ kN/m}^3$   
Effective Angle of Internal Friction  $\Phi = 38^\circ$   
Effective Cohesion  $c' = 0$

Bedrock at the site is understood to be granitic. We have assumed that rock fill for the project will be quarried locally and will be relatively strong and hard.

**Soil Properties :Rock Fill**

Total Unit Weight  $\gamma = 21.0 \text{ kN/m}^3$   
Buoyant Unit Weight  $\gamma' = 11.2 \text{ kN/m}^3$   
Angle of Internal Friction  $\Phi = 38^\circ$   
Effective Cohesion  $c' = 0$

Friction angle for Sliding Concrete =  $26^\circ$

Friction angle against the steel cell wall  $\delta = 19^\circ$   
Friction angle against the concrete caisson wall  $\delta = 26^\circ$

## **5.0 Geophysics Report**

---

Fugro Jacques Geosurveys (FJG) completed a geophysical investigation of the 4 site options in the fall of 2009. The FJG report is attached in Appendix B; Section 6 describes interpreted subsurface conditions at Site Options 1 to 4. The geophysicists made use of the Geocon borehole information to help in interpretation of the subsurface conditions but they describe the correlation between boreholes and seismic as 'somewhat tenuous'. They also indicate that interpretation was challenging in shallow water and where slopes were steep. However they were generally able to interpret bedrock as an acoustic basement and a change in acoustic character was interpreted as the base of fine grained sediments. Stantec has considered the "fine grained sediments" described in FJG report as the soft/loose sediments described above.

## **6.0 Analysis Findings and Discussion**

---

### **6.1 DEEP SEA WHARF: GLOBAL STABILITY, SLIDING AND BEARING CAPACITY**

Stantec has undertaken global stability and bearing capacity analyses for concrete caissons and sheet pile cells at the proposed Iqaluit wharf sites. The approach taken considers interpreted geotechnical properties, the geometry of the structures, slopes and subsurface stratigraphy. A detailed analysis of Option 4 was carried out and the results used to evaluate the remaining sites.

All of the proposed site options have relatively thick soft/loose sea bottom sediments. Initial review indicates that these sediments will be unsuitable for support of either concrete cribs or for construction of sheet pile cells due to estimated low undrained strength characteristics. We have assumed that the loose/soft sea bottom sediment will be dredged within its zone of influence under the wharf prior to construction. We have further assumed that fill used to re-

establish foundation grade and wharf backfill will consist of blasted bedrock from the onshore backup areas.

### **6.1.1 Concrete Caissons**

Global slope stability analyses were carried out for typical cross-sections using SLOPE//W 2007, a geotechnical modeling software developed by Geo-Slope International Limited.

We have undertaken a bearing capacity analysis for the concrete caisson sections as detailed in preceding Section 3 and on Drawing Sk106 using methods in the Foundation Engineering Handbook (Winterkorn and Fang).

Sliding analysis was undertaken for caissons sliding on rock fill mattress and for soil on bedrock assuming a friction angle of soil to bedrock of 26°.

Figure 1 shows the typical cross section of the concrete caisson at the centre of the wharf for Option 4. Using the previously stated soil parameters we calculate the following geotechnical factors of safety.

	<u>Calculated Global Factors of Safety</u>	<u>Recommended CFEM</u>
Bearing Capacity	2.2*	2 to 3
Global Slope Stability	1.5	1.5 to 2
Sliding Caisson	2.4	1.5 to 2
Sliding on Bedrock Surface	1.6	1.5 to 2

\* This is considered to be an acceptable lower bound factor of safety against bearing capacity. If excessive stresses are imposed from ice loads, the factor of safety could temporarily reduce below acceptable lower bound values. Unbalanced hydrostatic pressures are created by rapid falling tides. Although rock backfill should drain relatively freely we have assumed an unbalanced hydrostatic pressure equal to 2 metres in our calculations.

Fill height against the back of the end caissons tapers with the side slopes of the approach causeway resulting in reduced driving loads in relation to bearing capacity and sliding.

### **6.1.2 Sheet Pile Cells**

In our opinion steel sheet pile cells will be difficult or impractical for construction at this site due to the very high tide range, the length of sheets that would be required and the short construction season. Notwithstanding, we have undertaken analysis for global stability, bearing capacity and sliding for comparison.

Figure 2 shows the typical cross section of the steel sheet pile cell at the centre of the wharf for Option 4. Using the stated soil parameters we calculate the following geotechnical factors of safety. We have assumed sheet pile penetration into the rock mattress or dense granular deposits of 5 metres below toe elevation.

**121611767 IQALUIT PORT DEVELOPEMENT  
DEEP SEA WHARF OPTION 4  
CONCRETE CRIBS  
Method: Morgenstern-Price  
FOS: 1.519**

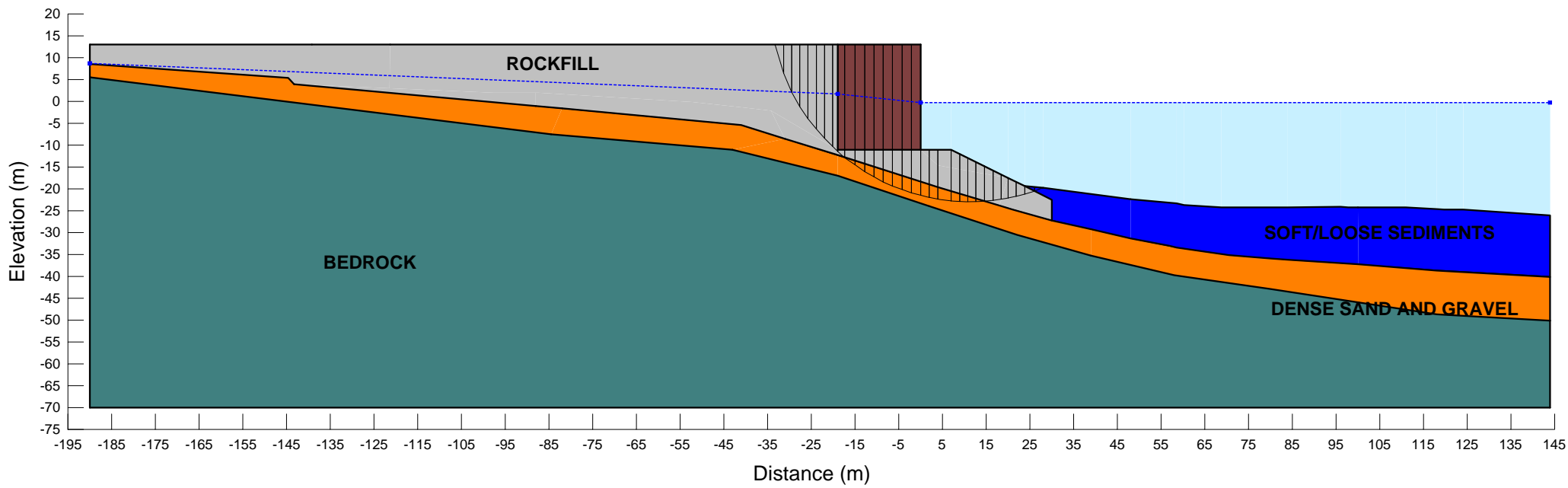


Figure 1

**121611767 IQALUIT PORT DEVELOPEMENT  
DEEP SEA WHARF OPTION 4  
SHEET PILE CELLS**

**Method: Morgenstern-Price  
FOS: 1.637**

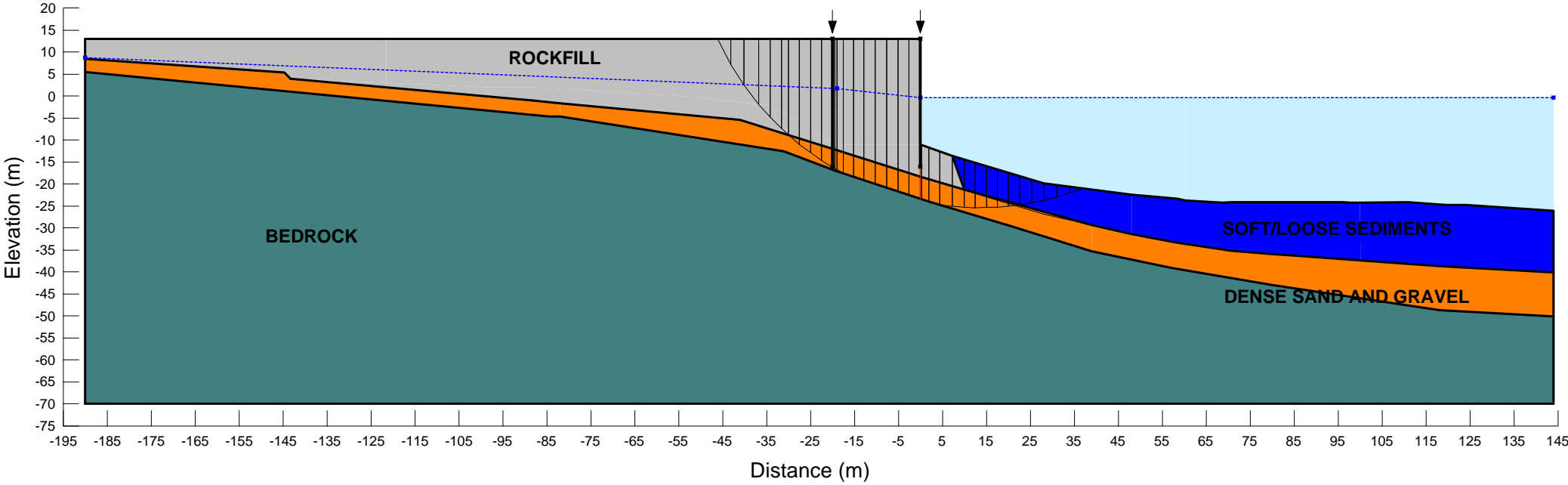


Figure 2

	<u>Calculated Global Factors of Safety</u>	<u>Recommended CFEM</u>
Bearing Capacity	2.8	2 to 3
Global Slope Stability	1.6	1.5 to 2
Sliding Cell	3.4	1.5 to 2
Sliding on Bedrock Surface	1.6	1.5 to 2

### **6.1.3 Small Craft Harbor**

Stantec has undertaken global slope stability analyses for typical cross-sections of the proposed causeway using SLOPE//W 2007. For the analysis we considered interpreted geotechnical properties, the geometry of the existing and proposed raised causeways, slopes and subsurface stratigraphy. We caution that the input data for this analysis is very approximate. The soil properties were obtained from boreholes drilled in 1975 at Site Option 1 located approximately 500 metres away. Fugro Jacques Geosurveys reported that they surveyed across the outer end of the old breakwater (causeway) but did not interpret beneath it, and that the gridding package interpolated through ignoring the causeway. Therefore in our opinion the thickness and consistency soft sediments below the causeway is questionable and must be verified by borehole investigation before final conclusions can be drawn.

We have assumed that the present causeway was placed over the soft sea bottom sediments without dredging. Figure 3 illustrates a typical section that may exist near the outer end of the causeway. The north side (left side of Fig. 3) of the present causeway would be dredged to approximately el. -1 m for the proposed harbour.

Global slope stability analysis indicates that the proposed causeway slopes and foundation would be unstable under undrained conditions using the assumed conditions and soil properties. We assumed increased undrained shear strength of the sediment layer directly below the existing causeway as a result of consolidation. We have analyzed several configurations including stabilizing berms but were unable to find a stable geometry especially on the north side of the causeway where dredging would be required for the harbour. Figure 4 illustrates one example raising the grade to just 7.5 metres with a stabilizing berm resulted in a factor of safety of 0.97.

A drained analysis indicates that under drained conditions the slopes would stand with a factor of safety of 2. It would be necessary to place fill in thin lifts in the order of 1 to 2 metres and wait for pore pressure dissipation to occur. Figure 6 illustrates a 2 metre rock blanket. The rate of dissipation would depend on the sediment thickness and permeability but could take several months between successive fill placements.

Based on observation of natural sea bottom slopes in the region it is unlikely that dredge slopes within the soft sediments would stand steeper than approximately 3 horizontal to 1 vertical. For preliminary design we recommend cut slopes of 4 horizontal to 1 vertical.

121611767 IQALUIT PORT DEVELOPEMENT  
TWO CARGO RAMP FACILITY OPTION 5  
EXISTING CONDITIONS, DRAINED  
Method: Morgenstern-Price  
FOS: 3.316

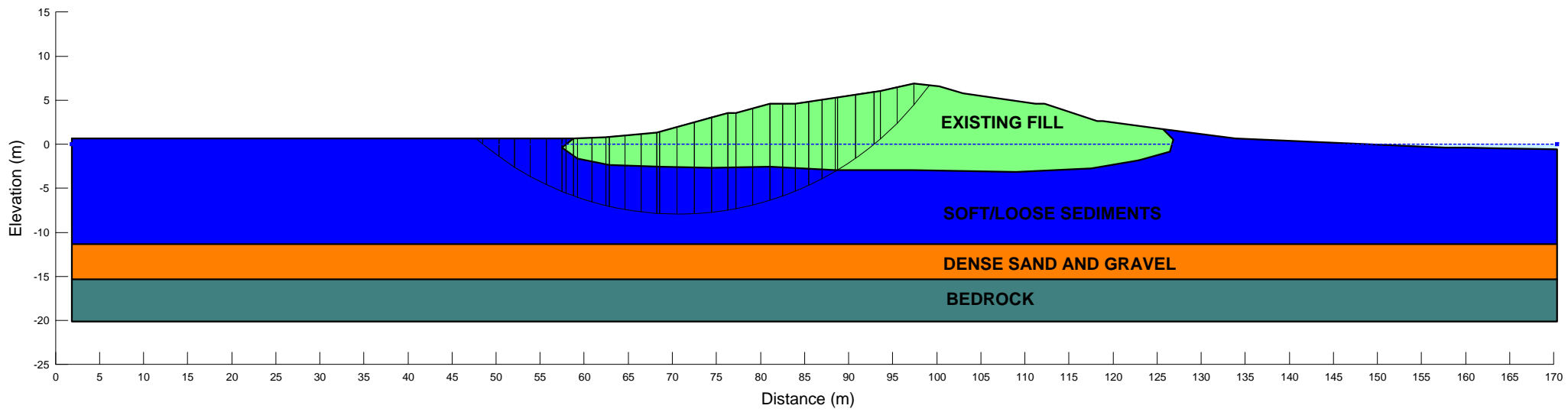


Figure 3

121611767 IQALUIT PORT DEVELOPEMENT  
TWO CARGO RAMP FACILITY OPTION 5  
BERM ELEVATION 7.8 m  
UNDRAINED CONDITION  
Method: Morgenstern-Price  
FOS: 0.967

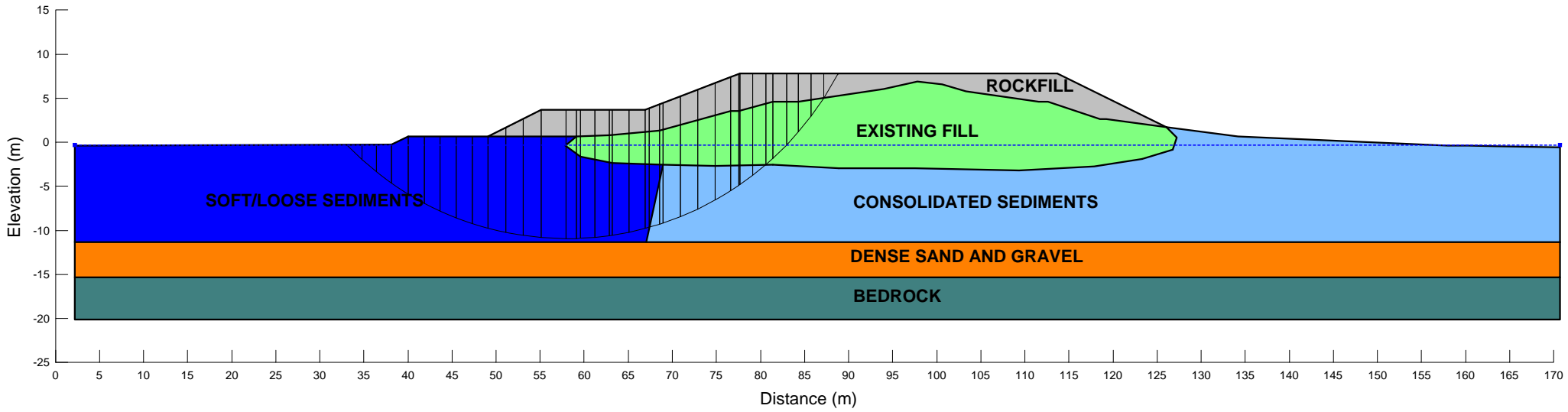


Figure 4

121611767 IQALUIT PORT DEVELOPEMENT  
TWO CARGO RAMP FACILITY OPTION 5  
DRAINED CONDITION  
Method: Morgenstern-Price  
FOS: 2.057

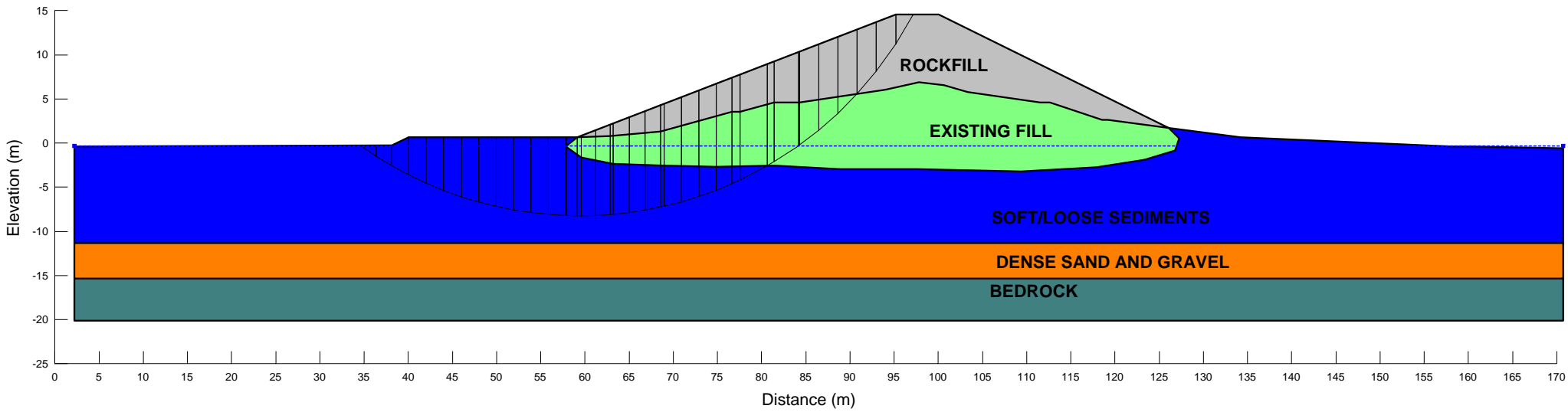


Figure 5

121611767 IQALUIT PORT DEVELOPEMENT  
TWO CARGO RAMP FACILITY OPTION 5  
2.0 m ROCKFILL BLANKET  
UNDRAINED CONDITION  
Method: Morgenstern-Price  
FOS: 1.158

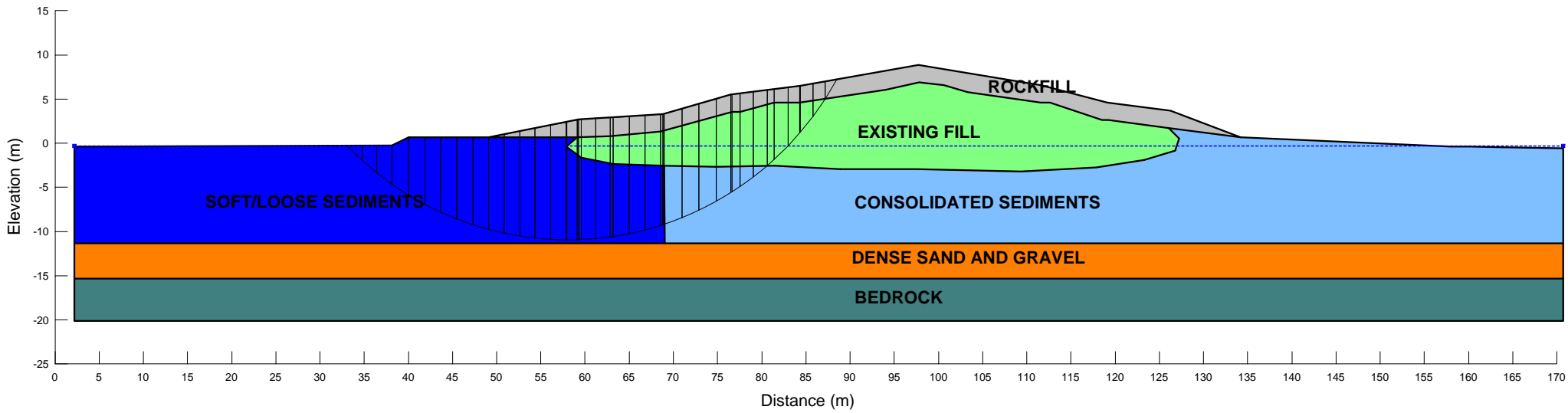


Figure 6

## 7.0 Site Options 1, 2 and 3

---

The geophysics survey indicated that Site Options 1, 2 and 3 are similar to Site Option 4 where we performed detailed analysis. In each case it would be necessary to remove and replace the loose/soft seabed sediments in order to construct a deep sea wharf. The primary differences between sites are the ground slope angle and the thickness of loose/soft sediments. The slopes at Site Options 2 and 3 are less steep and at Option 1 it is steeper than at Option 4 however, this condition would be rectified once the loose/soft sediments have been replaced with rock fill and the resulting factors of safety would be very similar.

## 8.0 Recommendations for Additional Investigation

---

Discussions provided in this report are based on very limited geotechnical data obtained approximately 35 years ago for site Option 1. It is recommended that additional geotechnical field investigations should be undertaken to verify assumptions made in this report. As part of the scope of work for this project Stantec is preparing recommendations for additional investigations associated with Options 4 and 5 which will be reported under separate cover.

This report was written by Dan R. McQuinn, P.Eng. and reviewed by Arun J. Valsangkar, Ph.D., P.Eng. We trust that it contains the information you require at this time. If you have any questions, please do not hesitate to contact the undersigned at your convenience.

Yours very truly,

**STANTEC CONSULTING LTD.**



---

Dan R McQuinn, P.Eng.

---

Arun J. Valsangkar, Ph.D., P.Eng.

**Stantec**

**GEOTECHNICAL DESK STUDY, PROPOSED MARINE DEVELOPMENT IQALUIT  
STANDING OFFER FOR THE ARCTIC REGION ENVIRONMENTAL GEOPHYSICAL AND  
GEOTECHNICAL SERVICES**

**APPENDIX A**

**Report to The St. Lawrence Seaway Authority on Subsurface Investigation  
Frobisher Bay Dock Study Geocon Ltd. June 30, 1975**

M 4176

REPORT

TO

THE ST. LAWRENCE SEAWAY AUTHORITY

MONTREAL

QUEBEC

ON

SUBSURFACE INVESTIGATION

FROBISHER BAY DOCK STUDY

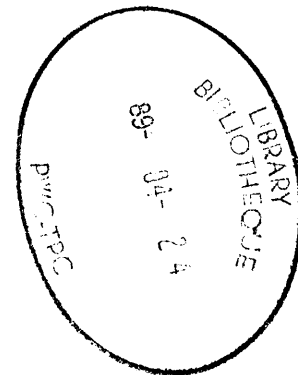
FROBISHER BAY

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6 copies - The St. Lawrence Seaway Authority  
Montreal, Quebec

3 copies - Geocon Ltd.



June 30th, 1975

**GEOCON**

# **GEOCON LTD**

Dorval, Quebec  
June 30th, 1975

The St. Lawrence Seaway Authority  
5250 Ferrier Street  
Montreal, Quebec  
Attn: Mr. D. J. Ferguson, Eng.,  
Marine Structures Engineer

Re: Subsurface Investigation  
Frobisher Bay Dock Study  
Northwest Territories

Dear Sirs:

This letter reports the results of the above investigation which was carried out in general accordance with Geocon Ltd. proposal dated February 14th, 1975 and by authorization of The St. Lawrence Seaway Authority Purchase Order: Number A5169C dated March 25th, 1975 and The St. Lawrence Seaway Authority Contract Number 14-272 dated April 10th, 1975.

The purpose of this investigation was to define the subsurface conditions at the location of the proposed Dock as they affect study of various design alternatives for the proposed Dock Structure. All of the factual information recovered during this investigation is given herein. Also included herein are some brief interpretative comments which are given in accordance with the above mentioned proposal and contract. We would be pleased to provide additional interpretative comments as required during design.

.....2

## 1.0 PROCEDURE AND FIELD EQUIPMENT

Mobilization of drilling equipment for this investigation was carried out between April 1st and 11th, 1975. The boreholes were put down between April 12th and April 27th, 1975. It was initially planned to put down a total of 7 boreholes, numbered 1 to 7 inclusive, at the locations shown on The St. Lawrence Seaway Authority Drawing Number SKC-460, Revision 1 dated April 8th, 1975. As shown on the above Drawing borehole 1 was to be located on land and boreholes 2 to 7 inclusive were to be located offshore. During the actual field work boreholes 2 and 2A were put down in the immediate vicinity of proposed borehole 2, boreholes 3 and 3A were put down in the immediate vicinity of proposed borehole 3 and boreholes 6 and 6A were put down in the immediate vicinity of proposed borehole 6. Also borehole 4 was put down about 41 feet west of its initially proposed location. These boreholes were put down from the surface of the ice. During the field work close liaison was maintained with personnel of The St. Lawrence Seaway Authority in respect to providing progress information. Based on this progress information and on the progress of the field work generally The St. Lawrence Seaway Authority requested that boreholes 1, 5 and 7 be deleted and that borehole 4 be relocated as mentioned above. In this regard borehole 1 was deleted mainly because it would have been extremely difficult and time consuming to move the drilling equipment across the broken ice in the tidal zone to gain access to the land. Borehole 4 was relocated as close to the edge of the broken ice as the safe setup of the drilling equipment would permit.

The boreholes were put down using a standard skid mounted machine drill rig. Initially a 4 1/2 to 5 inch diameter hole was augered through the ice and 20 feet of HX casing (4 1/2 inch outside diameter) was installed and clamped in position. After sounding to determine bottom elevation BX casing (2 7/8 inch outside diameter) was used to advance the borehole through the overburden. Sampling in the overburden was carried out at about 5 foot intervals using a 2 inch O.D. split spoon sampler. Also in borehole 2A a 2 inch thin walled tube sample of a cohesive layer was obtained. During the initial part of the work it was found

..... 3

1.0 PROCEDURE AND FIELD EQUIPMENT - continued

that the inner BX casing had to be removed at the end of each shift due to large tidal variations of the ice surface and possible freezing of the BX casing to the floating ice sheet. For this reason the boreholes had to be completed in stages since it was not possible to complete a borehole, including rock drilling, in one shift. Therefore supplementary boreholes 2A, 3A and 6A were put down adjacent to boreholes 2, 3 and 6 respectively to drill bedrock and also to obtain more information on the overburden strata. Borehole 4 was put down in stages at one location. Bedrock was core drilled for depths ranging from about 7 to 13 feet in AXT size in boreholes 2A, 3A, 4 and 6A. A detailed log for boreholes 2, 2A, 3, 3A, 4, 6 and 6A are given on the Office Reports on Soil Exploration in Appendix I of this report.

All recovered soil and rock samples were sent to our Dorval Soil Mechanics Laboratory and testing was carried out on selected soil samples. The results of these laboratory tests are shown on the individual Office Reports on Soil Exploration in Appendix I and on Figures 1 to 5 inclusive in Appendix II of this report. All samples remaining after examination and laboratory testing will be stored at our Dorval Laboratory until June 1976, at which time you will be contacted for instructions regarding their disposal.

Borehole locations and elevations were established in the field by Geocon Ltd personnel. The boreholes were located as close as possible to the locations shown on The St. Lawrence Seaway Authority Drawing Number SKC-460, Revision 1 dated April 8th, 1975 except for borehole 4 which was relocated as close as possible to the shoreline as mentioned earlier. The actual borehole locations are shown on Geocon Ltd. Drawing Number M 4176-1 located at the rear of this report. The following method was used for locating the boreholes:

- (i) A straight line between the two bollards on land was established and point Q (see Geocon Ltd Drawing M-4176-1 at the rear of this report) was located on this line 2 feet in a southerly direction from the south edge of the steel plate forming the deck of the existing structure.

.....4

1.0 PROCEDURE AND FIELD EQUIPMENT - continued

- (ii) A transit was set-up on point Q and a base-line was established by turning a counter-clockwise angle of 87 degrees from the southern bollard in the offshore direction.
- (iii) A number of survey stakes were installed along the base line (see Photo 2 in Appendix III) and distances to the survey stakes from Point Q were measured using a 200 foot chain. The locations of boreholes 3 and 6 were established at distances of 270 and 395 feet respectively along the base-line from point Q.
- (iv) The locations of the remaining boreholes were established with respect to chainages and offsets from the base-line.
- (v) During the field work temporary survey points P and S were established on the ice with respect to the base-line for elevation control as discussed later. At the end of the field work all borehole locations were checked by setting up the transit at point P and turning angles with respect to the line joining points P and Q and then measuring the distance between point P and the boreholes. This procedure confirmed the borehole locations established by chainages and offsets from the base-line.
- (vi) The actual borehole and reference point locations established with respect to the base-line are summarized as follows:

<u>Borehole No or Reference Point</u>	<u>Distance Along Base-line from Point Q - ft.</u>	<u>Offset Perpen- dicular to Base- Line - ft.</u>
2	266.5 East	125.3 North
2A	259.6 East	124.7 North

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1.0 PROCEDURE AND FIELD EQUIPMENT - continued

(vi) - continued

<u>Borehole No. or Reference Point</u>	<u>Distance Along Base-line from Point Q - ft.</u>	<u>Offset Perpen- dicular to Bas- Line - ft.</u>
3	270.0 East	0.0
3A	263.5 East	2.5 North
4	228.8 East	125.1 South
6	395.0 East	0.0
6A	395.0 East	1.0 North
P	329.2 East	19.0 North
S	230.7 East	68.8 South
R	25.3 West	24.3 South

The following method was used to measure borehole elevations, tidal variations and sample elevations:

- a) The elevation of the top of the  $\pm$  7 foot high steel structure defined as point R (see Photos 1, 3 and 4 in Appendix III) was established with respect to the bench mark consisting of the top of an iron bar embedded in rock and circled with red paint. The top of the iron bar was approximately flush with the surface of the rock outcrop and was located 40.6 feet north-west of the north bollard. The location of the bench mark is shown on Drawing M-4176-1 located at the rear of this report and is further illustrated on Photo 1 in Appendix III. The bench mark elevation was assumed to be 40.80 feet above Chart Datum as shown on The St. Lawrence Seaway Authority Drawing SKC-460 Revision 1 dated April 8th, 1975. The location of the bench mark shown on the above Drawing scales 56 feet from the north bollard compared to the actual measured distance of 40.6 feet.

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## 1.0 PROCEDURE AND FIELD EQUIPMENT - continued

- b) Reference point P was established on the ice with respect to the base-line and also the location of reference point R on land was established with respect to the base-line. The distance between P and R was computed and was then checked using the transit and stadia method to an accuracy of  $\pm 1$  foot. Bottom elevations at borehole locations, tidal variations of ice level and sample elevations were computed using vertical triangulation by measuring the vertical angle between point P and the top of the steel structure, point R. In a similar fashion point S was established in order to determine sample elevations for borehole 4.
- c) Bottom elevations at borehole locations prior to sampling were established by sounding in conjunction with determinations of ice surface elevation as described in item b) above. An elevation observation of ice surface was made for each sample taken.

Frequent checks were made during the field work, using the transit and stadia method, to determine the distance between reference points P and R and the distance between reference points S and R. As mentioned earlier the transit and stadia method was found to be accurate within about one foot. Based on these measurements no noticeable east-west movement of the ice occurred during the field work. Also based on observation of the alignment of the survey stakes established on the base-line no noticeable north-south movement of the ice occurred during the field work.

## 2.0 SITE CONDITIONS

The site is located about 2 miles south of the town of Frobisher Bay, Northwest Territories, on the west side of Koojesse

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## 2.0 SITE CONDITIONS - continued

Inlet as shown on the Key Plan on Drawing M-4176-1 located at the rear of this report. Specifically the area investigated was located immediately offshore from a rock outcrop forming part of Inuit Head and measured about 250 feet in the north-south direction by about 150 feet in the east-west direction. At the time of the investigation the ice thickness at the offshore borehole locations was about 5 to 6 feet. Also the ice surface varied with the tides and the maximum observed variation in the ice surface level occurred on April 25th and 26th, 1975 when the ice surface ranged from about elevation 0 to 35. At the time of the investigation broken ice occurred in the tidal zone as indicated on the photographs in Appendix III.

## 3.0 SOIL AND BEDROCK CONDITIONS

The principal soil and rock strata encountered at borehole locations are described below:

### 3.1 Very Loose to Loose Grey Organic Sandy Silt and Silty Sand with Occasional Gravel

Underlying the bottom of the bay a layer of grey organic sandy silt and silty sand with occasional gravel was encountered in all boreholes. The thickness of this layer varied from about 10 to 15 feet except in borehole 4 located closest to the shoreline where the thickness of this layer was 3 feet. However in borehole 4 a layer of organic sand was encountered underlying the sandy silt and silty sand and this layer is described separately below. The organic sandy silt and silty sand was generally grey or dark grey in colour and locally was black in colour. Generally the grey soil contained only minor organics but the black zones contained significant organics and exhibited a strong organic odour. On air drying the black soil became grey in colour.

Four grain size analysis tests were carried out on samples recovered from this stratum and results of this testing are plotted on Figure 1 of Appendix II. A number of moisture contents determined on samples from this stratum gave values ranging from about 25 to 44 percent with an average of about 34 percent.

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### 3.0 SOIL AND BEDROCK CONDITIONS - continued

#### 3.1 Very Loose to Loose Grey Organic Sandy Silt and Silty Sand with Occasional Gravel - continued

Standard penetration resistance 'N' values obtained during sampling within this deposit varied from less than 1 to 8 blows per foot of penetration indicating a very loose to loose state of relative density. In some cases the standard split spoon sampler advanced through this stratum under the weight of the A rods.

#### 3.2 Compact Grey/Black Organic Sand with Occasional Gravel

Underlying the organic sandy silt and silty sand layer in borehole 4 a layer of grey/black organic sand with occasional gravel was encountered for a thickness of about 5 feet.

A grain size analysis test was carried out on a sample recovered from this stratum and the results of this test are shown on Figure 2 in Appendix II.

One standard penetration resistance 'N' value of 12 blows per foot was obtained in this layer indicating a compact state of relative density.

#### 3.3 Very Soft to Soft Grey Organic Sandy/Clayey Silt

A layer of grey organic sandy/clayey silt was encountered underlying the silty sand to sandy silt layer in boreholes 2, 2A, 3, 3A and 6 and the organic sand layer in borehole 4. This stratum was encountered at the 4 locations investigated and is therefore inferred to be continuous within the limits investigated. The thickness of this layer varied between 1.6 feet in borehole 4 and 5.1 feet in borehole 3A.

Four grain size analysis tests were carried out on samples obtained from this layer and the results of this testing are plotted on Figure 3 of Appendix II. A number of natural water contents determined on samples from this stratum gave values ranging from 23 to 35 percent with an average of about 28 percent.

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3.0 SOIL AND BEDROCK CONDITIONS - continued3.3 Very Soft to Soft Grey Organic Sandy/Clayey Silt - continued

Four Atterberg limit tests were carried out on samples recovered from this stratum in their natural condition and one Atterberg limit test was carried out on an oven dried sample. The results of these tests are shown as a Plasticity Chart on Figure 5 of Appendix II and are also summarized below.

<u>Borehole Number</u>	<u>Sample Number</u>	<u>Depth (feet)</u>	<u>Liquid Limit</u>	<u>Plastic Limit</u>	<u>Plasticity Index</u>	<u>Natural Moisture Content - %</u>
2	2A	13.1-15.1	24.5	20.4	4.1	34.2
2A	2	13.0-13.3	21.0	20.7	0.3	26.8
2A	2*	13.0-13.3	18.7	17.3	1.4	-
3	2B	11.8-13.0	23.5	17.0	6.5	26.7
6	3A	15.2-17.3	23.5	17.3	6.2	29.8

\* Oven Dried

Based on the above plasticity testing the stratum may be described as a cohesive soil of low plasticity.

A laboratory vane test and a quick triaxial test were carried out on the 2 inch tube sample obtained from borehole 2A. The laboratory vane test gave an undrained shear strength of 25 pounds per square foot and it is considered that the section of the sample tested was disturbed. The quick triaxial test gave an undrained shear strength of 250 pounds per square foot and the part of the sample used is also considered to be somewhat disturbed. Standard penetration resistance 'N' values determined in the layer ranged generally from less than 1 to 3 blows per foot and in some cases the sampler advanced under the weight of the A rods. The higher 'N' values determined in boreholes 2 and 4 are not considered to be representative of the penetration resistance of this stratum.

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### 3.0 SOIL AND BEDROCK CONDITIONS - continued

#### 3.3 Very Soft to Soft Grey Organic Sandy/Clayey Silt - continued

Based on the above results it is considered that the sandy/clayey silt layer would have a very soft to soft consistency.

#### 3.4 Dense to Very Dense Grey/Brown Sand and Gravel

Immediately underlying the sandy/clayey silt layer a grey/brown sand and gravel stratum was encountered in all of the boreholes. The thickness of this stratum varied between 2.2 feet in borehole 2A and 17.9 feet in borehole 6A. The sand and gravel deposit was fully penetrated in boreholes 2A, 3A, 4 and 6A whereas boreholes 2, 3 and 6 were terminated within or at the base of this stratum.

Two laboratory grain size tests were carried out on samples obtained from this layer and the results of these tests are shown on Figure 4 of Appendix II. The above tests were carried out on the minus 1 1/2 inch fraction of the soil recovered using the standard split spoon sampler. It is possible that larger sizes including boulders occur within this stratum even though no evidence of boulders was encountered in the boreholes.

Standard penetration resistance 'N' values obtained in this stratum varied from 32 to greater than 100 blows per foot indicating a dense to very dense state of relative density.

#### 3.5 Grey Granitic Bedrock

Underlying the sand and gravel stratum grey granitic bedrock was encountered and core drilled in AXT size in boreholes 2A, 3A, 4 and 6A for depths of 7.3, 7.7, 13.1 and 10.5 feet respectively. The percentage rock core recovery ranged between 56 and 100 percent and was generally over 70 percent. Rock quality designation, RQD, values were between 0 and 66 percent. The recovered rock core was generally in good condition although occasional broken core zones were recovered. Also occasional fractures varying generally from about 45 degrees to vertical were observed.

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### 3.0 SOIL AND BEDROCK CONDITIONS - continued

#### 3.5 Grey Granitic Bedrock - continued

Generally the fractures were rust stained to a depth of about 8 feet below bedrock surface. Recovered core lengths ranged from about 1 to 4 inches although some longer cores were recovered particularly in borehole 4 where core lengths of up to 13 inches were recovered. The low core recovery may be due in part to the use of a small diameter rigid AXT core barrel in combination with difficult drilling conditions due to tidal variations of the ice surface. However it is probable that the bedrock is surficially weathered.

### 4.0 WATER AND ICE CONDITIONS

During the field work the ice surface varied with the tide from a maximum observed elevation of 34.8 on April 25<sup>th</sup>, 1975 to a minimum observed elevation of minus 0.1 on April 26<sup>th</sup>, 1975. The ice thickness at borehole locations ranged from about 5 to 6 feet. No artesian water conditions were observed in the overburden or bedrock during drilling operations. No permafrost conditions were encountered in the overburden. However the site is located close to the southern boundary of the continuous permafrost zone and therefore permafrost conditions may be expected on land.

### 5.0 DISCUSSION

It is understood that a study for a proposed Dock at Frobisher Bay is being carried out. At this time we do not have details of various alternatives which are being considered for the proposed Dock. However it is understood that one scheme presently being considered involves the use of steel sheet piles to form a three sided enclosure measuring about 250 feet along the east side and 150 feet along the north and south sides. It is further understood that this scheme would involve the use of rock fill which would be placed within the steel sheet pile enclosure to elevation 45.

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5.0 DISCUSSION - continued

At the outset of this project and prior to the start of the field work interpretative comments were requested on specific items indicated on data sheets accompanying your request for proposal dated February 3rd, 1975 and these items are quoted as follows:

- a) An assessment whether vertical excavations could be provided by line drilling and whether such vertical excavations, if possible, would be subject to spalling, weathering or other factors tending towards flatter slopes.
- b) An assessment whether steel sheet piles or steel H-piles could be driven economically through any overburden materials encountered.
- c) An assessment whether the overburden materials will remain stable under the weight of up to thirty five (35) feet of broken rockfill (underwater depth).

It is understood that the scheme using a vertical excavation in the rock for the face of the Dock is no longer being considered and that no comments with respect to Item a) above are required. In any event as discussed earlier borehole 1 which was to be put down on land to define bedrock conditions for this purpose was deleted from the drilling programme. Also it is now understood that the height of rock fill would be much greater than the 35 feet mentioned in Item c) above. A detailed discussion of the geotechnical factors involved in the Dock study is beyond our present terms of reference. However as design studies proceed we would be pleased to provide additional interpretative comments as required. Comments are given below with respect to Items b) and c) above and also some general comments otherwise are given.

- 1) The subsurface conditions encountered at the four offshore locations investigated consist of surficial deposits of loose silts and sands and soft clayey silt extending to depths of about 10 to 17 feet below bottom.

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5.0 DISCUSSION - continued

## 1) - continued

These strata contain some organics and are considered to be compressible. The above strata are underlain by a layer of generally dense sand and gravel ranging from about 3 to 18 feet in thickness. Although no boulders were encountered in the boreholes it is possible that boulders exist in this stratum. The total overburden thickness at borehole locations ranged from about 15 feet in the borehole closest to the shore to about 35 feet in the borehole furthest from the shore. The overburden is underlain by granitic bedrock which also outcrops at the shoreline.

- 2) Steel sheet piles or steel H-piles could be readily driven through the loose and soft bottom deposits of sands and silts and clayey silt. It is difficult to predict the penetration into the dense sand and gravel layer which could be achieved by driving steel sheet piles or steel H piles, without specific knowledge of the type of piles, hammer type, driving energy etc. Depending on the above factors and the necessity to achieve positive penetration to bedrock consideration should be given to the use of jetting assistance during driving.
- 3) Placement of end dumped rock fill on the soft bottom deposits would result in at least partial displacement of the soft bottom deposits, outright shear failure, or trapping of pockets of soft soil below the rock fill; depending on the method of fill placement, the height of fill placed and the thickness of sandy silt and clayey silt. Consideration should therefore be given to complete advance removal of the soft bottom soils to the surface of the dense sand and gravel layer before placement of end dumped rock fill to assure stability of the fill.


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5.0 DISCUSSION - continued

- 4) Placement of rock fill within an enclosure of steel sheet piling should not be carried out without the advance removal of the soft sediments to hard bottom as discussed in (3) above.
- 5) To develop adequate toe resistance for the steel sheet piling consideration may have to be given to provision of dowels or anchors into the rock at the tip of the steel sheet piling.
- 6) Use of gravity structures could be considered, where the soft sediments are removed in advance to hard bottom, and where a prepared mattress of granular fill is placed to required base level.
- 7) The design alternatives should incorporate protection against such factors as ice pressures, tidal variations and associated seepage/water pressures, wave forces, scour effects and the like.

We trust that this report which was reviewed by Mr. L. S. Brzezinski contains all of the information required from this investigation. However please do not hesitate to call should you have any questions regarding any aspect of this report.

Very truly yours,  
GEOCON LTD

  
H. L. MacPhie, Eng.,  
Regional Engineer

HLM:eh

M-4176

APPENDIX I

Office Reports on Soil Exploration

## EXPLANATION OF THE FORM "OFFICE REPORT ON SOIL EXPLORATION"

The object of this form is to enable a comprehensive study of the soil to be made by combining on one sheet all of the information obtained from the boring. An explanation of the various columns of the report follows.

### ELEVATION AND DEPTH

This column gives the elevation and depth of boundaries between the various soil strata. The elevation is referred to the datum shown in the general heading.

### WATER CONDITIONS

In this column the water level in the casing at the time of boring or the water table in the ground, determined by a series of observations in a piezometer or standpipe, is indicated to scale by a horizontal line with the symbol W.L. or W.T. above the line. A notation of any complicated groundwater conditions will be made in this column.

### DESCRIPTION

A description of the soil, using standard terminology, is contained in this column. The consistency of cohesive soils and the relative density of non-cohesive soils are described by the following terms:

<u>Consistency</u>	<u>U-Strength Tons/sq. ft.</u>	<u>Relative Density</u>	<u>Standard Penetration Resistance. Blows/ft.</u>
Very soft	0.03 to 0.25	Very loose	0 to 4
Soft	0.25 to 0.5	Loose	4 to 10
Firm	0.5 to 1.0	Compact	10 to 30
Stiff	1.0 to 2.0	Dense	30 to 50
Very stiff	2.0 to 4.0	Very dense	over 50
Hard	over 4.0		

### STRATIGRAPHIC PLOT

The stratigraphic plot follows the standard symbols of the National Research Council, Canada.

### ELEVATION SCALE

The information in all columns is plotted to a true elevation scale which is shown in this column.

### GRAPHS

The main body of the report forms a graph which is used to plot to correct elevation the important soil properties which are obtained through field and laboratory tests. The scales and symbols for the plotting are shown at the head of the column.

### OTHER TESTS

In this column are shown, by symbol, the other field or laboratory tests which have been performed on the soil and for which the results have not been plotted on the above graph.

### SAMPLES

The first three columns describe the condition, type and number of each sample obtained from the boring. The location and extent of each sample is plotted to scale.

In the last column is shown the penetration resistance in blows of 4200 inch-pounds required to drive one foot of the sampler into the ground. When a 2 inch Drive Sampler is used the result obtained is termed the "Standard Penetration Resistance".

**GEOCON**

OFFICE REPORT ON SOIL EXPLORATION

CONTRACT M-4176 BORING # 2 DATUM CHART CASING HX 4 BW  
 BORING DATE APR. 21, 1975 REPORT DATE MAY 9, 1975 COMPILED BY JRF CHECKED BY ZT  
 SAMPLER HAMMER WT 140 LBS DROP 30 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN. LBS. ENERGY)

SAMPLE CONDITION

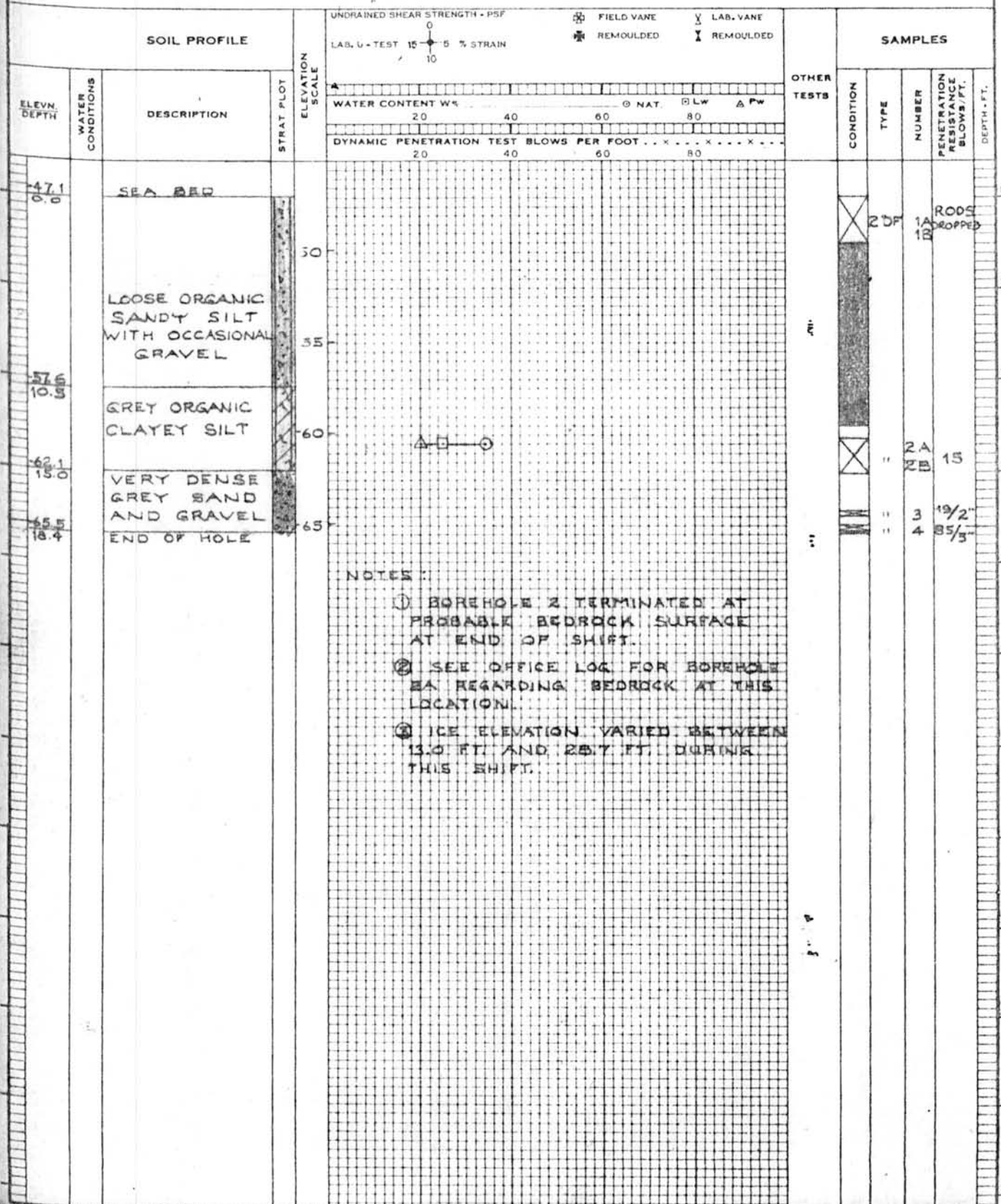
	DISTURBED
	FAIR
	GOOD
	LOST

SAMPLE TYPES

A.S. - AUGER SAMPLE	F.S. - FOIL SAMPLE
S.T. - SLOTTED TUBE	S.O. - SLEEVE-OPEN
W.S. - WASHED SAMPLE	S.F. - SLEEVE-FOOT VALVE
D.O. - DRIVE-OPEN	T.O. - THIN WALLED OPEN
D.F. - DRIVE FOOT VALVE	R.C. - ROCK CORE
C.S. - CHUNK SAMPLE	

ABBREVIATIONS

V. - IN-SITU VANE TEST	γ. - WET UNIT WEIGHT
M. - MECHANICAL ANALYSIS	K. - PERMEABILITY
U. - UNCONFINED COMPRESSION	C. - CONSOLIDATION
QC. - TRIAXIAL CONSOLIDATED UNDRAINED	WL. - WATER LEVEL IN CASING
Q. - TRIAXIAL UNDRAINED	WT. - WATER TABLE IN SOIL
S. - TRIAXIAL DRAINED	



OFFICE REPORT ON SOIL EXPLORATION

CONTRACT M-A-176 BORING 2A DATUM CHART CASING HX & BW&AX  
 BORING DATE APR. 25, 1975 REPORT DATE MAY 9, 1975 COMPILED BY JRF CHECKED BY ZT  
 SAMPLER HAMMER WT 140 LBS DROP 30 INCHES PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN. LBS ENERGY

SAMPLE CONDITION

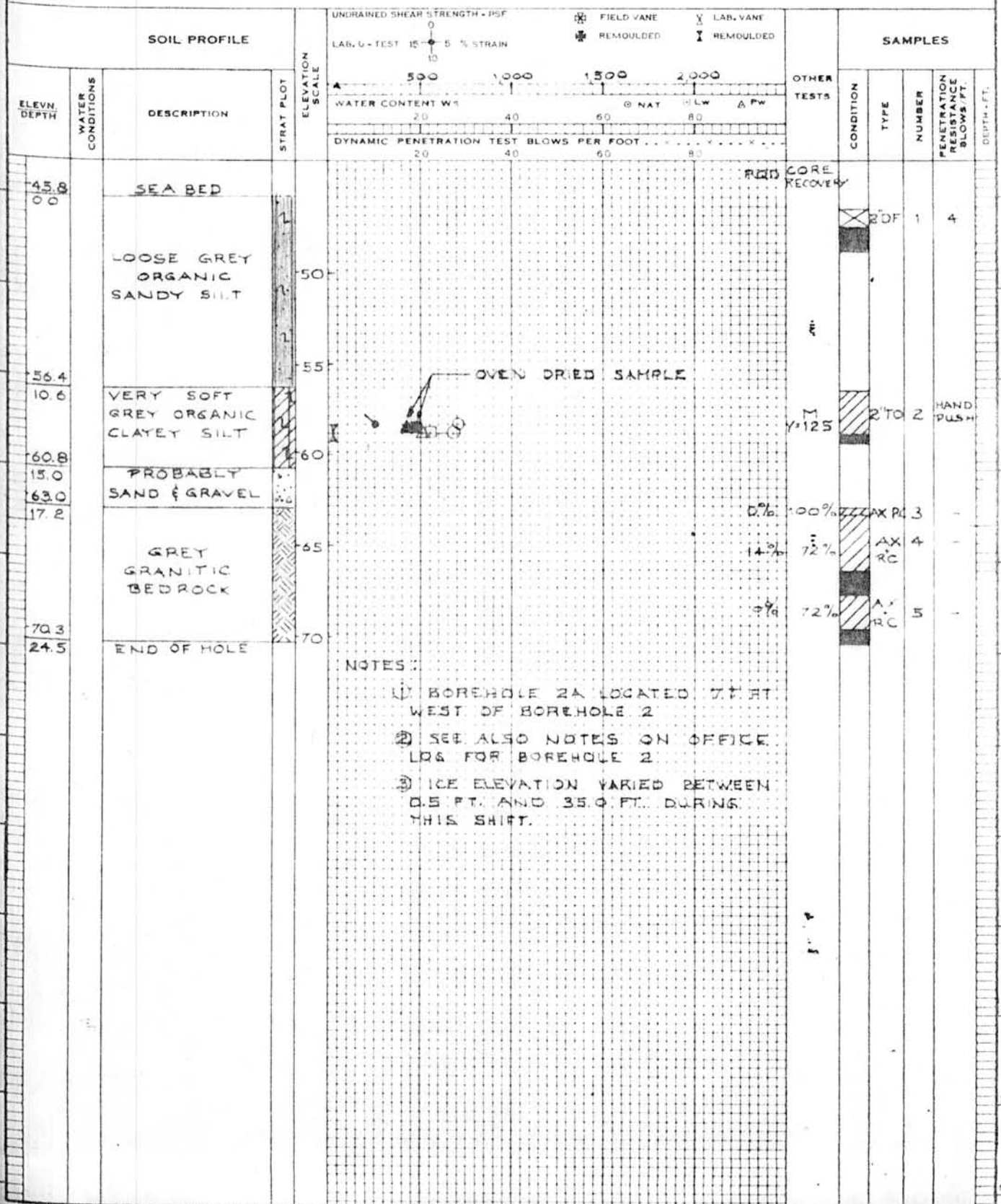
DISTURBED  
 FAIR  
 GOOD  
 LOST

SAMPLE TYPES

A.S. AUGER SAMPLE  
 S.T. SLOTTED TUBE  
 W.S. WASHED SAMPLE  
 D.O. DRIVE-OPEN  
 D.F. DRIVE-FOOT VALVE  
 C.S. CHUNK SAMPLE  
 F.S. FOIL SAMPLE  
 S.O. SLEEVE OPEN  
 S.P. SLEEVE FOOT VALVE  
 T.O. THIN WALLED OPEN  
 R.C. ROCK CORE

ABBREVIATIONS

V. IN-SITU VANE TEST  
 M. MECHANICAL ANALYSIS  
 U. UNCONFINED COMPRESSION  
 QC. TRIAXIAL CONSOLIDATED UNDRAINED  
 Q. TRIAXIAL UNDRAINED  
 S. TRIAXIAL DRAINED  
 W. WET UNIT WEIGHT (pcf)  
 K. PERMEABILITY  
 C. CONSOLIDATION  
 WL. WATER LEVEL IN CASING  
 WT. WATER TABLE IN SOIL



OFFICE REPORT ON SOIL EXPLORATION

CONTRACT M-4176 BORING # 3 DATUM CHART CASING HX & BX  
 BORING DATE APR. 12, 1975 REPORT DATE MAY 9, 1975 COMPILED BY JRF CHECKED BY ZT  
 SAMPLER HAMMER WT 140 LBS DROP 30 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN. LBS ENERGY)

SAMPLE CONDITION

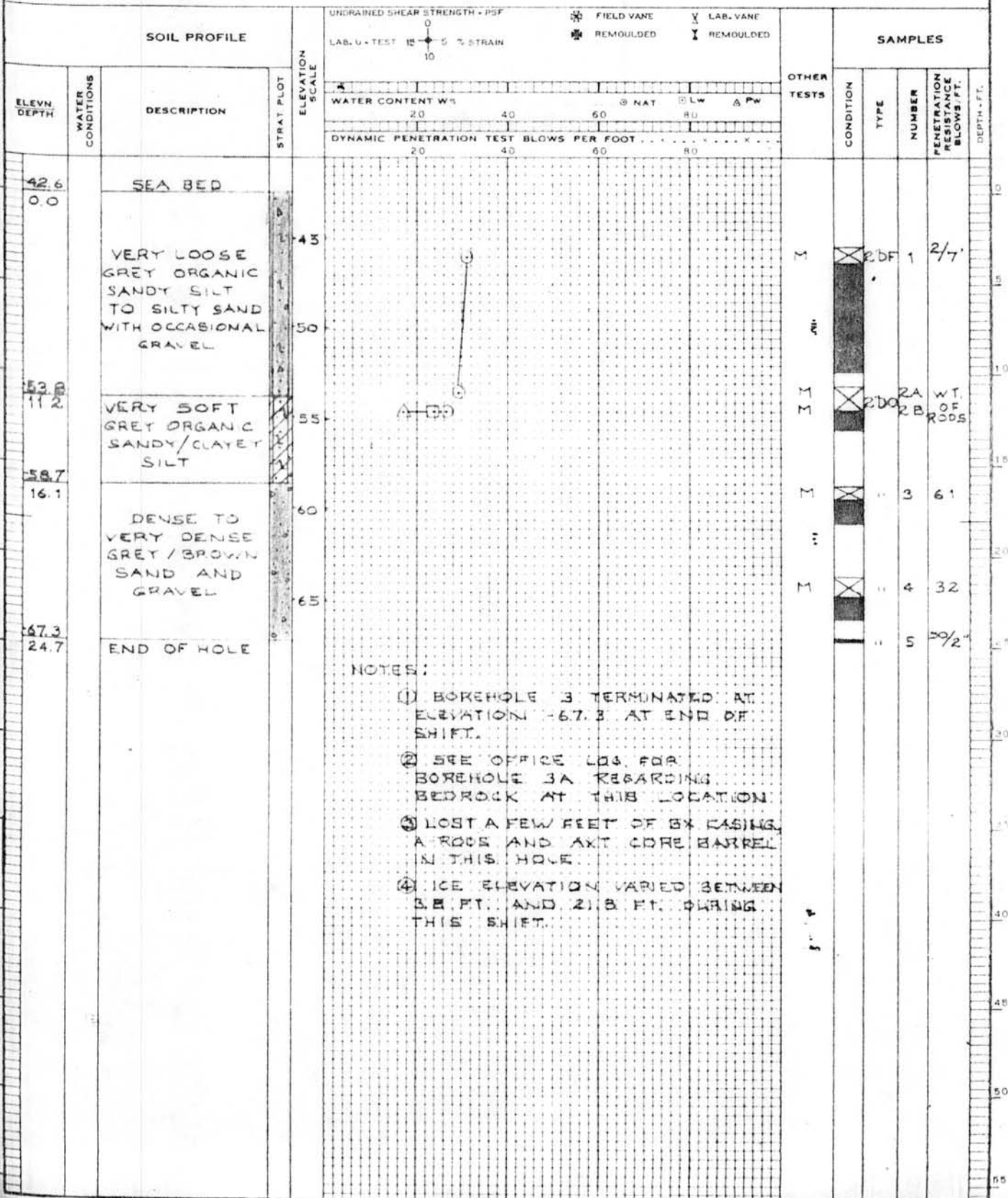
☒ DISTURBED  
 ▨ FAIR  
 ▩ GOOD  
 ▪ LOST

SAMPLE TYPES

AS - AUGER SAMPLE FS - FOIL SAMPLE  
 ST - SLOTTED TUBE SO - SLEEVE OPEN  
 WS - WASHED SAMPLE SF - SLEEVE FOOT VALVE  
 DO - DRIVE OPEN TO - THIN WALLED OPEN  
 DF - DRIVE FOOT VALVE RC - ROCK CORE  
 CS - CHUNK SAMPLE

ABBREVIATIONS

V - IN-SITU VANE TEST W - WET UNIT WEIGHT  
 M - MECHANICAL ANALYSIS K - PERMEABILITY  
 U - UNCONFINED COMPRESSION C - CONSOLIDATION  
 UC - TRIAXIAL CONSOLIDATED UNDRAINED  
 QU - TRIAXIAL UNDRAINED WL - WATER LEVEL IN CASING  
 S - TRIAXIAL DRAINED WT - WATER TABLE IN SOIL



NOTES:

- BOREHOLE 3 TERMINATED AT ELEVATION -67.3 AT END OF SHIFT.
- SEE OFFICE LOG FOR BOREHOLE 3A REGARDING BEDROCK AT THIS LOCATION.
- LOST A FEW FEET OF BX CASING, A ROD AND AXI CORE BARREL IN THIS HOLE.
- ICE ELEVATION VARIED BETWEEN 3.8 FT. AND 21.8 FT. DURING THIS SHIFT.

GEOCON

APPENDIX I

OFFICE REPORT ON SOIL EXPLORATION

CONTRACT M-4176 BORING # 3A DATUM CHART CASING HX & BW & AX  
 BORING DATE APR. 17-18, 1975 REPORT DATE MAY 9, 1975 COMPILED BY JRF CHECKED BY ZT  
 SAMPLER HAMMER WT 140 LBS DROP 30 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN - LBS ENERGY)

SAMPLE CONDITION

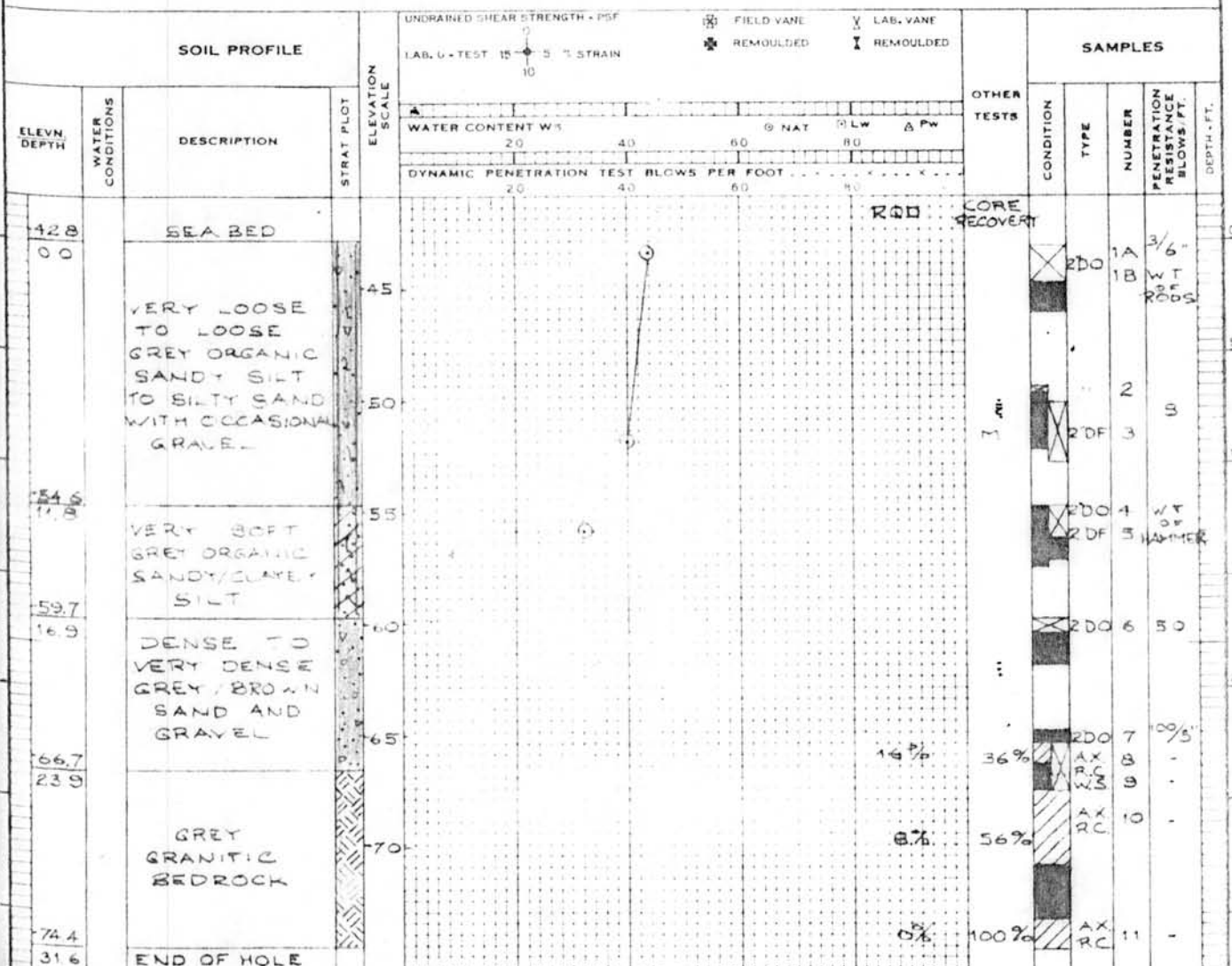
	DISTURBED
	FAIR
	GOOD
	LOST

SAMPLE TYPES

A.S. - AUGER SAMPLE	F.S. - FOIL SAMPLE
S.T. - SLOTTED TUBE	S.O. - SLEEVE OPEN
W.S. - WASHED SAMPLE	S.F. - SLEEVE FOOT VALVE
D.O. - DRIVE-OPEN	T.O. - THIN WALLED OPEN
D.F. - DRIVE-FOOT VALVE	R.C. - ROCK CORE
C.S. - CHUNK SAMPLE	

ABBREVIATIONS

V. - IN-SITU VANE TEST	W. - WET UNIT WEIGHT
M. - MECHANICAL ANALYSIS	K. - PERMEABILITY
U. - UNCONFINED COMPRESSION	C. - CONSOLIDATION
QC. - TRIAXIAL CONSOLIDATED UNDRAINED	WL. - WATER LEVEL IN CASING
Q. - TRIAXIAL UNDRAINED	WT. - WATER TABLE IN SOIL
S. - TRIAXIAL DRAINED	



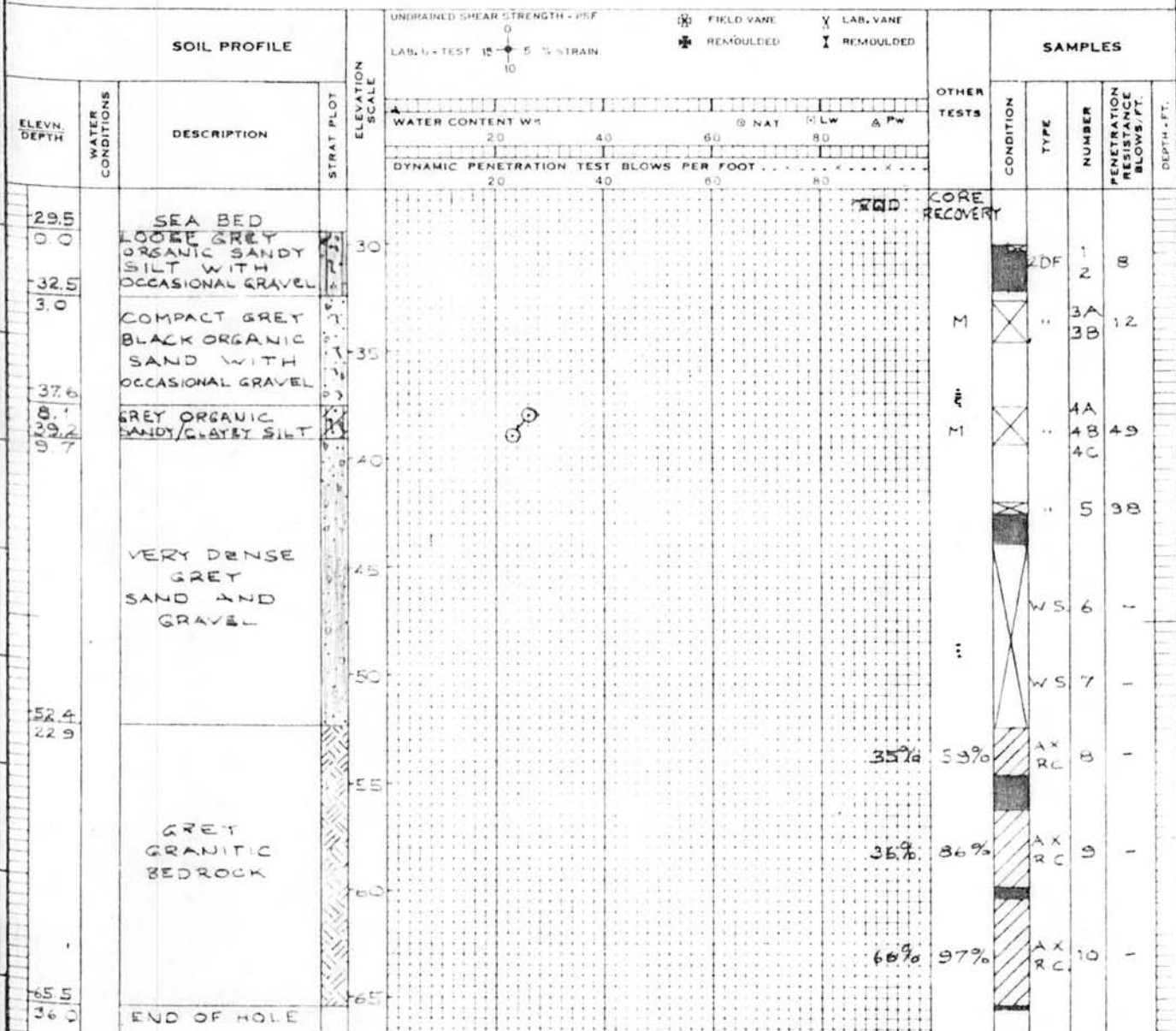
NOTES

- ① BOREHOLE 3A LOCATED 71 FT. NORTHWEST OF BOREHOLE 3
- ② SEE ALSO NOTES ON OFFICE LOGS FOR BOREHOLE 3
- ③ SAMPLING CARRIED DOWN TO ELEVATION 66.7 ON APRIL 17/75 TO PROBABLE BEDROCK SURFACE AT END OF SHIFT.
- ④ BEDROCK CORED ON APRIL 18/75 FROM ELEVATION 66.7 DOWN
- ⑤ ICE ELEVATION VARIED BETWEEN 72 FT. AND 29 FT. ON APRIL 17/1975 AND BETWEEN 83 FT AND 27.5 FT ON APRIL 18, 1975 DURING SHIFTS.

OFFICE REPORT ON SOIL EXPLORATION

CONTRACT M-4176 BORING # 4 DATUM CHART Casing HX & BW EAX  
 BORING DATE APR. 22-24, 1975 REPORT DATE MAY 9, 1975 COMPILED BY JRF CHECKED BY ZT  
 SAMPLER HAMMER WT 140 LBS DROP 30 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN-LBS. ENERGY)

SAMPLE CONDITION		SAMPLE TYPES			ABBREVIATIONS		
DISTURBED	A.S. AUGER SAMPLE	F.S. FOIL SAMPLE	V. IN SITU VANE TEST	Y. WET UNIT WEIGHT			
FAIR	S.T. SLOTTED TUBE	S.O. SLEEVE OPEN	M. MECHANICAL ANALYSIS	K. PERMEABILITY			
GOOD	W.S. WASHED SAMPLE	S.F. SLEEVE FOOT VALVE	U. UNCONFINED COMPRESSION	C. CONSOLIDATION			
LOST	D.O. DRIVE-OPEN	T.O. THIN WALLED OPEN	OC. TRIAXIAL CONSOLIDATED UNDRAINED	WL. WATER LEVEL IN CASING			
	DF. DRIVE-FOOT VALVE	R.C. ROCK CORE	O. TRIAXIAL UNDRAINED	WT. WATER TABLE IN SOIL			
	C.S. CHUNK SAMPLE		S. TRIAXIAL DRAINED				



NOTES:

- SAMPLING CARRIED DOWN TO ELEVATION -43.8 ON APRIL 22/75 AT END OF SHIFT
- SAMPLING CONTINUED FROM ELEVATION -43.8 DOWN AND BEDROCK CORED ON APRIL 24/75
- ICE ELEVATION VARIED BETWEEN 76 FT. AND 30.0 FT. ON APRIL 22, 1975, AND BETWEEN 21.0 FT. AND 35.7 FT. ON APRIL 24, 1975 DURING SHIFTS

OFFICE REPORT ON SOIL EXPLORATION

CONTRACT M-4176 BORING # 6 & 6A DATUM CHART CASING H X B W L A X  
 BORING DATE APR 19 27, 1975 REPORT DATE MAY 9, 1975 COMPILED BY JRF CHECKED BY ZT  
 SAMPLER HAMMER WT 140 LBS DROP 30 INCHES (PENETRATION RESISTANCES CONVERTED TO BLOWS OF 4200 IN - LBS ENERGY)

SAMPLE CONDITION		SAMPLE TYPES				ABBREVIATIONS							
[X] DISTURBED [ ] FAIR [ ] GOOD [ ] LOST	A S - AUGER SAMPLE S T - SLOTTED TUBE W S - WASHED SAMPLE D O - DRIVE OPEN D F - DRIVE FOOT VALVE C S - CHUNK SAMPLE	F S - FOIL SAMPLE S O - SLEEVE OPEN S F - SLEEVE FOOT VALVE T O - THIN WALLED OPEN R C - ROCK CORE	V - IN SITU VANE TEST M - MECHANICAL ANALYSIS U - UNCONFINED COMPRESSION Q C - TRIAXIAL CONSOLIDATED UNDRAINED Q - TRIAXIAL UNDRAINED S - TRIAXIAL DRAINED	γ - WET UNIT WEIGHT K - PERMEABILITY C - CONSOLIDATION W L - WATER LEVEL IN CASING W T - WATER TABLE IN SOIL									
ELEV. DEPTH	WATER CONDITIONS	SOIL PROFILE DESCRIPTION	STRAT. PLOT	ELEVATION SCALE	UNDRAINED SHEAR STRENGTH - PSF				OTHER TESTS	SAMPLES			
					LAB. U - TEST 15 5 5 STRAIN 10					FIELD VANE	LAB. VANE	REMOULDED	REMOULDED
					WATER CONTENT W <sub>s</sub>								
					DYNAMIC PENETRATION TEST BLOWS PER FOOT								
67.7	0 0	SEA BED											
82.9	15.2	VERY LOOSE GREY ORGANIC SANDY SILT TO SILTY SAND WITH OCCASIONAL GRAVEL											
84.8	17.1	VERY SOFT GREY ORGANIC SANDY/CLAYEY SILT											
88.7	21.0	DENSE TO VERY DENSE GREY SAND & GRAVEL											
		PROBABLY SAND AND GRAVEL											
102.7	35.0	GREY GRANITIC BEDROCK											
112.2	45.5	END OF HOLE											
					NOTE: (1) BOREHOLE 6 TERMINATED AT ELEVATION 188.7 ON APRIL 19, 1975 AT END OF SHIFT (2) BOREHOLE 6A LOCATED 12 FT. NORTH OF BOREHOLE 6. (3) BEDROCK LOGGED IN BOREHOLE 6A ON APRIL 27, 75 (4) ICE ELEVATION VARIED BETWEEN 10.5 FT. AND 26.7 FT. ON APRIL 19, 1975 AND BETWEEN 0.0 FT. AND 26.5 FT. ON APRIL 27, 1975.								
					0% 68% AX RC 5 - 99% 95% AX RC 6 - 0% 80% AX RC 7 -								

APPENDIX II

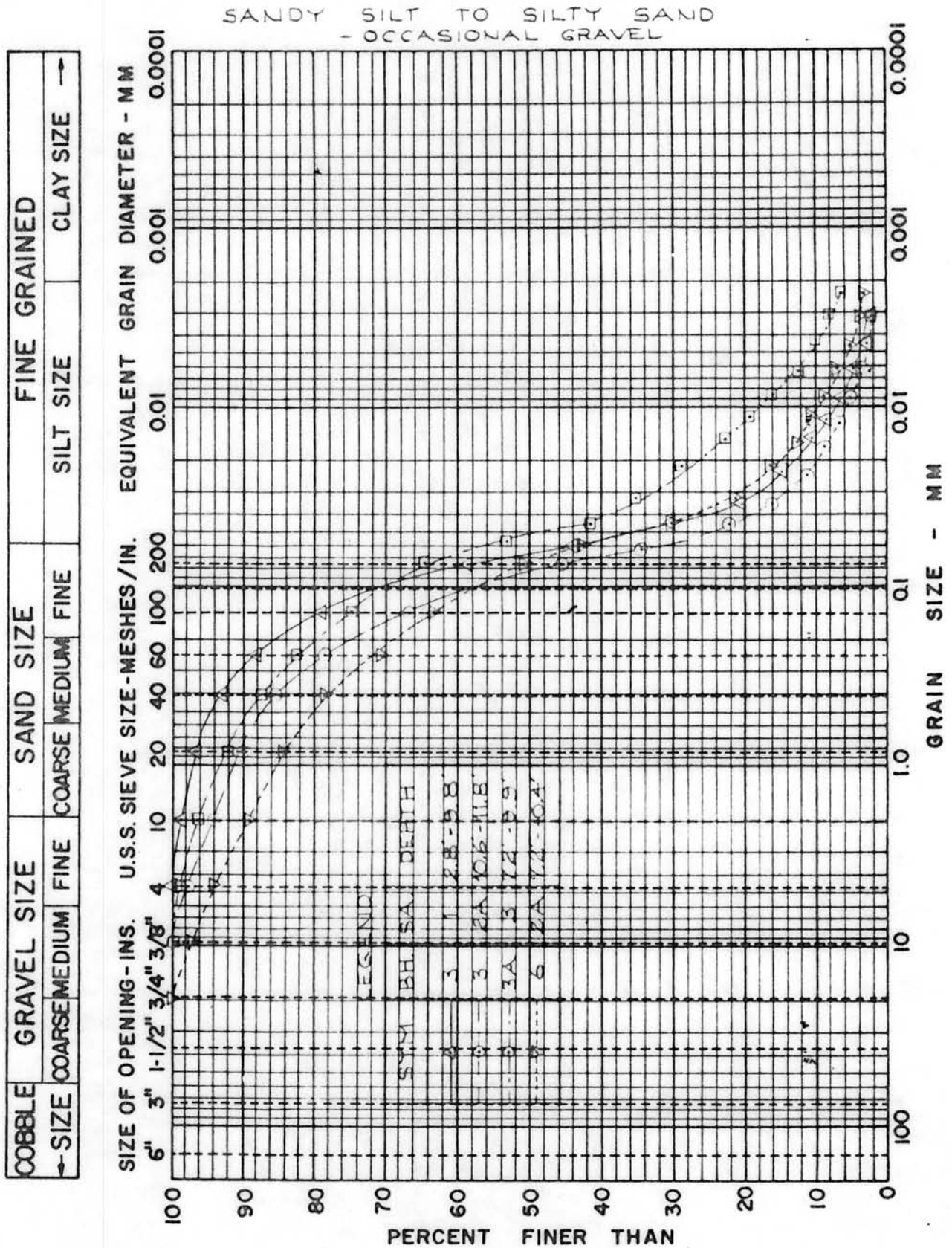
Figures - Laboratory Testing

# GRAIN SIZE DISTRIBUTION

APPENDIX II

FIGURE 1

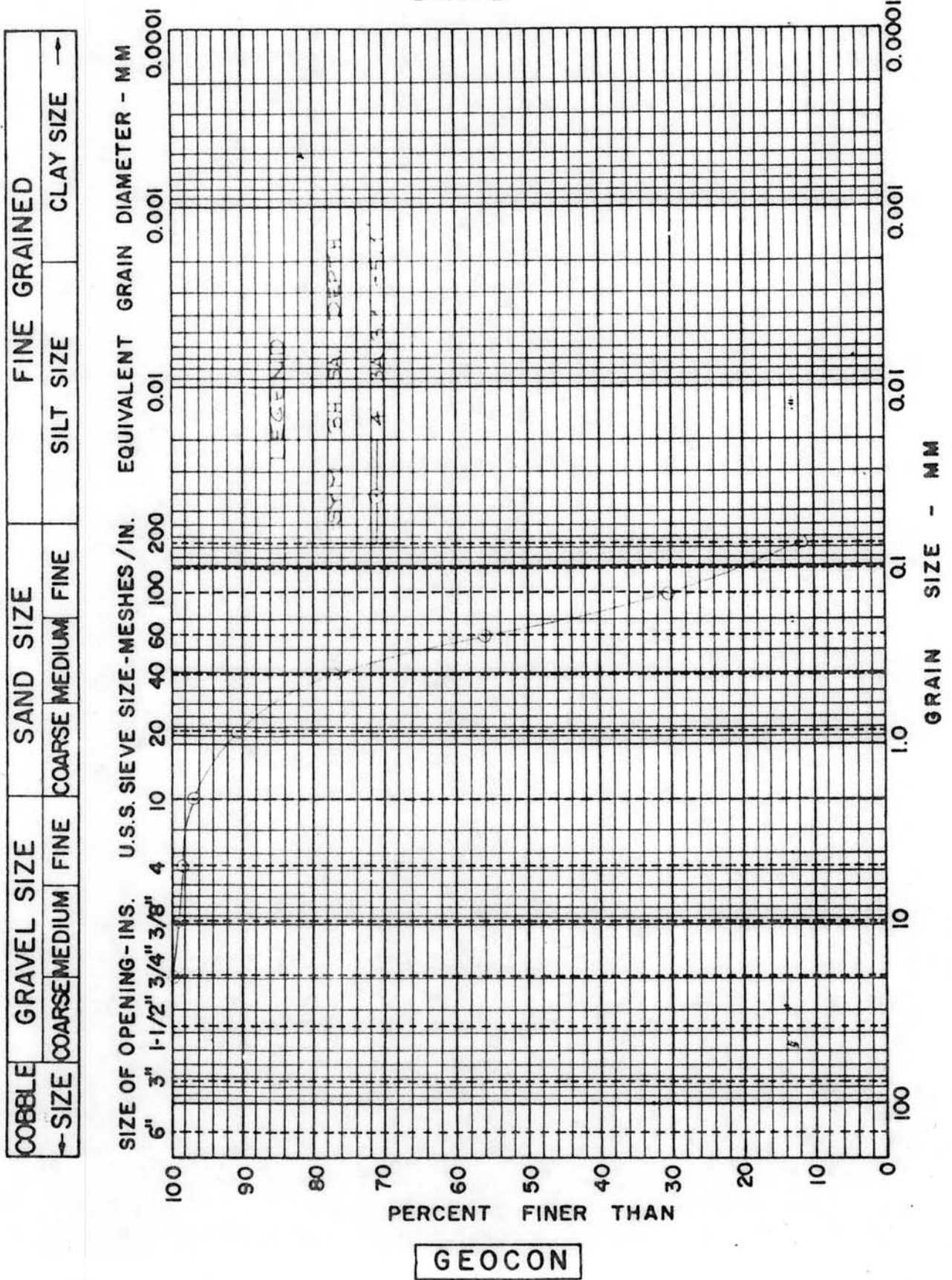
PROJECT M-4176



GEOCON

# GRAIN SIZE DISTRIBUTION

APPENDIX II  
FIGURE 2  
PROJECT M-4176



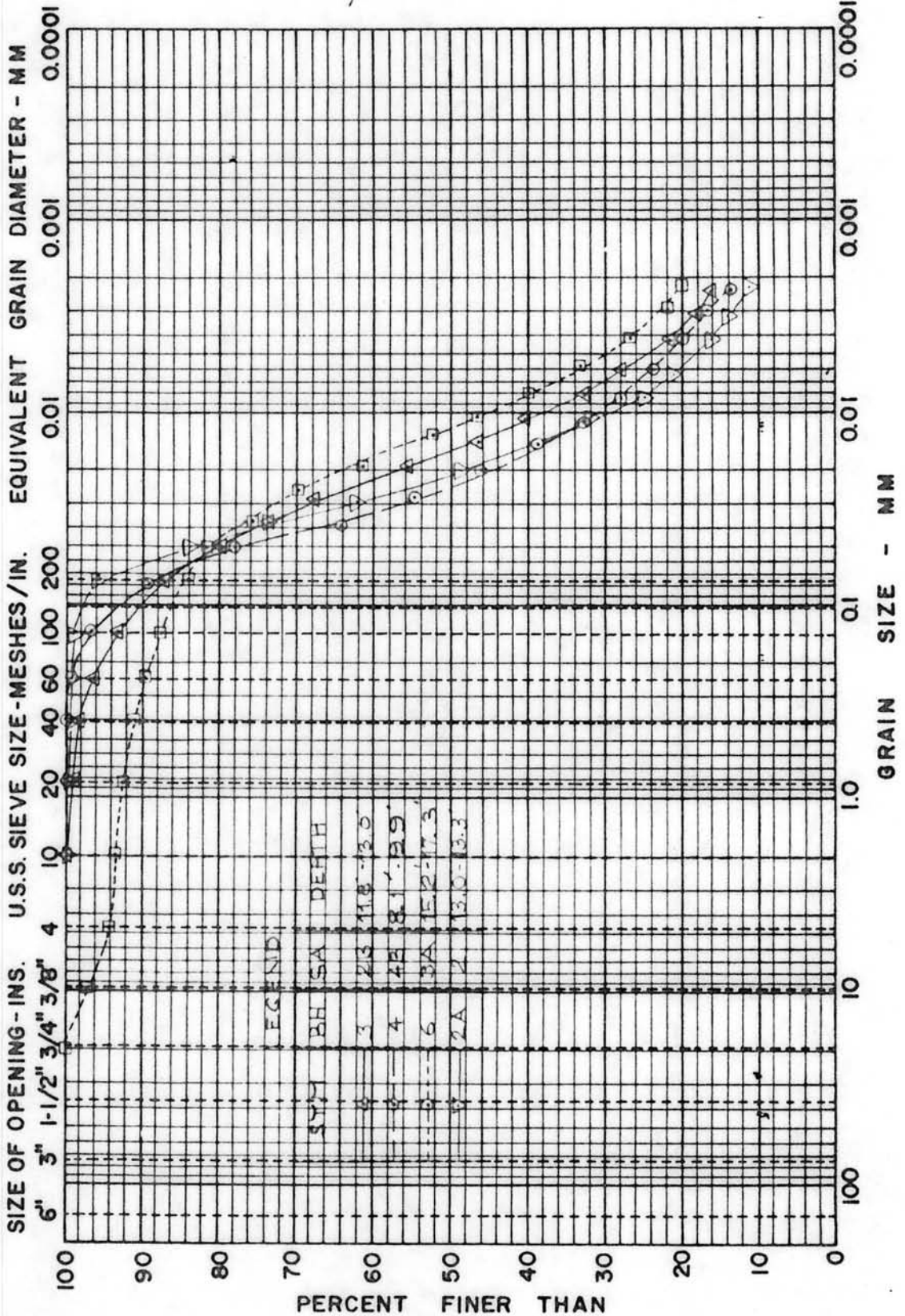
GEOCON

# GRAIN SIZE DISTRIBUTION

APPENDIX II  
FIGURE 3  
PROJECT M-4176

SANDY / CLAYEY SILT

COBBLE		GRAVEL SIZE		SAND SIZE			FINE GRAINED	
←	SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	CLAY SIZE →



GEOCON

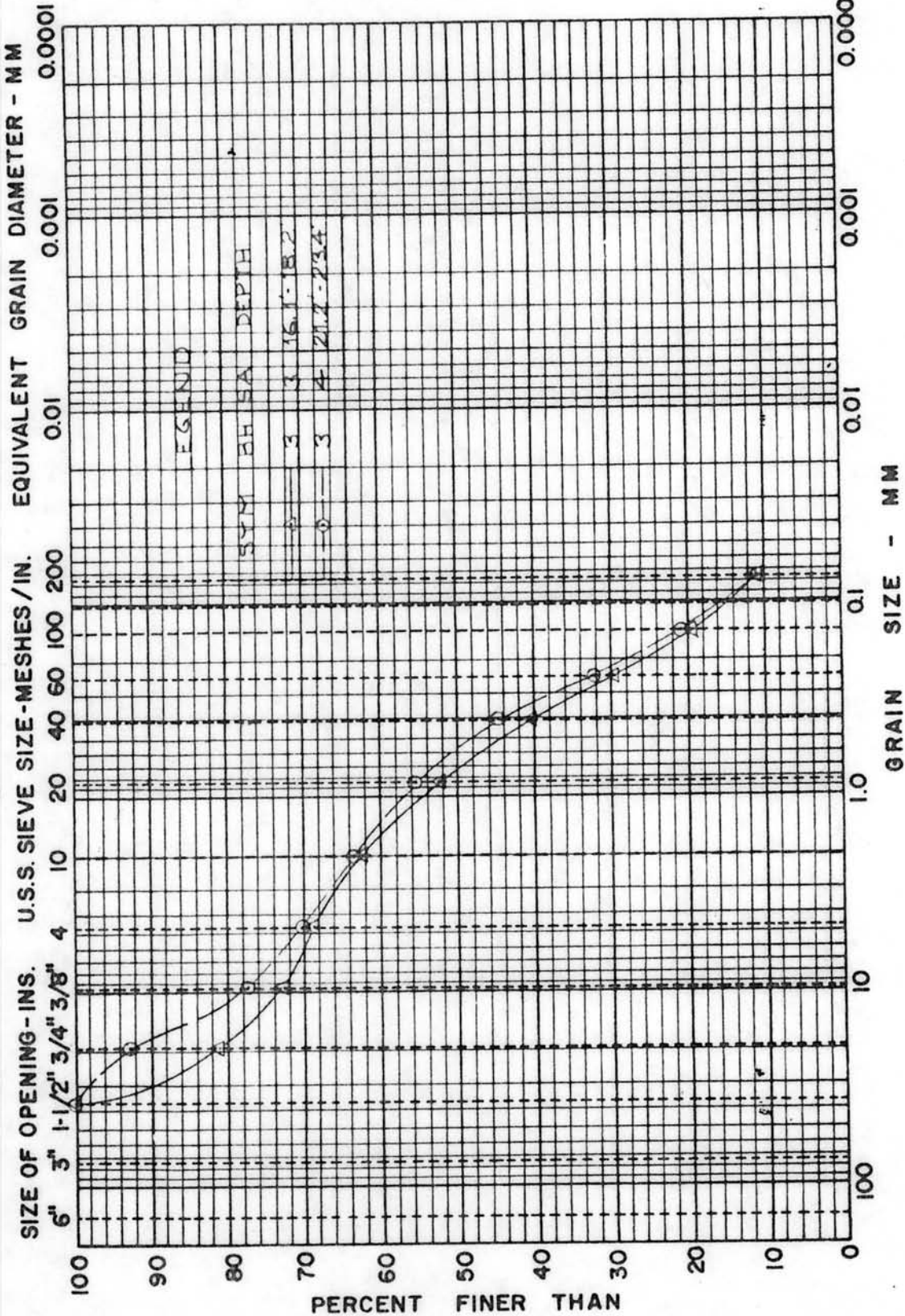
M.I.T. GRAIN SIZE SCALE

# GRAIN SIZE DISTRIBUTION

APPENDIX II  
 FIGURE 4  
 PROJECT M-4176

SAND AND GRAVEL

COBBLE		GRAVEL SIZE		SAND SIZE			FINE GRAINED	
→	SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	CLAY SIZE →

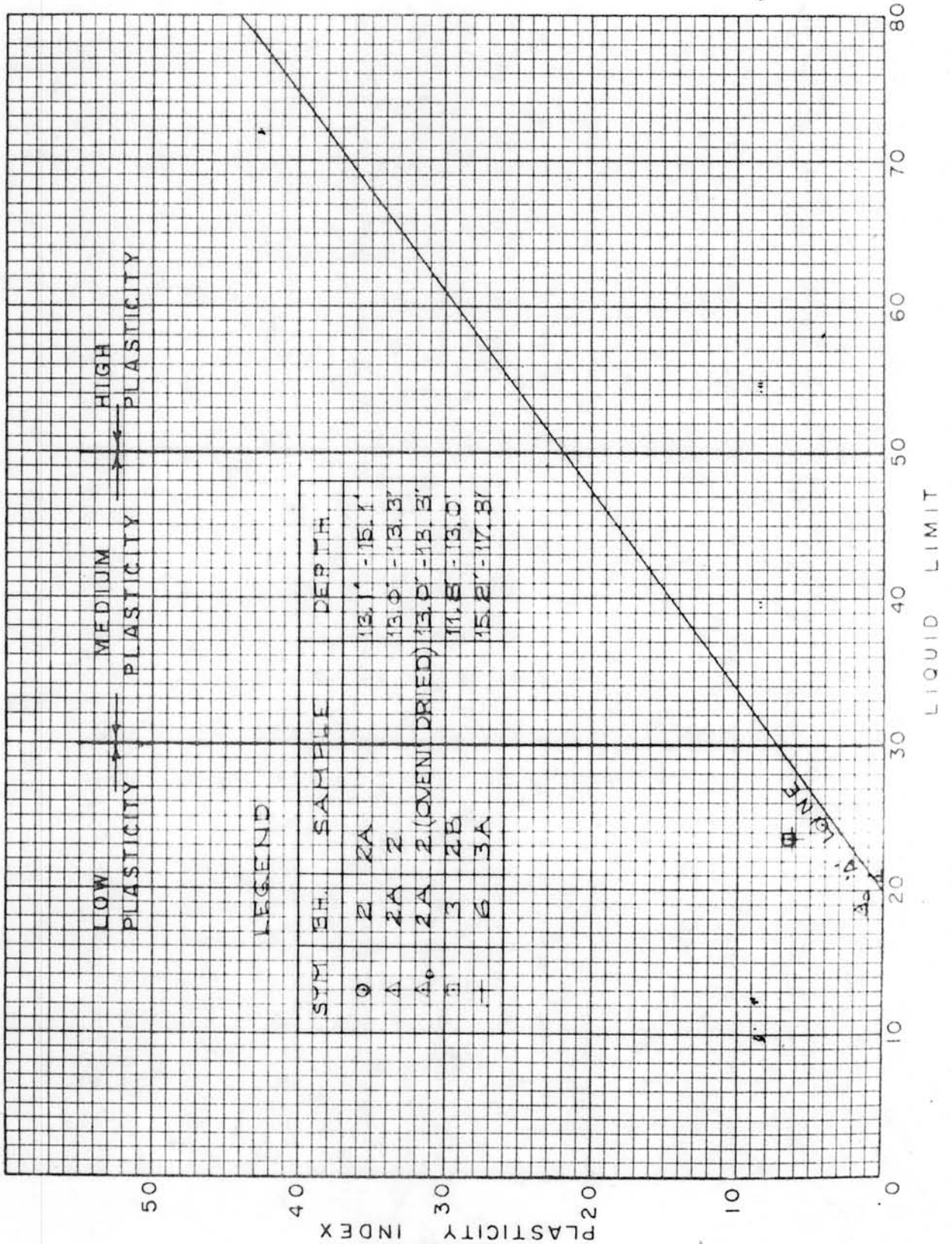


GEOCON

# PLASTICITY CHART

APPENDIX II  
 FIGURE 5  
 PROJECT M-472

SANDY / CLAYEY SILT



GEOCON

APPENDIX III - PHOTOGRAPHS

GEOCON

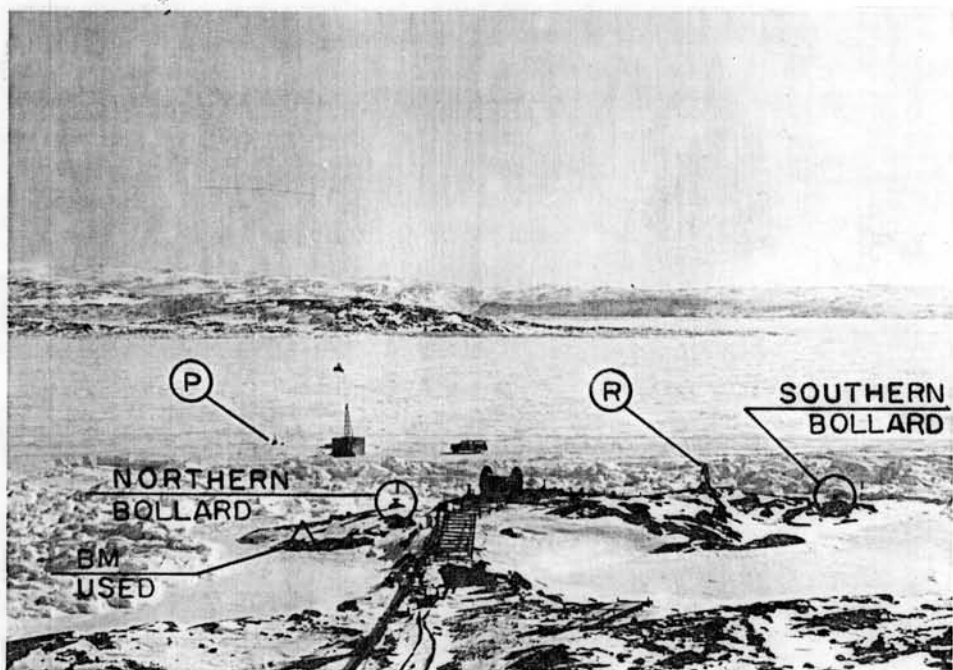


Photo 1 - General view of Site  
(Drill Rig at Borehole 3)

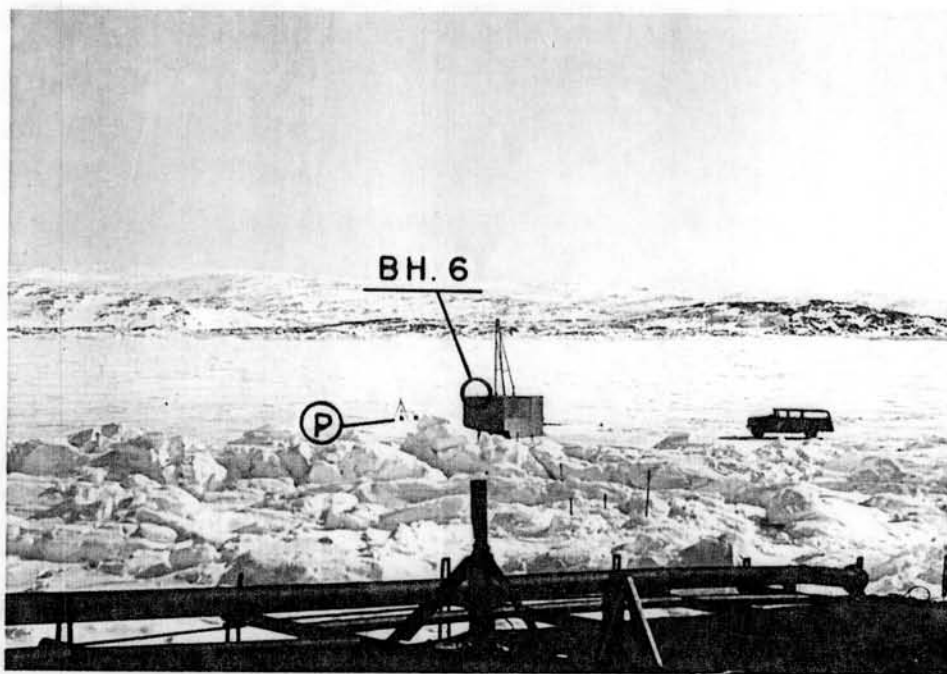


Photo 2 - Survey Line & Pressure ice  
(Drill Rig at Borehole 3)

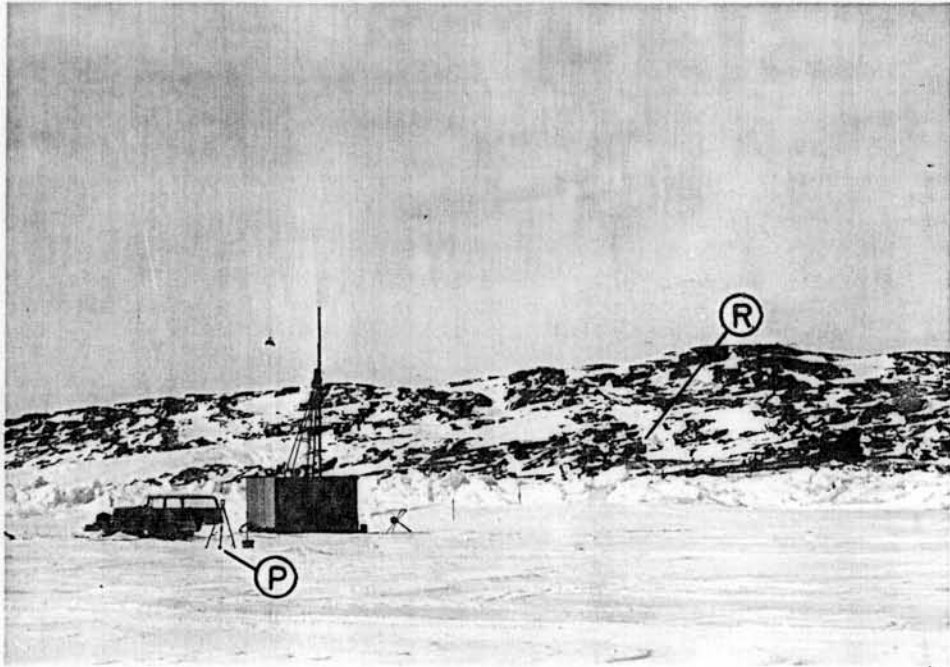


Photo 3 - Drill Rig at Borehole 3  
High Tide

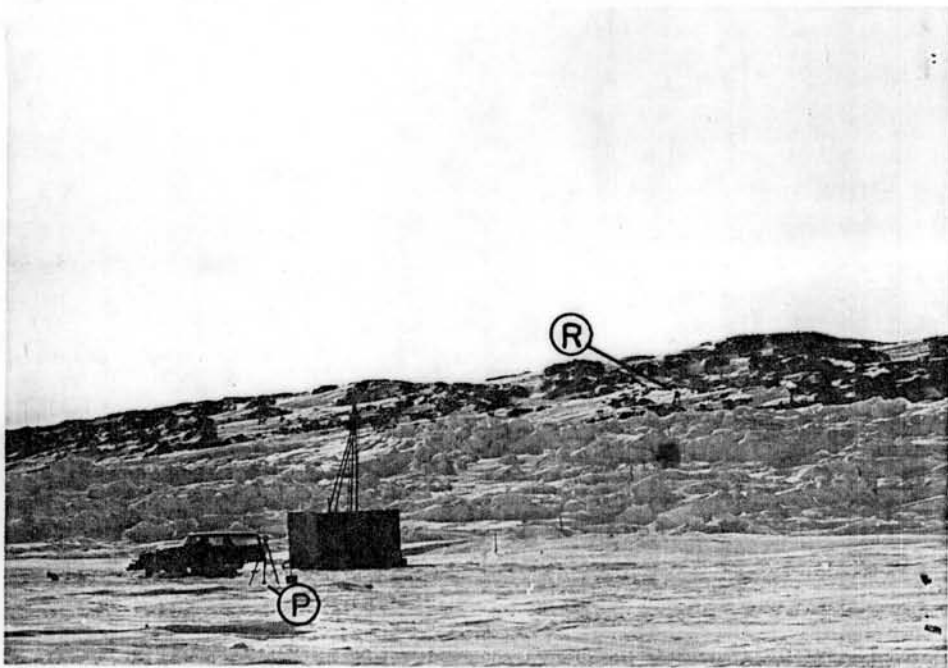


Photo 4 - Drill Rig at Borehole 3  
Low Tide

**Stantec**

**GEOTECHNICAL DESK STUDY, PROPOSED MARINE DEVELOPMENT IQALUIT  
STANDING OFFER FOR THE ARCTIC REGION ENVIRONMENTAL GEOPHYSICAL AND  
GEOTECHNICAL SERVICES**

**APPENDIX B**

Final Report Iqaluit Survey FJGI Doc. No. 9083SMN-001-RPT-002 Rev.0  
Fugro Jacques Geosurveys Inc. March 19, 2010

**FINAL REPORT**  
**IQALUIT PORT SURVEY**

**FJGI Doc. No. 9083SMN-001-RPT-002 Rev 0**

Prepared for:

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0	Issued for Review	C. Strickland / D. Upward	E. Cumming	E. Cumming	19 March 2010
Rev	Description	Prepared	Checked	Approved	Date

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## 1. INTRODUCTION

In September 2009, Stantec contracted Fugro Jacques GeoSurveys Inc (FJGI) to conduct sub bottom profiling near the head of Frobisher Bay located bordering Iqaluit, Nunavut. This survey was performed as a means of verifying past studies and determining the best location to develop a future port. The work was conducted for the Government of Nunavut.

Preparation for this survey began during the week of September 28<sup>th</sup>, 2009 with vessel mobilisation beginning on October 10<sup>th</sup>. Due to equipment troubles, mobilisation took longer than expected forcing our data collection to be delayed until October 18<sup>th</sup>. After very favourable weather conditions, our survey was completed on October 21<sup>st</sup>.

Considering the use of the NAD83 datum in client provided data, and use of NAD83-CSRS by our equipment, we also conducted static surveys to determine the shift between datums in the area. A static survey method was also used to verify CHS predicted high tide in Iqaluit.

Explanation of the methods used during this survey along with the resultant data will be further presented within this summary report.

### 1.1 Definitions

CACS	Canadian Active Control System
CHS	Canadian Hydrographic Services
CSRS	Canadian Spatial Reference System
DMA	Defence Mapping Agency
ITRF	International Terrestrial Reference Frame
FJGI	Fugro Jacques GeoSurveys Inc.
NAD83	North America Datum of 1983
TRNOBS	3D geodetic coordinate transformation tool (NAD83-CSRS to / from ITRF)
UTM	Universal Transverse Mercator
WGS84	World Geodetic System of 1984

### 1.2 Frobisher Bay / Iqaluit, NU

Frobisher Bay is an inlet of the Labrador Sea located on the southeast corner of Baffin Island, Nunavut, Canada. Overall it has a length of approximately 230 km and width at the inland side of approximately 20 km. The capital of the territory of Nunavut, Iqaluit, lies at the head of Frobisher Bay, seen in Figure 1.1.



Figure 1.1: Iqaluit - North American Map

### 1.3 Survey Area

As seen within Figure 1.2, the survey area covered two zones. The first section was along the southwest shoreline and the second surrounding the municipal wharf.



Figure 1.2: Survey Zones

The first zone contained four options for the future port. Previous geotechnical studies had been completed within Option 1. These options can be seen below in Figure 1.3. The dots located within Option 1 represent borehole samples taken during the 1975 Geocon study.

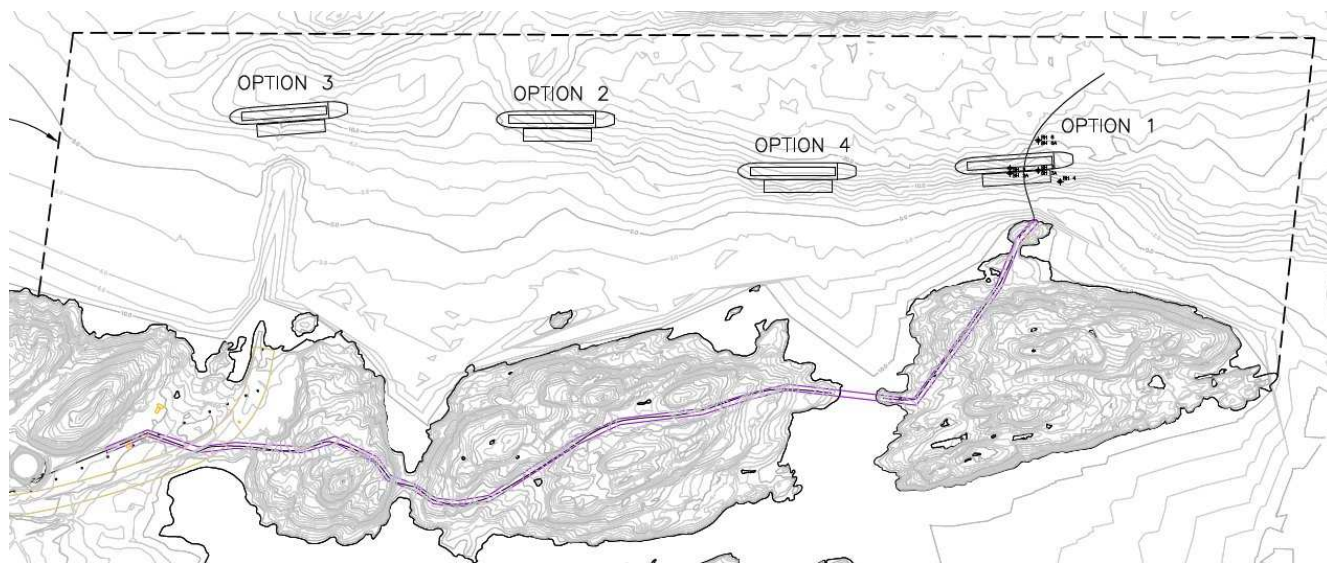


Figure 1.3: Port Options

The second zone, as seen in Figure 1.4, surrounds the municipal wharf and is completely high and dry at low tide. There was originally some concern that the large number of boats secured west of the wharf may cause survey equipment to become entangled. On the morning of the survey however, most boats had been removed and very calm conditions allowed anchoring lines to be visible. Secured boats were less restrictive than expected, allowing nearly the entire area to be surveyed.

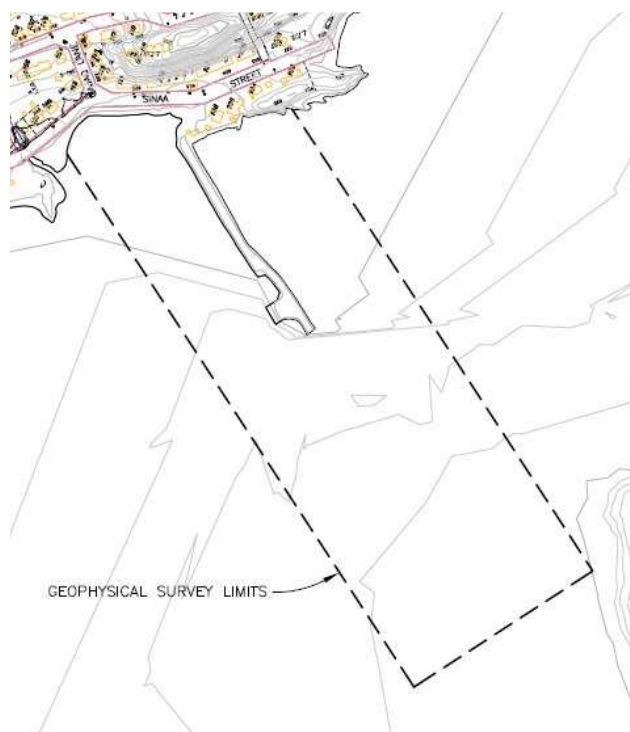


Figure 1.4: Municipal Wharf

## 2. CONTROL

To allow data from multiple surveys to be accurately combined, a common datum must be available. After reviewing previously collected data related to this project, it was determined that the local NAD83(Original) datum had been used. Considering the Fugro Starpack XP system uses a global based reference of ITRF2005 that would be translated to NAD83-CSRS, it was determined that the shift from NAD83(Original) to NAD83-CSRS in the Iqaluit area should be verified. Determining this shift is discussed in Section 3.

### 2.1 Datums

A datum is a known mathematical model that represents a surface used to describe the coordinates of a position on the earth. Due to datums having different mathematical definitions, a position given in one datum will not be the same in a second datum. As a result, when comparing values it is important to ensure that all values are in the same datum; else a transformation will have to be applied. Throughout this project, three datums were used:

<b>Shore Based Territorial Control</b>	NAD83(Original)
<b>Vessel Raw GPS Data</b>	ITRF2005
<b>Vessel Survey Data</b>	NAD83-CSRS

**Table 2.1: Datums Used**

Datums may be local, ie the North America Datum of 1983 (NAD83) or global such as the World Geodetic System of 1984 (WGS84). ITRF is another datum used that is geocentric and is actively defined (changes over time). This definition accounts for movement between the earths tectonic plates and is defined based on a particular “epoch” in time.

NAD83-CSRS is the primary datum used within Canada’s offshore oil industry. NAD83-CSRS is based on the NAD83(GRS80) Reference Ellipsoid. WGS84 is closely aligned with the latest epoch of ITRF. WGS84 is geocentric and globally consistent within  $\pm 1$  m. Positions compared between datums will show a shift in approximately 2 cms. A program TRNOBS provides 7 parameter shifts from NAD83-CSRS to ITRF

### 2.2 Grid Projections

Grid based coordinate systems allow positions to be communicated using Northing and Eastings. There are a large number of grid projections with the most commonly used in our area being UTM. This system defines the globe between 80° South and 84° North into 60 zones, each with 6° of longitude. These zones are created to minimize distortion caused using a 2D grid over a spherical surface. As with datums, it is important to ensure that data collected is defined correctly or values will not be comparable, ie Iqaluit, NU UTM Coordinates are defined as UTM Zone 19.

### 2.3 Transformations

A seven parameter (Bursa / Wolf) transformation can be used to convert from one datum to another. This definition is based on X, Y, Z shifts and rotations, along with a scale factor. When obtaining ITRF epoch information, it is these parameters that are used to define your datum.

It is important to remember the convention used when entering these parameters. Some software may

require DMA convention where by rotations will be reversed with respect to the definition provided by TRNOBS.

## 2.4 Definitions

The ITRF05 epoch used for transformation to CSRS was from October 10, 2009. The transformation parameters can be found below:

CCM49 – Control Point

**Latitude:** N 63 degrees 44 minutes 54.933248 seconds

**Longitude:** 068 degrees 30 minutes 44.256634 seconds

**Ellipsoidal Height:** 0 meters

**Transformations:** ITRF2005 -> NAD83CSRS

**ITRF EPOCH:** 2009/10/10

**Reference Ellipsoid - GRS80**

**Transformation Parameters (Bursa/Wolfe)**

**FROM ITRF2005 to NAD83 (CSRS98)**

\* [Rotations positive clockwise]

\* TX = 1.0026 m

\* TY = -1.9101 m

\* TZ = -0.5390 m

\* RX = -0.026766 sec

\* RY = 0.000248 sec

\* RZ = -0.010944 sec

\* DS = -0.000528 ppm

Using the above definition, the geodesy of the Starfix.Nav survey software was configured. The geodesy configuration screen can be seen in Figure 2.1. Take note that Starfix.Nav uses the DMA convention, therefore rotations will be right handed and carry opposite +/- notation.

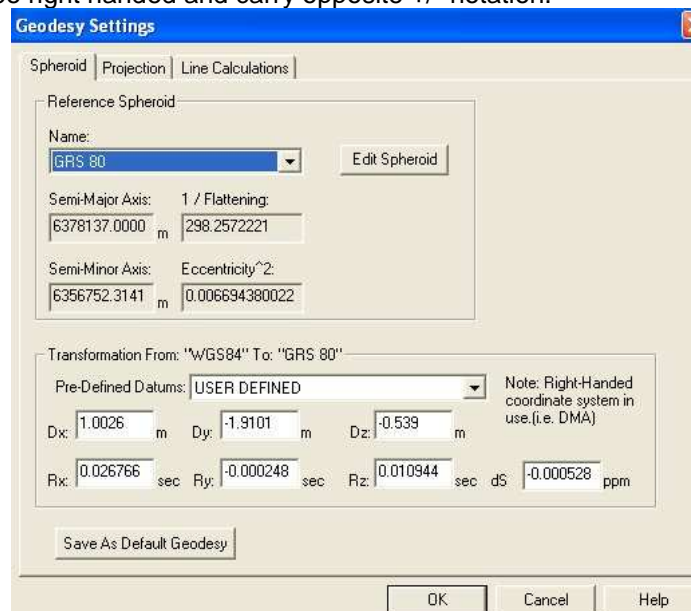


Figure 2.1: Starfix.Nav Geodesy (DMA)

After configuring Starfix.Nav, a check was made to ensure the transformation was being performed correctly. A coordinate in ITRF datum was input into Starfix.Nav using the MailDriver GPS simulator. Starfix.Nav outputs this coordinate in NAD83-CSRS based on the definition. The same ITRF position was manually converted to NAD83(CSRS) using independent software (TRNOBS). These two positions were compared and did match. If they do not match the definition must be rechecked.

### 3. SEISMIC SURVEY

#### 3.1 Mobilisation

Mobilisation of the Papiuruq began on October 10<sup>th</sup>, 2009 and was completed by the end of the day. A dry test of installed systems was then held outside the warehouse. After successfully running both navigation and seismic systems for a short period the boomer system then failed. Attempts to troubleshoot and repair were unsuccessful and therefore a replacement seismic system was shipped to carry out the project. The new system arrived in the afternoon of October 17<sup>th</sup>. This system was installed and short test completed with all tests being successful. Equipment used on this project can be found in Tables 3.1 through 3.3 and Figures 3.1 through 3.6.

During the seven day shipping period, a number of actions were carried out. A larger power generator was obtained to run the boomer system and a replacement heater was purchased for the boat's cabin. Static surveys (Section 4) were also completed to obtain transformation data. Finally a verification of CHS predicted high tide was carried out (Section 5).

#### 3.2 Equipment

Quantity	Description	Serial Number
2	EDGEPORT BOXES, DLINK HUB, LMR 400 CABLE	N/A
1	REGULATED POWER SUPPLY	N/A
1	TRIPOD	N/A
1	UPS UNIT RACKMOUNT	XS9911000107
1	STARFIX 3000L RECEIVER	RD353368
1	ALISON ANTENNA GPS AD316-11-3141	925
1	TRIMBLE DSM	0224091964
1	TRIMBLE GPS/COASTGUARD ANTENNA	0220348124
1	NOVATEL CDGPS PRO PAK V3 RECEIVER	NAP07030017
1	ALISON AD492 GPS/GLONASS W.NOTCH	046
1	STARPACK BASIC UNIT	SPK0292
1	STEALTH LPC 650	STL0902LPC28102
1	STEALTH LPC 650	STL0902LPC28103
1	LCD MONITOR 19" PHILLIPS	AU3A0922010823
1	LCD MONITOR 19" PHILLIPS	AU3A0922010900
1	NOVATEL L1L2 CDGPS ANTENNA	NZT09310002

**Table 3.1: Navigation Equipment**

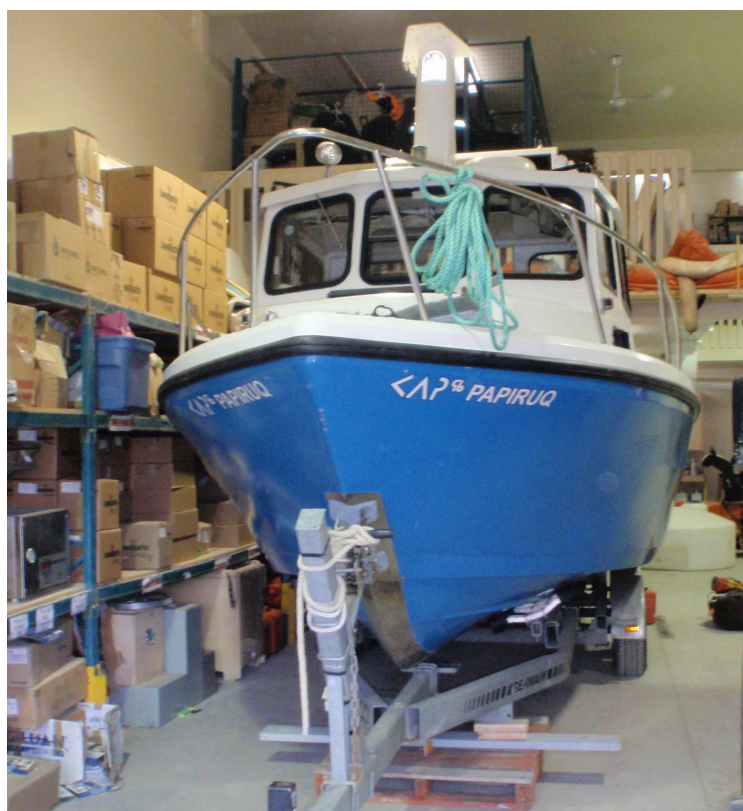
Quantity	Description	Serial Number
1	Boomer Plate Sled	N/A
1	EPC Boomer Source	N/A
1	Single Channel Streamer	N/A

1	Subsea Systems, Inc. Elver, SPSU-500	3000
1	EPC Boomer Power Supply	3020
1	Pentax PocketJet Printer	3013

**Table 3.2: Original EPC Seismic Equipment**

Quantity	Description	Serial Number
1	Applied Acoustics AA301 Boomer Plate	2050022
1	Applied Acoustics CSP 300P Power Supply	2070397
1	Applied Acoustics CSP HV Junction Box	2020329HVJB
1	Applied Acoustics CSP HV Output Cable	2030207
1	Applied Acoustics CAT200 Boomer Catamaran	2010725

**Table 3.3: Replacement Applied Acoustics Seismic Equipment**



**Figure 3.1: Papiuruq**



Figure 3.2: Navigation Rack

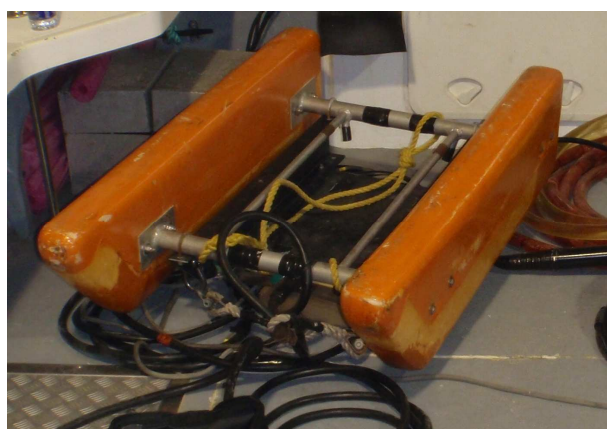


Figure 3.3: Original Boomer Plate Sled



Figure 3.4: EPC Boomer Power Supply

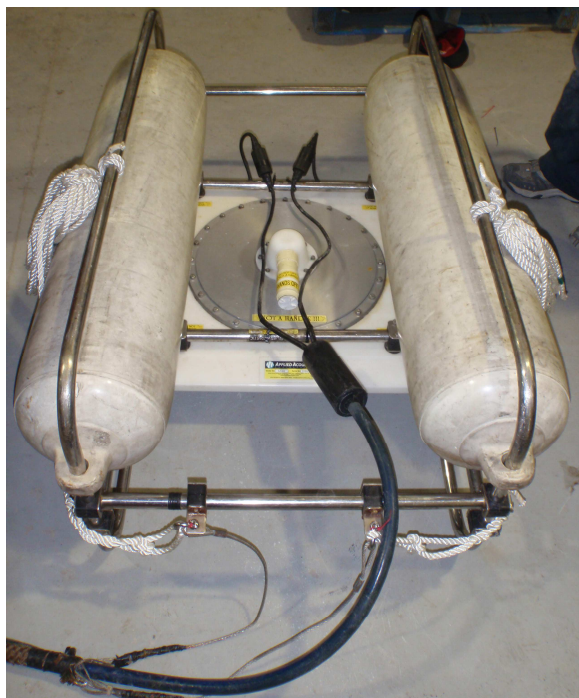


Figure 3.5: Applied Acoustics Boomer Plate & Catamaran



Figure 3.6: Applied Acoustics CSP 300P Power Supply

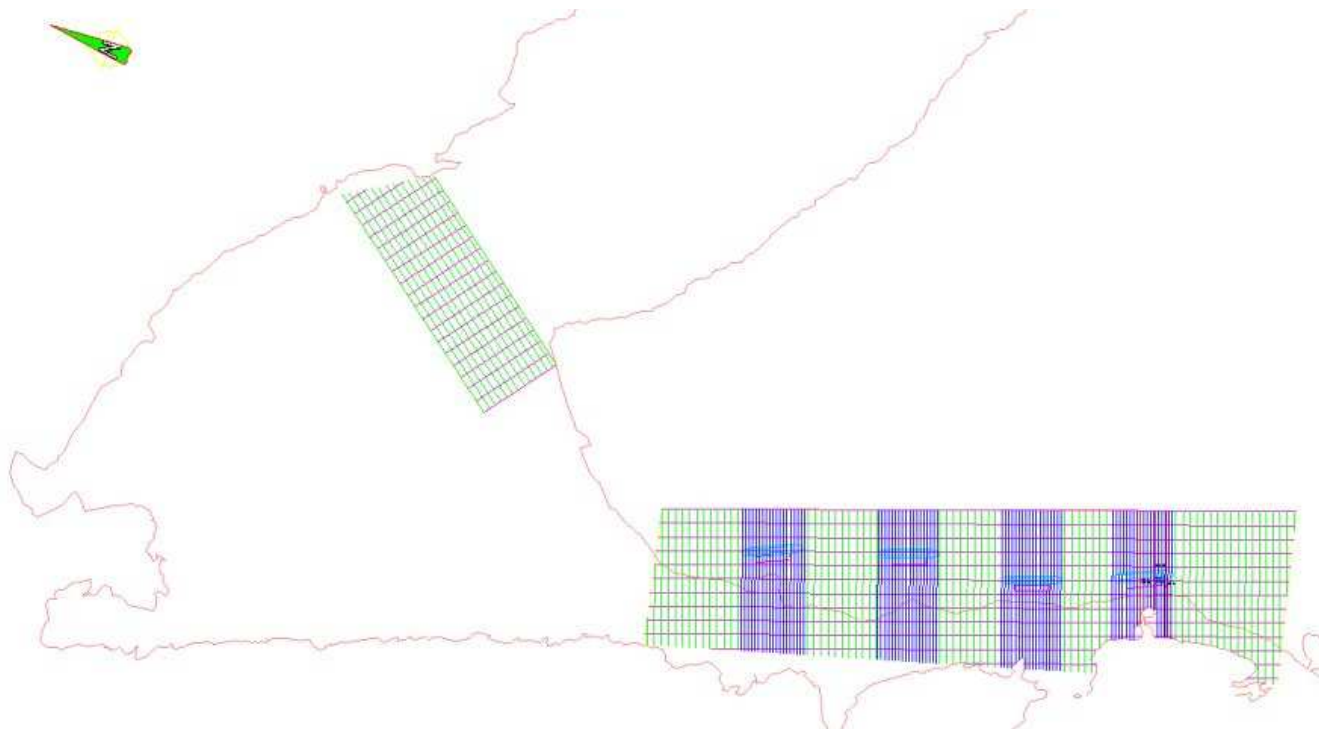
### 3.3 Personnel

Name	Company	Position / Title
Derrick Upward	FJGI	Party Chief / Surveyor
Doug Bowlus	FWI	Geophysical Tech
Pat Tatchell	Government of Nunavut	Captain
Mike Alexander	Government of Nunavut	Deckhand

Table 3.4: Personnel

### 3.4 Operations

The Papiuruq was launched near high tide on the morning of October 18<sup>th</sup>. Conditions were less than favourable; however time was available to wet test equipment and complete final adjustments. Several test lines were then ran with favourable results. By noon conditions had improved, and surveying the grid had begun.



**Figure 3.7: Survey Grid**

The survey grid was assigned spacing of 20 meters for survey lines, 40 meters for tie lines and 10 meters for priority areas. Independent lines were also run through bore holes locations within the 'Option 1' zone. The contours within Figure 3.7 represent the 0 meter and +10 meter elevations in chart datum. The 0 meter contour is the southern contour, running through the middle of the main survey grid.

One of the greatest factors influencing this survey was the large tide variation. Tide ranges of approximately 10 meters were experienced during this project thereby being the main influence on the order of the line survey. Outer tie lines and lower priority areas were ran during lower tides. Priority areas required high tide to maximize survey coverage. This was especially so with respect to the municipal wharf zone. A prime example of use of high tide occurred when running lines over the causeway and in close proximity to shoals. A large percentage of the survey area was fully visible during low tide. Figure 3.8 displays a good representation of the tides in the area. The square represents an approximation of the survey zone surrounding the municipal wharf. Note the shoal in the background is submerged during high tide.



Figure 3.8: Low Tide – Municipal Wharf

### 3.5 Track Plots

Over three days of survey time, planned survey grids were ran to achieve maximum coverage possible. Figures 3.9 and Figure 3.10 show the navigation track plot at each survey zone at the end of the project.

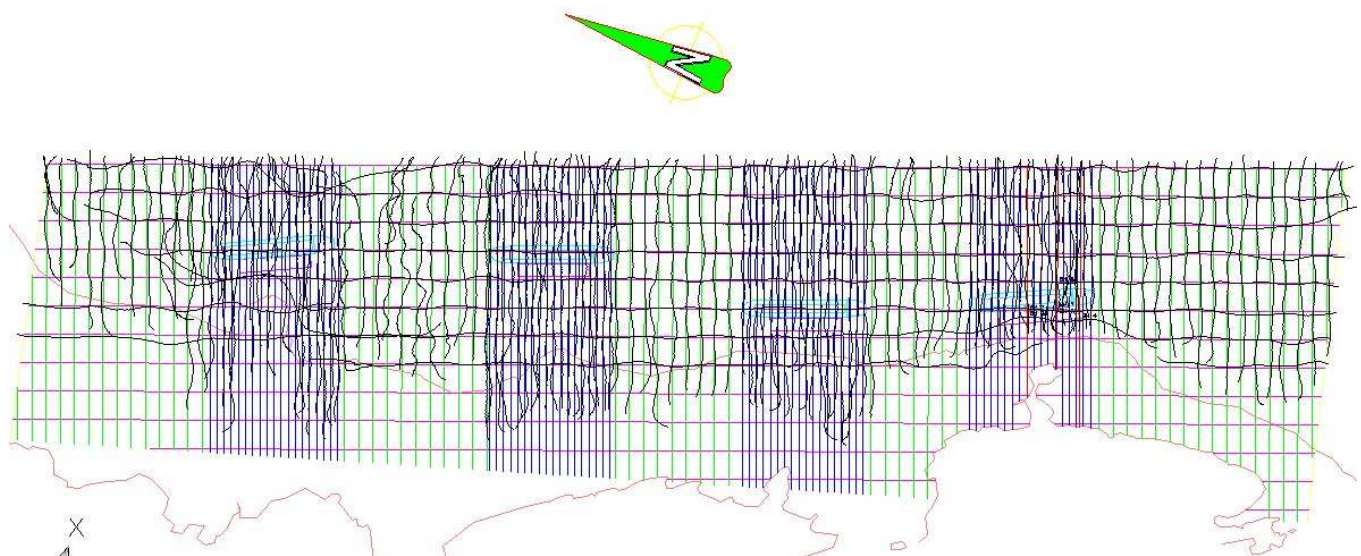
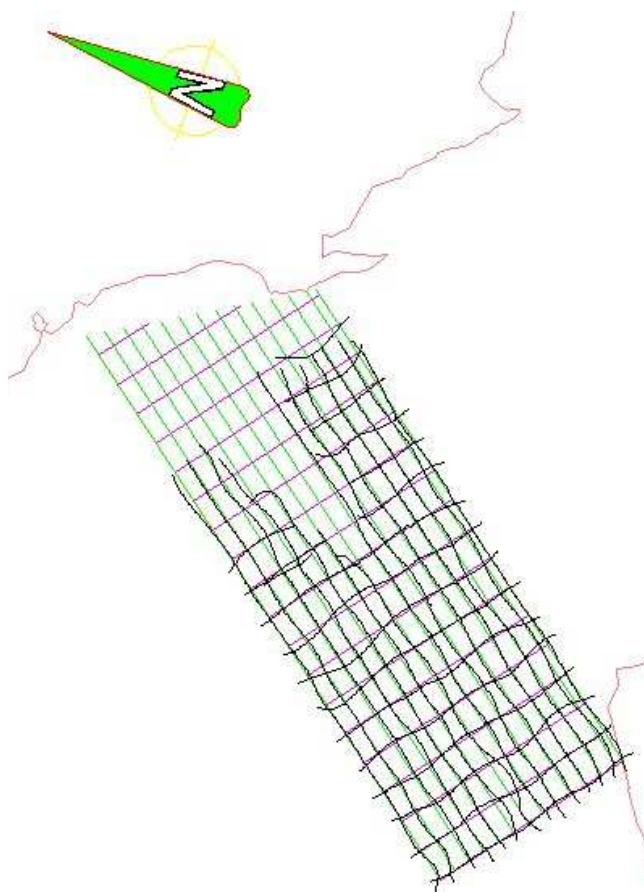


Figure 3.9: Track Plot – Main Grid



**Figure: 3.10: Trackplot – Municipal Wharf Grid**

### **3.6 Demobilisation**

Survey operations were completed on the afternoon of October 21. Tide level was still high enough to allow the recovery of the vessel. The Papiuruq was returned to the warehouse where all data was transferred to external hard drives to be hand carried back to the home office. Equipment was removed from the vessel disassembled and packed for shipping. The following day the shipping containers were brought to Canadian North Airlines to be return shipped to their origins. Flights for Fugro personal departed at approximately 2pm on October 22<sup>nd</sup>.

## 4. STATIC SURVEY

### 4.1 NAD83 to NAD83-CSRS Shift

Because a direct mathematical conversion from NAD83(Original) to NAD83-CSRS is not possible, shift values must be determined through an alternate method. Within Nunavut a database of federally established control monuments is available. Before beginning this project, a summary of all control monuments in the Iqaluit area was obtained (Appendix A). It was found that four monuments were surveyed in both NAD83(Original) and NAD83-CSRS. Because the station positions were observed in both datums, the difference between these positions can be calculated. This in turn, produces the shift required to transform coordinates from one datum to the other within the Iqaluit area. This shift can then be applied to all UTM Zone 19, NAD83 coordinates used during the project to convert to or from UTM Zone 19, NAD83-CSRS.

Control Monument	NAD83-CSRS		NAD83(Original)		NAD83-CSRS to NAD83(Original)	
	Northing	Easting	Northing	Easting	Delta N	Delta E
IQALUIT GPS	7068847.495	522420.113	7068847.405	522420.093	-0.090	-0.020
CCM49	7069091.503	524068.704	7069091.199	524067.692	-0.304	-1.012
CCM28 PALUG3608	7068622.895	525561.284	7068622.572	525560.261	-0.323	-1.023
CCM6	7070285.252	522960.307	7070284.955	522959.292	-0.308	-1.017

**Table 4.1: NAD83-CSRS to NAD83(Original) Deltas**

After calculating the shifts, it was discovered that the monument IQALUIT GPS did not match the shift found between datums of the other control monuments. This can be found in Table 3.1. Considering the monument IQALUIT GPS was located at a local Environment Canada weather station, it was felt it would likely be better observed and maintained. In turn it was decided to perform an independent group of static surveys to determine the shift between datums.

### 4.2 Method

#### 4.2.1 Hardware

After a control monument was located, a static survey was completed in the following steps:

- A tripod supporting an Alison AD316 antenna is setup (Figure 3.1).
- LMR cable was connected and ran from the antenna to the Starpack receiver.
- The antenna was levelled and centered over the control point.
- The height of the antenna is measured and recorded. In this case, a slope measurement was taken.
- Power cables were connected to the Starpack and logging laptop computer. Then plugged into a surge protector attached to a 1000 watt Yamaha generator.
- A Cat5 network cable is connected between the Starpack and Laptop. Final physical setup can be seen in Figure 4.2.



Figure 4.1: Static Survey - Antenna Setup



Figure 4.2: Static Survey – Starpack & Logging Laptop Setup

#### 4.2.2 Software

Software was setup to log DGPS and Raw GPS data (RINEX format) simultaneously through Starfix Logging. This setup was completed as per Document SP-PROC-047 Rev 0 Section 6. When using the Starpack, Raw GPS data collection requires IOWIN drivers for the Novatel OEM to be setup using 'Network' and the port number being the 'Starpack base port + 6'. DGPS data is logged through the 'Fugro HP Position Format In' driver using 'Network' and port number being the 'Starpack base port + 2'.

Once the system setup was complete, it was verified that XP was converged and logging, and a 2 hour session was conducted. This data was then backed up and stored for future processing.

#### 4.2.3 Processing

Collected DGPS data was transferred into Excel where average positions standard deviations and spread could be calculated. Scatter plots representing collected DGPS data can be found in Appendix D.

Static data was post processed but was found to be inconsistent, possibly due to the short logging session at high latitude. Due to XP, DGPS data also being collected, it was decided to use it as our main source of survey data.

#### 4.2.4 Results

After processing the static survey data our resultant data is displayed in Tables 4.2 through 4.5

Control Monument	NAD83-CSRS		NAD83(Original)		NAD83-CSRS to NAD83(Original)	
	Northing	Easting	Northing	Easting	Delta N	Delta E
IQALUIT GPS	7068847.495	522420.113	7068847.405	522420.093	-0.090	-0.020
CCM49	7069091.503	524068.704	7069091.199	524067.692	-0.304	-1.012
CCM28 PALUG3608	7068622.895	525561.284	7068622.572	525560.261	-0.323	-1.023

Table 4.2: Survey Database Shifts

Control Monument	NAD83-CSRS OBSERVED EPOCH: OCT 10,2009			NAD83-CSRS EPOCH: 1997.0			CALCULATED - OBSERVED		
	Northing	Easting	Elev	Northing	Easting	Elev	Delta N	Delta E	Delta Elev
IQALUIT GPS	7068847.504	522420.024	20.844	7068847.495	522420.113	20.87	0.009	0.089	0.026
CCM49	7069091.497	524068.694	45.696	7069091.503	524068.704	45.61	0.006	0.010	0.086
CCM28	7068622.813	525561.311	107.443	7068622.895	525561.284	107.43	0.082	0.027	0.013

Table 4.3: Observed vs Survey Database

Control Monument	OBSERVED NAD83-CSRS to NAD83 ORIGINAL	
	Delta N	Delta E
IQALUIT GPS	-0.099	0.069
CCM49	-0.298	-1.002
CCM28	-0.241	-1.050

**Table 4.4: Observed NAD83-CSRS to NAD83(Original)**

After comparing the Observed NAD83-CSRS to NAD83 Original deltas, the inconsistency can still be seen on control point 'IQALUIT GPS'. Considering our observed position and the database's position are within 9cms of one another, it's possible the control point's NAD83(Original) position value contains an error. If shifting datums between NAD83-CSRS and NAD83(Original), it is recommended to exclude the IQALUIT GPS control point as a factor in determining the shift. Considering the transformation deltas of CCM49 and CCM28 are consistent with those observed, the average of these shifts can be used to determine the transformation between NAD83-CSRS to NAD83(Original) as seen in Table 4.5.

Control Monument	NAD83-CSRS to NAD83(Original)	
	Delta N	Delta E
CCM49	-0.304	-1.012
CCM28 PALUG3608	-0.323	-1.023
<b>AVERAGE</b>	<b>-0.314</b>	<b>-1.018</b>

**Table 4.5: NAD83-CSRS to NAD83(Original) Shift in Iqaluit, NU**

## 5. HIGH TIDE VERIFICATION

To verify CHS predicted high tide for Iqaluit, a multiple step process was used. First when using GPS, a reference ellipsoid is used. This means that height measurement on a GPS system will not match tidal heights which are referenced to "Chart Datum".

The first step in our process was to determine the separation between Chart Datum and the Reference Ellipsoid. This is done by performing a static survey, as in Section 4, over a benchmark. The difference between the published height of the benchmark and the observed ellipsoidal height is then calculated. This value can then be used to translate other ellipsoidal heights to chart datum. In this case, we performed our static survey at the CHS benchmark FB2-1969, Chart Datum Elevation 10.303m (Figure 4.3). Benchmark data can be found in Appendix B.



Figure 5.1: CHS Benchmark FB2-1969

The second step taken was to determine the elevation (ellipsoid) of a reference point located at the municipal wharf. We chose to use a steel ledge on the upper part of the wharf as a reference. This ledge could be surveyed using DGPS without blockage and also allow the water level to directly measured from if necessary. As with the previous static surveys, a two hour logging session was recorded.

The bottom level of the wharf allowed an easier means of measuring the water level and also contained a steel ledge to reference. We measured and recorded the vertical offset between the steel ledges of the upper and lower levels of the wharf. By applying the offset to the ellipsoidal height of the upper ledge, we were able to determine the ellipsoidal height of the lower ledge. This setup can be viewed in Figure 5.2.

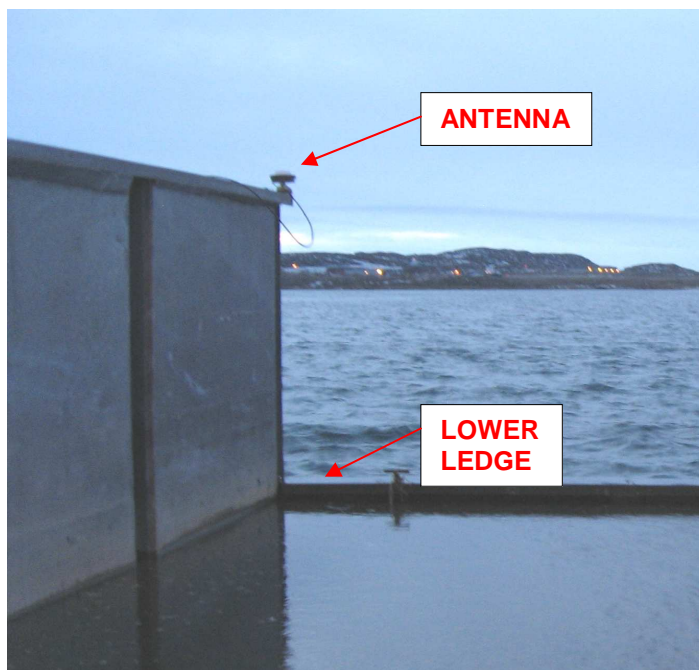


Figure 5.2: Tide Observation

On October 15, 2009 at 1705 EDT we began our observation of the water level as it approached high tide. We recorded the distance from the lower wharf ledge to the water level at a 5 minute intervals, for one hour. These observations can be seen in Table 5.1. CHS predicted high tide for Iqaluit was 9.7meters at 1736 EDT. Table 5.2 represents our tidal observations in chart datum. High tide was observed at 1730 EDT reaching 9.55 meters. Tidal calculations can be found in Appendix C.

Time (EDT)	Water Level (cm) (Lower Ledge Reference)
1705	24.0
1712	21.0
1715	18.5
1720	16.5
1725	13.0
1730	12.5
1735	12.0
1740	12.5
1745	13.5
1750	14.5
1755	17.0
1800	22.0
1805	25.5

**Table 5.1: Tide Observation**

TIME (EDT)	Water Level (Chart Datum)
1705	9.43
1712	9.46
1715	9.49
1720	9.51
1725	9.54
1730	9.55
1735	9.55
1740	9.55
1745	9.54
1750	9.53
1755	9.50
1800	9.45
1805	9.42

**Table 5.2: Tide Observation in Chart Datum**

## 6. Geophysical Survey Results

### 6.1 Data

Seismic data were processed for noise suppression using Gedco's Vista 9.0 software in order to improve data quality (a function of surveying in very shallow water). Once data were processed, they were imported into Fugro Jacques GeoSurvey's SMT "Kingdom Suite" interpretation package for horizon mapping.

The Seismic data were of good quality overall, especially in light of the shallow water conditions and sloping seabed. Seismic data quality was still somewhat dependent on water depth. In shallow waters along the nearshore, seafloor multiples tended to overprint and obscure real reflectors within the data. This is a normal limitation of shallow water seismic survey work. Seafloor multiples were especially notable at the northeastern (Municipal Wharf) site.

CHS bathymetry data was available in the area. There was good coverage over the proposed locations on the western side of Frobisher Bay (Options 1 to 4). However; the municipal wharf location did not have sufficient coverage to generate a sediment thickness below chart datum map.

### 6.2 Existing Borehole Information

A limited amount of borehole data was available from a Geocon (1975) report, which had been submitted to the St. Lawrence Seaway Authority. Data from the six available boreholes was used to help correlate horizon interpretation in Kingdom Suite. However, the boreholes were all situated within the wharf area of Option 1 (Enclosures 1 to 4), and given their location in relatively shallow water, with a relatively steep slope into deeper water, the correlation between boreholes and seismic over much of the site is considered somewhat tenuous.

The following strata were identified within the boreholes:

#### Very Loose to Loose Grey Organic Sandy Silt and Silty Sand with Occasional Gravel (Geocon)

Seabed was composed of a layer of grey organic sandy silt and sandy silt with occasional gravel in all boreholes. The thickness of this layer varied from 10 to 15 feet except in borehole 4 located closest to the shoreline where the thickness of this layer was 3 feet. However, in borehole 4, a layer of organic sand was encountered underlying the sandy silt and silty sand and this layer is described separately below. The organic sandy silt and silty sand was generally grey or dark grey in colour and locally was black in colour. Generally the grey soil contained significant organics and exhibited a strong organic odour. On air drying the black soil became grey in colour.

#### Compact Grey/Black Organic Sand with Occasional Gravel (Geocon)

Underlying the organic sandy silt and silty sand layer in borehole 4, a layer of grey/black organic sand with occasional gravel was encountered for a thickness of about 5 feet.

#### Very Soft to Soft Grey Organic Sandy/Clayey Silt (Geocon)

A layer of grey organic sandy/clayey silt was encountered underlying the silty sand to sandy silt layer in boreholes 2, 2A, 3, 3A and 6 and the organic sand layer in borehole 4. This stratum was encountered at the 4 locations investigated and is therefore inferred to be continuous within the limits investigated. The thickness of this layer varied between 1.6 ft in borehole 4 and 5.1 feet in borehole 3A.

#### Dense to Very Dense Grey/Brown Sand and Gravel (Geocon)

Immediately underlying the sandy/clayey silt layer a grey/brown sand and gravel stratum was encountered in all of the boreholes. The thickness of this stratum varied between 2.2 feet in borehole 2A and 17.9 feet in borehole 6A. The sand and gravel deposit was fully penetrated in boreholes 2A, 3A, 4 and 6A whereas boreholes 2, 3 and 6 were terminated within or at the base of this stratum.

#### Grey Granitic Bedrock (Geocon)

Underlying the sand and gravel stratum grey granitic bedrock was encountered and core drilled in AXT size in boreholes 2A, 3A, 4 and 6A for depths of 7.3, 7.7, 13.1 and 10.5 feet respectively. Also, occasional fractures varying generally from about 45 degrees to vertical were observed. Generally the fractures were rust stained to a depth of about 8 feet below bedrock surface.

### **6.3 Horizon Interpretation**

Two horizons were interpreted. These horizons are interpreted, based upon correlations with boreholes (somewhat tenuous, as noted above) and acoustic character, to represent:

- acoustic basement (interpreted as bedrock) and
- a change in acoustic character, interpreted as base of fine-grained sediments

As noted, horizon interpretation was challenging in shallow water areas where seafloor multiples occurred more frequently, and in areas of steep slope, immediately seaward of the wharf area(s). However, reasonably consistent ties between primary (shore perpendicular) and tie lines (alongshore) provide some confidence in the interpretation.

The interpreted bedrock horizon is characterized by a semi-continuous reflector (with decreased continuity in the vicinity of Options 2 and 3 (Enclosures 1 to 4)). This reflector was occasionally difficult to carry, and in places the interpretation was based on change in acoustic character (more so than a well defined reflection). This was generally true in the deepest water areas, offshore from Option 1, and occasionally on the slope.

In the vicinity of the Municipal Wharf site to the NE, bedrock was apparent as a weak reflector dipping towards offshore. The presence of multiples in this area reduces confidence in its accuracy.

The interval between acoustic basement and the base of fine sediments (interpreted to be the sand/gravel interval seen in the borehole data) does display some internal structure, suggestive that the sands and gravels are not massive.

Within the vicinity of Options 1 to 4, the interval between the seabed and the interpreted base of fine-grained sediments contains semi-continuous to continuous reflections, suggestive of stratification.

At the Municipal Wharf site, the base of fine-grained sediment is not as obvious as at Options 1 to 4. However there does appear to be an equivalent reflector present, which is tentatively correlated on the basis of acoustic character. The presence of multiples again limits confidence in this pick.

It should be noted that the interpretations presented above, and the horizon mapping, represent the interpreter's best efforts. The lack of clearly defined, continuous reflections, and relatively subtle variations in acoustic character, suggest that some contingency (10 to 15%) should be factored into the use of this data.

Having made that point, it should be noted that the data quality was quite high for a shallow water, northern region investigation.

## **6.4 Mapping**

Various maps were generated.

Isopachs indicate the thickness of sediment from seafloor to the mapped horizon (either fine-grained sediment thickness or total overburden thickness). Plates 6.1 to 6.10 display isopach maps for each of the 4 port options, as well as the Municipal Wharf. Enclosures 2 and 3 are also isopach maps.

The Depth Map (Enclosure 4) illustrates the depth below chart datum (as per bathymetric data provided) to acoustic basement (interpreted bedrock). Due to insufficient data density, a depth to bedrock map could not be generated for the Municipal Wharf site.

Enclosure 1 displays the bathymetry data provided.

The following are descriptions of the results at each of the Port Options and at the Municipal Wharf.

### **6.4.1 Option 1**

Interpretation of Option 1 site was aided by the presence of borehole data and was not as influenced by multiples as the other sites. Overburden thickness ranged between approximately 7m near shore to 24m (Plate 6.1). Fine-grained sediment thickness ranged from 2m to 16m (Plate 6.2).

### **6.4.2 Option 2**

Option 2 had no borehole data nearby to assist in correlating horizons. Overburden thickness ranged between 7m and 17m (Plate 6.3). Fine-grained sediment thickness ranged from 3m to 13m (Plate 6.4).

#### **6.4.3 Option 3**

Data in the vicinity of Option 3 were subjected to multiples. Overburden thickness ranged from approximately 7m to 20m (Plate 6.5). Fine-grained sediment thickness ranged from approximately 5m to 19m (Plate 6.6).

#### **6.4.4 Option 4**

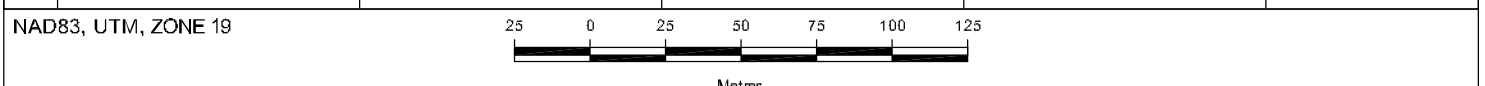
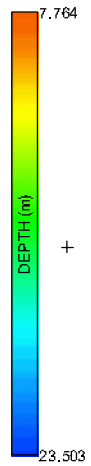
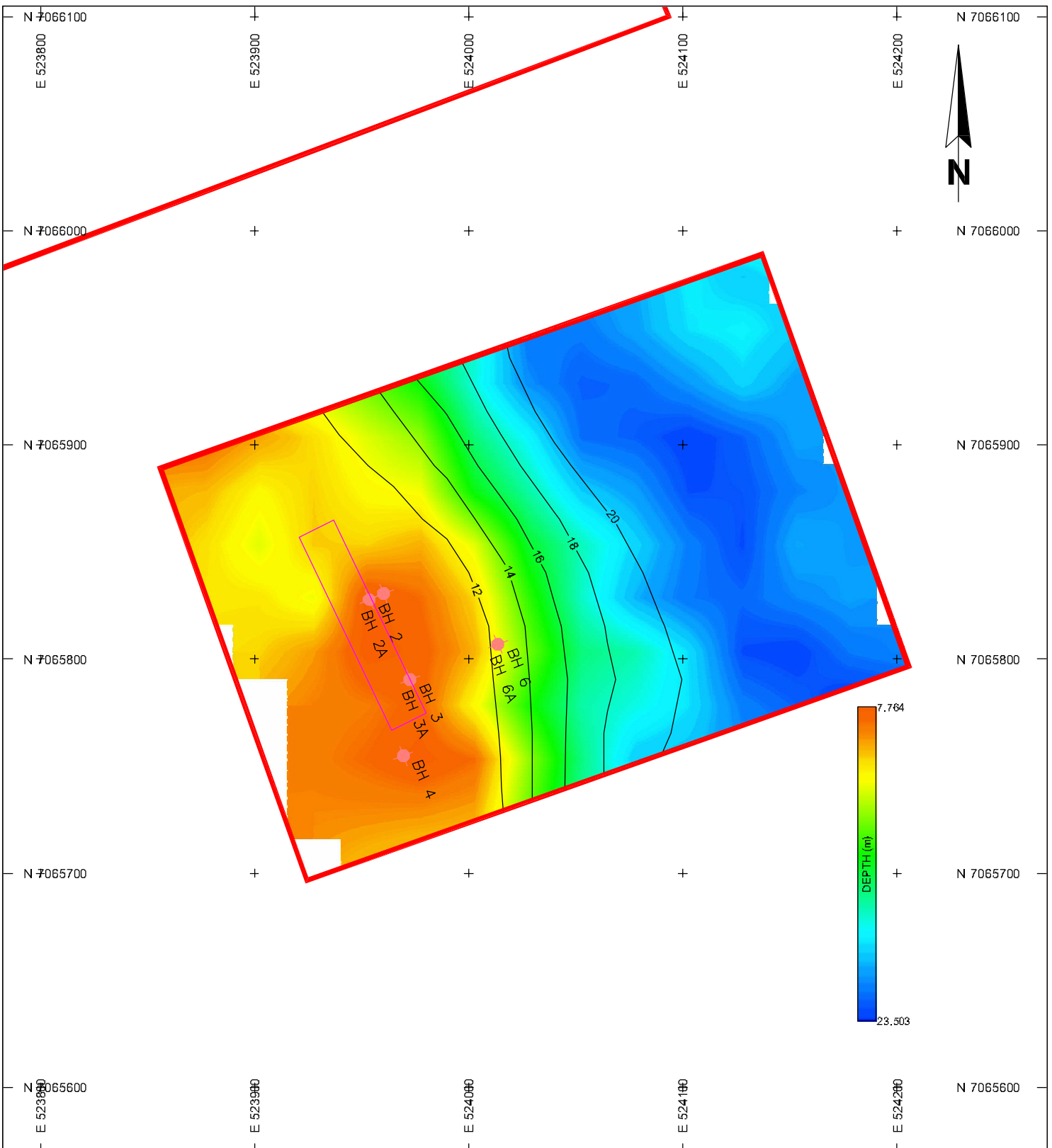
Data from the Option 4 area were not as degraded by multiples, due to greater water depths. The overburden thickness ranged from approximately 4m to 25m (Plate 6.7). Fine-grained sediment thickness ranged from 2m to 16m (Plate 6.8).

#### **6.4.5 Municipal Wharf**

The municipal wharf site to the North Eastern side of the area was largely affected by seafloor multiples. As a result, confidence in the interpretation is limited since shallow occurring multiples will mask any real reflectors. The overburden thickness is interpreted to be between 8m to 37m thick (Plate 6.9). The fine-grained sediment thickness is interpreted to be between 1m and 32m thick (Plate 6.10).

## **7. CONCLUSION**

This survey will be used to aid the Stantec and the Government of Nunavut in the development of a port within the community of Iqaluit. Due to the remoteness of Iqaluit, the shipment of the replacement boomer system took a considerable amount of time. While awaiting arrival of equipment, CHS predicted high tide was verified and several static surveys were conducted. Weather conditions played to be very favourable making ideal conditions on the water for most of the project. The coverage of the survey area was maximised by taking advantage of high tides. Support personnel were also extremely versatile and contributed greatly with respect to the project being fulfilled. Good quality sub-bottom data were acquired, and have been interpreted herein.

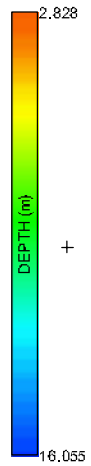
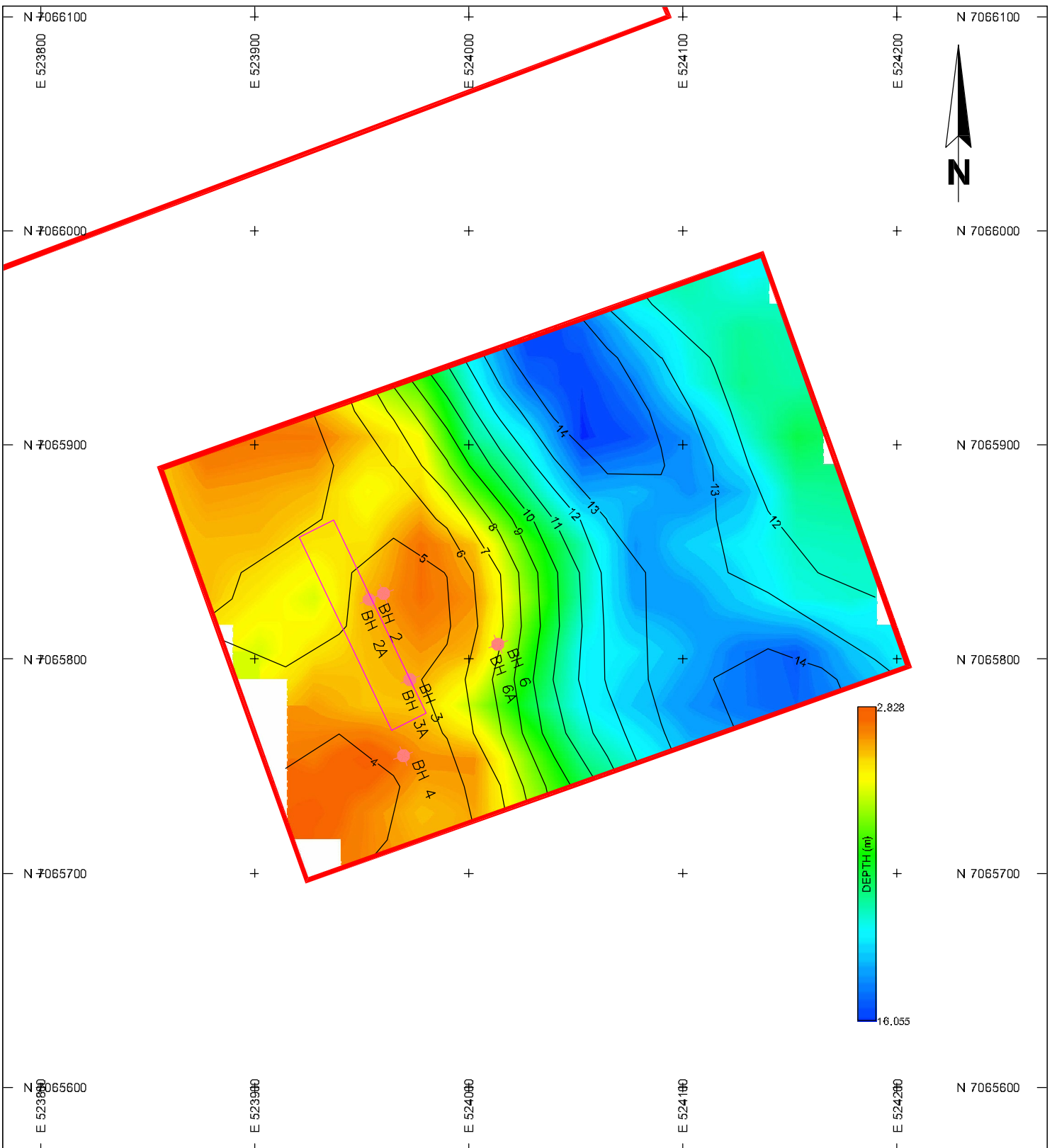


- SURVEY EXTENTS
- 40 — THICKNESS CONTOUR (m)
- WHARF
- BOREHOLE

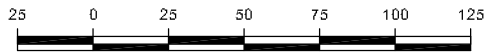
VELOCITY OF 1600 m/sec USED FOR CONVERSION

**WHARF OPTION 1 ISOPACH MAP  
INTERPRETED OVERBURDEN THICKNESS**

PLATE 6.1



NAD83, UTM, ZONE 19



Metres  
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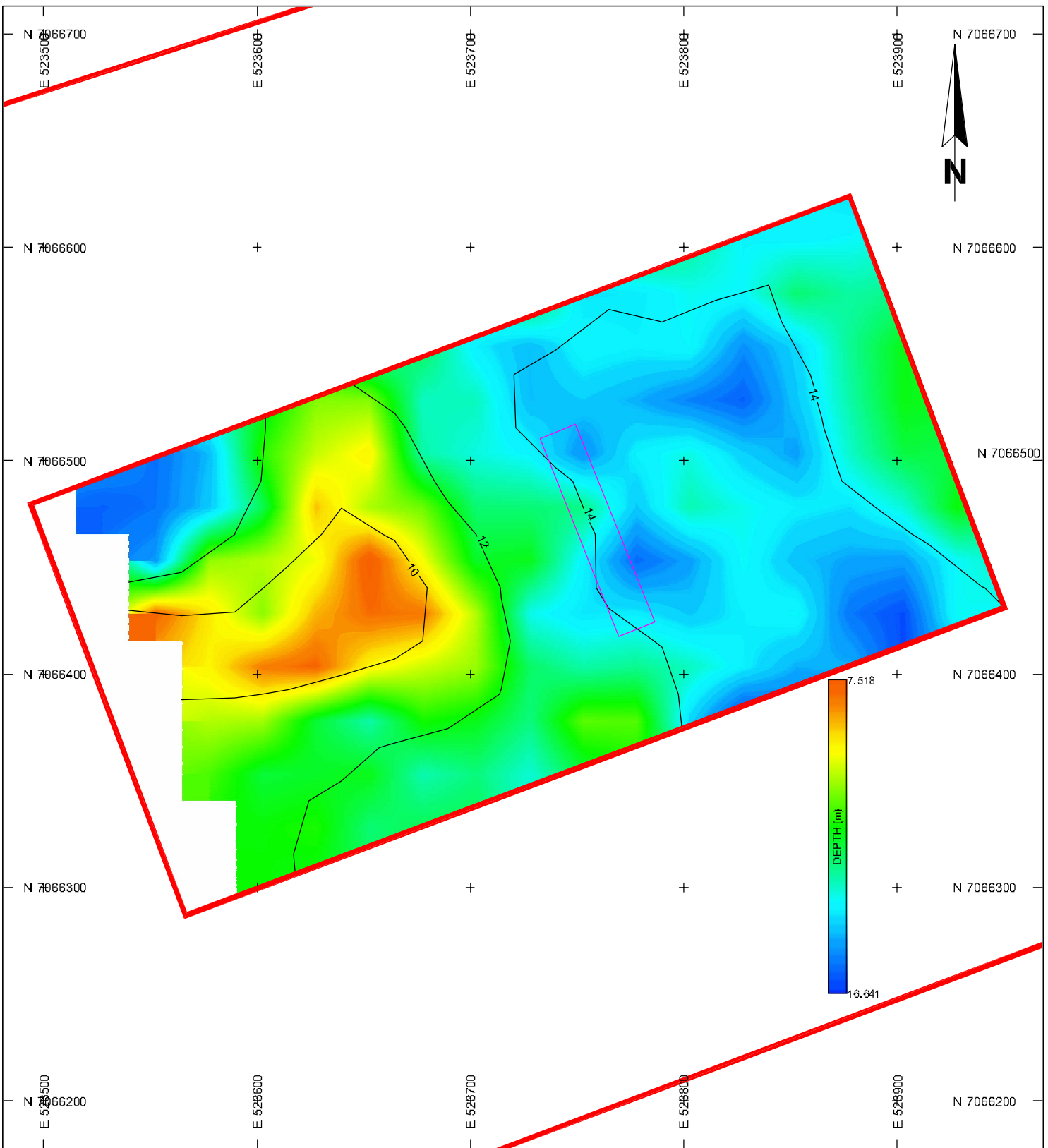
- SURVEY EXTENTS
- 40 — THICKNESS CONTOUR (m)
- WHARF
- BOREHOLE

VELOCITY OF 1600 m/sec USED FOR CONVERSION

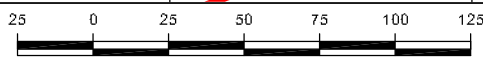
**WHARF OPTION 1 ISOPACH MAP**  
**INTERPRETED SOFT SEDIMENT THICKNESS**

PLATE 6.2

Project No. 9083SMN



NAD83, UTM, ZONE 19



Metres  
1:2500

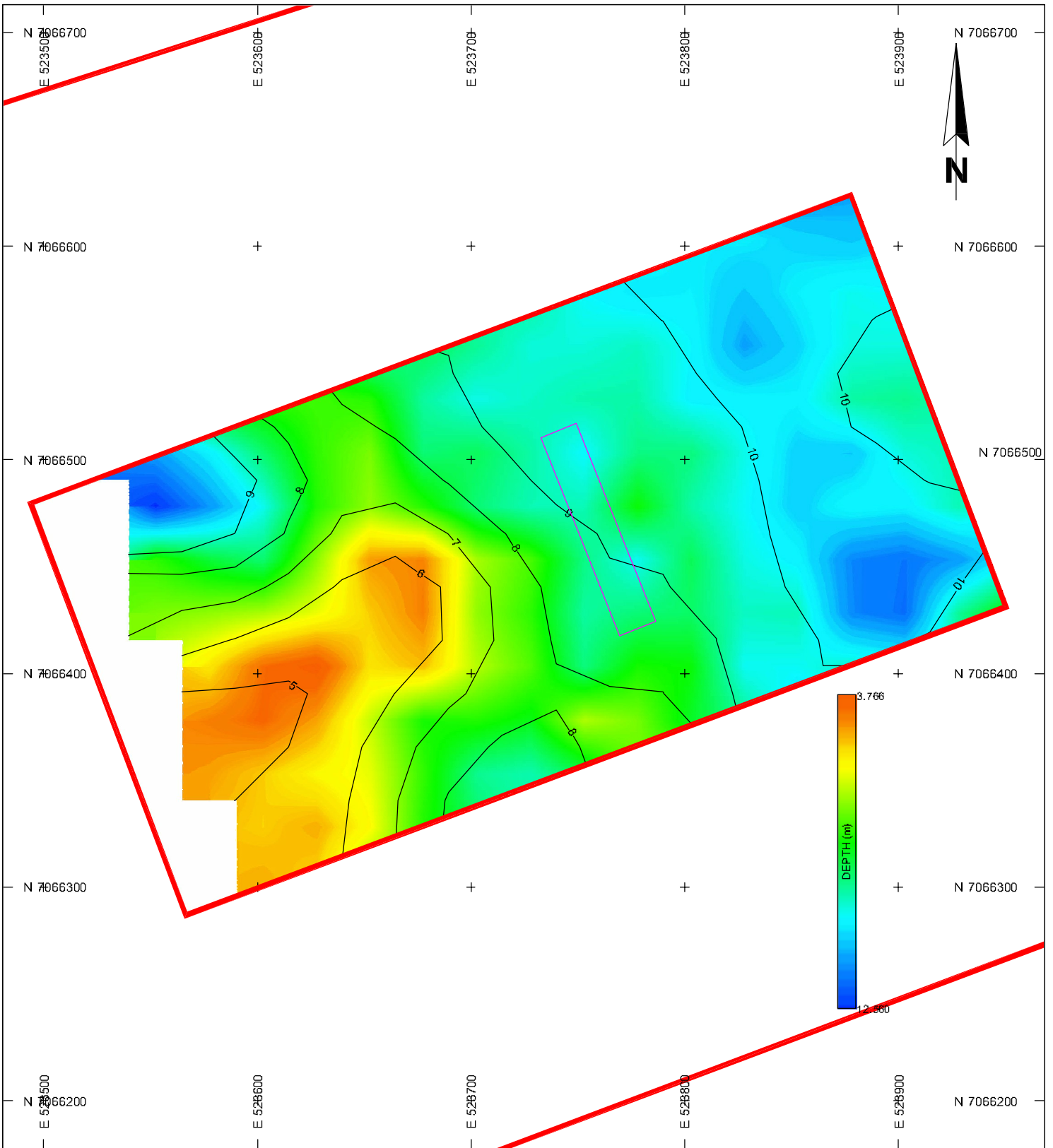
- SURVEY EXTENTS
- 40 — THICKNESS CONTOUR (m)
- WHARF

VELOCITY OF 1600 m/sec USED FOR CONVERSION

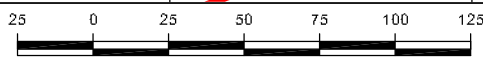
WHARF OPTION 2 ISOPACH MAP  
INTERPRETED OVERBURDEN THICKNESS

PLATE 6.3

Project No. 9083SMN



NAD83, UTM, ZONE 19



Metres  
1:2500

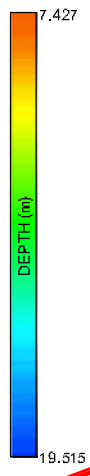
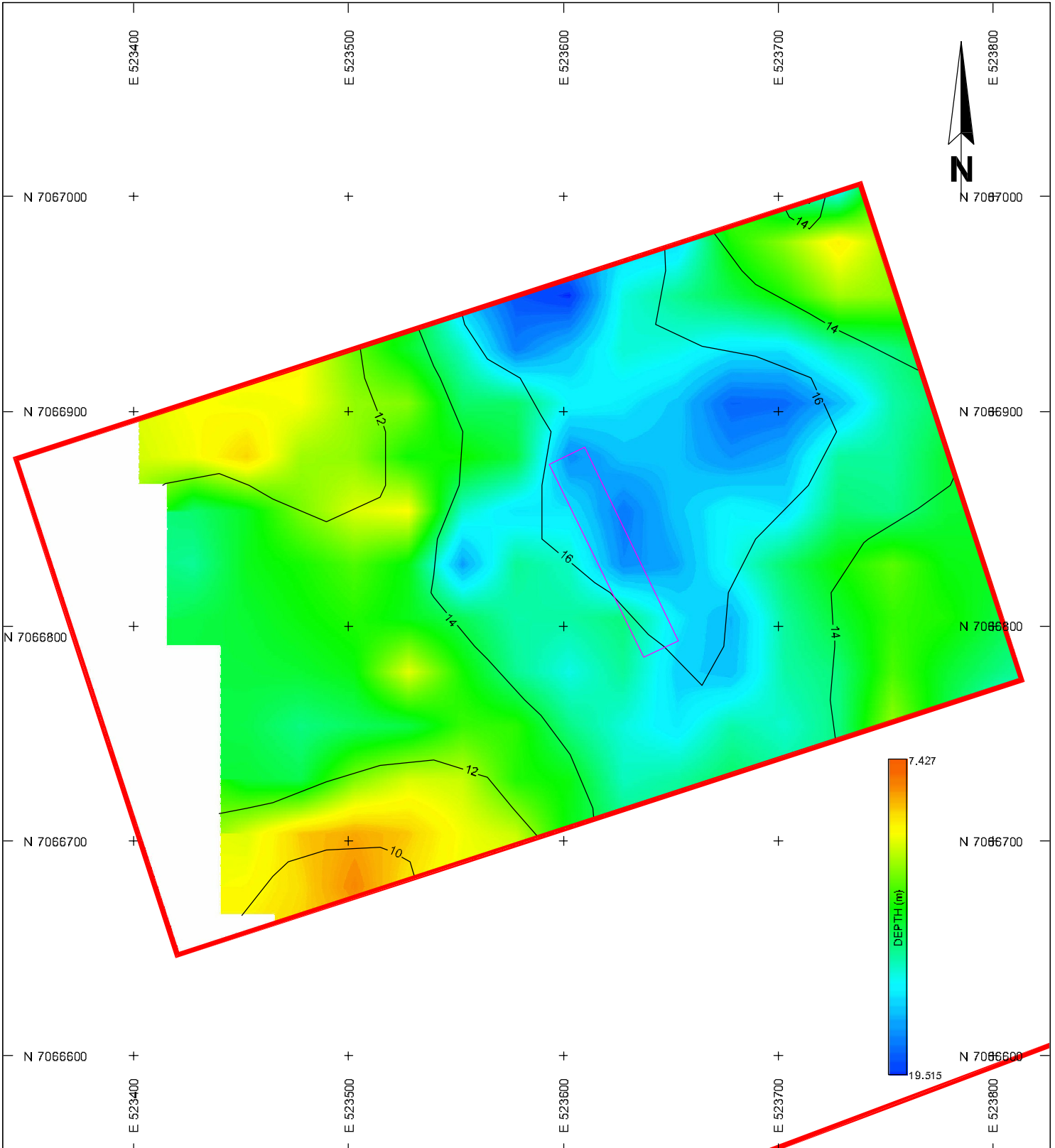
- SURVEY EXTENTS
- 40 — THICKNESS CONTOUR (m)
- WHARF

VELOCITY OF 1600 m/sec USED FOR CONVERSION

WHARF OPTION 2 ISOPACH MAP  
INTERPRETED SOFT SEDIMENT THICKNESS

PLATE 6.4

Project No. 9083SMN



NAD83, UTM, ZONE 19

Metres  
1 : 2500

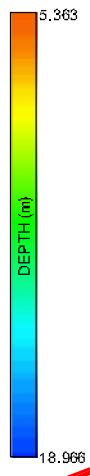
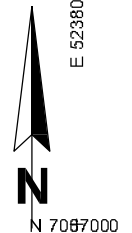
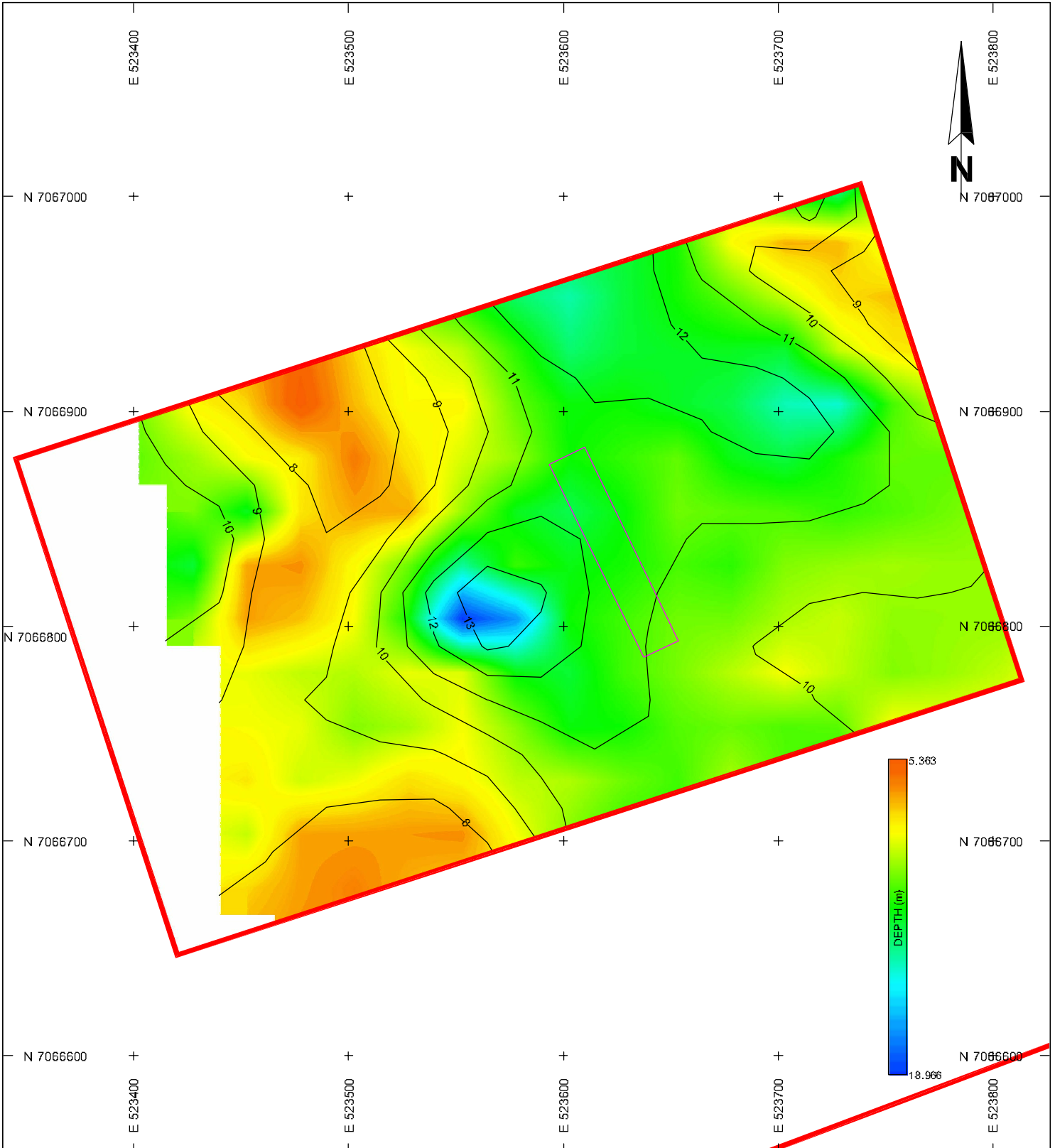
- SURVEY EXTENTS
- 40 — THICKNESS CONTOUR (m)
- WHARF

VELOCITY OF 1600 m/sec USED FOR CONVERSION

**WHARF OPTION 3 ISOPACH MAP**  
**INTERPRETED OVERBURDEN THICKNESS**

PLATE 6.5

Project No. 9083SMN



NAD83, UTM, ZONE 19

Metres  
1 : 2500

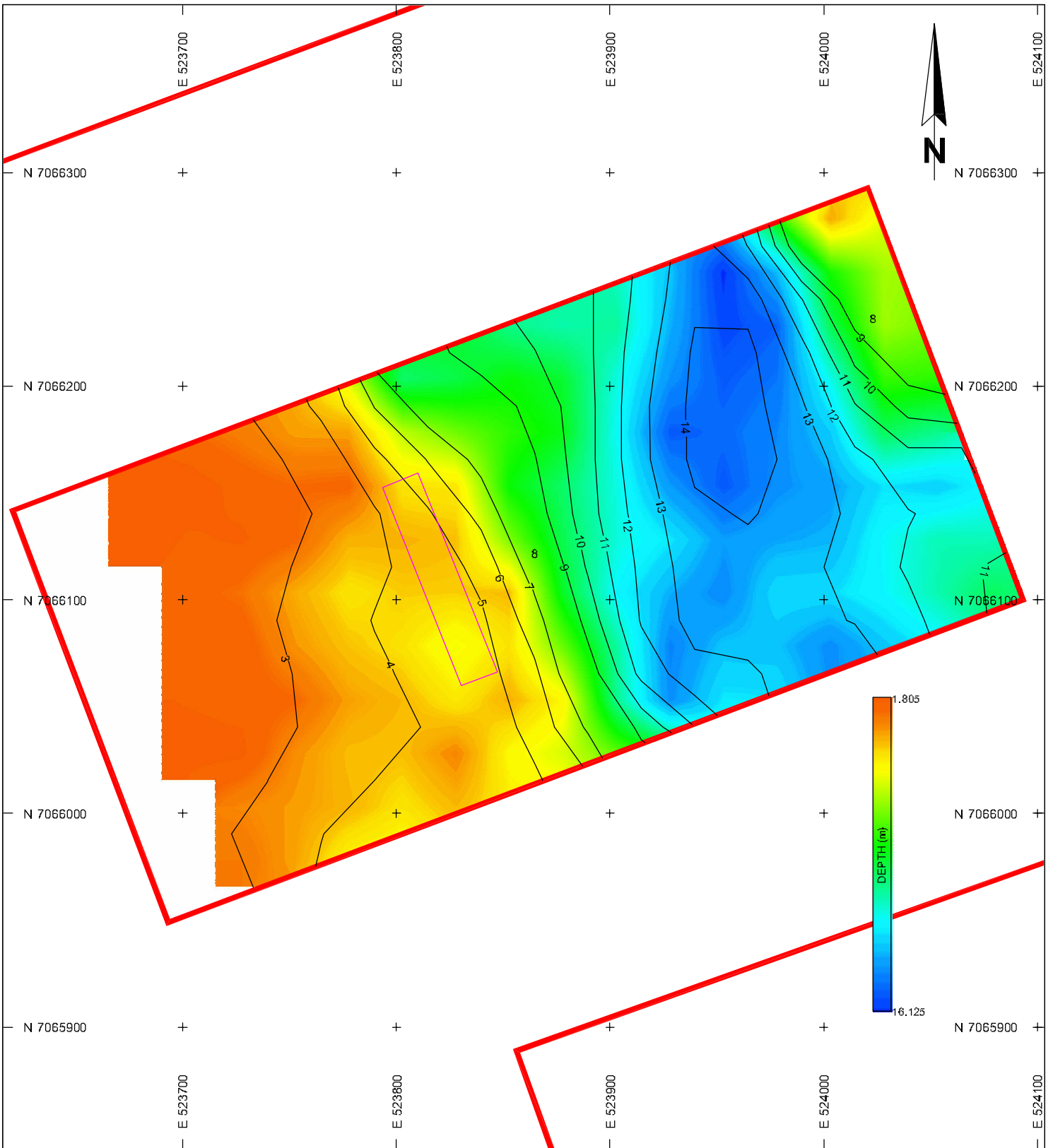
- SURVEY EXTENTS
- 40 — THICKNESS CONTOUR (m)
- WHARF

VELOCITY OF 1600 m/sec USED FOR CONVERSION

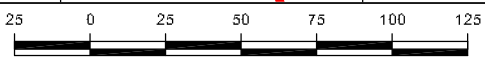
**WHARF OPTION 3 ISOPACH MAP**  
**INTERPRETED SOFT SEDIMENT THICKNESS**

PLATE 6.6

Project No. 9083SMN



NAD83, UTM, ZONE 19



Metres  
1 : 2500

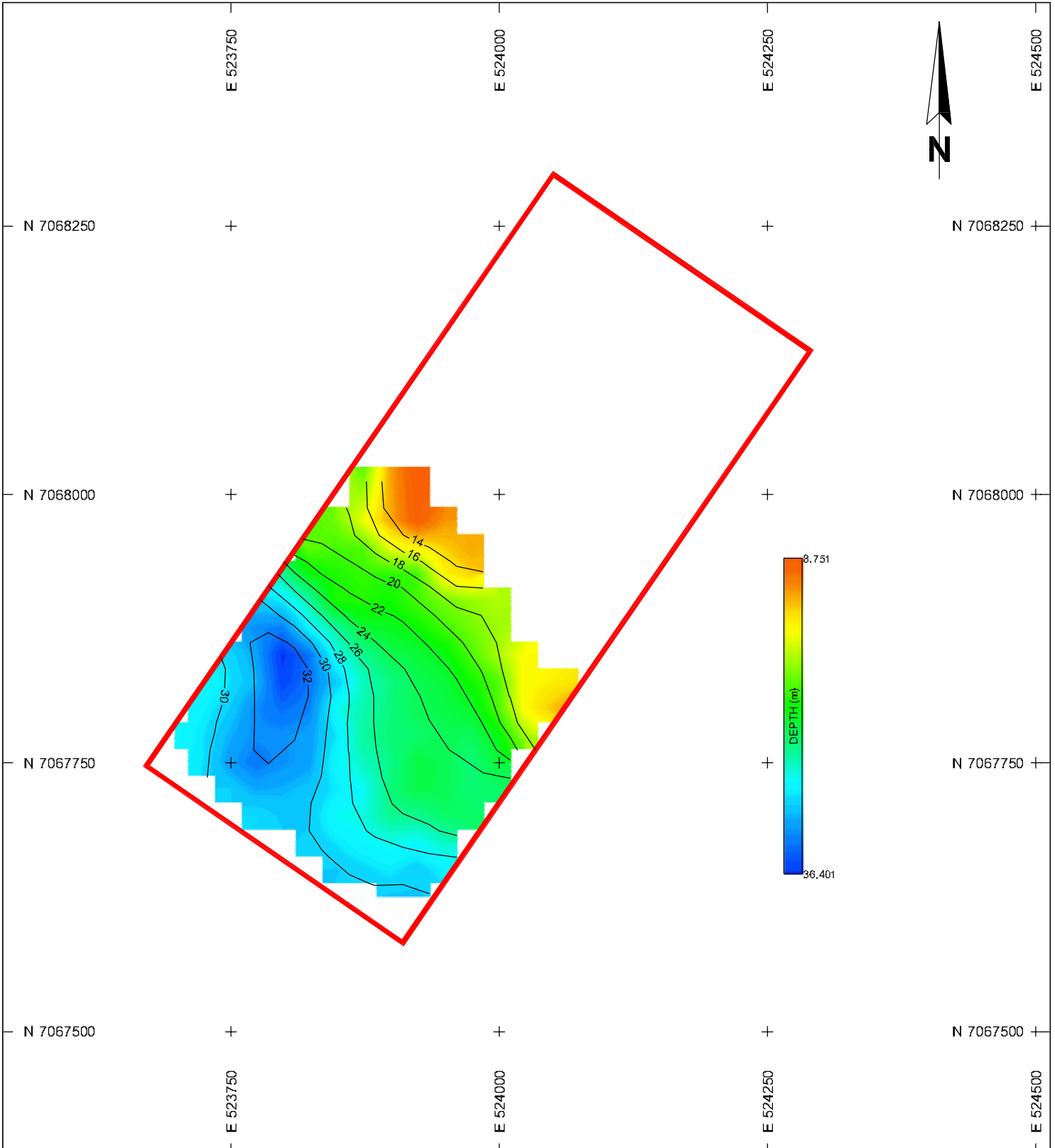
- SURVEY EXTENTS
- 40 — THICKNESS CONTOUR (m)
- WHARF

VELOCITY OF 1600 m/sec USED FOR CONVERSION

WHARF OPTION 4 ISOPACH MAP  
INTERPRETED SOFT SEDIMENT THICKNESS

PLATE 6.8

Project No. 9083SMN



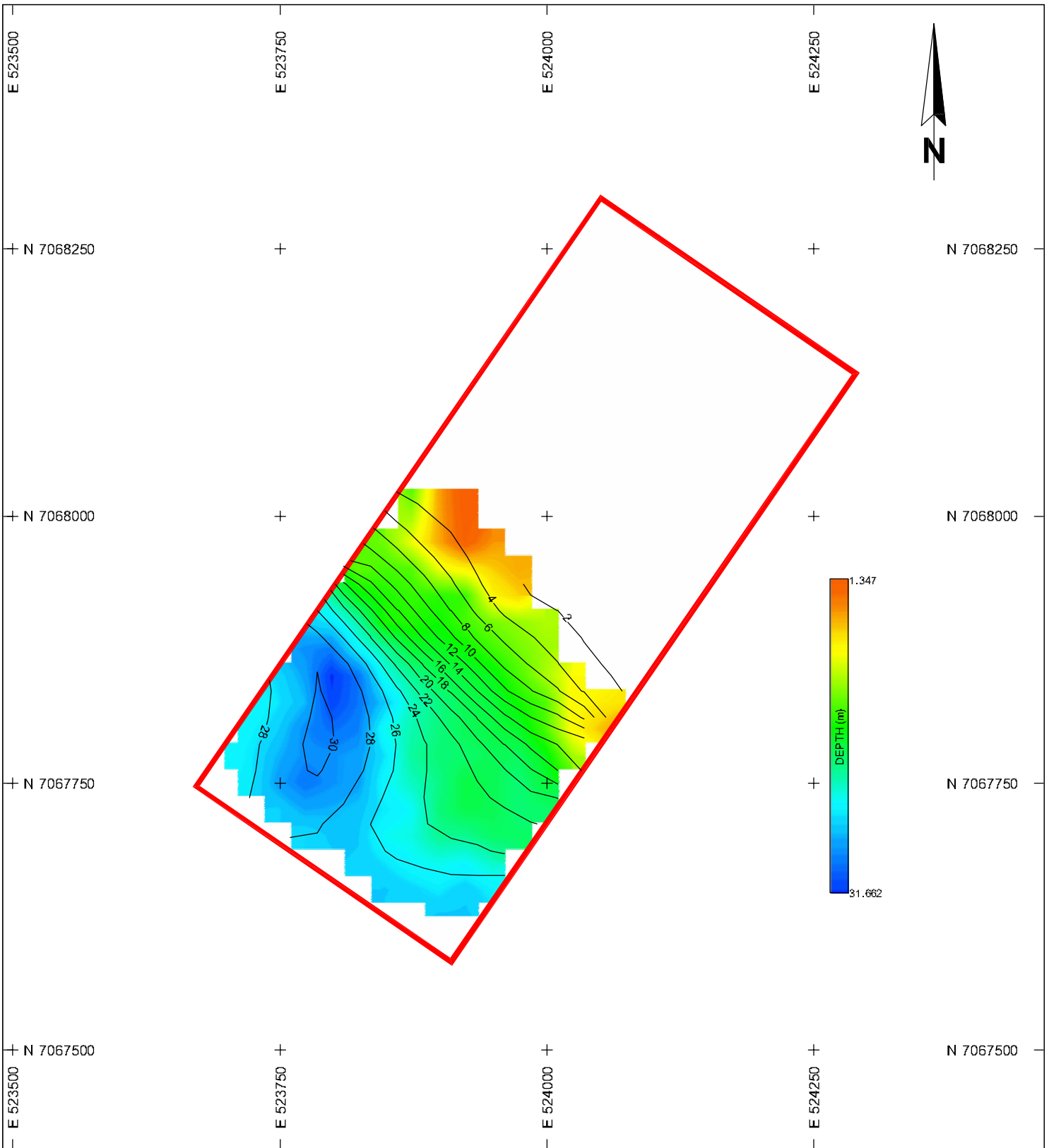
NAD83, UTM, ZONE 19

— SURVEY EXTENTS  
 — 40 — THICKNESS CONTOUR (m)

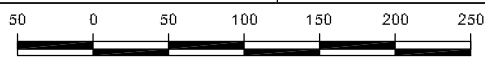
VELOCITY OF 1600 m/sec USED FOR CONVERSION

MUNICIPAL WHARF ISOPACH MAP  
 INTERPRETED OVERBURDEN THICKNESS

PLATE 6.9



NAD83, UTM, ZONE 19



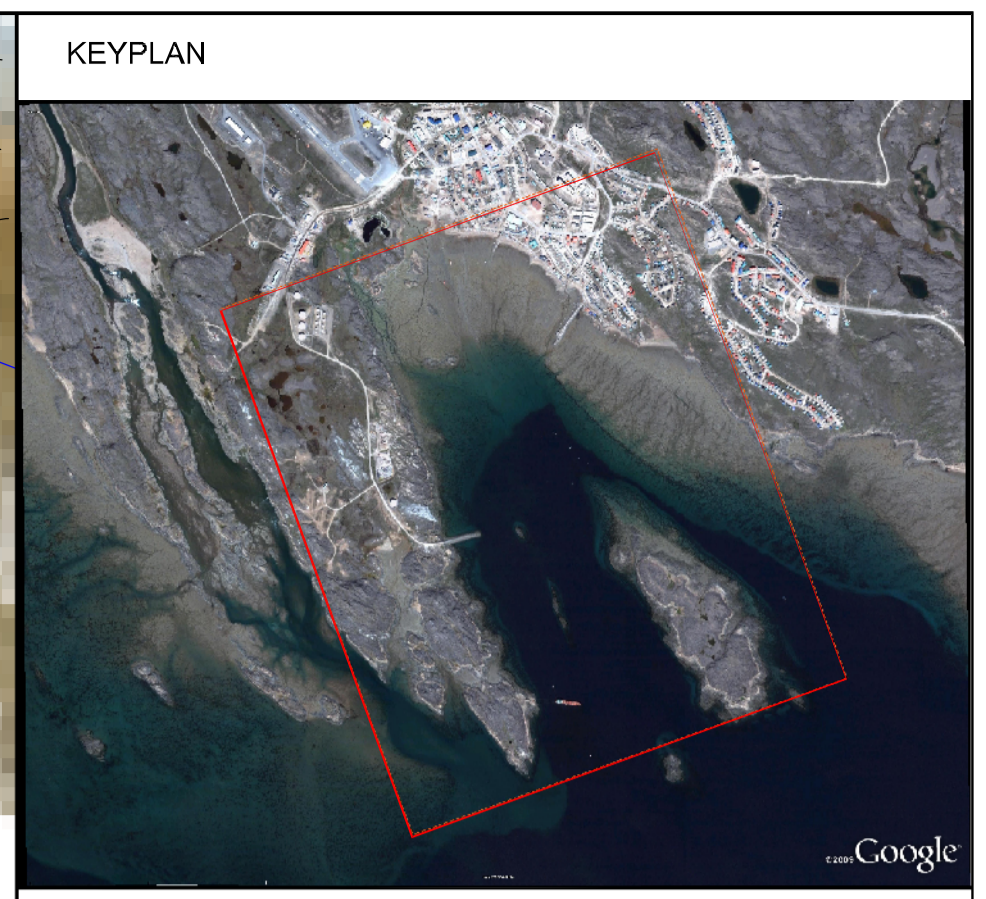
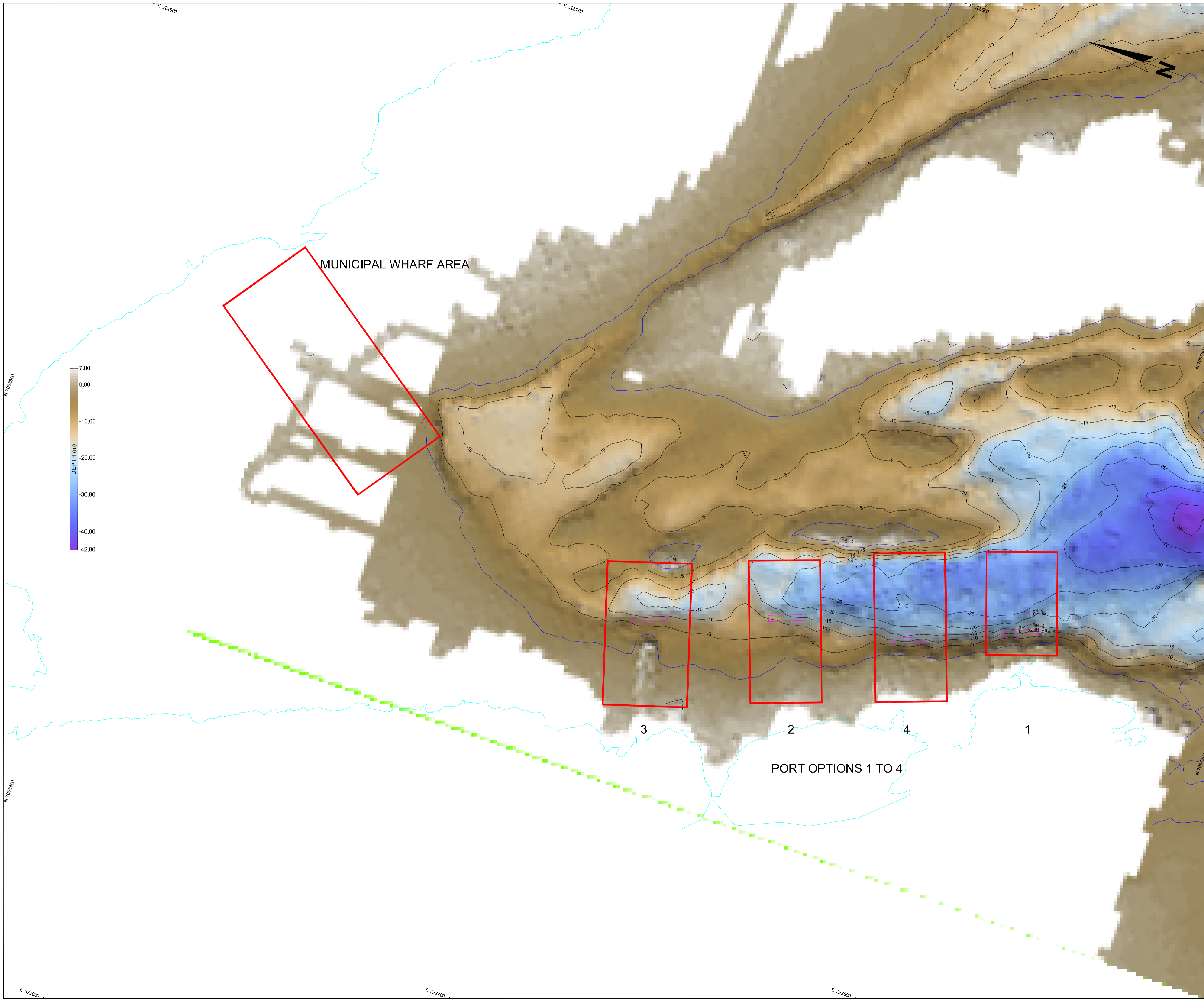
Metres  
1:5000

- SURVEY EXTENTS
- 40 — THICKNESS CONTOUR (m)

VELOCITY OF 1600 m/sec USED FOR CONVERSION

MUNICIPAL WHARF ISOPACH MAP  
INTERPRETED SOFT SEDIMENT THICKNESS

PLATE 6.10  
Project No. 9083SMN



**LEGEND AND NOTES**

BATHYMETRY PROVIDED BY CLIENT

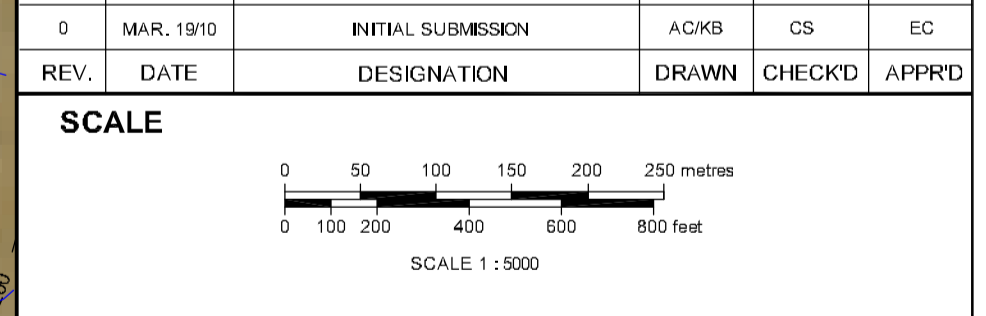
- 25— DEPTH CONTOURS (5m interval)
- HIGH TIDE SHORELINE
- LOW TIDE SHORELINE
- WHARF OPTIONS
- BOREHOLES

**MAP PROJECTION DETAILS**

NORTH AMERICAN DATUM 1983  
 GRS80 ELLIPSOID  
 SEMI-MAJOR AXIS 6378137.00  
 INVERSE FLATTENING 298.257222101  
 6° UNIVERSAL TRANSVERSE MERCATOR  
 ZONE 19 CENTRAL MERIDIAN: 69° W  
 SCALE FACTOR AT C.M.: 0.9996  
 FALSE EASTING: 500,000M  
 FALSE NORTHING: 0M

**REVISIONS**

REV.	DATE	DESIGNATION	DRAWN	CHECKD	APPRD
0	MAR. 1910	INITIAL SUBMISSION	ACKS	CS	EC



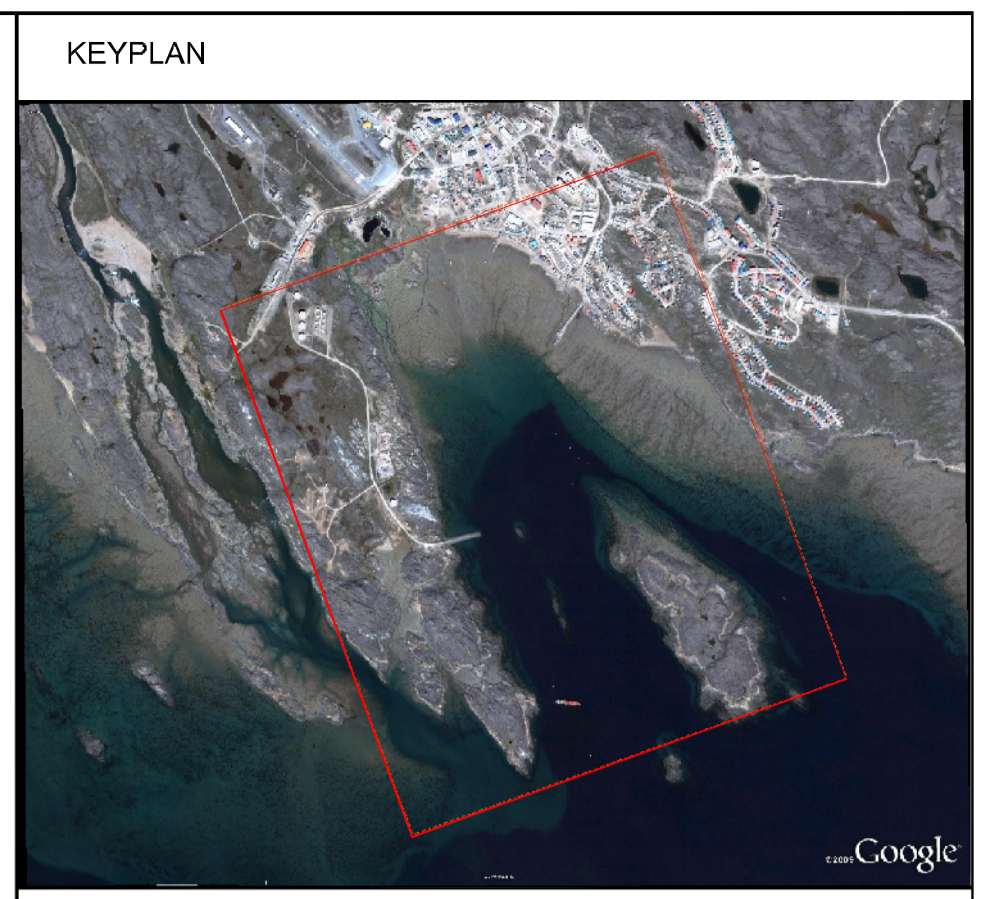
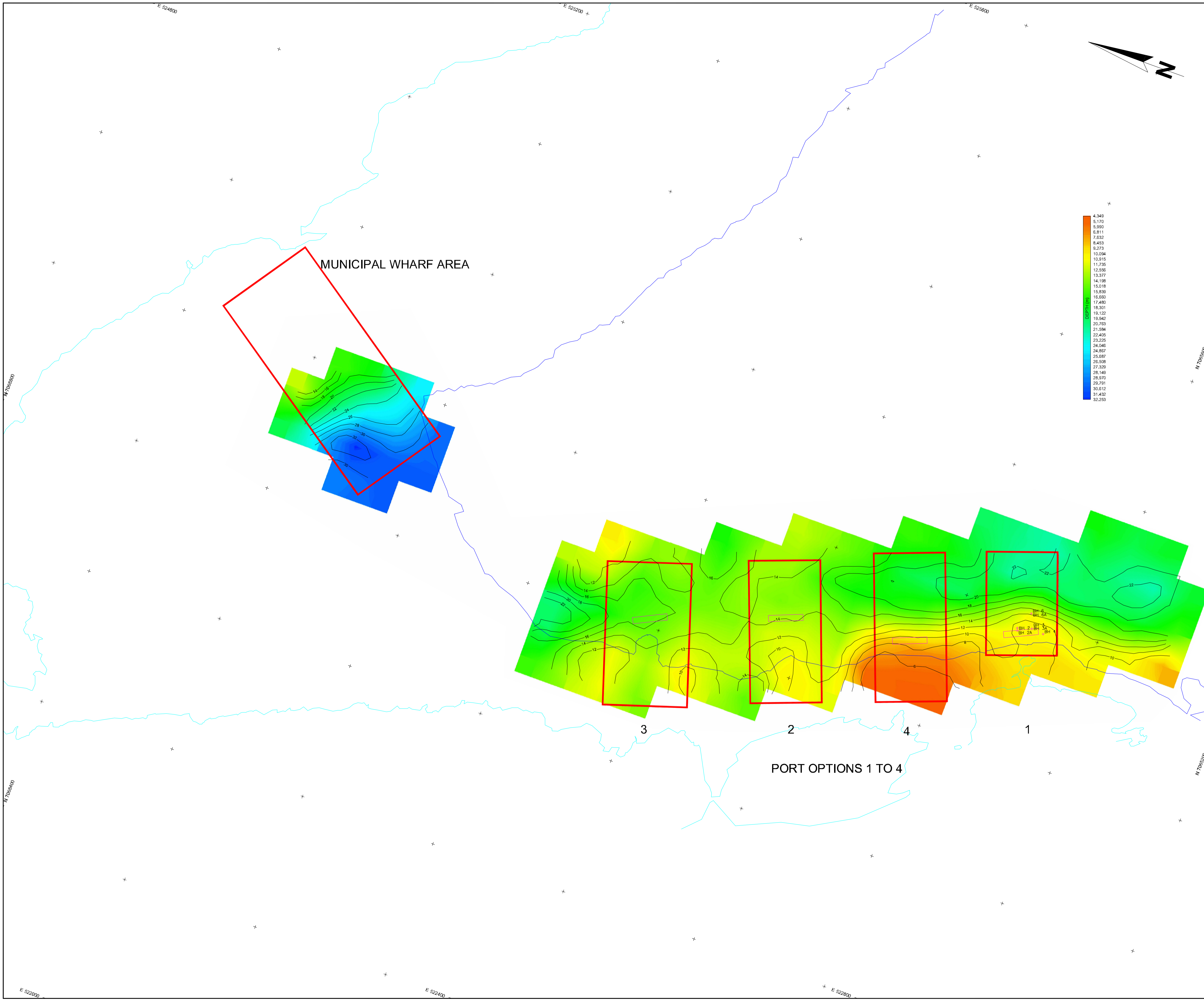
**PREPARED BY**  
 Fugro Jacques GeoSurveys Inc.  
 25 Royce Place  
 St. John's, Newfoundland  
 CANADA A1B 3Z2

**CLIENT**

**IQUALUIT PORT SURVEY**

**BATHYMETRY MAP**

JOB NUMBER: 9083SMN	DATE: MARCH 19, 2010	FJG DWG. No: 9083SMN-001-BTY-REG-01-0
<b>ENCLOSURE 1</b>		REV 0



**LEGEND AND NOTES**

DATA ACQUIRED WITH A BOOMER SOURCE AND EXTENDED STREAMER

ALL DATA POSITIONED WITH DIFFERENTIAL GPS

BATHYMETRY DATA PROVIDED BY CLIENT

ACOUSTIC VELOCITY OF 1600 m/s ASSUMED FOR THE TIME/DEPTH CONVERSION

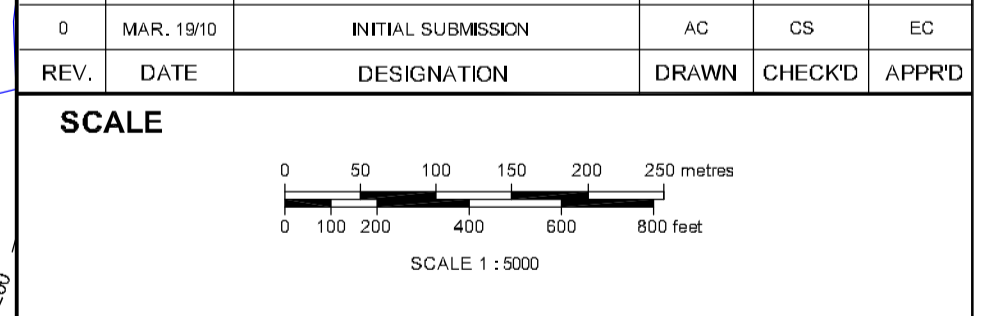
- 25— DEPTH CONTOURS (5m interval)
- HIGH TIDE SHORELINE
- LOW TIDE SHORELINE
- WHARF OPTIONS
- BOREHOLES

**MAP PROJECTION DETAILS**

NORTH AMERICAN DATUM 1983  
 GRS80 ELLIPSOID  
 SEMI-MAJOR AXIS 6378137.00  
 INVERSE FLATTENING 298.257222101  
 6° UNIVERSAL TRANSVERSE MERCATOR  
 ZONE 19 CENTRAL MERIDIAN: 69° W  
 SCALE FACTOR AT C.M.: 0.9996  
 FALSE EASTING: 500,000M  
 FALSE NORTHING: 0M

**REVISIONS**

REV.	DATE	DESIGNATION	DRAWN	CHECKD	APPRD
0	MAR. 1910	INITIAL SUBMISSION	AC	CS	EC

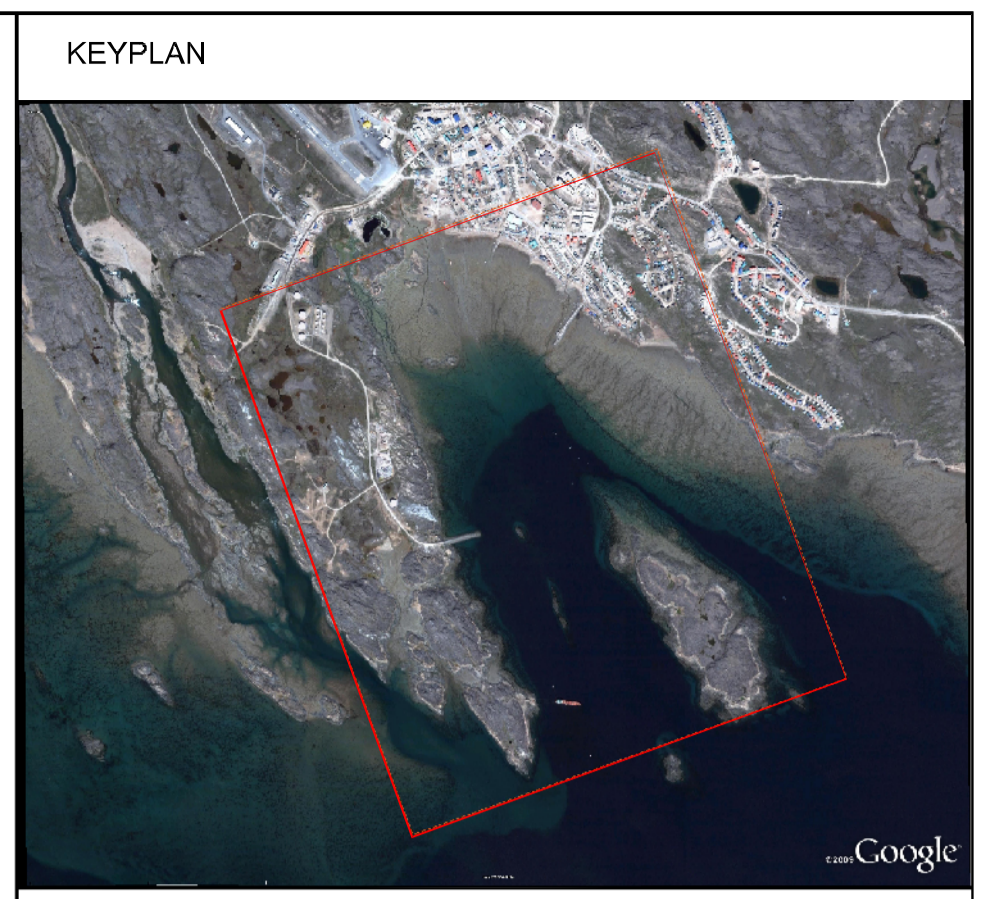
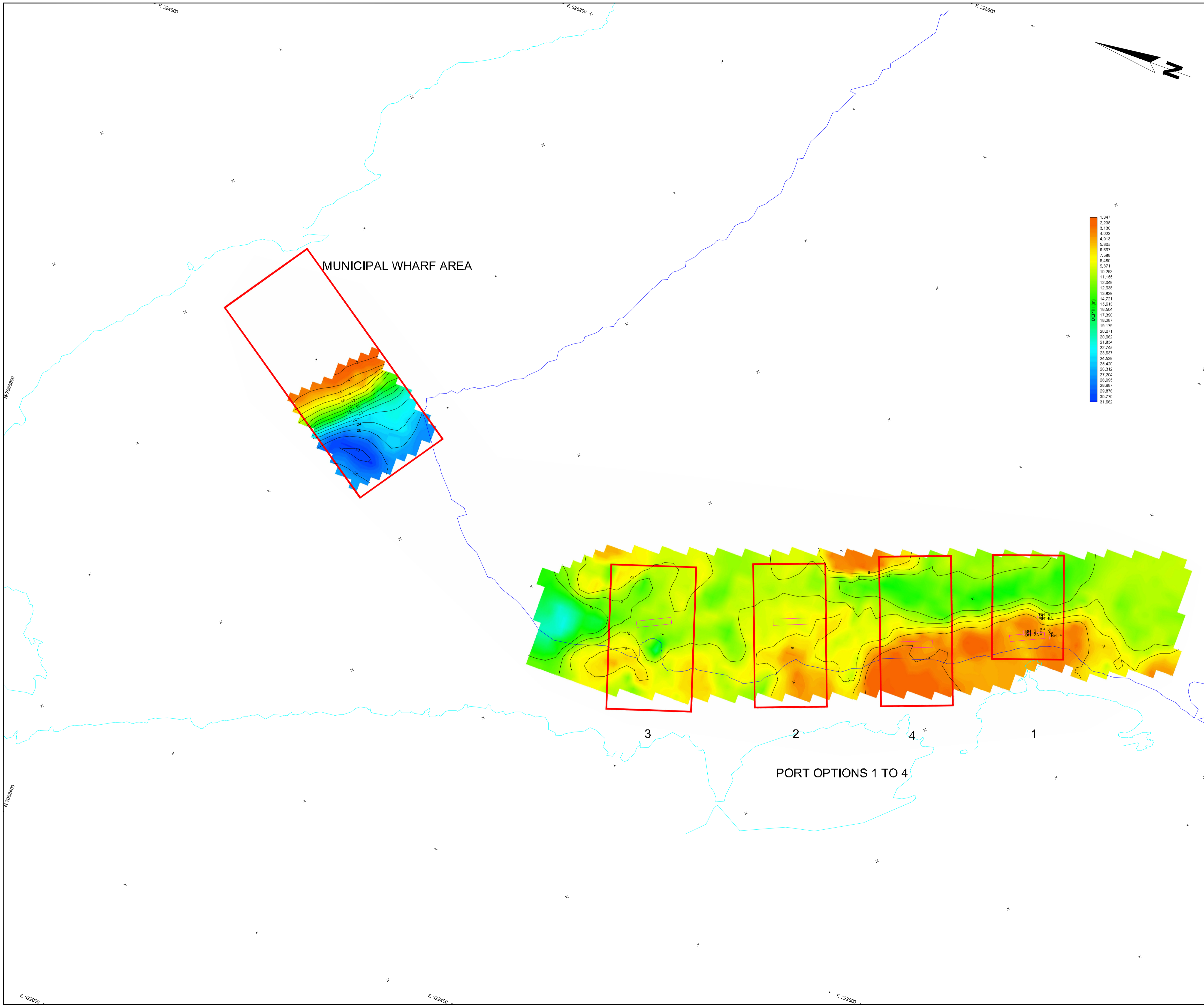


<p><b>PREPARED BY</b></p> <p>Fugro Jacques GeoSurveys Inc. 25 River Place St. John's, Newfoundland CANADA A1B 3Z2</p>	<p><b>CLIENT</b></p> <p>Stantec</p>
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**IQUALUIT PORT SURVEY**

**ISOPACH MAP  
INTERPRETED OVERBURDEN THICKNESS**

JOB NUMBER: 9083SMN	
DATE: MARCH 19, 2010	FJG DWG. No: 9083SMN-001-ISO-ALLOBT-02-0
<b>ENCLOSURE 2</b>	REV 0



**LEGEND AND NOTES**

DATA ACQUIRED WITH A BOOMER SOURCE AND EXTENDED STREAMER

ALL DATA POSITIONED WITH DIFFERENTIAL GPS

BATHYMETRY DATA PROVIDED BY CLIENT

ACOUSTIC VELOCITY OF 1600 m/s ASSUMED FOR THE TIME/DEPTH CONVERSION

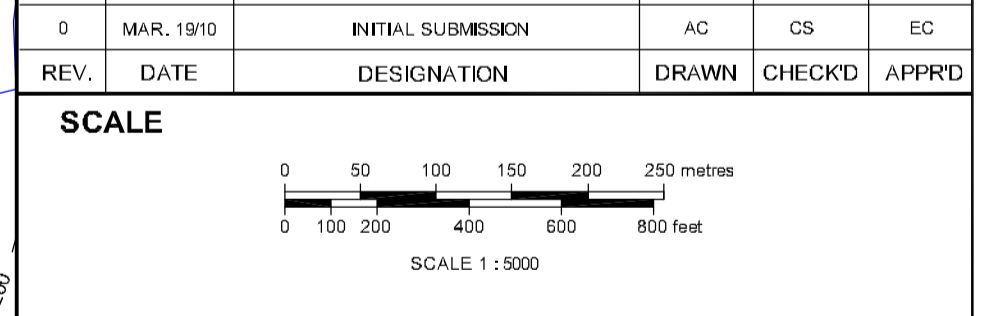
- 25— DEPTH CONTOURS (5m interval)
- HIGH TIDE SHORELINE
- LOW TIDE SHORELINE
- WHARF OPTIONS
- BOREHOLES

**MAP PROJECTION DETAILS**

NORTH AMERICAN DATUM 1983  
 GRS80 ELLIPSOID  
 SEMI-MAJOR AXIS 6378137.00  
 INVERSE FLATTENING 298.257222101  
 6° UNIVERSAL TRANSVERSE MERCATOR  
 ZONE 19 CENTRAL MERIDIAN: 69° W  
 SCALE FACTOR AT C.M.: 0.9996  
 FALSE EASTING: 500,000M  
 FALSE NORTHING: 0M

**REVISIONS**

REV.	DATE	DESIGNATION	DRAWN	CHECKD	APPRD
0	MAR. 1910	INITIAL SUBMISSION	AC	CS	EC

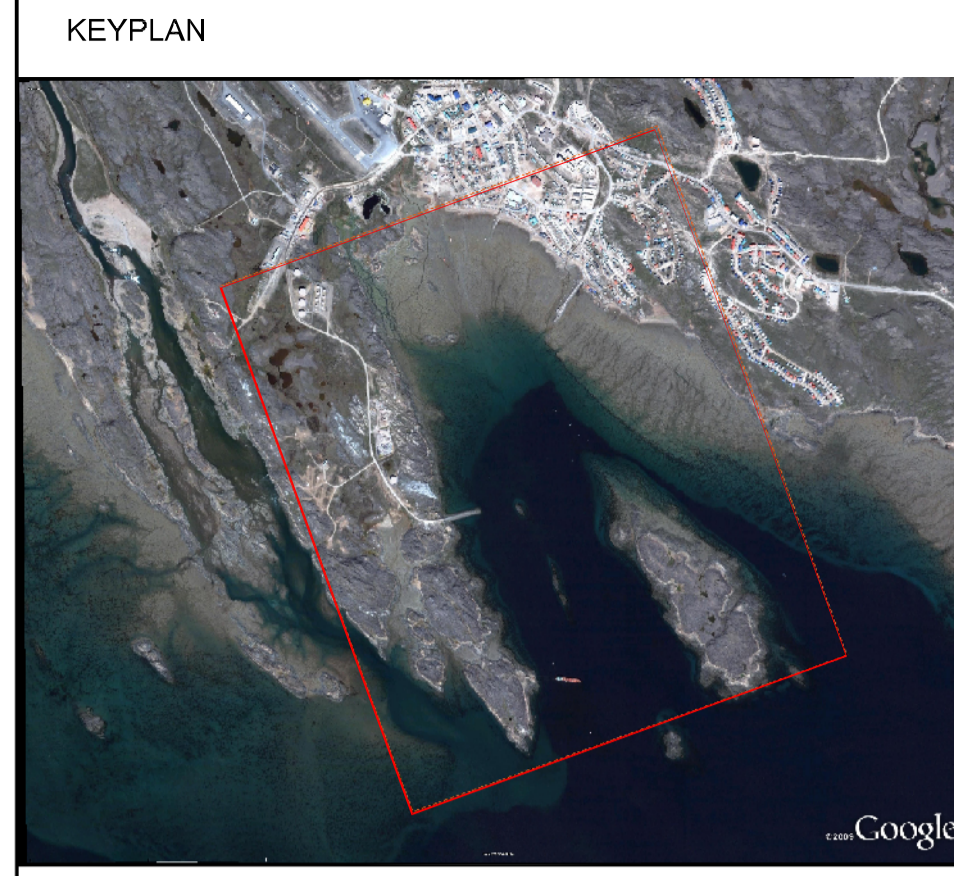
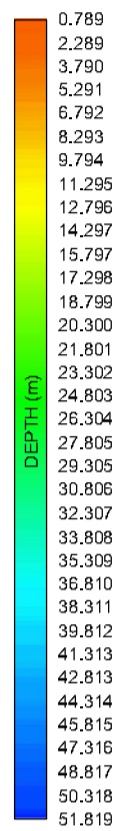
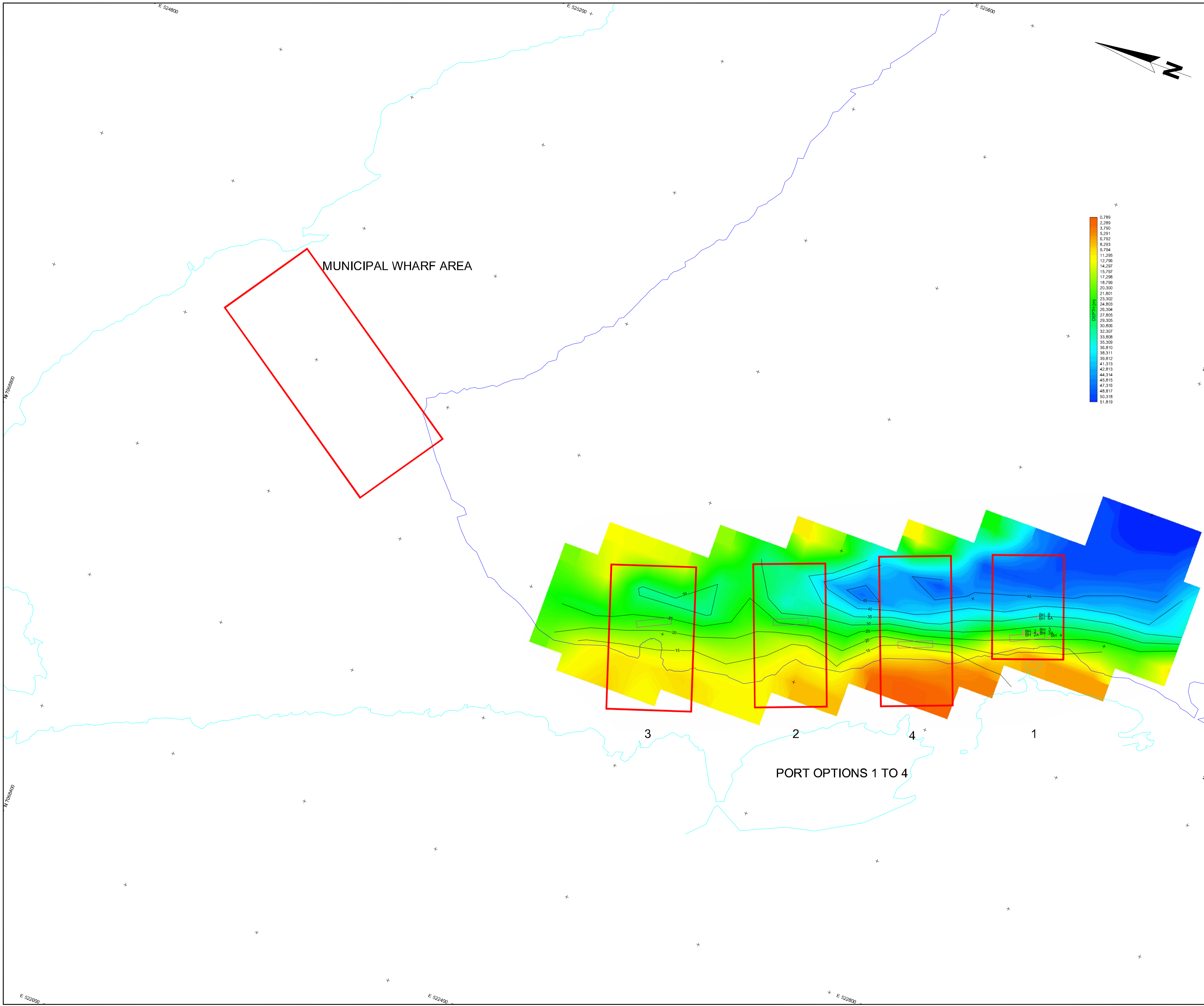


<p><b>PREPARED BY</b></p> <p>Fugro Jacques GeoSurveys Inc. 25 Royal Place St. John's, Newfoundland Canada A1B 2P2</p>	<p><b>CLIENT</b></p> <p>Stantec</p>
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**IQUALUIT PORT SURVEY**

**ISOPACH MAP  
INTERPRETED SOFT SEDIMENT THICKNESS**

JOB NUMBER: 9083SMN	REV
DATE: MARCH 19, 2010	0
ENCLOSURE 3	



**LEGEND AND NOTES**

DATA ACQUIRED WITH A BOOMER SOURCE AND EXTENDED STREAMER

ALL DATA POSITIONED WITH DIFFERENTIAL GPS

BATHYMETRY DATA PROVIDED BY CLIENT

ACOUSTIC VELOCITY OF 1600 m/s ASSUMED FOR THE TIME/DEPTH CONVERSION

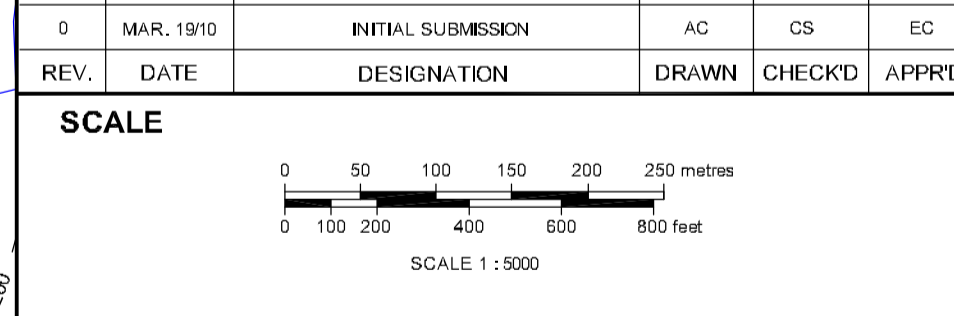
- 25— DEPTH CONTOURS (5m interval)
- HIGH TIDE SHORELINE
- LOW TIDE SHORELINE
- WHARF OPTIONS
- BOREHOLES

**MAP PROJECTION DETAILS**

NORTH AMERICAN DATUM 1983  
 GRS80 ELLIPSOID  
 SEMI-MAJOR AXIS 6378137.00  
 INVERSE FLATTENING 298.257222101  
 6° UNIVERSAL TRANSVERSE MERCATOR  
 ZONE 19 CENTRAL MERIDIAN: 69° W  
 SCALE FACTOR AT C.M.: 0.9996  
 FALSE EASTING: 500,000M  
 FALSE NORTHING: 0M

**REVISIONS**

REV.	DATE	DESIGNATION	DRAWN	CHECKD	APPRD
0	MAR. 1910	INITIAL SUBMISSION	AC	CS	EC



<p><b>PREPARED BY</b></p> <p>Fugro Jacques GeoSurveys Inc. 25 Riley Place St. John's, Newfoundland CANADA A1B 3Z2</p>	<p><b>CLIENT</b></p> <p><b>Stantec</b></p>
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**IQUALUIT PORT SURVEY**

**DEPTH TO INTERPRETED BEDROCK**

JOB NUMBER: 9083SMN	REV
DATE: MARCH 19, 2010	0
FJG DWG. No: 9083SMN-001-DPH-BDRK-04-0	
<b>ENCLOSURE 4</b>	



**A Control**



**B**    **Benchmarks**



**C Tidal Calculations**



**D Static Survey Scatter Plots**



**E Safety**

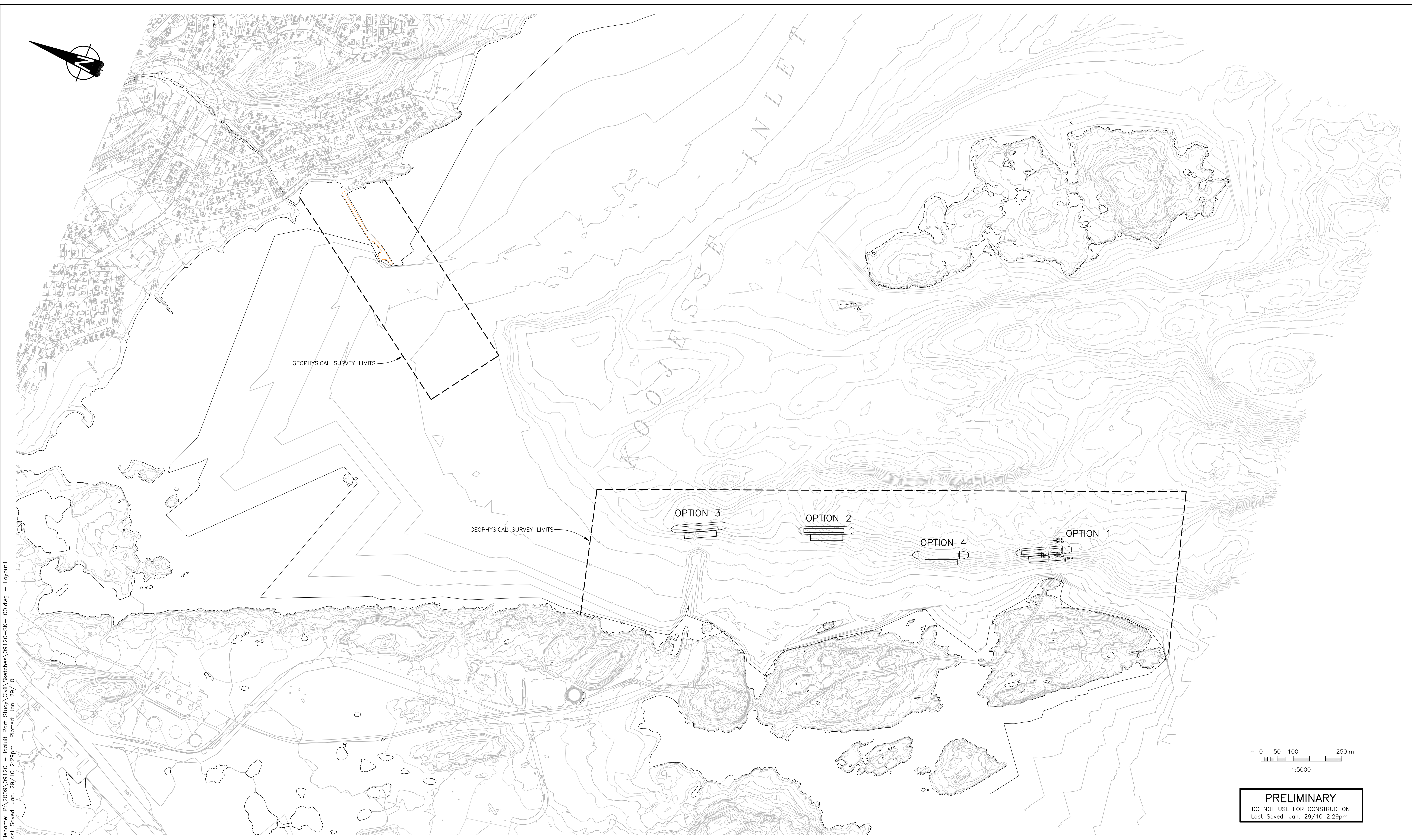
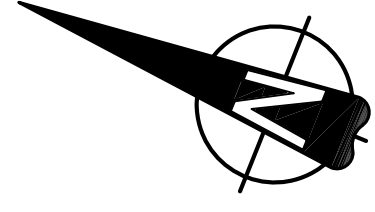
**Stantec**

**GEOTECHNICAL DESK STUDY, PROPOSED MARINE DEVELOPMENT IQALUIT  
STANDING OFFER FOR THE ARCTIC REGION ENVIRONMENTAL GEOPHYSICAL AND  
GEOTECHNICAL SERVICES**

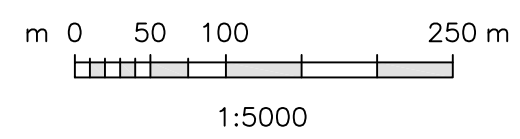
### APPENDIX C

Worley Parsons Westmar Preliminary Drawings Iqaluit Port Development.

Drawing Numbers 100P1, 101P2, 101AP2, 102P2, 102AP2, 103P2,  
103AP2, 104P2, 104AP, 105P2, 105AP1, 106P2, 107P2, 108P1, 108AP1,  
109P1, 110P1, 111P1



Filename: P:\2009\09120 - Iqaluit Port Study\Civil Sketches\09120-SK-100.dwg - Layout1  
 Last Saved: Jan. 29/10 2:29pm Plotted: Jan. 29/10



**PRELIMINARY**  
 DO NOT USE FOR CONSTRUCTION  
 Last Saved: Jan. 29/10 2:29pm

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ISSUE / REVISIONS								

No.	DATE	DESCRIPTION	DRAWN	DWG CHKD	DESIGN	DES CHKD	QA	APPROVED
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ISSUE / REVISIONS								

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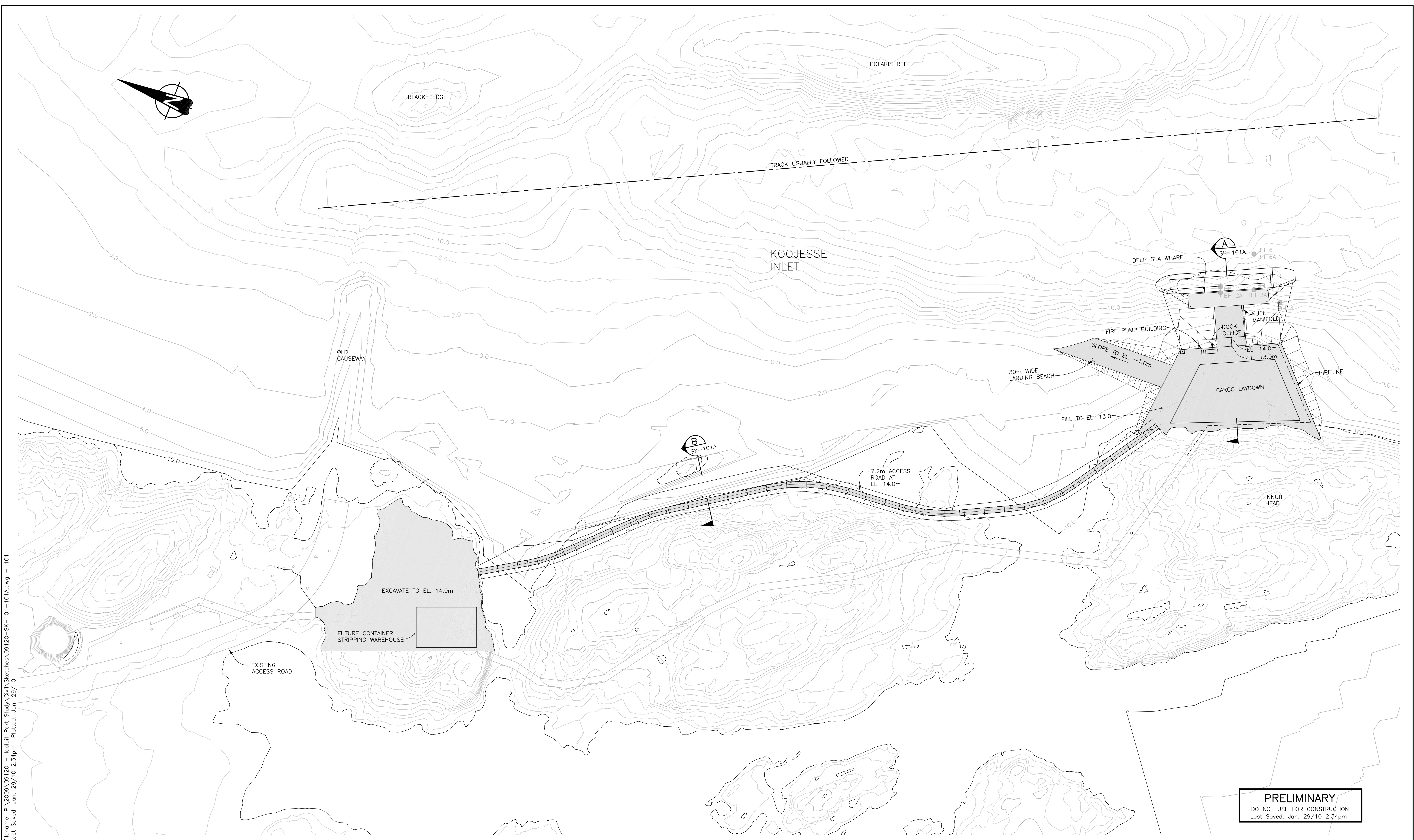
CLIENT  
 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION

PROJECT  
**IQALUIT PORT DEVELOPMENT**

**WorleyParsons Westmar**

TITLE  
**GEOPHYSICAL SURVEY LIMITS SITE PLAN**

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**PRELIMINARY**  
 DO NOT USE FOR CONSTRUCTION  
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ISSUE / REVISIONS								

P2	JAN29/10	RE-ISSUED FOR CLIENT REVIEW	BJM	-	-	HG	-	HGK	-	-	-	HGK	-
P1	OCT29/09	ISSUED FOR CLIENT REVIEW	BJM	-	-	HG	-	HGK	-	-	-	HGK	-

ENGINEER OF RECORD  
 DIV/DEP MGR: -

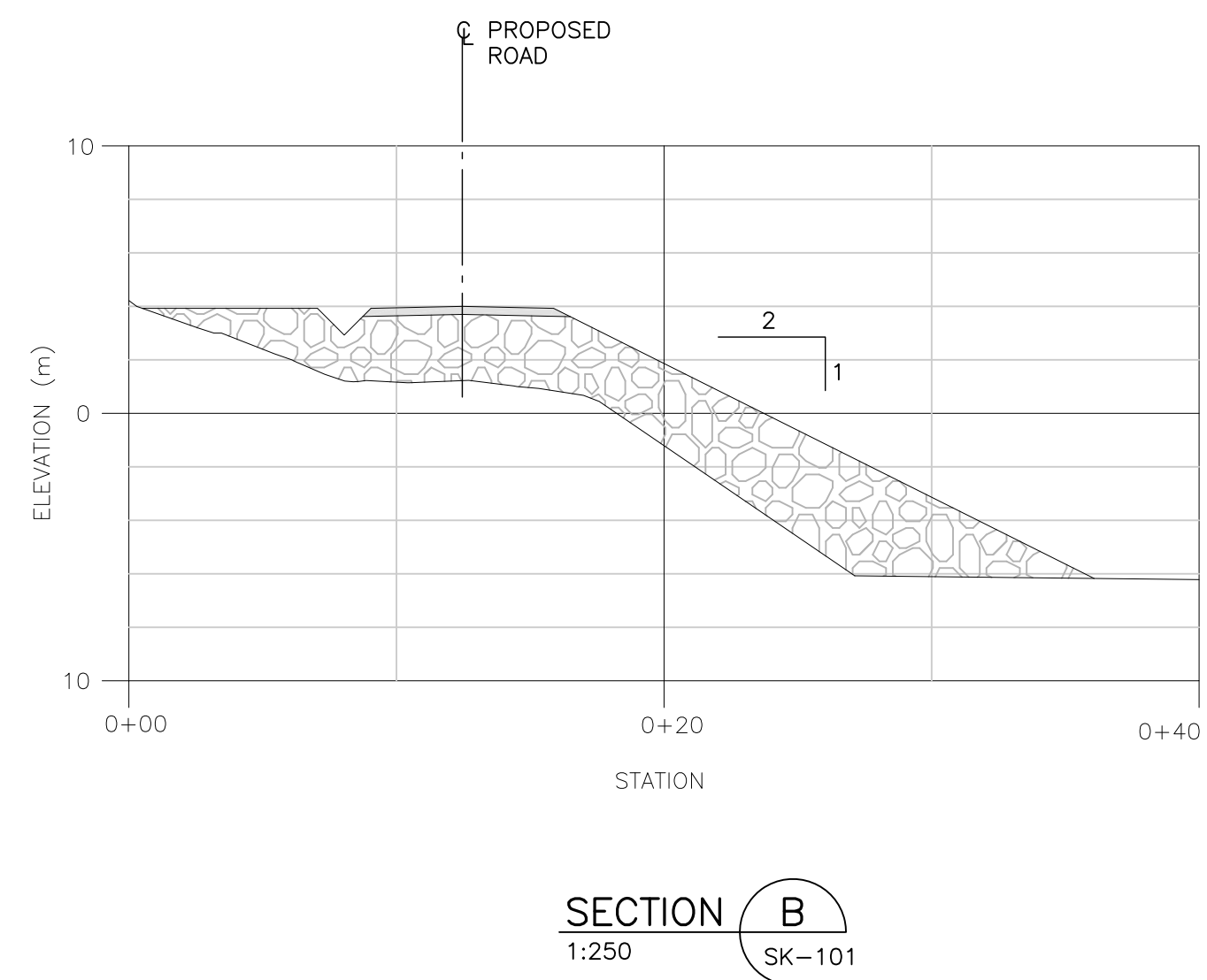
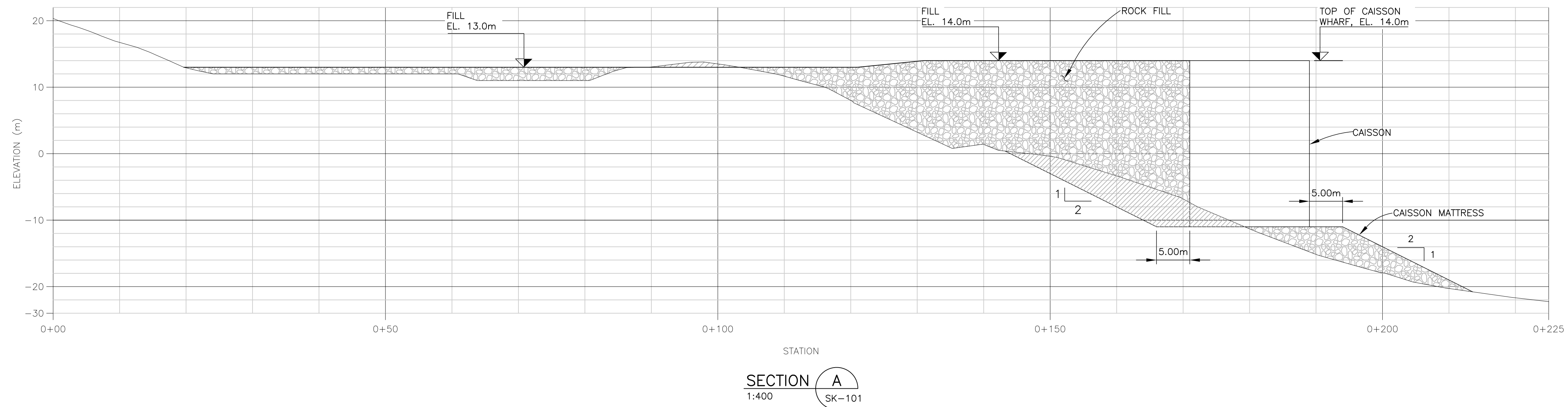
CLIENT  

 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT  
**IQALUIT PORT DEVELOPMENT**

**WorleyParsons Westmar**  
 TITLE  
**DEEP SEA WHARF  
 OPTION 1 - INNUIT HEAD  
 SITE PLAN**  

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
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Filename: P:\2009\09120 - Iqaluit Port Study\Civil\Sketches\09120-SK-101-101A.dwg - 101A  
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**PRELIMINARY**  
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 Last Saved: Jan. 29/10 2:34pm

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ISSUE / REVISIONS								

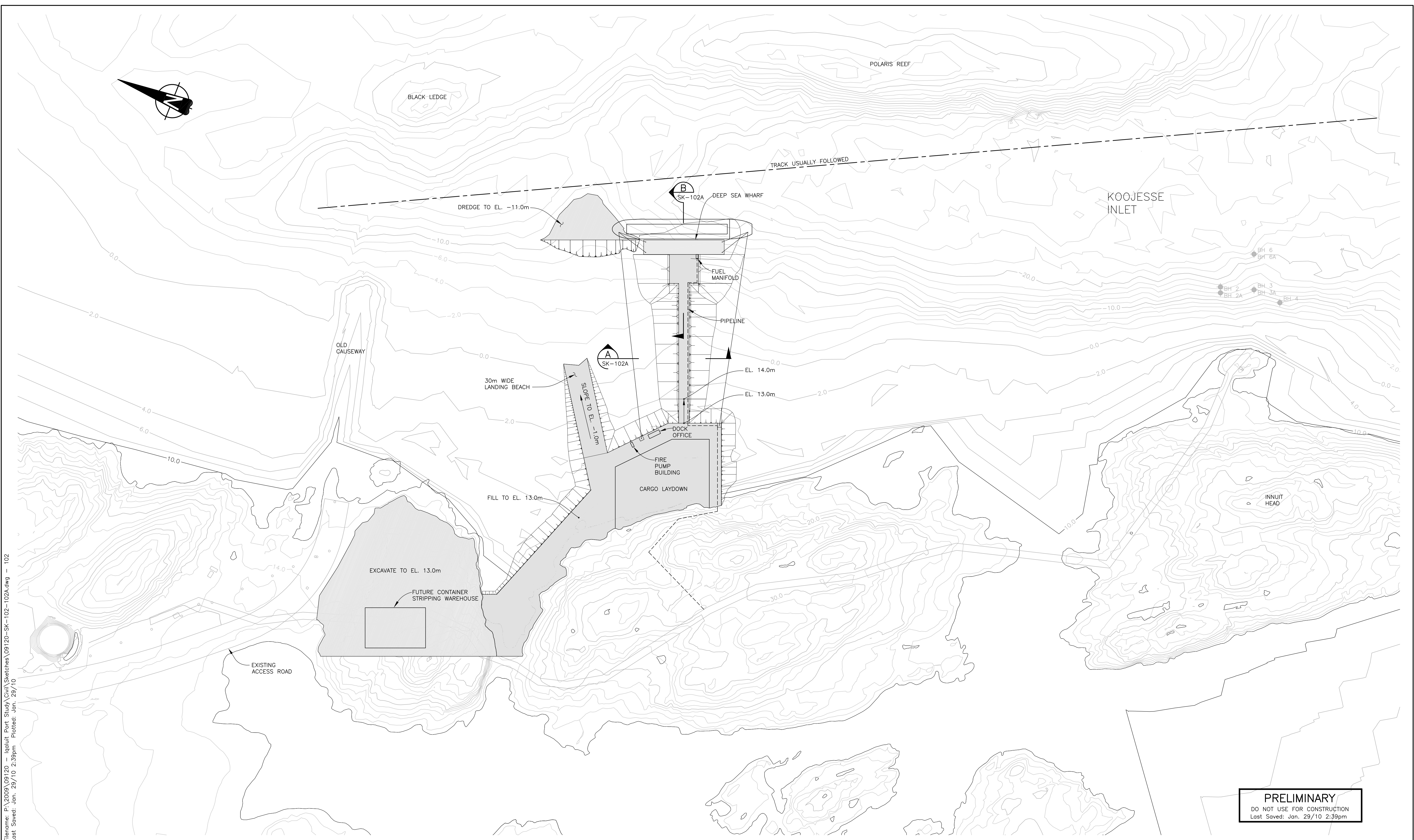
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P1	OCT29/09	ISSUED FOR CLIENT REVIEW	BMW	-	-	-	HG	-	HGK	-	-	-	HGK	-
No.	DATE	DESCRIPTION	DRAWN	DWG CHKD	DESIGN	DES CHKD	QA	APPROVED						
ISSUE / REVISIONS														

ENGINEER OF RECORD  
 DIV/DEP MGR: -

CLIENT: DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT: IQUALUIT PORT DEVELOPMENT

TITLE: DEEP SEA WHARF OPTION 1 - INNUIT HEAD SECTIONS

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
SHOWN	09120	SK-101A	P2



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 Last Saved: Jan. 29/10 2:39pm Plotted: Jan. 29/10

**PRELIMINARY**  
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 Last Saved: Jan. 29/10 2:39pm

No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED
ISSUE / REVISIONS								

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P1	OCT29/09	ISSUED FOR CLIENT REVIEW	BJM	-	-	HG	-	HGK	-	-	-	HGK	-

CLIENT: DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT: IQUALUIT PORT DEVELOPMENT  
 ENGINEER OF RECORD: \_\_\_\_\_  
 DIV/DEP MGR: \_\_\_\_\_

**WorleyParsons Westmar**  
 TITLE: DEEP SEA WHARF OPTION 2 - NORTH POLARIS SITE PLAN  

DRAWING SCALE: 1:2000	PROJECT NUMBER: 09120	DRAWING NUMBER: SK-102	REV.: P2
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ISSUE / REVISIONS								

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ENGINEER OF RECORD  
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CLIENT  

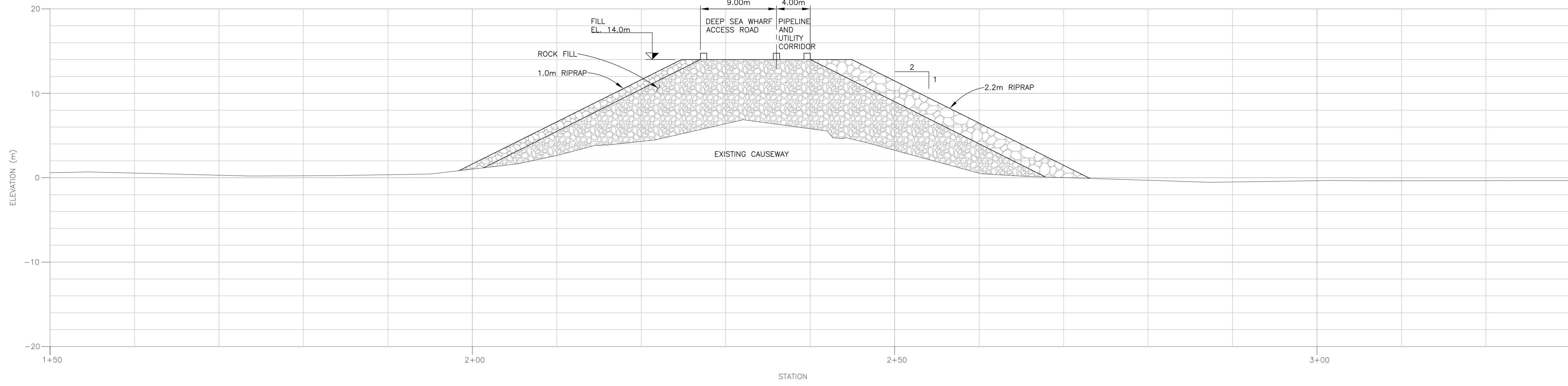
 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION

PROJECT  
**IQALUIT PORT DEVELOPMENT**

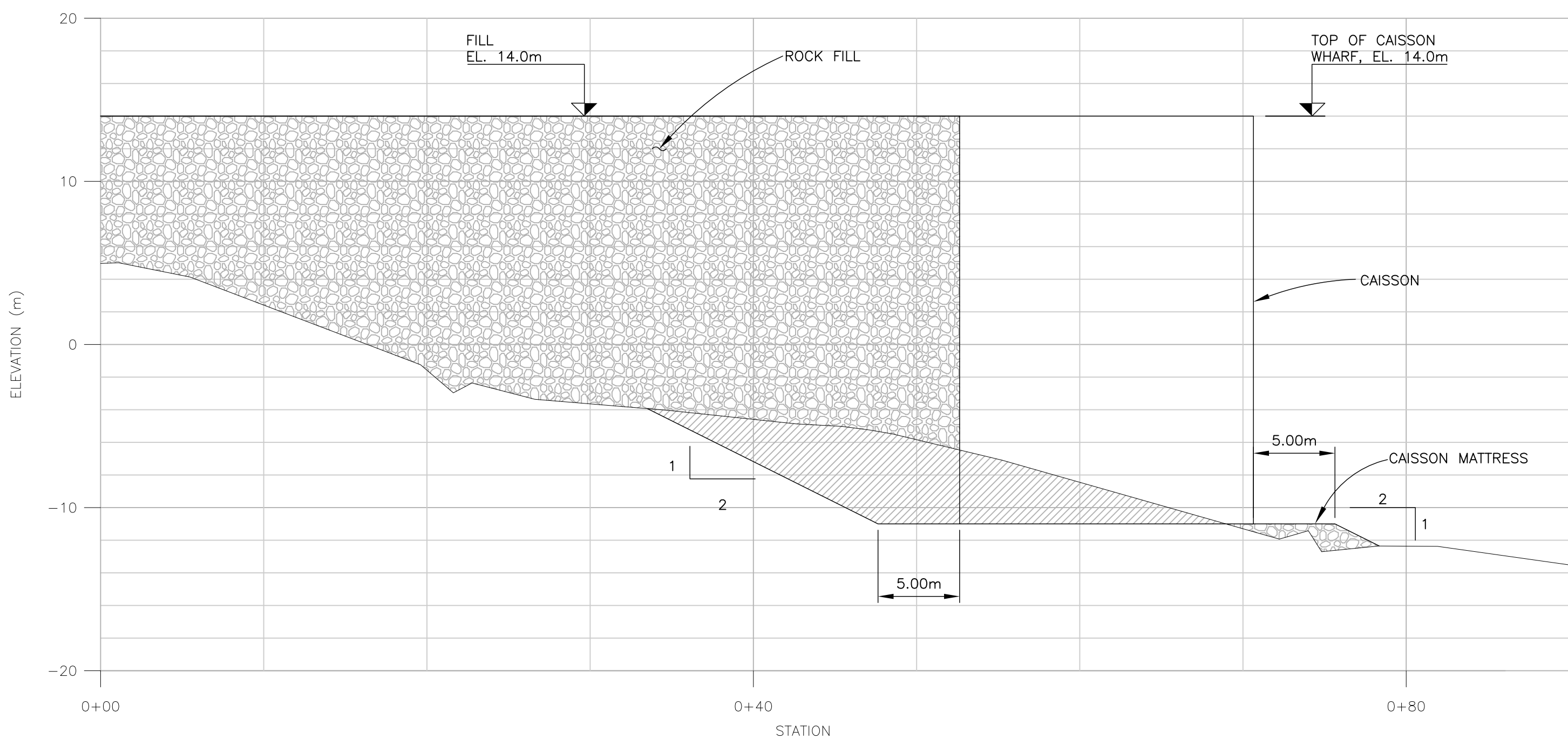
**WorleyParsons Westmar**

TITLE  
**DEEP SEA WHARF  
 OPTION 3 - OLD CAUSEWAY  
 SITE PLAN**

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
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1:250  
SK-103

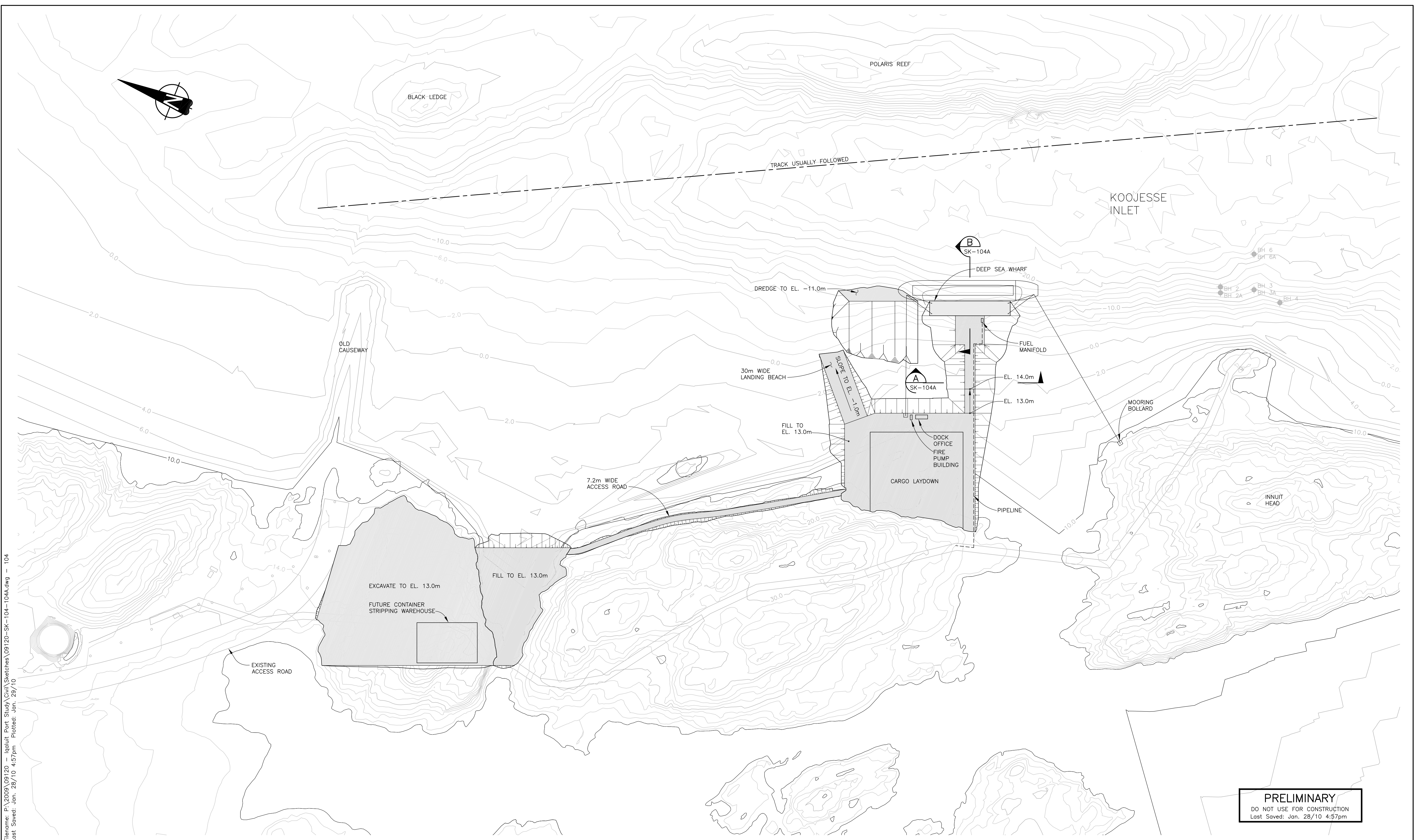


SECTION B  
1:250  
SK-103

**PRELIMINARY**  
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																				 CLIENT <b>DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION</b>		 <b>WorleyParsons Westmar</b>	
																				PROJECT <b>IQUALUIT PORT DEVELOPMENT</b>		TITLE <b>DEEP SEA WHARF OPTION 3 - OLD CAUSEWAY SECTIONS</b>	
No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED	No.	DATE	DESCRIPTION	DRAWN	DWG CHKD	DESIGN	DES CHKD	QA	APPROVED	ENGINEER OF RECORD	DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.	
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ISSUE / REVISIONS										ISSUE / REVISIONS										DIV/DEP MGR: -			



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 Last Saved: Jan. 28/10 4:57pm

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ISSUE / REVISIONS								

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P1	OCT29/09	ISSUED FOR CLIENT REVIEW	BJM	-	-	HG	-	HGK	-	-	-	HGK	-

ENGINEER OF RECORD  
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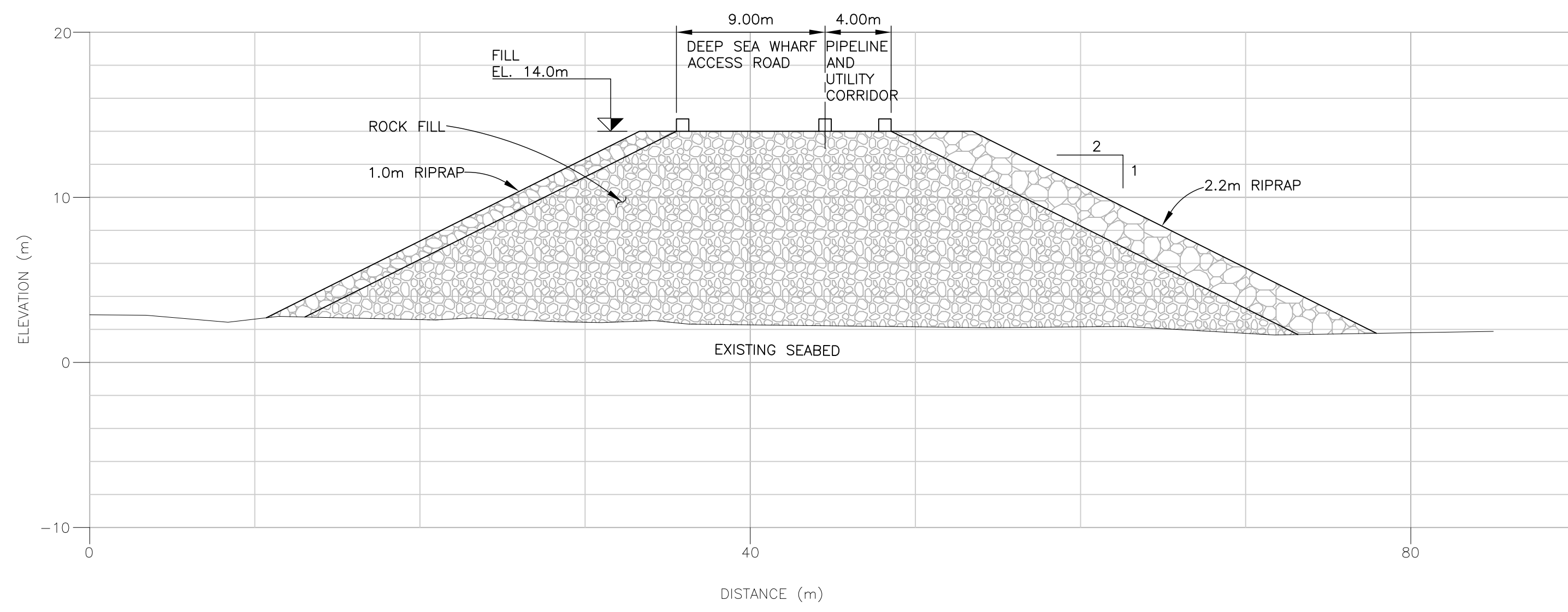
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 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT  
**IQALUIT PORT DEVELOPMENT**

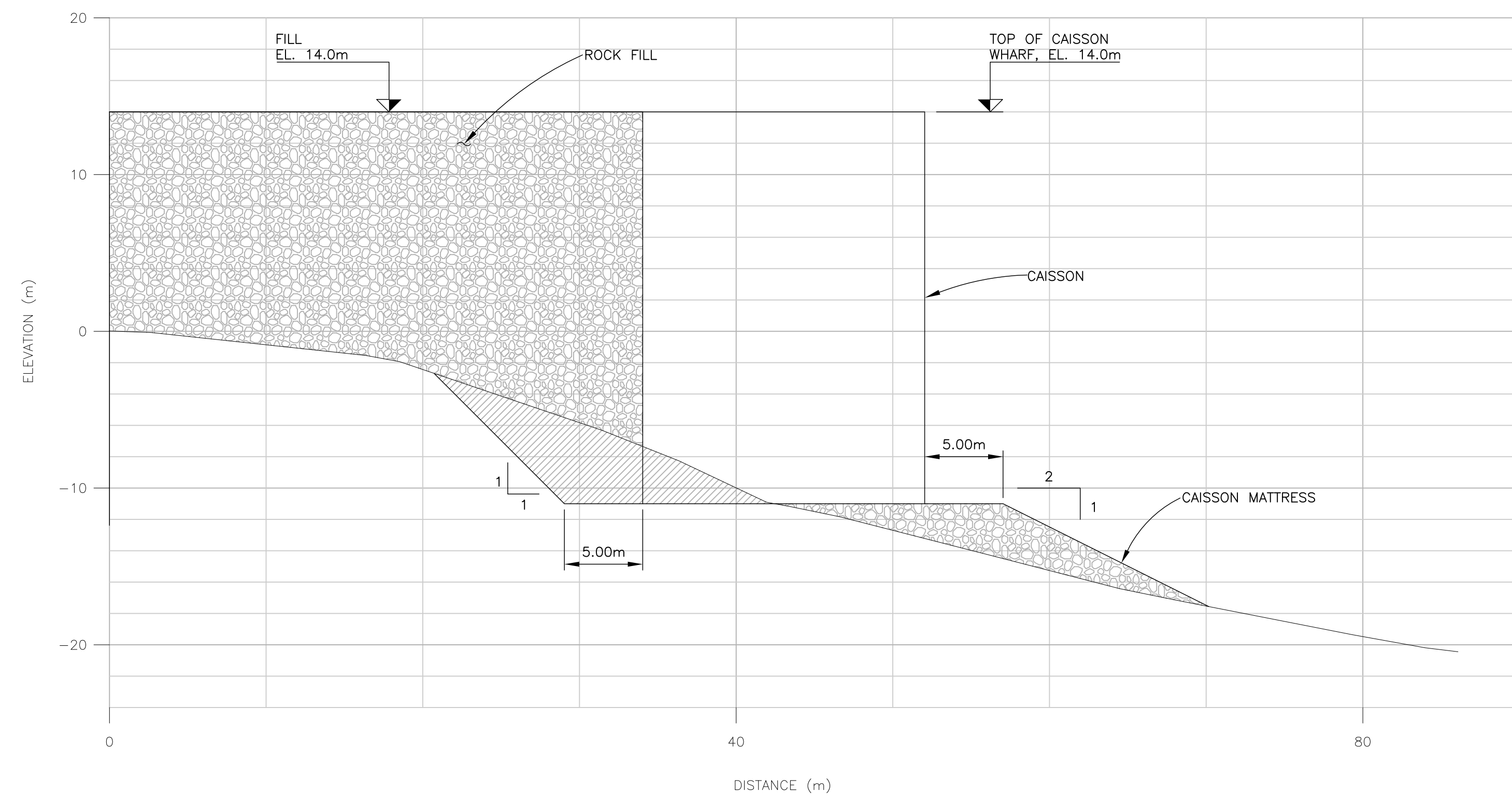
**WorleyParsons Westmar**  
 TITLE  
**DEEP SEA WHARF  
 OPTION 4 - SOUTH POLARIS  
 SITE PLAN**  

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
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 Last Saved: Jan. 29/10 2:44pm Plotted: Jan. 29/10



SECTION A  
1:250  
SK-104



SECTION B  
1:250  
SK-104

**PRELIMINARY**  
 DO NOT USE FOR CONSTRUCTION  
 Last Saved: Jan. 29/10 2:44pm

DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION										<b>WorleyParsons Westmar</b>														
PROJECT: IQUALUIT PORT DEVELOPMENT										TITLE: DEEP SEA WHARF OPTION 4 - SOUTH POLARIS SECTIONS														
No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED	No.	DATE	DESCRIPTION	DRAWN	DWG CHKD	DESIGN	DES CHKD	QA	APPROVED	ENGINEER OF RECORD	DIV/DEP MGR:	DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.	
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**PRELIMINARY**  
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ISSUE / REVISIONS								

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ISSUE / REVISIONS														

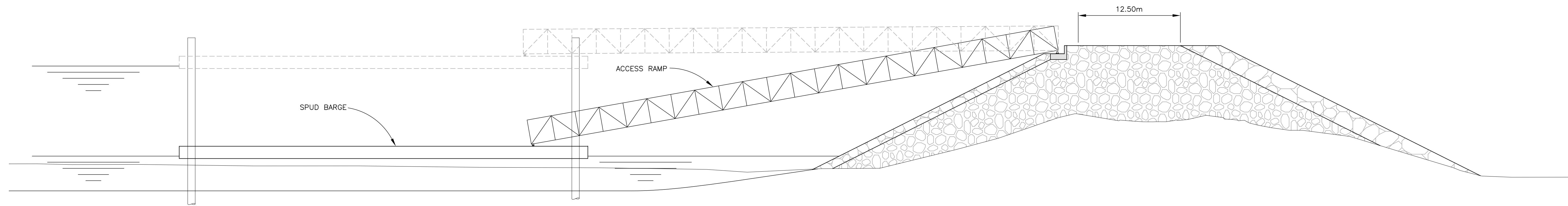
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 PROJECT  
**IQUALUIT PORT DEVELOPMENT**  
 ENGINEER OF RECORD  
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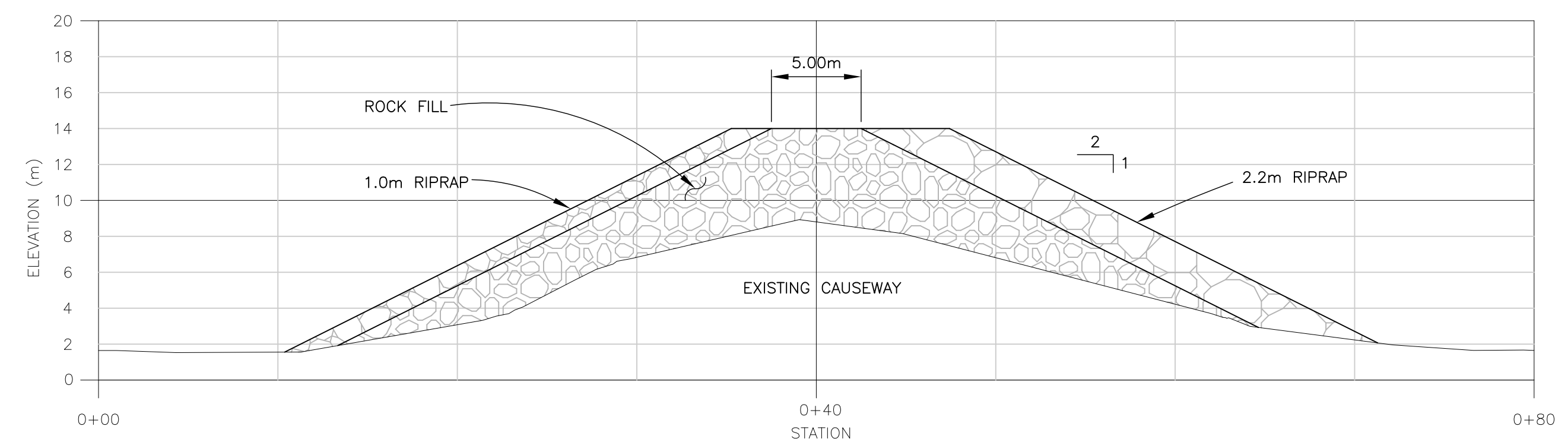
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 TITLE  
**TWO CARGO RAMP FACILITY  
 OPTION 5 - OLD CAUSEWAY  
 SITE PLAN**  

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**ELEVATION – ACCESS RAMP AND SMALL CRAFT DOCK**  
1:250



**SECTION A**  
1:250  
SK-105

**PRELIMINARY**  
 DO NOT USE FOR CONSTRUCTION  
 Last Saved: Jan. 29/10 2:57pm

No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED
ISSUE / REVISIONS								

No.	DATE	DESCRIPTION	DRAWN	DWG CHKD	DESIGN	DES CHKD	QA	APPROVED
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ISSUE / REVISIONS								

ENGINEER OF RECORD  
DIV/DEP MGR: -

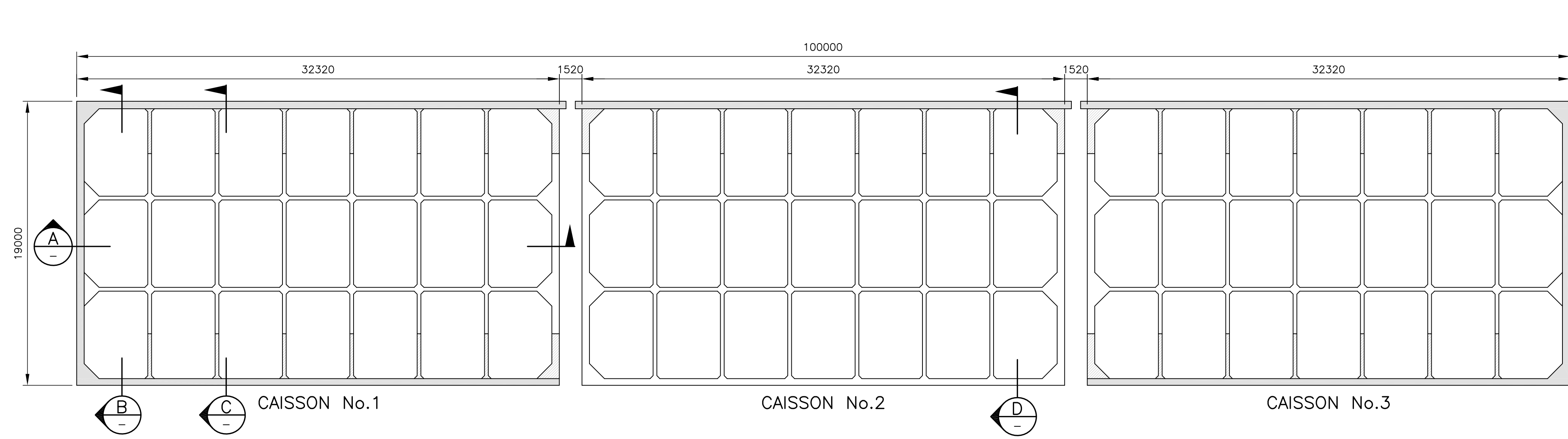
CLIENT  
**DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION**

PROJECT  
**IQUALUIT PORT DEVELOPMENT**

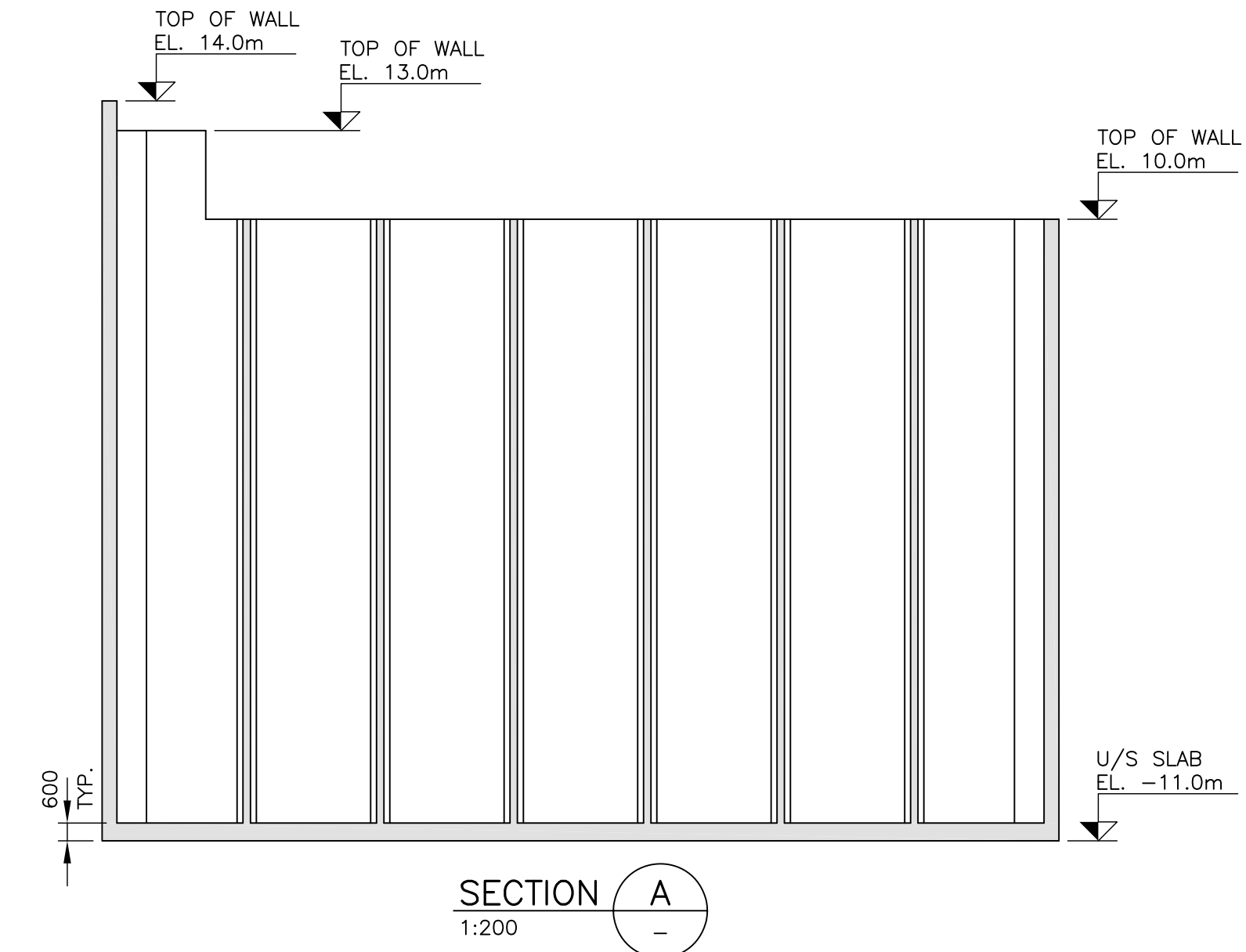
**WorleyParsons Westmar**

TITLE  
**TWO CARGO RAMP FACILITY  
 OPTION 5 – OLD CAUSEWAY  
 SECTIONS**

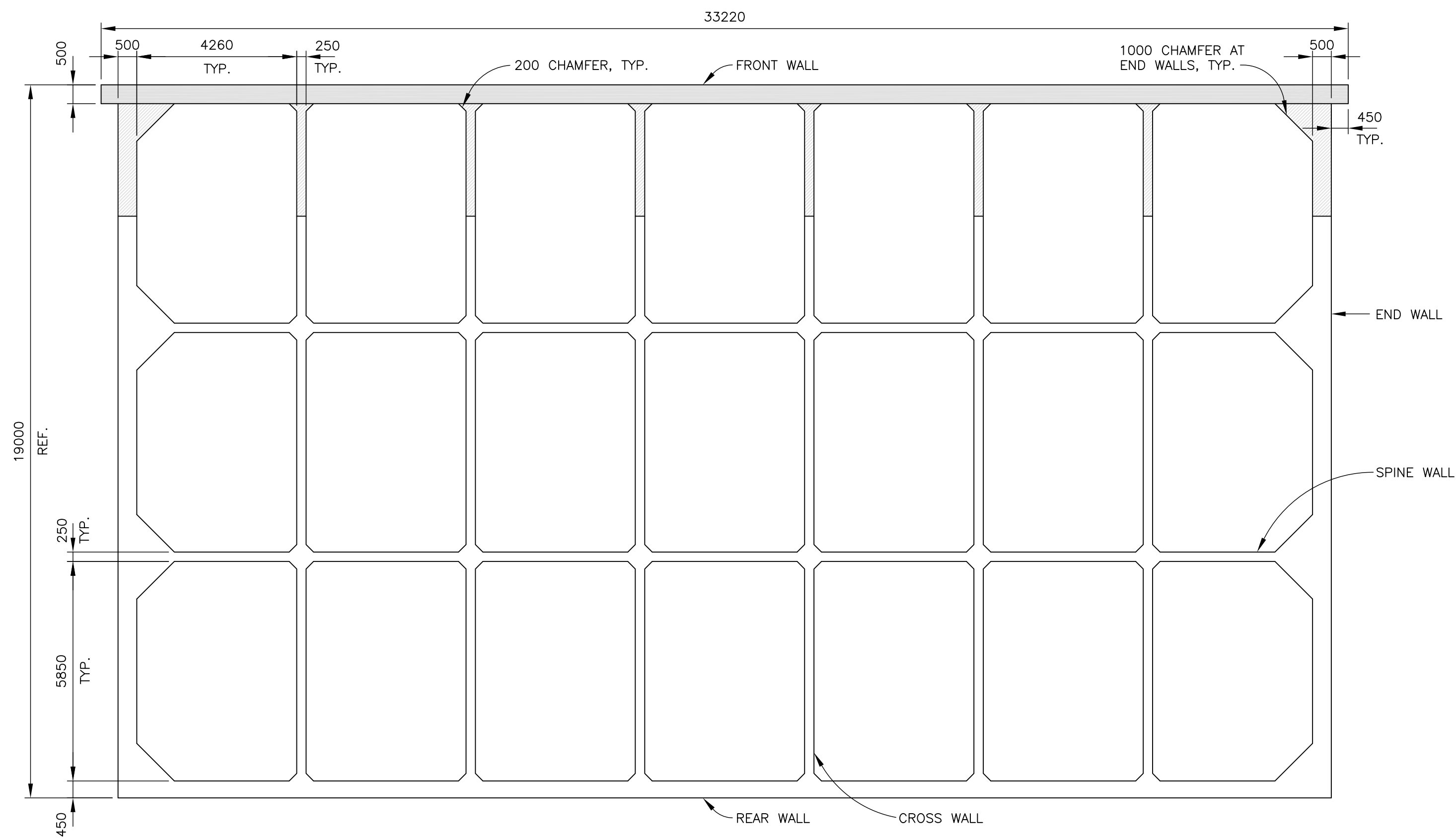
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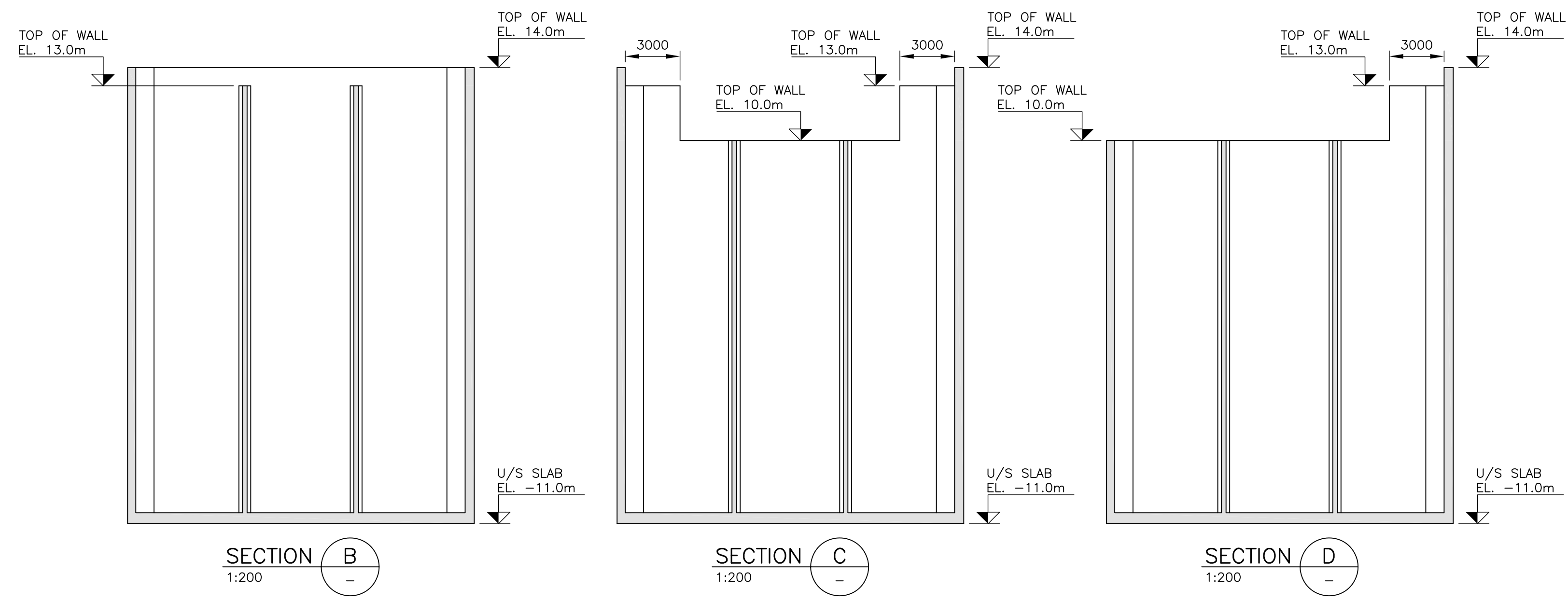
PLAN - CAISSON LAYOUT  
1:200



SECTION A  
1:200



PLAN - CAISSON No.2  
1:100



SECTION B  
1:200

SECTION C  
1:200

SECTION D  
1:200

TOTAL CAISSON WALL HEIGHT:  
REFER TO PLAN VIEWS

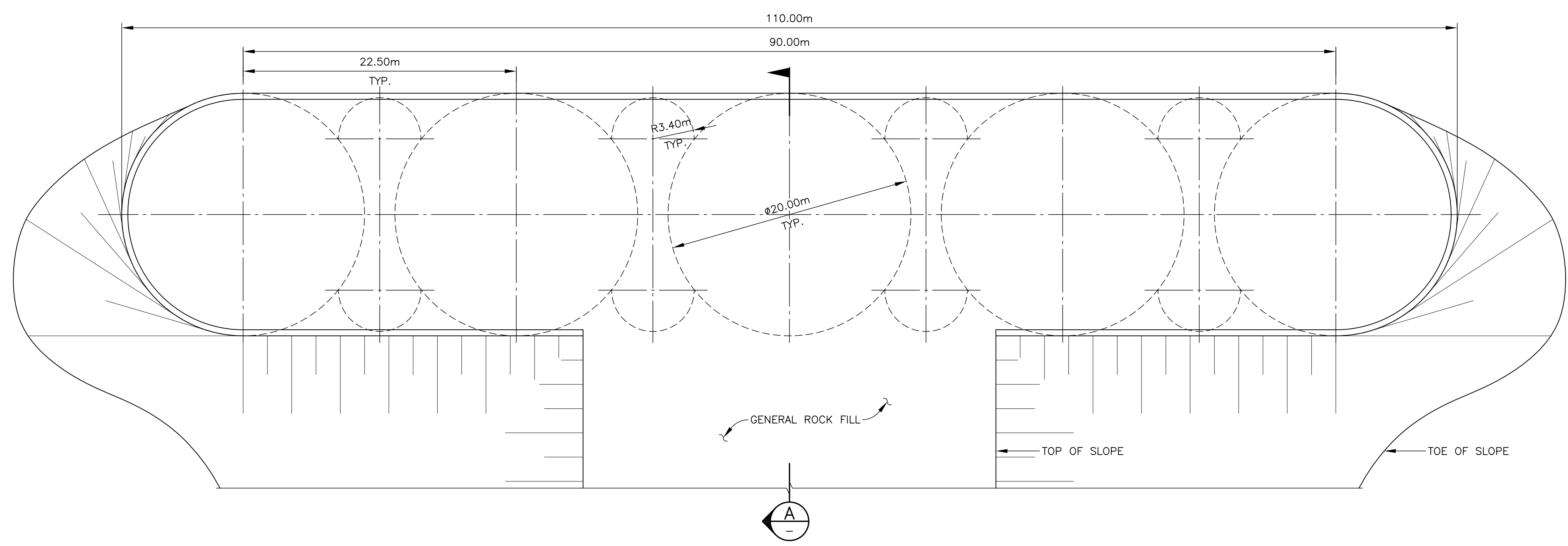
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- 24000 (EL. 13.0m)
- 21000 (EL. 10.0m)

**PRELIMINARY**  
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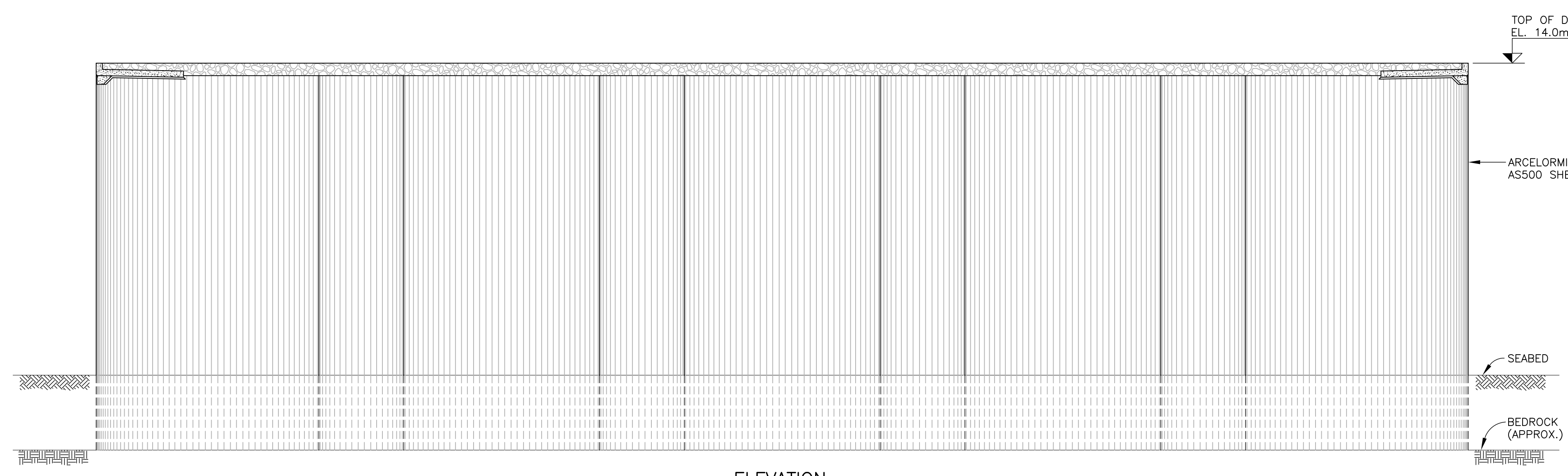
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CLIENT DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION										TITLE DEEP SEA WHARF CAISSON GENERAL ARRANGEMENT																																																						
PROJECT IQUALUIT PORT DEVELOPMENT										DRAWING SCALE: SHOWN PROJECT NUMBER: 09120 DRAWING NUMBER: SK-106 REV.: P2																																																						
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P1	OCT29/09	ISSUED FOR CLIENT REVIEW																																																														
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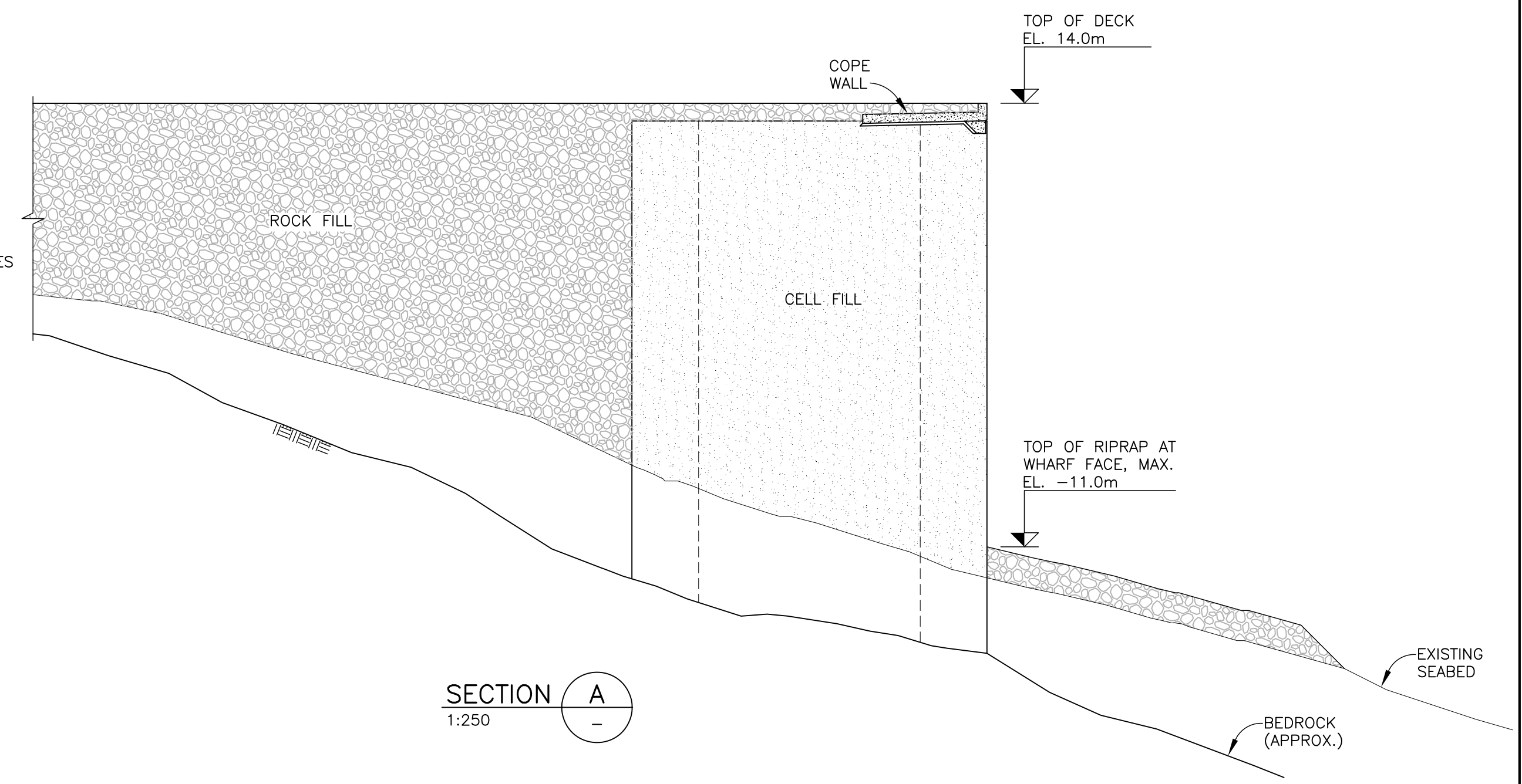
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**PLAN - SHEET PILE CELLS**  
1:250



**ELEVATION**  
1:250



**SECTION A**  
1:250

**PRELIMINARY**  
 DO NOT USE FOR CONSTRUCTION  
 Last Saved: Jan. 29/10 3:16pm

No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED
ISSUE / REVISIONS								

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P1	OCT29/09	ISSUED FOR CLIENT REVIEW	DN	-	-	HG	-	HGK
ISSUE / REVISIONS								

ENGINEER OF RECORD  
DIV/DEP MGR: -

CLIENT  
**DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION**

PROJECT  
**IQALUIT PORT DEVELOPMENT**

**WorleyParsons Westmar**

TITLE  
**DEEP SEA WHARF SHEET PILE CELL GENERAL ARRANGEMENT**

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
SHOWN	09120	SK-107	P2



Filename: P:\2009\09120 - Iqaluit Port Study\Civil Sketches\09120-SK-108-108A.dwg - 108  
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**PRELIMINARY**  
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 Last Saved: Jan. 29/10 3:19pm

No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED	No.	DATE	DESCRIPTION	DRAWN	DWG CHKD	DESIGN	DES CHKD	QA	APPROVED	ENGINEER OF RECORD

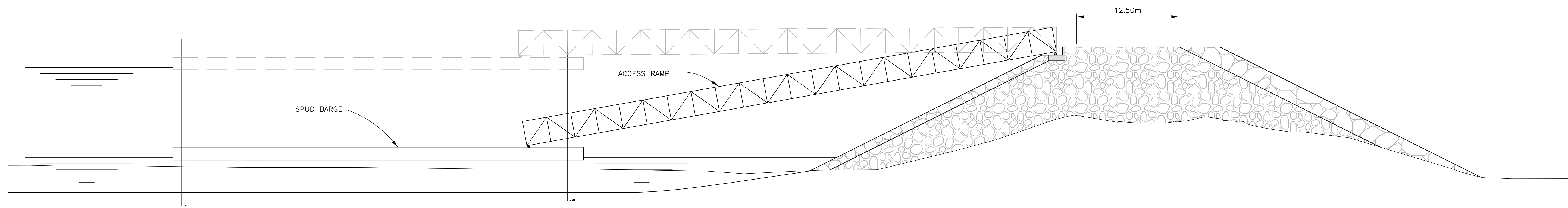
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 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT  
**IQUALUIT PORT DEVELOPMENT**

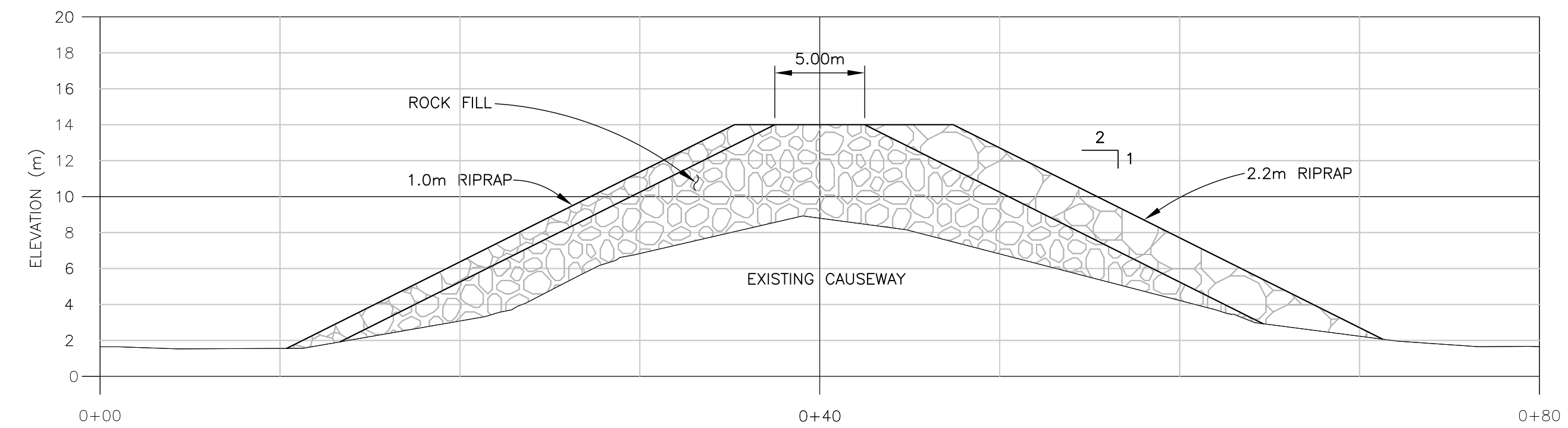
**WorleyParsons Westmar**  
 TITLE  
**SMALL CRAFT HARBOUR  
 OPTION A - OLD CAUSEWAY  
 SITE PLAN**  

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
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**ELEVATION – ACCESS RAMP AND SMALL CRAFT DOCK**  
1:250



**SECTION A**  
1:250  
SK-108

**PRELIMINARY**  
 DO NOT USE FOR CONSTRUCTION  
 Last Saved: Jan. 29/10 3:23pm

No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED
ISSUE / REVISIONS								

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ISSUE / REVISIONS								

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DIV/DEP MGR: -

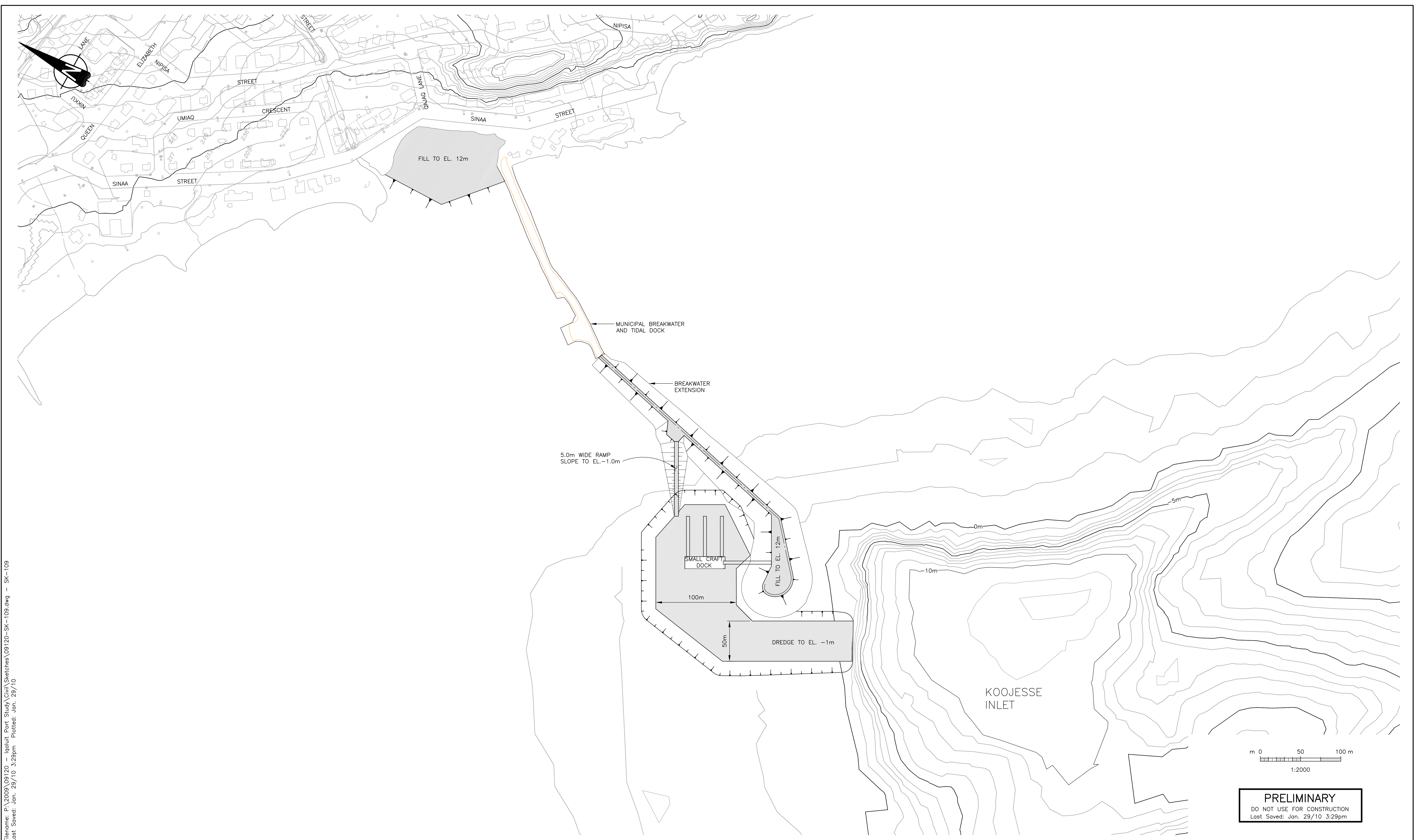
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**DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION**

PROJECT  
**IQUALUIT PORT DEVELOPMENT**

**WorleyParsons Westmar**

TITLE  
**SMALL CRAFT HARBOUR  
 OPTION A – OLD CAUSEWAY  
 SECTIONS**

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
SHOWN	09120	SK-108A	P1



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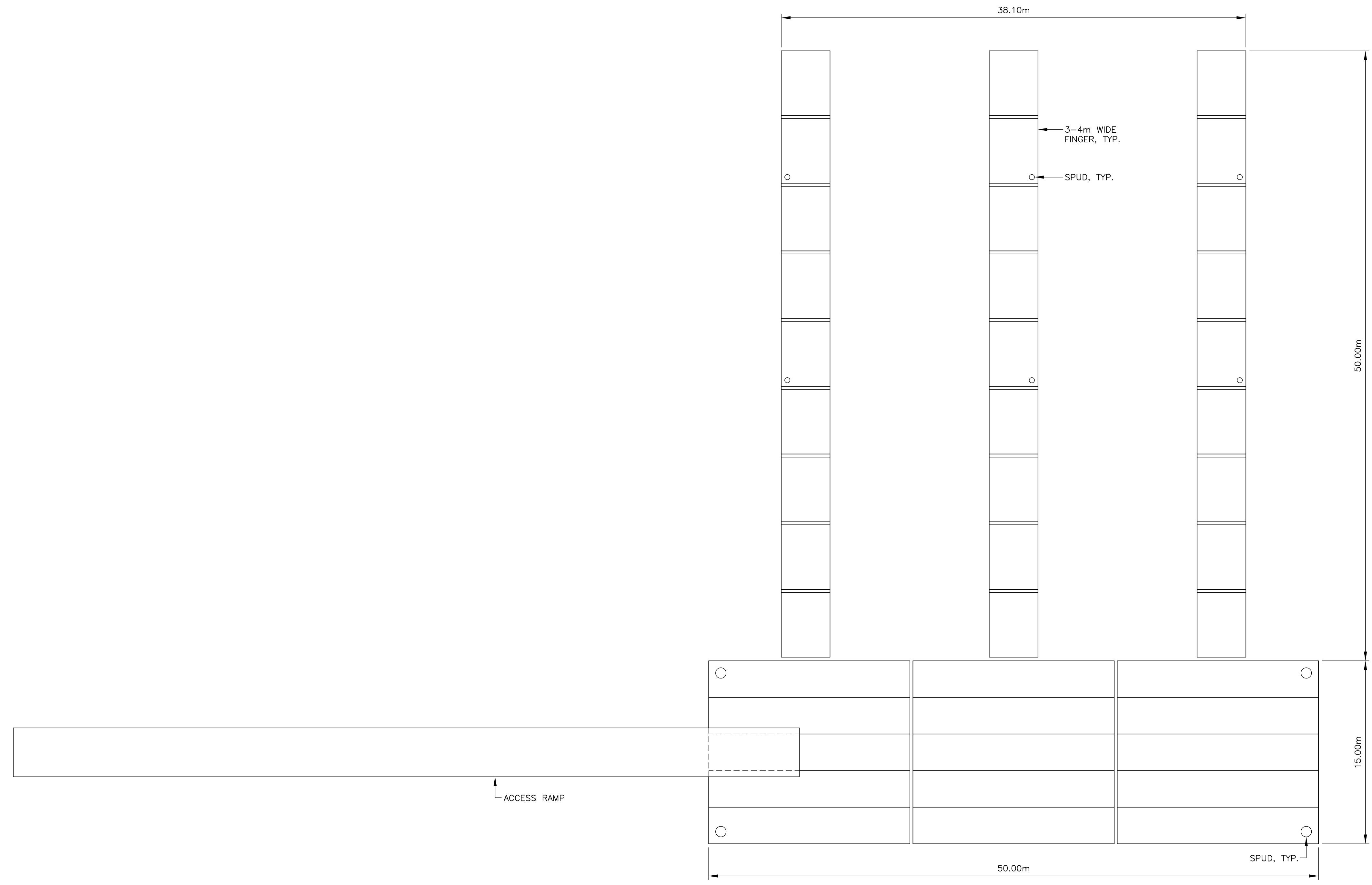
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ISSUE / REVISIONS								

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ISSUE / REVISIONS								

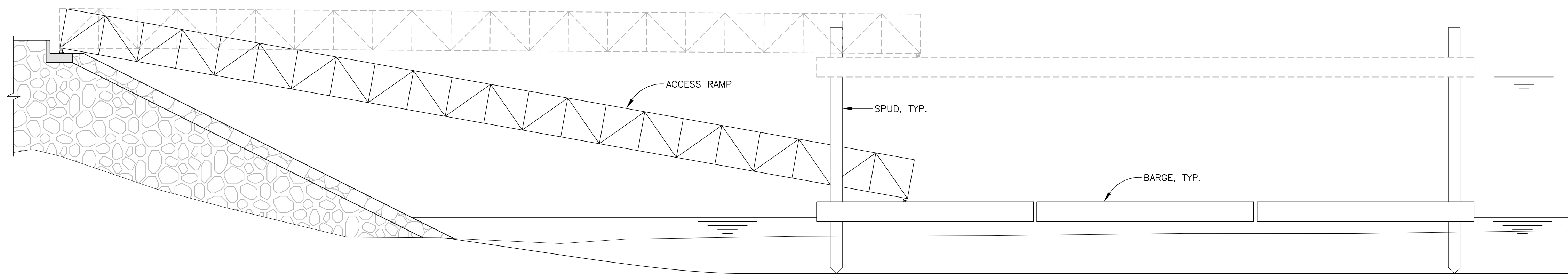
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 PROJECT: IQUALUIT PORT DEVELOPMENT  
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 DIV/DEP MGR: -

TITLE: SMALL CRAFT HARBOUR  
 OPTION B - MUNICIPAL BREAKWATER  
 SITE PLAN  
 DRAWING SCALE: 1:2000 PROJECT NUMBER: 09120 DRAWING NUMBER: SK-109 REV.: P1

Filename: P:\2009\09120 - Iqaluit Port Study\Civil Sketches\09120-SK-110.dwg - SK-110  
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PLAN - ACCESS RAMP AND SMALL CRAFT DOCK  
1:200



ELEVATION - ACCESS RAMP AND SMALL CRAFT DOCK  
1:200

**PRELIMINARY**  
 DO NOT USE FOR CONSTRUCTION  
 Last Saved: Jan. 29/10 3:30pm

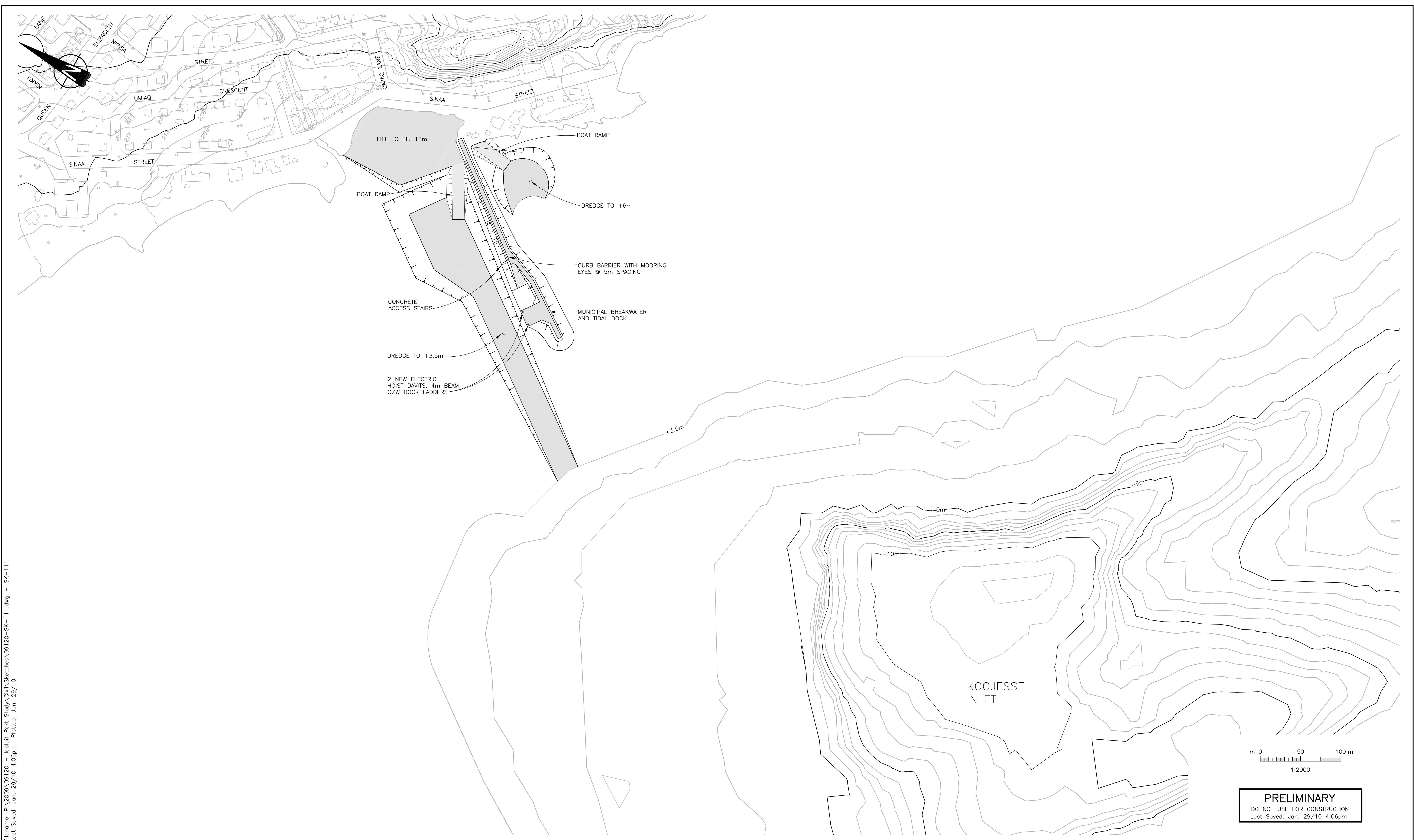
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ISSUE / REVISIONS								

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ISSUE / REVISIONS														

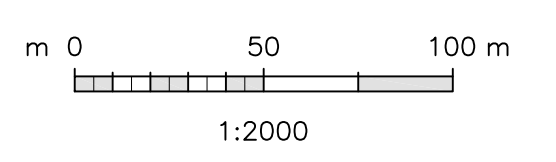
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CLIENT: DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT: IQUALUIT PORT DEVELOPMENT

TITLE: SMALL CRAFT DOCK GENERAL ARRANGEMENT  
 DRAWING SCALE: SHOWN PROJECT NUMBER: 09120 DRAWING NUMBER: SK-110 REV.: P1



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 Last Saved: Jan. 29/10 4:06pm Plotted: Jan. 29/10



**PRELIMINARY**  
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 Last Saved: Jan. 29/10 4:06pm

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ISSUE / REVISIONS								

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							HGK	-
ISSUE / REVISIONS								

ENGINEER OF RECORD  
 DIV/DEP MGR: -

CLIENT  

 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT  
**IQUALUIT PORT DEVELOPMENT**

**WorleyParsons Westmar**  
 TITLE  
**SMALL CRAFT HARBOUR MUNICIPAL BREAKWATER IMPROVEMENTS SITE PLAN**  

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
1:2000	09120	SK-111	P1

**Stantec**

**GEOTECHNICAL DESK STUDY, PROPOSED MARINE DEVELOPMENT IQALUIT  
STANDING OFFER FOR THE ARCTIC REGION ENVIRONMENTAL GEOPHYSICAL AND  
GEOTECHNICAL SERVICES**

## APPENDIX D

### Photographs of the Breakwater Site Option 3



**Stantec**

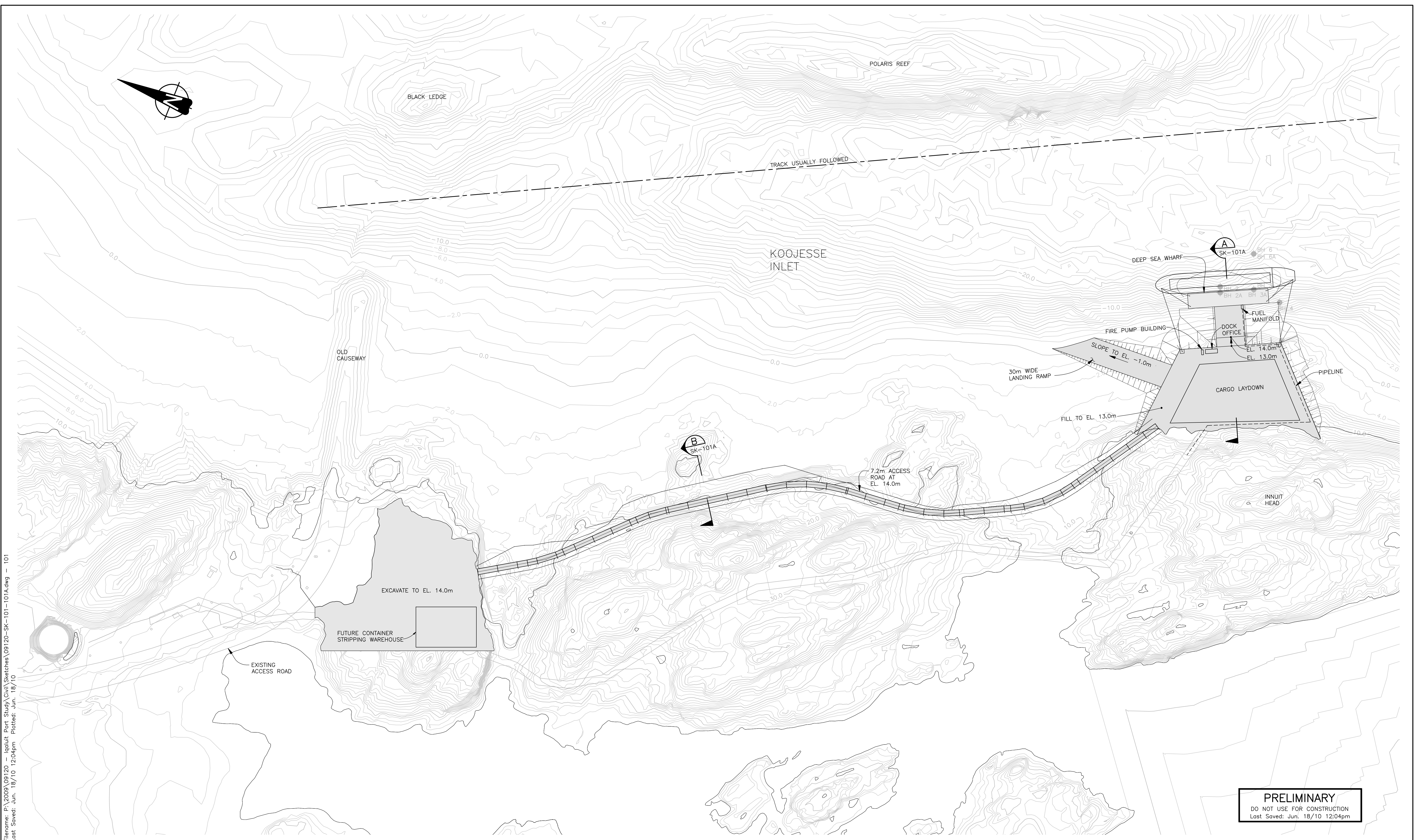
*Photographs of the Breakwater Site Option 3*



GOVERNMENT OF NUNAVUT  
IQALUIT PORT DEVELOPMENT

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## Appendix D Drawings



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P2	JAN29/10	RE-ISSUED FOR CLIENT REVIEW	BJM	-	-	-	HG	-	HGK	-	-	-	HGK	-
P1	OCT29/09	ISSUED FOR CLIENT REVIEW	BJM	-	-	-	HG	-	HGK	-	-	-	HGK	-

ENGINEER OF RECORD  
 DIV/DEP MGR: -

CLIENT  

 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION

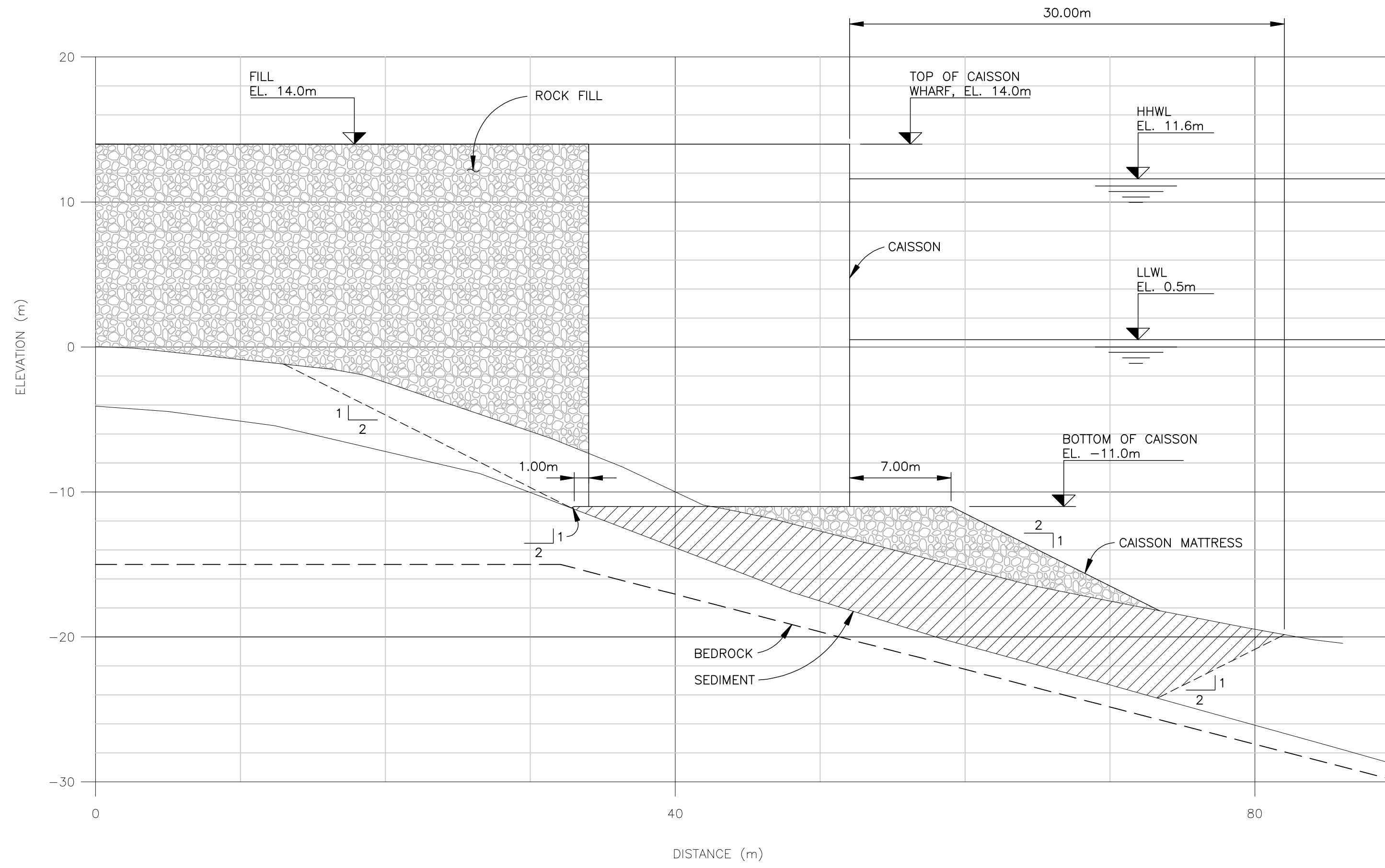
PROJECT  
 IQUALUIT PORT DEVELOPMENT

**WorleyParsons Westmar**

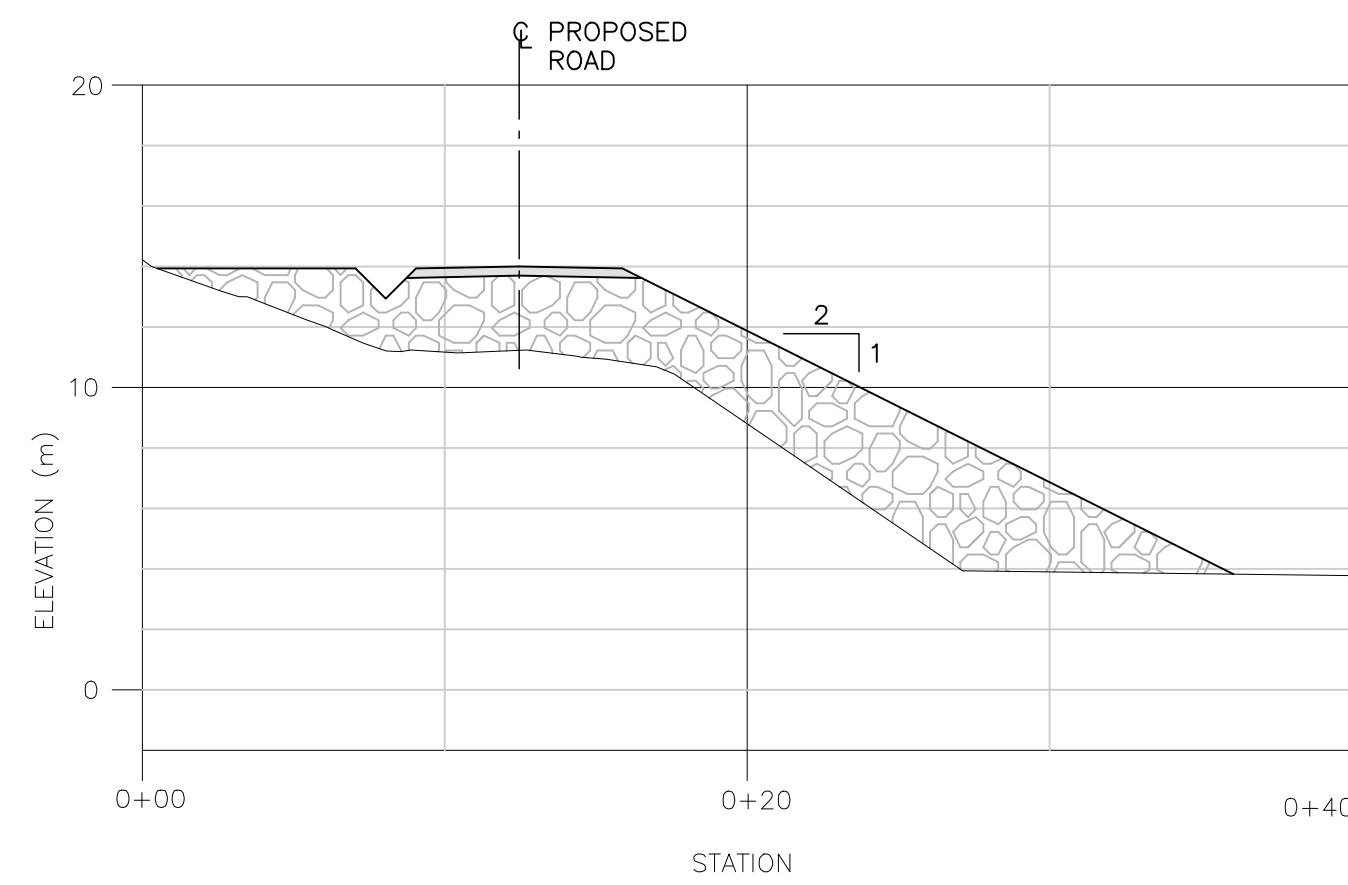
TITLE  
 DEEP SEA WHARF  
 OPTION 1 - INNUIT HEAD  
 SITE PLAN

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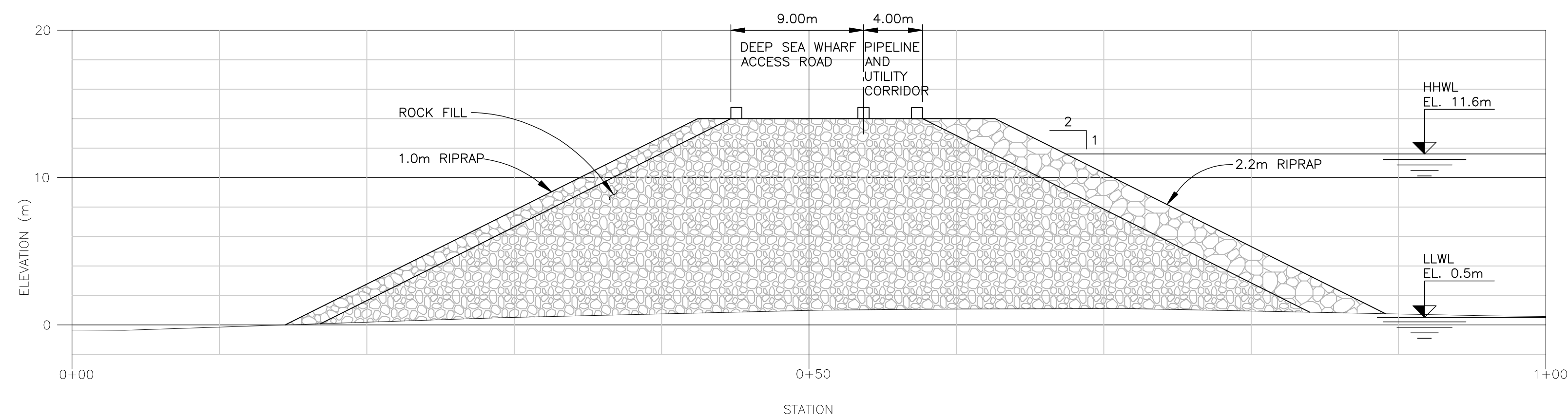
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SECTION A  
1:250  
SK-101



SECTION B  
1:250  
SK-101



SECTION C  
1:250  
SK-102

**PRELIMINARY**  
 DO NOT USE FOR CONSTRUCTION  
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P2	JAN29/10	RE-ISSUED FOR CLIENT REVIEW	BMW	-	-	HG	-	HGK
P1	OCT29/09	ISSUED FOR CLIENT REVIEW	BMW	-	-	HG	-	HGK
ISSUE / REVISIONS								

ENGINEER OF RECORD  
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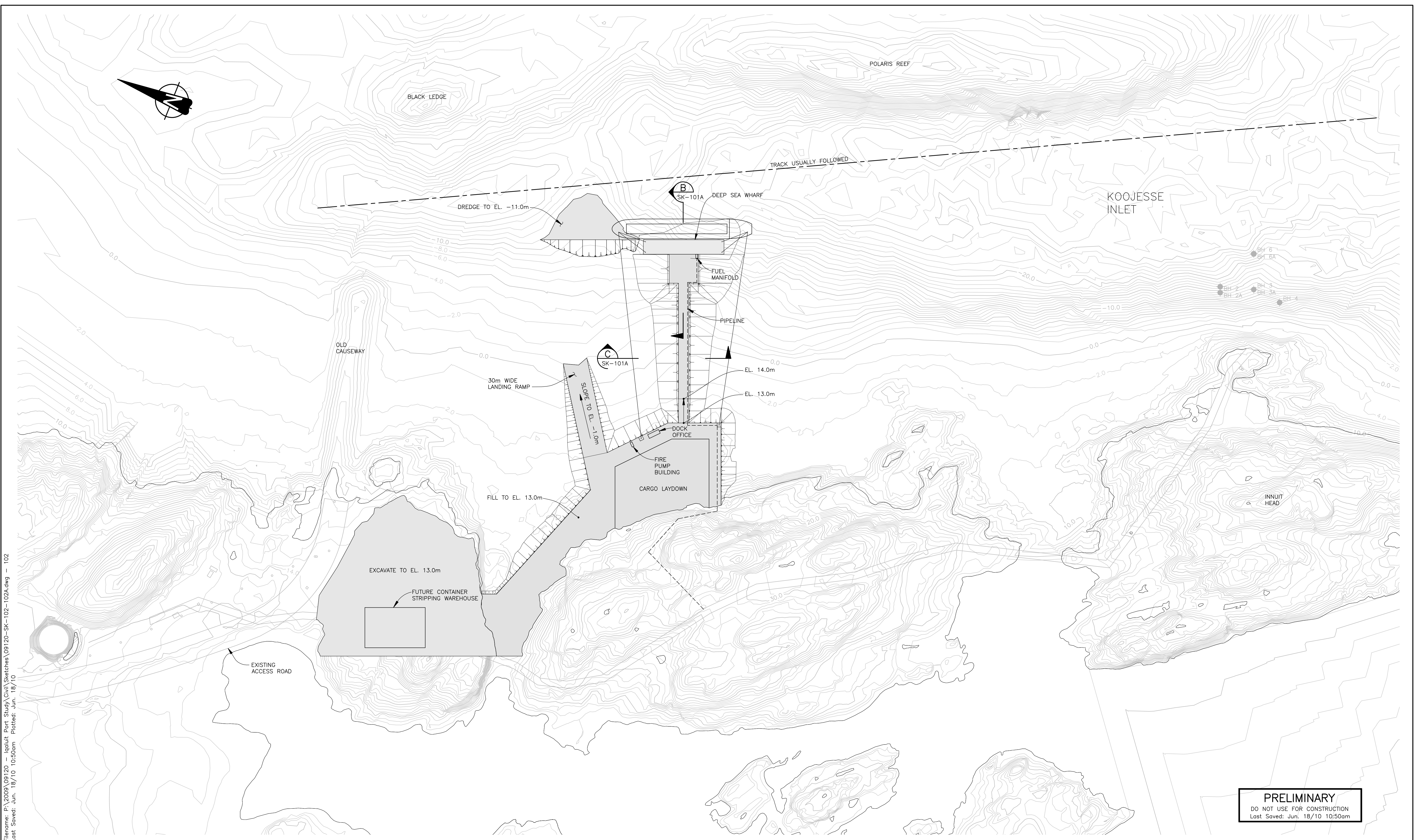
CLIENT  

 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT  
 IQUALUIT PORT DEVELOPMENT

**WorleyParsons Westmar**

TITLE  
 DEEP SEA WHARF  
 OPTION 1 - INNUIT HEAD  
 SECTIONS

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
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ISSUE / REVISIONS								

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P2	JAN29/10	RE-ISSUED FOR CLIENT REVIEW	BJM	-	-	-	HG	-	HGK	-	-	-	HGK	-
P1	OCT29/09	ISSUED FOR CLIENT REVIEW	BJM	-	-	-	HG	-	HGK	-	-	-	HGK	-

ENGINEER OF RECORD  
 DIV/DEP MGR: -

CLIENT  

 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT  
**IQALUIT PORT DEVELOPMENT**

**WorleyParsons Westmar**  
 TITLE  
**DEEP SEA WHARF  
 OPTION 2 - NORTH POLARIS REEF  
 SITE PLAN**  

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
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ENGINEER OF RECORD  
 DIV/DEP MGR: -

CLIENT  
 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION

PROJECT  
 IQUALUIT PORT DEVELOPMENT

**WorleyParsons Westmar**

TITLE  
 DEEP SEA WHARF  
 OPTION 3 - OLD CAUSEWAY  
 SITE PLAN

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
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ISSUE / REVISIONS								

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ISSUE / REVISIONS								

ENGINEER OF RECORD  
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CLIENT  

 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION

PROJECT  
**IQALUIT PORT DEVELOPMENT**

**WorleyParsons Westmar**

TITLE  
**DEEP SEA WHARF  
 OPTION 4 - SOUTH POLARIS REEF  
 SITE PLAN**

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ISSUE / REVISIONS								

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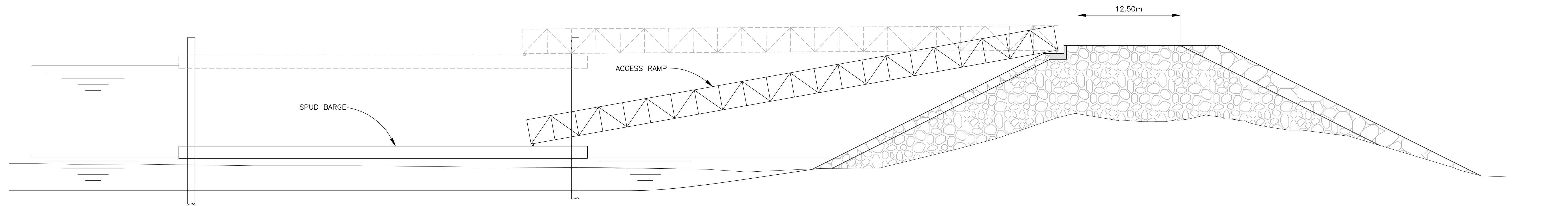
PROJECT  
**IQALUIT PORT DEVELOPMENT**

**WorleyParsons Westmar**

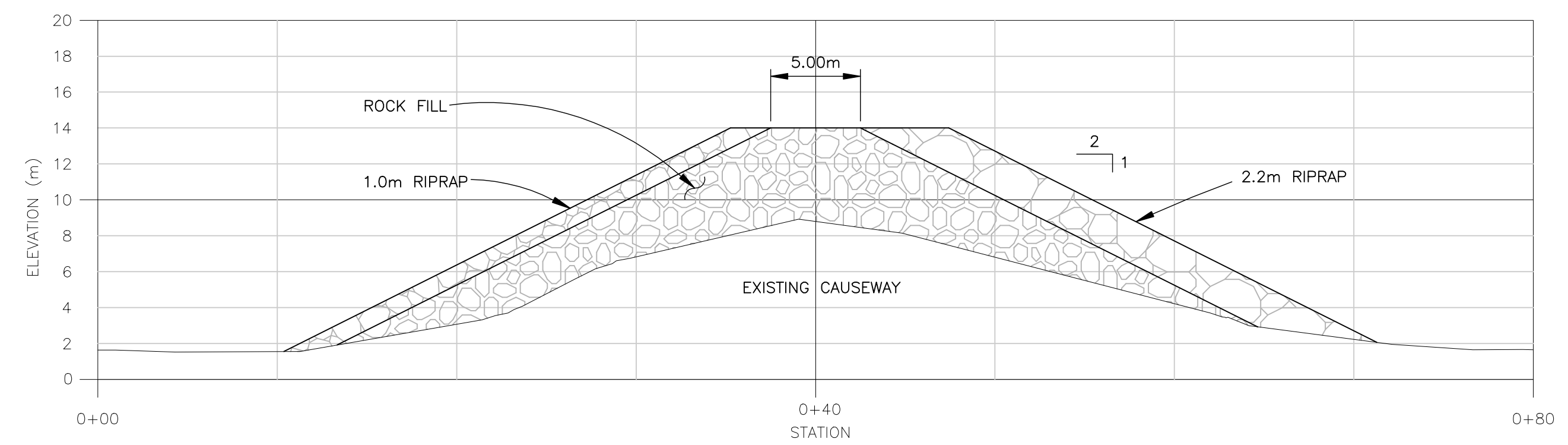
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**DEEP SEA WHARF  
 OPTION 5 - TWIN LANDING RAMPS  
 SITE PLAN**

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**ELEVATION – ACCESS RAMP AND SMALL CRAFT DOCK**  
1:250



**SECTION A**  
1:250 SK-105

**PRELIMINARY**  
 DO NOT USE FOR CONSTRUCTION  
 Last Saved: Jun. 18/10 11:03am

No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED
ISSUE / REVISIONS								

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ISSUE / REVISIONS														

ENGINEER OF RECORD  
DIV/DEP MGR: -

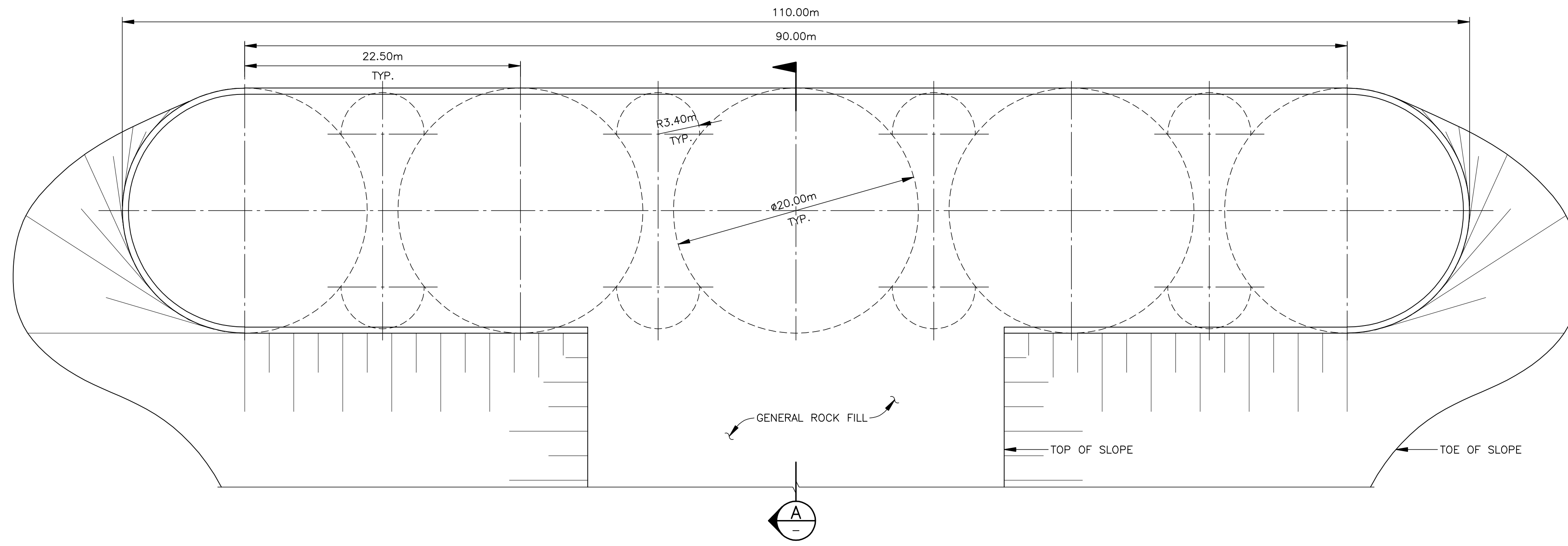
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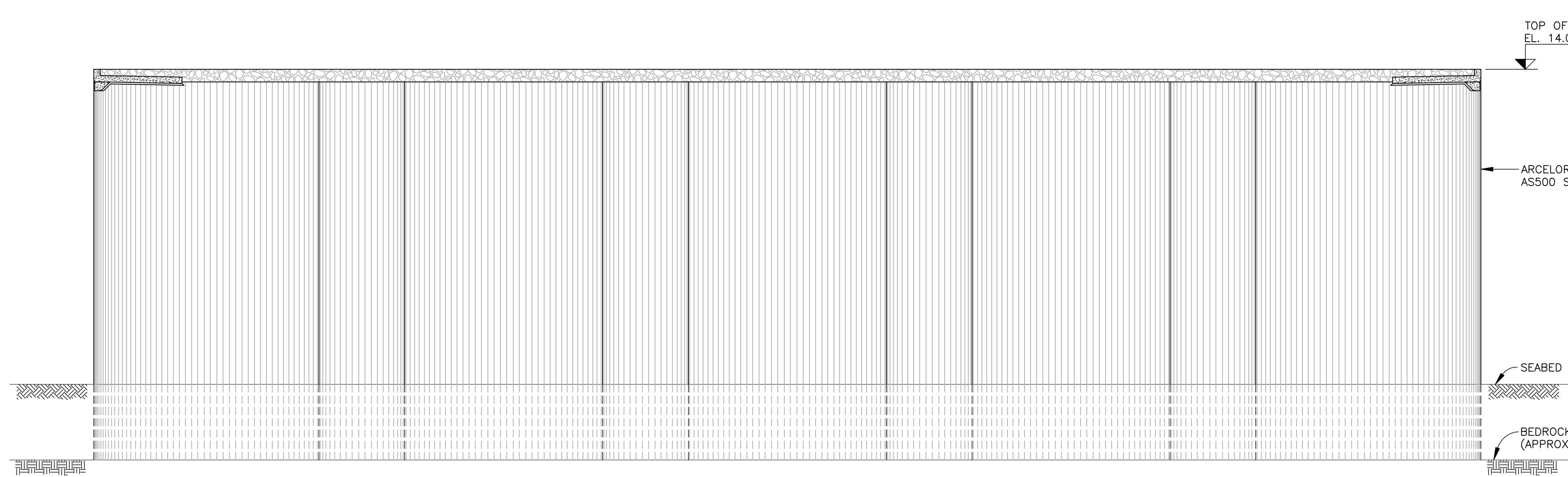
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 TITLE  
**DEEP SEA WHARF  
 OPTION 5 – TWIN LANDING RAMPS  
 SECTIONS**

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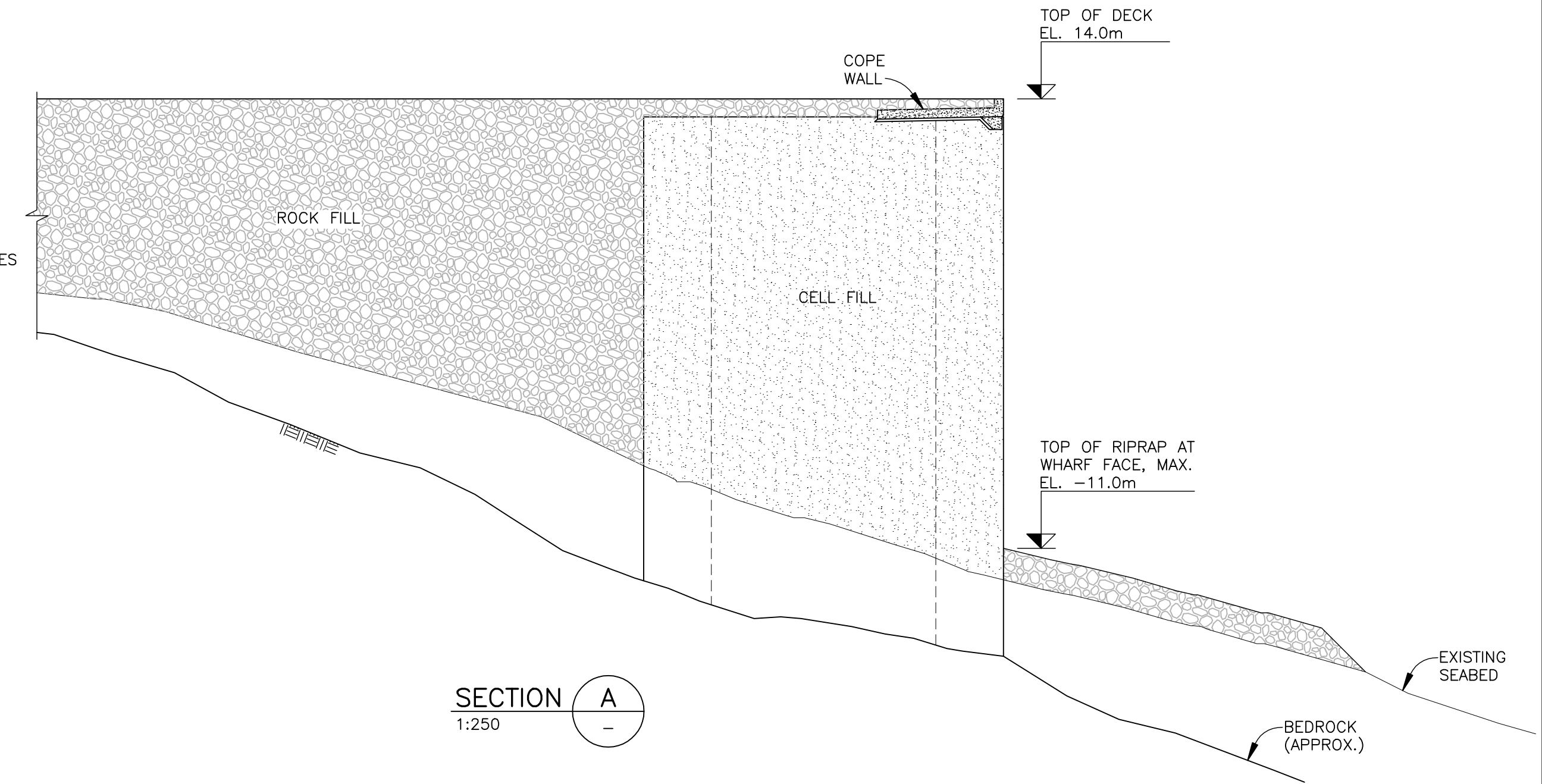




PLAN - SHEET PILE CELLS  
1:250



ELEVATION  
1:250



SECTION A  
1:250

**PRELIMINARY**  
DO NOT USE FOR CONSTRUCTION  
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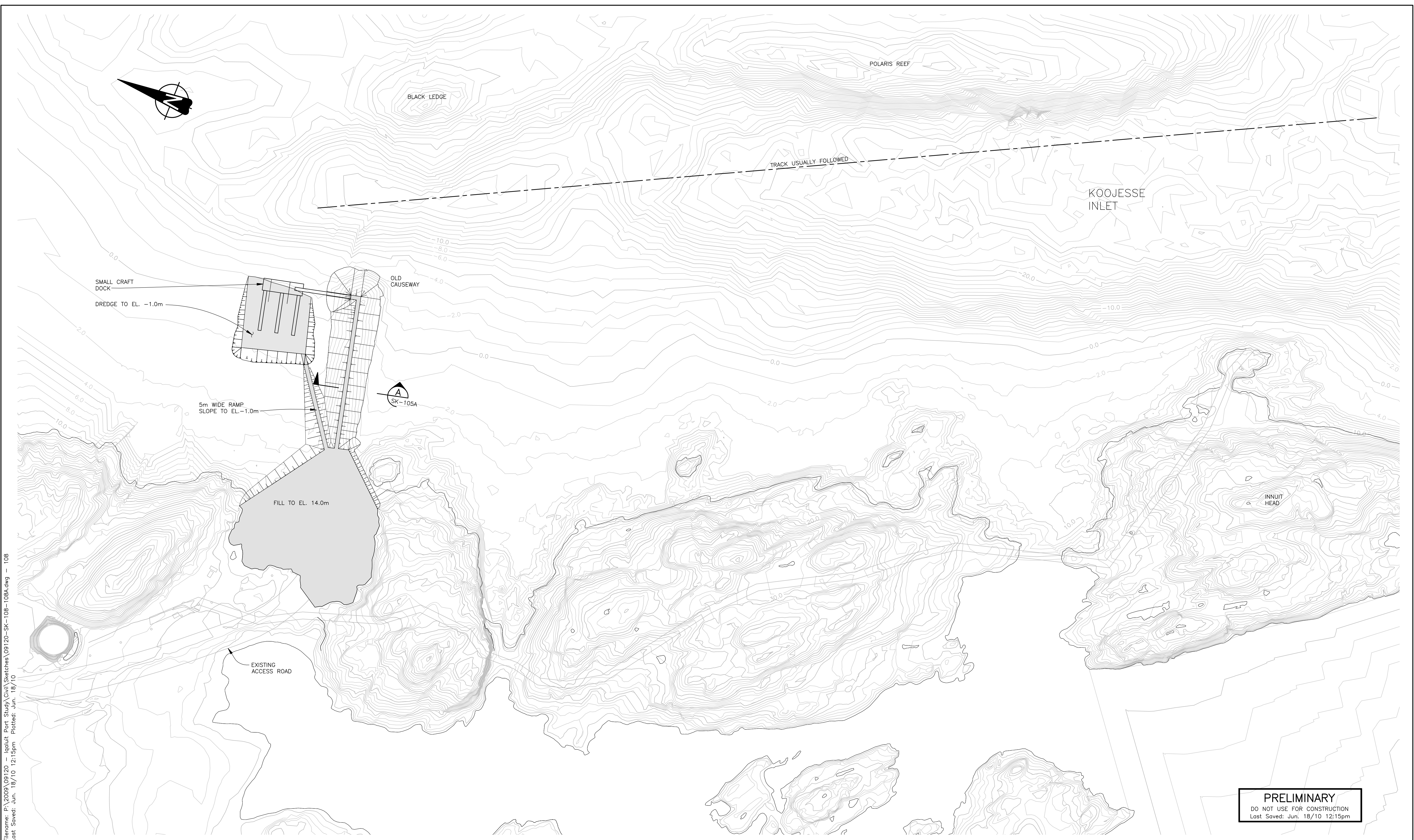
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ISSUE / REVISIONS								

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P2	JAN29/10	RE-ISSUED FOR CLIENT REVIEW	BJM	-	-	-	HG	-	HGK	-	-	-	HGK	-
P1	OCT29/09	ISSUED FOR CLIENT REVIEW	DN	-	-	-	HG	-	HGK	-	-	-	HGK	-

ENGINEER OF RECORD  
DIV/DEP MGR: -

CLIENT  
 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
PROJECT  
IQALUIT PORT DEVELOPMENT

<b>WorleyParsons Westmar</b>			
TITLE DEEP SEA WHARF SHEET PILE CELL GENERAL ARRANGEMENT			
DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
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No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED
ISSUE / REVISIONS								

P2	JUN18/10	ISSUED WITH DRAFT REPORT	MRW	-	-	-	HG	-	HGK	-	-	-	HGK	-
P1	JAN29/10	ISSUED FOR CLIENT REVIEW	AUS	-	-	-	HG	-	HGK	-	-	-	HGK	-

ENGINEER OF RECORD  
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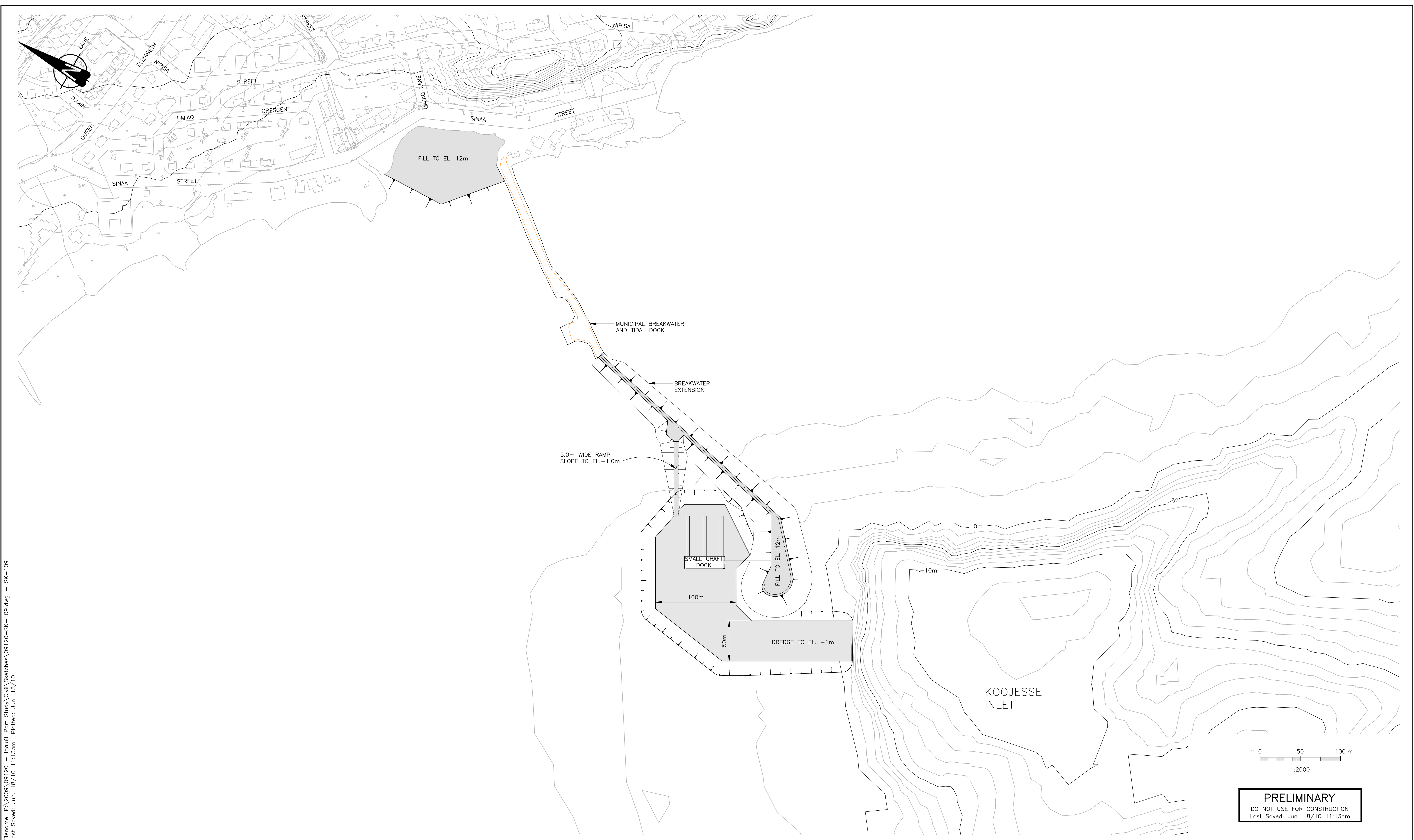
CLIENT  
 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION

PROJECT  
 IQUALUIT PORT DEVELOPMENT

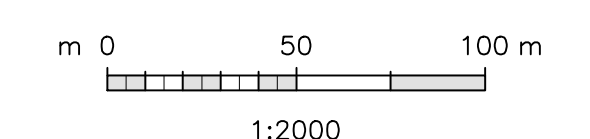
**WorleyParsons Westmar**

TITLE  
 SMALL CRAFT HARBOUR  
 OPTION A - OLD CAUSEWAY  
 SITE PLAN

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
1:2000	09120	SK-108	P2



Filename: P:\2009\09120 - Iqaluit Port Study\Civil\Sketches\09120-SK-109.dwg - SK-109  
 Last Saved: Jun. 18/10 11:13am Plotted: Jun. 18/10



**PRELIMINARY**  
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 Last Saved: Jun. 18/10 11:13am

No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED
ISSUE / REVISIONS								

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P1	JAN 29/10	ISSUED FOR CLIENT REVIEW	BJM	-	-	-	HG	-	HGK	-	-	-	-	HGK	-
ISSUE / REVISIONS															

ENGINEER OF RECORD  
 DIV/DEP MGR: -

CLIENT  
 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION

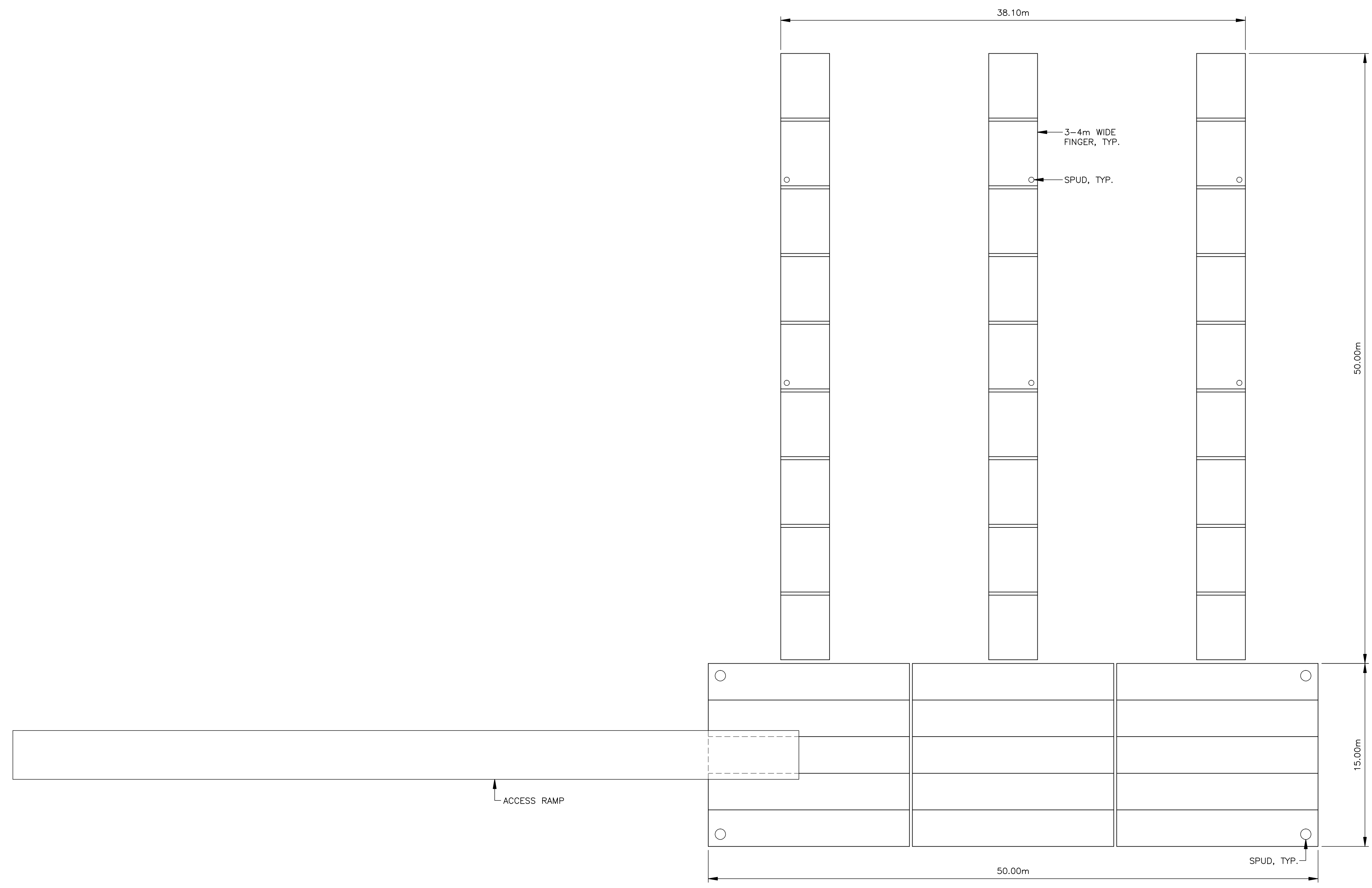
PROJECT  
 IQUALUIT PORT DEVELOPMENT

**WorleyParsons Westmar**

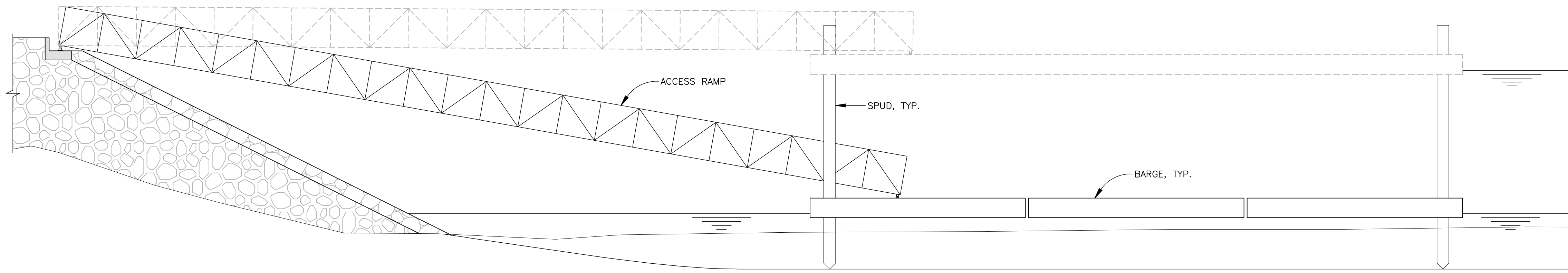
TITLE  
 SMALL CRAFT HARBOUR  
 OPTION B - MUNICIPAL BREAKWATER EXPANSION  
 SITE PLAN

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
1:2000	09120	SK-109	P2

Filename: P:\2009\09120 - Iqaluit Port Study\Civil\Sketches\09120-SK-110.dwg - SK-110  
 Last Saved: Jan. 29/10 4:30pm Plotted: Jun. 18/10



PLAN - ACCESS RAMP AND SMALL CRAFT DOCK  
1:200



ELEVATION - ACCESS RAMP AND SMALL CRAFT DOCK  
1:200

**PRELIMINARY**  
 DO NOT USE FOR CONSTRUCTION  
 Last Saved: Jan. 29/10 4:30pm

No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED
ISSUE / REVISIONS								

No.	DATE	DESCRIPTION	DRAWN	DWG CHKD	DESIGN	DES CHKD	QA	APPROVED
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P1	JAN29/10	ISSUED FOR CLIENT REVIEW	DN	-	-	HG	-	HGK
ISSUE / REVISIONS								

ENGINEER OF RECORD  
DIV/DEP MGR: -

CLIENT  

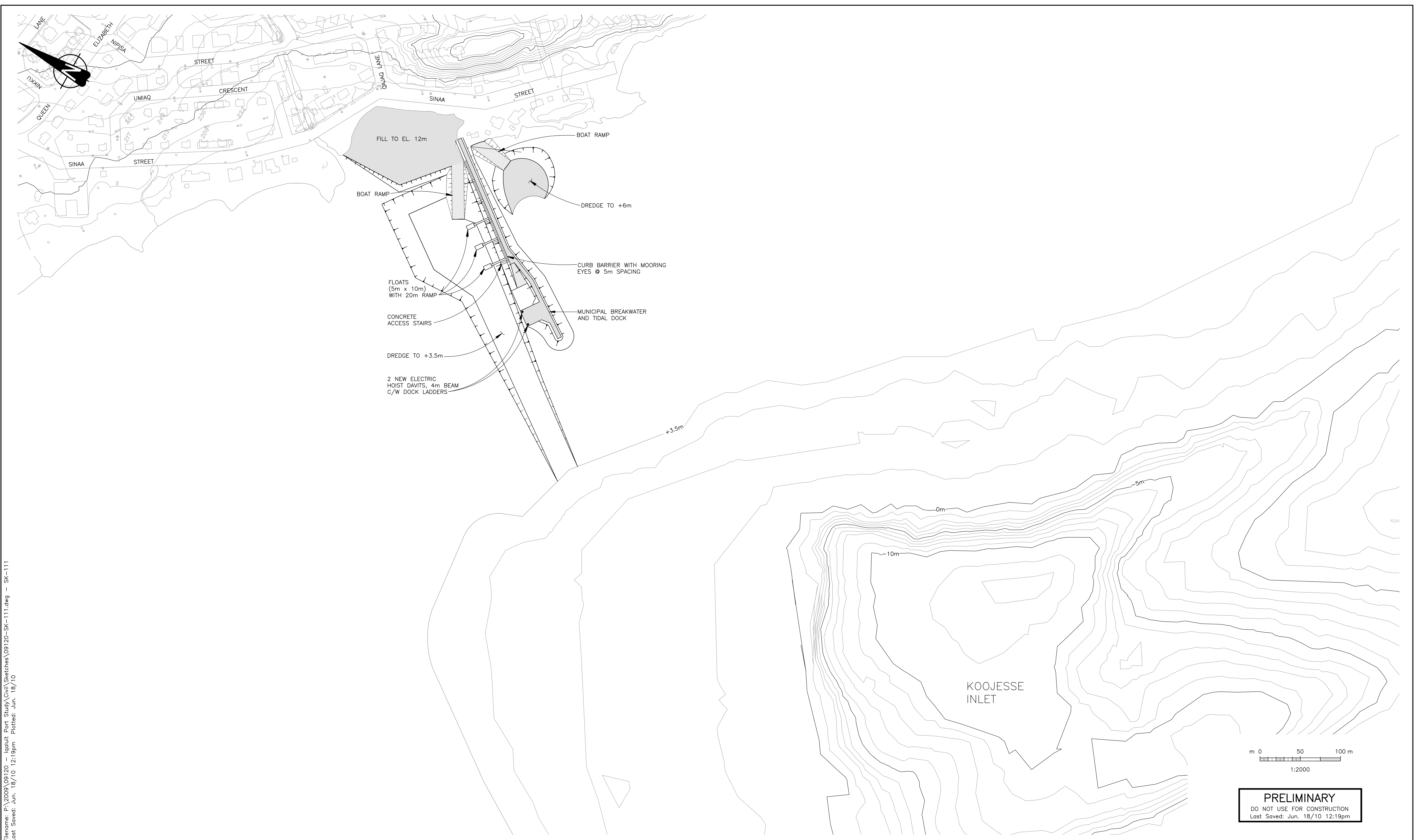
 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION

PROJECT  
**IQUALUIT PORT DEVELOPMENT**

**WorleyParsons Westmar**

TITLE  
**SMALL CRAFT DOCK  
 GENERAL ARRANGEMENT**

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
SHOWN	09120	SK-110	P2





Filename: P:\2009\09120 - Iqaluit Port Study\Civil Sketches\09120-SK-111.dwg - SK-111  
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No.	DATE	DESCRIPTION	DRAWN	DWG CHK	DESIGN	DES CHK	QA	APPROVED
ISSUE / REVISIONS								

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P1	JAN29/10	ISSUED FOR CLIENT REVIEW	BJM	-	-	-	HG	-	HGK	-	-	-	HGK	-

ENGINEER OF RECORD  
DIV/DEP MGR: -

CLIENT  
 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT  
 IQUALUIT PORT DEVELOPMENT

  
 TITLE  
 SMALL CRAFT HARBOUR  
 OPTION C - MUNICIPAL BREAKWATER UPGRADES  
 SITE PLAN  
 DRAWING SCALE: 1:2000 PROJECT NUMBER: 09120 DRAWING NUMBER: SK-111 REV.: P2



Filename: P:\2009\09120 - Iqaluit Port Study\Civil Sketches\09120-SK-112.dwg - 112  
 Last Saved: Jun. 18/10 12:21pm Plotted: Jun. 18/10

**PRELIMINARY**  
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 Last Saved: Jun. 18/10 12:21pm

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ISSUE / REVISIONS								

No.	DATE	DESCRIPTION	DRAWN	DWG CHKD	DESIGN	DES CHKD	QA	APPROVED
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ISSUE / REVISIONS								

ENGINEER OF RECORD  
 DIV/DEP MGR: -

CLIENT  

 DEPARTMENT OF ECONOMIC DEVELOPMENT AND TRANSPORTATION  
 PROJECT  
**IQALUIT PORT DEVELOPMENT**

**WorleyParsons Westmar**  
 TITLE  
**DEEP SEA WHARF  
 OPTION 6 - SOUTH POLARIS REEF - STAGE 1 ONLY  
 SITE PLAN**  

DRAWING SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
1:2000	09120	SK-112	P1



GOVERNMENT OF NUNAVUT  
IQALUIT PORT DEVELOPMENT

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## Appendix E Detailed Cost Estimate

**Iqaluit Port Development**  
Project 09120

Quantity and Capital Cost Estimation						
Item	Description	Quantity	Unit	Unit Rate	Total	Remarks
<b>Option 1 - Innuvit Head</b>						
<b>GENERAL</b>						
<b>1.00</b>	<b>Mobilization</b>					
1.01	Crushing, Screening, Stacking equipment	1	l.s.	\$1,650,000.0	\$1,650,000	Kudlik
1.02	General and Floating Equipment	1	l.s.	\$2,500,000.0	\$2,500,000	
1.03	Overwintering Allowance	1	l.s.	\$500,000.0	\$500,000	
	<b>Subtotal</b>				<b>\$4,650,000</b>	
<b>2.00</b>	<b>Demobilization</b>	1	l.s.	\$1,000,000.0	\$1,000,000	
	<b>Subtotal</b>				<b>\$1,000,000</b>	
<b>DREDGING</b>						
<b>3.00</b>	<b>Dredging and Offshore Disposal</b>					
3.01	Dredge for Caissons/cells Foundation (17400 to -11.0 m + 16200 soft material)	33,600	cu.m	\$75.0	\$2,520,000	adjusted DB rate
3.02	Dredge for Caissons/cells Backfill and Causeway	30,000	cu.m	\$75.0	\$2,250,000	
3.03	Sediment Treatment / Silt Curtain (Allowance)	0	l.s.	\$0.0	\$0	
	<b>Subtotal</b>	<b>63,600</b>			<b>\$4,770,000</b>	
<b>EARTHWORKS</b>						
<b>4.00</b>	<b>Rock Excavation</b>					
4.01	Drill and Blast rock (total volume required based on the total volume of fill, mattress and rip rap. Add 30% void for volume after blasting)	258,000	cu.m	\$19	\$4,902,000	Kudlik
	<b>Subtotal</b>	<b>258,000</b>			<b>\$4,902,000</b>	
<b>5.00</b>	<b>Fill (onshore and offshore) Production of Material - Deep Sea Wharf</b>					
5.01	Crushing and Stockpiling Mattress (75mm minus)	22,500	cu.m	\$20.0	\$450,000	Kudlik
5.02	Crushing and Stockpiling Caisson Fill (200mm minus)	45,100	cu.m	\$20.0	\$902,000	Kudlik
5.03	Stockpile General Fill (600mm minus) (Deep Sea Wharf and Roadway)	215,000	cu.m	\$0.0	\$0	included in Drill and Blast
5.04	Break and Sort Riprap (1,200mm to 300mm) (Deep Sea Wharf and Roadway)	48,600	cu.m	\$10.0	\$486,000	Kudlik
5.05	Crushing and Stockpiling Road Sub-base (Crushing - 150mm minus)	2,000	cu.m	\$20.0	\$40,000	Kudlik
5.06	Crushing and Stockpiling Road Base (Crushing - 25mm minus)	2,000	cu.m	\$20.0	\$40,000	Kudlik
	<b>Subtotal</b>	<b>335,200</b>			<b>\$1,918,000</b>	
<b>6.00</b>	<b>Fill (onshore and offshore) Installation - Deep Sea Wharf</b>					
6.01	Haul, Load Barge, Dump, and Level Mattress	22,500	cu.m	\$75.0	\$1,687,500	adjusted DB rate
6.02	Haul, Load Barge, and Clam Caisson Fill	44,000	cu.m	\$75.0	\$3,300,000	adjusted DB rate
6.03	Caisson Top Fill (Sub-base 450 mm thick and base courses 150 mm thick), Placing	1,100	cu.m	\$24.5	\$26,950	Kudlik
6.04	Causeway Lower Fill (General Fill), Hauling, and Placing	215,000	cu.m	\$24.5	\$5,267,500	Kudlik
6.05	Causeway Top Fill (Sub-base 450 mm thick and base courses 150 mm thick), Hauling, Placing, and Compacting	0	cu.m	\$24.5	\$0	Included in 6.04 rate by Kudlik
6.06	Riprap Scour Protection, Hauling, Placing, and Shaping	2,200	cu.m	\$110.0	\$242,000	adjusted DB rate
6.07	Riprap Shoreline Protection, Hauling, Placing, and Shaping	46,400	cu.m	\$34.5	\$1,600,800	Kudlik
	<b>Subtotal</b>				<b>\$12,124,750</b>	
<b>7.00</b>	<b>Roadway - Deep Sea Wharf</b>					
7.01	Place and Compact Road Base/Sub-base	4,000	cu.m	\$23.0	\$92,000	Kudlik
7.02	Widening of the Existing Road	2,000	m	\$0.0	\$0	no allowance
	<b>Subtotal</b>				<b>\$92,000</b>	
<b>WHARF</b>						
<b>8.00</b>	<b>Deep Sea Wharf Structure (Concrete Caisson)</b>					
8.01	Concrete Caissons Off-site Construction	1	l.s.	\$8,600,000.0	\$8,600,000	from Beaver Marine
8.02	Caisson Storage and Manoeuvring (onto semi-submersible)	1	l.s.	\$250,000.0	\$250,000	adjusted DB rate
8.03	Concrete Caisson Transportation to Site	1	l.s.	\$6,000,000.0	\$6,000,000	from Dockwise
8.04	Additional Costs for Caisson Transportation (allowance for: import duty, marine surveyor, fuel surcharge)	1	l.s.	\$500,000.0	\$500,000	from DB
8.05	Caisson Temporary Moorage and Site Towing/manoeuvring	1	l.s.	\$800,000.0	\$800,000	from DB
8.06	Sink Concrete Caissons onto Mattress Foundation (level, ballast, place)	1	l.s.	\$500,000.0	\$500,000	from DB
	<b>Subtotal</b>				<b>\$16,650,000</b>	
<b>9.00</b>	<b>Wharf Hardware, Utilities, and Equipment</b>					
<b>Mechanical</b>						
9.01	Steel Pipe Guardrails	1	l.s.	\$120,000	\$120,000	installed in south on caissons
9.02	Removable Handrails	1	l.s.	\$20,000	\$20,000	
9.03	Ladders (heavy chain-type, removable)	5	ea.	\$6,000	\$30,000	
9.04	Fenders	1	l.s.	\$500,000	\$500,000	allowance for foam-filled
9.05	Rubbing Timbers	1	l.s.	\$100,000	\$100,000	installed in south on caissons
9.06	Wharf Bollards	1	l.s.	\$0	\$0	included in caisson cost
9.07	Shore Bollards	2	ea.	\$20,000	\$40,000	not including bases
9.08	New Powered Capstans	2	ea.	\$60,000	\$120,000	
9.09	Miscellaneous Mooring/Standing Lines and Safety Equipment	1	l.s.	\$10,000	\$10,000	
9.10	Gangway	1	l.s.	\$0	\$0	no allowance
9.11	Navigation Aids - Lights	1	ea.	\$20,000	\$20,000	on dock only
9.12	Navigation Aids - Range Targets	1	ea.	\$100,000	\$100,000	relocated existing
9.13	Oil Spill Boom Brackets	1	l.s.	\$20,000	\$20,000	
9.14	Oil Spill Boom	1	l.s.	\$50,000	\$50,000	basic lightweight only
9.15	Caisson Keys	39	cu.m.	\$2,500	\$97,500	fabricated on site
9.16	Miscellaneous Precast Concrete Footings	1	l.s.	\$100,000	\$100,000	
9.17	Shore Bollards Footings	100	cu.m.	\$1,500	\$150,000	cast-in-place
9.18	Scour Protection Mats	1	l.s.	\$1,500,000	\$1,500,000	precast in south
9.19	Dock Office, Lunch Room, Washroom Facilities (~5m x 15m)	1	l.s.	\$500,000	\$500,000	
9.20	Fencing	1	l.s.	\$200,000	\$200,000	
9.21	Shoreline and Other Barriers	1	l.s.	\$50,000	\$50,000	
<b>Piping</b>						
9.22	New Fuel Manifold	1	l.s.	\$200,000	\$200,000	
9.23	Demolish Old Fuel Manifold	1	l.s.	\$50,000	\$50,000	
9.24	Demolish Old Fuel Line	1	l.s.	\$20,000	\$20,000	
9.25	Extend New Fuel Line to Dock and Fuel Manifold	1	l.s.	\$500,000	\$500,000	
9.26	Water Supply	1	l.s.	\$0	\$0	no allowance
9.27	Fire Protection	1	l.s.	\$1,000,000	\$1,000,000	assumes seawater system based on well and pre-fab container
9.28	Allowance for Temporary Tanker Berth	1	l.s.	\$2,000,000	\$2,000,000	need to move moorings and manifold
<b>Electrical and Lighting</b>						
9.29	Wharf Lighting and Electrical	1	l.s.	\$500,000	\$500,000	
9.30	Yard Lighting (Dock Back-up Lands)	1	l.s.	\$1,000,000	\$1,000,000	
9.31	Yard Lighting (Dock Secondary Yard/Parking Area)	1	l.s.	\$1,000,000	\$1,000,000	
9.32	Poles to Wharf	1	l.s.	\$1,000,000	\$1,000,000	
9.31	Delivering Power to the Site	1	l.s.	\$0	\$0	assumes existing is about 12kV and enough for all services
	<b>Subtotal</b>				<b>\$10,997,500</b>	
	<b>Subtotal</b>				<b>\$57,104,250</b>	
<b>10.00</b>	<b>General Indirects</b>					
10.01	Contingency and Escalation Allowance (allow 15%)	1	l.s.	\$8,600,000	\$8,600,000	
10.02	Engineering and Project Management (allow 8%)	1	l.s.	\$5,300,000	\$5,300,000	
	<b>Subtotal</b>				<b>\$13,900,000</b>	
	<b>Total</b>				<b>\$71,004,250</b>	

**Iqaluit Port Development**  
 Project 09120

Quantity and Capital Cost Estimation						
Item	Description	Quantity	Unit	Unit Rate	Total	Remarks
<b>Option 2 - North Polaris Reef</b>						
<b>GENERAL</b>						
<b>1.00</b>	<b>Mobilization</b>					
1.01	Crushing, Screening, Stacking equipment	1	l.s.	\$1,650,000.0	\$1,650,000	Kudlik
1.02	General and Floating Equipment	1	l.s.	\$2,500,000.0	\$2,500,000	
1.03	Overwintering Allowance	1	l.s.	\$500,000.0	\$500,000	
	<b>Subtotal</b>				<b>\$4,650,000</b>	
<b>2.00</b>	<b>Demobilization</b>	1	l.s.	\$1,000,000.0	\$1,000,000	
	<b>Subtotal</b>				<b>\$1,000,000</b>	
<b>DREDGING</b>						
<b>3.00</b>	<b>Dredging and Offshore Disposal</b>					
3.01	Dredge to El -11.0 m	6,700	cu.m	\$75.0	\$502,500	adjusted DB rate
3.02	(empty)					
3.03	Dredge for Caissons/cells Foundation (0 to -11.0 m + 16,200 soft material)	22,700	cu.m	\$75.0	\$1,702,500	
3.04	Dredge for Caissons/cells Backfill and Causeway	66,000	cu.m	\$75.0	\$4,950,000	
3.05	Sediment Treatment / Silt Curtain (Allowance)	0	l.s.	\$0.0	\$0	
	<b>Subtotal</b>	<b>95,400</b>			<b>\$7,155,000</b>	
<b>EARTHWORKS</b>						
<b>4.00</b>	<b>Rock Excavation</b>					
4.01	Drill and Blast Rock (total volume required based on the total volume of fill, mattress and rip rap. Add 30% void for volume after blasting)	418,000	cu.m	\$19	\$7,942,000	Kudlik
	<b>Subtotal</b>	<b>418,000</b>			<b>\$7,942,000</b>	
<b>5.00</b>	<b>Fill (onshore and offshore) Production of Material</b>					
5.01	Crushing and Stockpiling Mattress (75mm minus)	22,500	cu.m	\$20.0	\$450,000	Kudlik
5.02	Crushing and Stockpiling Caisson Fill (200mm minus)	45,100	cu.m	\$20.0	\$902,000	Kudlik
5.03	Stockpile General Fill (600mm minus) (Deep Sea Wharf and Roadway)	433,000	cu.m	\$0.0	\$0	included in Drill and Blast
5.04	Break and Sort Riprap (1,200mm to 300mm) (Deep Sea Wharf and Roadway)	39,800	cu.m	\$10.0	\$398,000	Kudlik
5.05	Crushing and Stockpiling Road Sub-base (Crushing - 150mm minus)	1,500	cu.m	\$20.0	\$30,000	Kudlik
5.06	Crushing and Stockpiling Road Base (Crushing - 25mm minus)	1,500	cu.m	\$20.0	\$30,000	Kudlik
	<b>Subtotal</b>	<b>543,400</b>			<b>\$1,810,000</b>	
<b>6.00</b>	<b>Fill (onshore and offshore) Installation</b>					
6.01	Haul, Load Barge, Dump, and Level Mattress	22,500	cu.m	\$75.0	\$1,687,500	adjusted DB rate
6.02	Haul, Load Barge, and Clam Caisson Fill	44,000	cu.m	\$75.0	\$3,300,000	adjusted DB rate
6.03	Caisson Top Fill (sub-base 450 mm thick and base courses 150 mm thick), Placing	1,100	cu.m	\$23.0	\$25,300	Kudlik
6.04	Causeway Lower Fill (General Fill), Hauling, and Placing	433,000	cu.m	\$23.0	\$9,959,000	Kudlik
	Causeway Top Fill (sub-base 450 mm thick and base courses 150 mm thick),	0	cu.m	\$23.0	\$0	Included in 6.04
6.05	Hauling, Placing, and Compacting	0	cu.m			rate by Kudlik
6.06	Riprap Scour Protection, Hauling, Placing, and Shaping	2,200	cu.m	\$110.0	\$242,000	adjusted DB rate
6.07	Riprap Shoreline Protection, Hauling, Placing, and Shaping	37,600	cu.m	\$33.0	\$1,240,800	Kudlik
	<b>Subtotal</b>				<b>\$16,454,600</b>	
<b>7.00</b>	<b>Roadway</b>					
7.01	Place and Compact Road Base/Sub-base	3,000	cu.m	\$21.0	\$63,000	Kudlik
7.02	Widening of the Existing Road (Allowance)	2,000	m	\$0.0	\$0	no allowance
	<b>Subtotal</b>				<b>\$63,000</b>	
<b>WHARF</b>						
<b>8.00</b>	<b>Deep Sea Wharf Structure (Concrete Caisson)</b>					
8.01	Concrete Caissons Off-site Construction	1	l.s.	\$8,600,000.0	\$8,600,000	from Beaver Marine
8.02	Caisson Storage and Manoeuvring (onto semi-submersible)	1	l.s.	\$250,000.0	\$250,000	adjusted DB rate
8.03	Concrete Caisson Transportation to Site (3 vessels)	1	l.s.	\$6,000,000.0	\$6,000,000	from Dockwise
8.04	Additional Costs for Caisson Transportation (allowance for: import duty, marine surveyor, fuel surcharge)	1	l.s.	\$500,000.0	\$500,000	from DB
8.05	Caisson Temporary Moorage and Site Towing/manoeuvring	1	l.s.	\$800,000.0	\$800,000	from DB
8.06	Sink Concrete Caissons onto Mattress Foundation (level, ballast, place)	1	l.s.	\$500,000.0	\$500,000	from DB
	<b>Subtotal</b>				<b>\$16,650,000</b>	
<b>9.00</b>	<b>Wharf Hardware, Utilities, and Equipment</b>					
<b>Mechanical</b>						
9.01	Steel Pipe Guardrails	1	l.s.	\$120,000	\$120,000	installed in south on caissons
9.02	Removable Handrails	1	l.s.	\$20,000	\$20,000	
9.03	Ladders (heavy chain-type, removable)	5	ea.	\$6,000	\$30,000	
9.04	Fenders	1	l.s.	\$500,000	\$500,000	allowance for foam-filled
9.05	Rubbing Timbers	1	l.s.	\$100,000	\$100,000	installed in south on caissons
9.06	Wharf Bollards	1	l.s.	\$0	\$0	included in caisson cost
9.07	Shore Bollards	2	ea.	\$20,000	\$40,000	not including bases
9.08	New Powered Capstans	2	ea.	\$60,000	\$120,000	
9.09	Miscellaneous Mooring/Standing Lines and Safety Equipment	1	l.s.	\$10,000	\$10,000	
9.10	Gangway	1	l.s.	\$0	\$0	no allowance
9.11	Navigation Aids - Lights	1	ea.	\$20,000	\$20,000	on dock only
9.12	Navigation Aids - Range Targets	1	ea.	\$100,000	\$100,000	relocated existing
9.13	Oil Spill Boom Brackets	1	l.s.	\$20,000	\$20,000	
9.14	Oil Spill Boom	1	l.s.	\$50,000	\$50,000	basic lightweight only
9.15	Caisson Keys	39	cu.m.	\$2,500	\$97,500	fabricated on site
9.16	Miscellaneous Precast Concrete Footings	1	l.s.	\$100,000	\$100,000	
9.17	Shore Bollards Footings	100	cu.m.	\$1,500	\$150,000	cast-in-place
9.18	Scour Protection Mats	1	l.s.	\$1,500,000	\$1,500,000	precast in south
9.19	Dock Office, Lunch Room, Washroom Facilities (~5m x 15m)	1	l.s.	\$500,000	\$500,000	
9.20	Fencing	1	l.s.	\$200,000	\$200,000	
9.21	Shoreline and other barriers	1	l.s.	\$50,000	\$50,000	
<b>Piping</b>						
9.22	New Fuel Manifold	1	l.s.	\$200,000	\$200,000	
9.23	Demolish Old Fuel Manifold	1	l.s.	\$50,000	\$50,000	
9.24	Demolish Old Fuel Line	1	l.s.	\$100,000	\$100,000	
9.25	Extend New Fuel Line to Dock and Fuel Manifold	1	l.s.	\$500,000	\$500,000	
9.26	Water Supply	1	l.s.	\$0	\$0	no allowance
9.27	Fire Protection	1	l.s.	\$1,000,000	\$1,000,000	assumes seawater system based on well and pre-fab container
9.28	Allowance for Temporary Tanker Berth	1	l.s.	\$0	\$0	no allowance
<b>Electrical and Lighting</b>						
9.29	Wharf Lighting and Electrical	1	l.s.	\$500,000	\$500,000	
9.30	Yard Lighting (Dock Back-up Lands)	1	l.s.	\$1,000,000	\$1,000,000	
9.31	Yard Lighting (Dock Secondary Yard/Parking Area)	1	l.s.	\$1,000,000	\$1,000,000	
9.32	Poles to Wharf	1	l.s.	\$100,000	\$100,000	
9.31	Delivering power to the site	1	l.s.	\$0	\$0	assumes existing is about 12kV and enough for all services
	<b>Subtotal</b>				<b>\$8,177,500</b>	
	<b>Subtotal</b>				<b>\$63,902,100</b>	
<b>10.00</b>	<b>General Indirects</b>					
10.01	Contingency and Escalation Allowance (allow 15%)	1	l.s.	\$9,600,000	\$9,600,000	
10.02	Engineering and Project Management (allow 8%)	1	l.s.	\$5,900,000	\$5,900,000	
	<b>Subtotal</b>				<b>\$15,500,000</b>	
	<b>Total</b>				<b>\$79,402,100</b>	

**Iqaluit Port Development**  
Project 09120

Quantity and Capital Cost Estimation						
Item	Description	Quantity	Unit	Unit Rate	Total	Remarks
<b>Option 3 - Old Causeway</b>						
<b>GENERAL</b>						
<b>1.00</b>	<b>Mobilization</b>					
1.01	Crushing, Screening, Stacking equipment	1	l.s.	\$1,650,000.0	\$1,650,000	Kudlik
1.02	General and Floating Equipment	1	l.s.	\$2,500,000.0	\$2,500,000	
1.03	Overwintering Allowance	1	l.s.	\$500,000.0	\$500,000	
	<b>Subtotal</b>				<b>\$4,650,000</b>	
<b>2.00</b>	<b>Demobilization</b>	1	l.s.	\$1,000,000.0	\$1,000,000	
	<b>Subtotal</b>				<b>\$1,000,000</b>	
<b>DREDGING</b>						
<b>3.00</b>	<b>Dredging and Offshore Disposal</b>					
3.01	Dredge to El -11.0 m	36,700	cu.m	\$75.0	\$2,752,500	adjusted DB rate
3.02	Dredge for Caissons/cells Foundation (13,800 to -11.0 m + 16,200 soft material)	42,000	cu.m	\$75.0	\$3,150,000	
3.03	Dredge for Caissons/cells Backfill and Causeway	0	cu.m	\$75.0	\$0	
3.04	Sediment Treatment / Silt Curtain (Allowance)	0	l.s.	\$0.0	\$0	
	<b>Subtotal</b>	<b>78,700</b>			<b>\$5,902,500</b>	
<b>EARTHWORKS</b>						
<b>4.00</b>	<b>Rock Excavation</b>					
4.01	Drill and Blast Rock (total volume required based on the total volume of fill, mattress and rip rap. Add 30% void for volume after blasting)	334,000	cu.m	\$19	\$6,346,000	Kudlik
	<b>Subtotal</b>	<b>334,000</b>			<b>\$6,346,000</b>	
<b>5.00</b>	<b>Fill (onshore and offshore) Production of Material</b>					
5.01	Crushing and Stockpiling Mattress (75mm minus)	28,000	cu.m	\$20.0	\$560,000	Kudlik
5.02	Crushing and Stockpiling Caisson Fill (200mm minus)	45,100	cu.m	\$20.0	\$902,000	Kudlik
5.03	Stockpile General Fill (600mm minus) (Deep Sea Wharf and Roadway)	321,200	cu.m	\$0.0	\$0	included in Drill and Blast
5.04	Break and Sort Riprap (1,200mm to 300mm) (Deep Sea Wharf and Roadway)	37,000	cu.m	\$10.0	\$370,000	Kudlik
5.05	Crushing and Stockpiling Road Sub-base (Crushing - 150mm minus)	1,500	cu.m	\$20.0	\$30,000	Kudlik
5.06	Crushing and Stockpiling Road Base (Crushing - 25mm minus)	1,500	cu.m	\$20.0	\$30,000	Kudlik
	<b>Subtotal</b>	<b>434,300</b>			<b>\$1,892,000</b>	
<b>6.00</b>	<b>Fill (onshore and offshore) Installation</b>					
6.01	Haul, Load Barge, Dump, and Level Mattress	22,500	cu.m	\$75.0	\$1,687,500	adjusted DB rate
6.02	Haul, Load Barge, and Clam Caisson Fill	44,000	cu.m	\$75.0	\$3,300,000	adjusted DB rate
6.03	Caisson Top Fill (sub-base 450 mm thick and base courses 150 mm thick), Placing	1,100	cu.m	\$21.0	\$23,100	Kudlik
6.04	Causeway Lower Fill (General Fill), Hauling, and Placing	321,200	cu.m	\$30.0	\$9,636,000	Kudlik
6.05	Causeway Top Fill (sub-base 450 mm thick and base courses 150 mm thick), Hauling, Placing, and Compacting	0	cu.m	\$21.0	\$0	Included in 6.04 rate by Kudlik
6.06	Riprap Scour Protection, Hauling, Placing, and Shaping	2,200	cu.m	\$110.0	\$242,000	adjusted DB rate
6.07	Riprap Shoreline Protection, hauling, placing and shaping	34,800	cu.m	\$31.0	\$1,078,800	Kudlik
	<b>Subtotal</b>				<b>\$15,967,400</b>	
<b>7.00</b>	<b>Roadway</b>					
7.01	Place and compact road base/sub-base	3,000	cu.m	\$21.0	\$63,000	Kudlik
7.02	Widening of the existing road (allowance)	2,000	m	\$0.0	\$0	no allowance
	<b>Subtotal</b>				<b>\$63,000</b>	
<b>WHARF</b>						
<b>8.00</b>	<b>Deep Sea Wharf Structure (Concrete Caisson)</b>					
8.01	Concrete Caissons off-site construction	1	l.s.	\$8,600,000.0	\$8,600,000	from Beaver Marine
8.02	Caisson Storage and Manoeuvring (onto semi-submersible)	1	l.s.	\$250,000.0	\$250,000	adjusted DB rate
8.03	Concrete Caisson Transportation to Site (3 vessels)	1	l.s.	\$6,000,000.0	\$6,000,000	from Dockwise
8.04	Additional Costs for Caisson Transportation (allowance for: import duty, marine surveyor, fuel surcharge)	1	l.s.	\$500,000.0	\$500,000	from DB
8.05	Caisson Temporary Moorage and Site Towing/manoeuvring	1	l.s.	\$800,000.0	\$800,000	from DB
8.06	Sink Concrete Caissons onto Mattress Foundation (level, ballast, place)	1	l.s.	\$500,000.0	\$500,000	from DB
	<b>Subtotal</b>				<b>\$16,650,000</b>	
<b>9.00</b>	<b>Wharf Hardware, Utilities, and Equipment</b>					
<b>Mechanical</b>						
9.01	Steel Pipe Guardrails	1	l.s.	\$120,000	\$120,000	installed in south on caissons
9.02	Removable Handrails	1	l.s.	\$20,000	\$20,000	
9.03	Ladders (heavy chain-type, removable)	5	ea.	\$6,000	\$30,000	
9.04	Fenders	1	l.s.	\$500,000	\$500,000	allowance for foam-filled
9.05	Rubbing Timbers	1	l.s.	\$100,000	\$100,000	installed in south on caissons
9.06	Wharf Bollards	1	l.s.	\$0	\$0	included in caisson cost
9.07	Shore Bollards	2	ea.	\$20,000	\$40,000	not including bases
9.08	New Powered Capstans	2	ea.	\$60,000	\$120,000	
9.09	Miscellaneous Mooring/Standing Lines and Safety Equipment	1	l.s.	\$10,000	\$10,000	
9.10	Gangway	1	l.s.	\$0	\$0	no allowance
9.11	Navigation Aids - Lights	1	ea.	\$20,000	\$20,000	on dock only
9.12	Navigation Aids - Range Targets	1	ea.	\$100,000	\$100,000	relocated existing
9.13	Oil Spill Boom Brackets	1	l.s.	\$20,000	\$20,000	
9.14	Oil Spill Boom	1	l.s.	\$50,000	\$50,000	basic lightweight only
9.15	Caisson Keys	39	cu.m.	\$2,500	\$97,500	fabricated on site
9.16	Miscellaneous Precast Concrete Footings	1	l.s.	\$100,000	\$100,000	
9.17	Shore Bollards Footings	100	cu.m.	\$1,500	\$150,000	cast-in-place
9.18	Scour Protection Mats	1	l.s.	\$1,500,000	\$1,500,000	precast in south
9.19	Dock Office, Lunch Room, Washroom Facilities (~5m x 15m)	1	l.s.	\$500,000	\$500,000	
9.20	Fencing	1	l.s.	\$150,000	\$150,000	
9.21	Shoreline and other barriers	1	l.s.	\$50,000	\$50,000	
<b>Piping</b>						
9.22	New Fuel Manifold	1	l.s.	\$200,000	\$200,000	
9.23	Demolish Old Fuel Manifold	1	l.s.	\$50,000	\$50,000	
9.24	Demolish Old Fuel Line	1	l.s.	\$150,000	\$150,000	
9.25	Extend New Fuel Line to Dock and Fuel Manifold	1	l.s.	\$500,000	\$500,000	
9.26	Water Supply	1	l.s.	\$0	\$0	no allowance
9.27	Fire Protection	1	l.s.	\$1,000,000	\$1,000,000	assumes seawater system based on well and pre-fab container
9.28	Allowance for Temporary Tanker Berth	1	l.s.	\$0	\$0	no allowance
<b>Electrical and Lighting</b>						
9.29	Wharf Lighting and Electrical	1	l.s.	\$500,000	\$500,000	
9.30	Yard Lighting (Dock Back-up Lands)	1	l.s.	\$1,000,000	\$1,000,000	
9.31	Yard Lighting (Dock Secondary Yard/Parking Area)	1	l.s.	\$0	\$0	
9.32	Poles to Wharf	1	l.s.	\$0	\$0	
9.31	Delivering power to the site	1	l.s.	\$0	\$0	assumes existing is about 12kV and enough for all services
	<b>Subtotal</b>				<b>\$7,077,500</b>	
	<b>Subtotal</b>				<b>\$59,548,400</b>	
<b>10.00</b>	<b>General Indirects</b>					
10.01	Contingency and Escalation Allowance (allow 15%)	1	l.s.	\$8,900,000	\$8,900,000	
10.02	Engineering and Project Management (allow 8%)	1	l.s.	\$5,500,000	\$5,500,000	
	<b>Subtotal</b>				<b>\$14,400,000</b>	
	<b>Total</b>				<b>\$73,948,400</b>	

Iqaluit Port Development  
Project 09120

Quantity and Capital Cost Estimation						
Item	Description	Quantity	Unit	Unit Rate	Total	Remarks
<b>Option 4 - South Polaris Reef</b>						
<b>GENERAL</b>						
<b>1.00</b>	<b>Mobilization</b>					
1.01	Crushing, Screening, Stacking Equipment	1	I.s.	\$1,650,000.0	\$1,650,000	Kudlik
1.02	General and Floating Equipment	1	I.s.	\$2,500,000.0	\$2,500,000	
1.03	Overwintering Allowance	1	I.s.	\$500,000.0	\$500,000	
	<b>Subtotal</b>				<b>\$4,650,000</b>	
<b>2.00</b>	<b>Demobilization</b>	1	I.s.	\$1,000,000.0	\$1,000,000	
	<b>Subtotal</b>				<b>\$1,000,000</b>	
<b>DREDGING</b>						
<b>3.00</b>	<b>Dredging and Offshore Disposal</b>					
3.01	Dredge to El -11.0 m (Slope 6:1) (empty)	16,000	cu.m	\$75.0	\$1,200,000	adjusted DB rate
3.03	Dredge for Caissons/Cells Foundation	24,800	cu.m	\$75.0	\$1,860,000	
3.04	Dredge for Caissons/Cells Backfill and Causeway	24,000	cu.m	\$75.0	\$1,800,000	
3.05	Sediment Treatment / Silt Curtain (Allowance)	0	I.s.	\$0.0	\$0	
	<b>Subtotal</b>	<b>64,800</b>			<b>\$4,860,000</b>	
<b>EARTHWORKS</b>						
<b>4.00</b>	<b>Rock Excavation</b>					
4.01	Drill and Blast Rock (total volume required based on the total volume of fill, mattress and rip rap. Add 30% void for volume after blasting)	291,000	cu.m	\$19	\$5,529,000	Kudlik
	<b>Subtotal</b>	<b>291,000</b>			<b>\$5,529,000</b>	
<b>5.00</b>	<b>Fill (onshore and offshore) Production of Material</b>					
5.01	Crushing and Stockpiling Mattress (75mm minus)	22,500	cu.m	\$20.0	\$450,000	Kudlik
5.02	Crushing and Stockpiling Caisson Fill (200mm minus)	45,100	cu.m	\$20.0	\$902,000	Kudlik
5.03	Stockpile General Fill (600mm minus) (Deep Sea Wharf and Roadway)	272,000	cu.m	\$0.0	\$0	included in Drill and Blast
5.04	Break and Sort Riprap (1,200mm to 300mm) (Deep Sea Wharf and Roadway)	37,200	cu.m	\$10.0	\$372,000	Kudlik
5.05	Crushing and Stockpiling Road Sub-base (Crushing - 150mm minus)	750	cu.m	\$20.0	\$15,000	Kudlik
5.06	Crushing and Stockpiling Road Base (Crushing - 25mm minus)	750	cu.m	\$20.0	\$15,000	Kudlik
	<b>Subtotal</b>	<b>378,300</b>			<b>\$1,754,000</b>	
<b>6.00</b>	<b>Fill (onshore and offshore) Installation</b>					
6.01	Haul, Load Barge, Dump, and Level Mattress	22,500	cu.m	\$75.0	\$1,687,500	adjusted DB rate
6.02	Haul, Load Barge, and Clam Caisson Fill	44,000	cu.m	\$75.0	\$3,300,000	adjusted DB rate
6.03	Caisson Top Fill (Sub-base 450 mm thick and base courses 150 mm thick), Placing	1,100	cu.m	\$22.0	\$24,200	Kudlik
6.04	Causeway Lower Fill (General Fill), Hauling, and Placing	272,000	cu.m	\$22.0	\$5,984,000	Kudlik
	Causeway Top Fill (Sub-base 450 mm thick and base courses 150 mm thick), Hauling, Placing, and Compacting	0	cu.m	\$22.0	\$0	Included in 6.04 rate by Kudlik
6.05	Riprap Scour Protection, Hauling, Placing, and Shaping	2,200	cu.m	\$110.0	\$242,000	adjusted DB rate
6.07	Riprap Shoreline Protection, Hauling, Placing, and Shaping	35,000	cu.m	\$32.0	\$1,120,000	Kudlik
	<b>Subtotal</b>				<b>\$12,357,700</b>	
<b>7.00</b>	<b>Roadway</b>					
7.01	Place and Compact Road Base/Sub-base	1,500	cu.m	\$21.0	\$31,500	Kudlik
7.02	Widening of the Existing Road (Allowance)	2,000	m	\$0.0	\$0	no allowance
	<b>Subtotal</b>				<b>\$31,500</b>	
<b>WHARF</b>						
<b>8.00</b>	<b>Deep Sea Wharf Structure (Concrete Caisson)</b>					
8.01	Concrete Caissons Off-site Construction	1	I.s.	\$8,600,000.0	\$8,600,000	from Beaver Marine
8.02	Caisson Storage and Manoeuvring (onto semi-submersible)	1	I.s.	\$250,000.0	\$250,000	adjusted DB rate
8.03	Concrete Caisson Transportation to Site (3 vessels)	1	I.s.	\$6,000,000.0	\$6,000,000	from Dockwise
8.04	Additional Costs for Caisson Transportation (allowance for: import duty, marine surveyor, fuel surcharge)	1	I.s.	\$500,000.0	\$500,000	from DB
8.05	Caisson Temporary Moorage and Site Towing/Manoeuvring	1	I.s.	\$800,000.0	\$800,000	from DB
8.06	Sink Concrete Caissons onto Mattress Foundation (level, ballast, place)	1	I.s.	\$500,000.0	\$500,000	from DB
	<b>Subtotal</b>				<b>\$16,650,000</b>	
<b>9.00</b>	<b>Wharf Hardware, Utilities, and Equipment</b>					
<b>Mechanical</b>						
9.01	Steel Pipe Guardrails	1	I.s.	\$120,000	\$120,000	installed in south on caissons
9.02	Removable Handrails	1	I.s.	\$20,000	\$20,000	
9.03	Ladders (heavy chain-type, removable)	5	ea.	\$6,000	\$30,000	
9.04	Fenders	1	I.s.	\$500,000	\$500,000	allowance for foam-filled
9.05	Rubbing Timbers	1	I.s.	\$100,000	\$100,000	installed in south on caissons
9.06	Wharf Bollards	1	I.s.	\$0	\$0	included in caisson cost
9.07	Shore Bollards	2	ea.	\$20,000	\$40,000	not including bases
9.08	New Powered Capstans	2	ea.	\$60,000	\$120,000	
9.09	Miscellaneous Mooring/Standing Lines and Safety Equipment	1	I.s.	\$10,000	\$10,000	
9.10	Gangway	1	I.s.	\$0	\$0	no allowance
9.11	Navigation Aids - Lights	1	ea.	\$20,000	\$20,000	on dock only
9.12	Navigation Aids - Range Targets	1	ea.	\$100,000	\$100,000	relocated existing
9.13	Oil Spill Boom Brackets	1	I.s.	\$20,000	\$20,000	
9.14	Oil Spill Boom	1	I.s.	\$50,000	\$50,000	basic lightweight only
9.15	Caisson Keys	39	cu.m.	\$2,500	\$97,500	fabricated on site
9.16	Miscellaneous Precast Concrete Footings	1	I.s.	\$100,000	\$100,000	
9.17	Shore Bollards Footings	100	cu.m.	\$1,500	\$150,000	cast-in-place
9.18	Scour Protection Mats	1	I.s.	\$1,500,000	\$1,500,000	precast in south
9.19	Dock Office, Lunch Room, Washroom Facilities (~5m x 15m)	1	I.s.	\$500,000	\$500,000	
9.20	Fencing	1	I.s.	\$200,000	\$200,000	
9.21	Shoreline and Other Barriers	1	I.s.	\$50,000	\$50,000	
<b>Piping</b>						
9.22	New Fuel Manifold	1	I.s.	\$200,000	\$200,000	
9.23	Demolish Old Fuel Manifold	1	I.s.	\$50,000	\$50,000	
9.24	Demolish Old Fuel Line	1	I.s.	\$50,000	\$50,000	
9.25	Extend New Fuel Line to Dock and Fuel Manifold	1	I.s.	\$500,000	\$500,000	
9.26	Water Supply	1	I.s.	\$0	\$0	no allowance
	<b>Subtotal</b>				<b>\$1,000,000</b>	assumes seawater system based on well and pre-fab container
9.27	Fire Protection	1	I.s.	\$1,000,000	\$1,000,000	no allowance
9.28	Allowance for Temporary Tanker Berth	1	I.s.	\$0	\$0	
<b>Electrical and Lighting</b>						
9.29	Wharf Lighting and Electrical	1	I.s.	\$500,000	\$500,000	
9.30	Yard Lighting (Dock Back-up Lands)	1	I.s.	\$1,000,000	\$1,000,000	
9.31	Yard Lighting (Dock Secondary Yard/Parking Area)	1	I.s.	\$1,000,000	\$1,000,000	
9.32	Poles to Wharf	1	I.s.	\$500,000	\$500,000	
9.31	Delivering Power to the Site	1	I.s.	\$0	\$0	assumes existing is about 12kV and enough for all services
	<b>Subtotal</b>				<b>\$8,527,500</b>	
	<b>Subtotal</b>				<b>\$55,359,700</b>	
<b>10.00</b>	<b>General Indirects</b>					
10.01	Contingency and Escalation Allowance (allow 15%)	1	I.s.	\$8,300,000	\$8,300,000	
10.02	Engineering and Project Management (allow 8%)	1	I.s.	\$5,100,000	\$5,100,000	
	<b>Subtotal</b>				<b>\$13,400,000</b>	
	<b>Total</b>				<b>\$68,759,700</b>	

**Iqaluit Port Development**

Project 09120

Quantity and Capital Cost Estimation						
Item	Description	Quantity	Unit	Unit Rate	Total	Remarks
<b>Option 5 - Two Landing Ramps and Small Craft Dock at the Existing Causeway</b>						
<b>GENERAL</b>						
<b>1.00</b>	<b>Mobilization</b>					
1.01	Crushing, Screening, Stacking equipment	1	l.s.	\$1,650,000.0	\$1,650,000	Kudlik
1.02	General and Floating Equipment	1	l.s.	\$1,500,000.0	\$1,500,000	
1.03	Overwintering Allowance	1	l.s.	\$500,000.0	\$500,000	
	<b>Subtotal</b>				<b>\$3,650,000</b>	
<b>2.00</b>	<b>Demobilization</b>	1	l.s.	\$1,000,000.0	\$1,000,000	
	<b>Subtotal</b>				<b>\$1,000,000</b>	
<b>DREDGING</b>						
<b>3.00</b>	<b>Dredging and Offshore Disposal</b>					
3.01	Dredge to EI -5.0	0	cu.m	\$75.0	\$0	rate from CR
3.02	Dredge to EI -1.0	24,000	cu.m	\$75.0	\$1,800,000	rate from CR
3.03	Dredge for Causeway	0	cu.m	\$75.0	\$0	rate from CR
3.04	Sediment Treatment / Silt Curtain (Allowance)	0	l.s.	\$0.0	\$0	
	<b>Subtotal</b>	<b>24,000</b>			<b>\$1,800,000</b>	
<b>EARTHWORKS</b>						
<b>4.00</b>	<b>Rock Excavation</b>					
4.01	Drill and Blast Rock (total volume required based on the total volume of fill and rip rap. Add 30% void for volume after blasting)	168,500	cu.m	\$19	\$3,201,500	rate by Kudlik
	<b>Subtotal</b>	<b>168,500</b>			<b>\$3,201,500</b>	
<b>5.00</b>	<b>Fill (onshore and offshore) Production of Material</b>					
5.01	Stockpile General Fill (600mm minus) (Causeway and Landing Beach)	179,000	cu.m	\$0.0	\$0	included in Drill and Blast
5.02	Break and Sort Riprap (1,200mm to 300mm) (Causeway and Landing Beach)	40,000	cu.m	\$10.0	\$400,000	rate by Kudlik
5.03	Crushing and Stockpiling Road Sub-base (Crushing - 150mm minus)	0	cu.m	\$20.0	\$0	rate by Kudlik
5.04	Crushing and Stockpiling Road Base (Crushing - 25mm minus)	0	cu.m	\$20.0	\$0	rate by Kudlik
	<b>Subtotal</b>	<b>219,000</b>			<b>\$400,000</b>	
<b>6.00</b>	<b>Fill (onshore and offshore) Installation</b>					
6.01	Causeway Lower Fill (General Fill), Hauling, and Placing	179,000	cu.m	\$30.0	\$5,370,000	rate by Kudlik
6.02	Causeway Top Fill (Sub-base 450 mm thick and base courses 150 mm thick), Hauling, Placing, and Compacting	0	cu.m	\$21.0	\$0	Included in 6.01
6.03	Riprap Shoreline Protection, Hauling, Placing, and Shaping	40,000	cu.m	\$31.0	\$1,240,000	rate by Kudlik
	<b>Subtotal</b>				<b>\$6,610,000</b>	
<b>7.00</b>	<b>Roadway</b>					
7.01	Place and Compact Road Base/Sub-base	0	cu.m	\$21.0	\$0	rate by Kudlik
	<b>Subtotal</b>				<b>\$0</b>	
<b>WHARF</b>						
<b>8.00</b>	<b>Small Craft Floating Wharf</b>					
8.01	Floating Wharf - Supply	1	l.s.	\$3,500,000	\$3,500,000	from Groupe Ocean
8.02	Transportation to the Site	1	l.s.	\$400,000	\$400,000	
8.03	Temp Onshore Storage	1	l.s.	\$0	\$0	
8.04	Installation	1	l.s.	\$200,000	\$200,000	with Groupe Ocean
8.05	Access Ramp (Gangway)	1	l.s.	\$350,000	\$350,000	
	<b>Subtotal</b>				<b>\$4,450,000</b>	
<b>9.00</b>	<b>Wharf Hardware, Utilities, and Equipment</b>					
<b>Mechanical</b>						
9.01	Fencing	1	l.s.	\$150,000	\$150,000	
9.02	Shoreline and Other Barriers	1	l.s.	\$50,000	\$50,000	
<b>Electrical</b>						
9.03	Seawater Fire Protection on Floats	1	l.s.	\$100,000	\$100,000	
9.04	Floats and Roadway Lighting (Allowance)	1	l.s.	\$250,000	\$250,000	
9.05	Delivering Power to the Site (Allowance)	1	l.s.	\$0	\$0	
	<b>Subtotal</b>				<b>\$350,000</b>	
<b>TANKER BERTH IMPROVEMENT</b>						
<b>10.00</b>	<b>Supply Chain and Mooring Buoy</b>					
10.01	Chain (2" stud link, Grade 2, 525 m)	6	shot	\$3,250.0	\$19,500	
10.02	Chain links (20 for 19 shots)	7	ea.	\$275.0	\$1,925	
10.03	Swivels	2	ea.	\$1,060.0	\$2,120	Rates by Washington Chain
10.04	Shackles	3	ea.	\$335.0	\$1,005	
10.05	Quick Release Hook	1	ea.	\$2,850.0	\$2,850	
10.06	Anchor (lightweight, fluke anchor)	20,000	lbs	\$1.25	\$25,000	
10.07	Buoy (peg top)	1	ea.	\$88,000.0	\$88,000	\$25,000 for used
10.08	Concrete Sinkers	1	ea.	\$5,000.0	\$5,000	Allowance
10.09	Shipping from Montreal	30	tonnes	\$500.0	\$15,000	
	<b>Subtotal</b>				<b>\$160,400</b>	
<b>11.00</b>	<b>Install Chain and Mooring Buoy and Move Existing Moorings</b>					
11.01	Receive, Assemble, and Install	1	l.s.	\$100,000.0	\$100,000	allowance, assumes NEAS or Desgagnes barge available for use
11.02	Proof Loading	1	ea.	\$0.0	\$0	included above
11.03	Move two existing moorings	1	l.s.	\$250,000.0	\$250,000	
	<b>Subtotal</b>				<b>\$350,000</b>	
	<b>Subtotal</b>				<b>\$21,971,900</b>	
<b>12.00</b>	<b>General Indirects</b>					
12.01	Contingency and Escalation Allowance (allow 15%)	1	l.s.	\$3,300,000	\$3,300,000	
12.02	Engineering and Project Management (allow 8%)	1	l.s.	\$2,000,000	\$2,000,000	
	<b>Subtotal</b>				<b>\$5,300,000</b>	
	<b>Total</b>				<b>\$27,271,900</b>	

**Iqaluit Port Development**  
Project 09120

Quantity and Capital Cost Estimation						
Item	Description	Quantity	Unit	Unit Rate	Total	Remarks
<b>Option 6 - South Polaris Reef - Stage 1 Only</b>						
<b>GENERAL</b>						
<b>1.00</b>	<b>Mobilization</b>					
1.01	Crushing, Screening, Stacking Equipment	1	I.s.	\$1,650,000.0	\$1,650,000	Kudlik
1.02	General and Floating Equipment	1	I.s.	\$2,500,000.0	\$2,500,000	
1.03	Overwintering Allowance	1	I.s.	\$500,000.0	\$500,000	
	<b>Subtotal</b>				<b>\$4,650,000</b>	
<b>2.00</b>	<b>Demobilization</b>	1	I.s.	\$1,000,000.0	\$1,000,000	
	<b>Subtotal</b>				<b>\$1,000,000</b>	
<b>DREDGING</b>						
<b>3.00</b>	<b>Dredging and Offshore Disposal</b>					
3.01	Dredge to El -11.0 m (Slope 6:1)	0	cu.m	\$75.0	\$0	adjusted DB rate
3.02	(empty)					
3.03	Dredge for Caissons/Cells Foundation	0	cu.m	\$75.0	\$0	
3.04	Dredge for Causeway	24,000	cu.m	\$75.0	\$1,800,000	
3.05	Sediment Treatment / Silt Curtain (Allowance)	0	I.s.	\$0.0	\$0	
	<b>Subtotal</b>	<b>24,000</b>			<b>\$1,800,000</b>	
<b>EARTHWORKS</b>						
<b>4.00</b>	<b>Rock Excavation</b>					
4.01	Drill and Blast Rock (total volume required based on the total volume of fill, mattress and rip rap. Add 30% void for volume after blasting)	237,300	cu.m	\$19	\$4,508,700	Kudlik
	<b>Subtotal</b>	<b>237,300</b>			<b>\$4,508,700</b>	
<b>5.00</b>	<b>Fill (onshore and offshore) Production of Material</b>					
5.01	Crushing and Stockpiling Mattress (75mm minus)	0	cu.m	\$20.0	\$0	Kudlik
5.02	Crushing and Stockpiling Caisson Fill (200mm minus)	0	cu.m	\$20.0	\$0	Kudlik
5.03	Stockpile General Fill (600mm minus) (Deep Sea Wharf and Roadway)	272,000	cu.m	\$0.0	\$0	included in Drill and Blast
5.04	Break and Sort Riprap (1,200mm to 300mm) (Deep Sea Wharf and Roadway)	35,000	cu.m	\$10.0	\$350,000	Kudlik
5.05	Crushing and Stockpiling Road Sub-base (Crushing - 150mm minus)	750	cu.m	\$20.0	\$15,000	Kudlik
5.06	Crushing and Stockpiling Road Base (Crushing - 25mm minus)	750	cu.m	\$20.0	\$15,000	Kudlik
	<b>Subtotal</b>	<b>308,500</b>			<b>\$380,000</b>	
<b>6.00</b>	<b>Fill (onshore and offshore) Installation</b>					
6.01	Haul, Load Barge, Dump, and Level Mattress	0	cu.m	\$75.0	\$0	adjusted DB rate
6.02	Haul, Load Barge, and Clam Caisson Fill	0	cu.m	\$75.0	\$0	adjusted DB rate
6.03	Caisson Top Fill (Sub-base 450 mm thick and base courses 150 mm thick), Placing	0	cu.m	\$22.0	\$0	Kudlik
6.04	Causeway Lower Fill (General Fill), Hauling, and Placing	272,000	cu.m	\$22.0	\$5,984,000	Kudlik
	Causeway Top Fill (Sub-base 450 mm thick and base courses 150 mm thick), Hauling, Placing, and Compacting	0	cu.m	\$22.0	\$0	Included in 6.04
6.05	Hauling, Placing, and Compacting	0	cu.m	\$0	\$0	rate by Kudlik
6.06	Riprap Scour Protection, Hauling, Placing, and Shaping	0	cu.m	\$110.0	\$0	adjusted DB rate
6.07	Riprap Shoreline Protection, Hauling, Placing, and Shaping	35,000	cu.m	\$32.0	\$1,120,000	Kudlik
	<b>Subtotal</b>				<b>\$7,104,000</b>	
<b>7.00</b>	<b>Roadway</b>					
7.01	Place and Compact Road Base/Sub-base	1,500	cu.m	\$21.0	\$31,500	Kudlik
7.02	Widening of the Existing Road (Allowance)	2,000	m	\$0.0	\$0	no allowance
	<b>Subtotal</b>				<b>\$31,500</b>	
<b>WHARF</b>						
<b>8.00</b>	<b>Deep Sea Wharf Structure (Concrete Caisson)</b>					
8.01	Concrete Caissons Off-site Construction	0	I.s.	\$8,600,000.0	\$0	from Beaver Marine
8.02	Caisson Storage and Manoeuvring (onto semi-submersible)	0	I.s.	\$250,000.0	\$0	adjusted DB rate
8.03	Concrete Caisson Transportation to Site (3 vessels)	0	I.s.	\$6,000,000.0	\$0	from Dockwise
8.04	Additional Costs for Caisson Transportation (allowance for: import duty, marine surveyor, fuel surcharge)	0	I.s.	\$500,000.0	\$0	from DB
8.05	Caisson Temporary Moorage and Site Towing/Manoeuvring	0	I.s.	\$800,000.0	\$0	from DB
8.06	Sink Concrete Caissons onto Mattress Foundation (level, ballast, place)	0	I.s.	\$500,000.0	\$0	from DB
	<b>Subtotal</b>				<b>\$0</b>	
<b>9.00</b>	<b>Wharf Hardware, Utilities, and Equipment</b>					
<b>Mechanical</b>						
9.01	Steel Pipe Guardrails	0	I.s.	\$120,000	\$0	installed in south on caissons
9.02	Removable Handrails	0	I.s.	\$20,000	\$0	
9.03	Ladders (heavy chain-type, removable)	0	ea.	\$6,000	\$0	
9.04	Fenders	0	I.s.	\$500,000	\$0	allowance for foam-filled
9.05	Rubbing Timbers	0	I.s.	\$100,000	\$0	installed in south on caissons
9.06	Wharf Bollards	0	I.s.	\$0	\$0	included in caisson cost
9.07	Shore Bollards	0	ea.	\$20,000	\$0	not including bases
9.08	New Powered Capstans	0	ea.	\$60,000	\$0	
9.09	Miscellaneous Mooring/Standing Lines and Safety Equipment	0	I.s.	\$10,000	\$0	
9.10	Gangway	0	I.s.	\$0	\$0	no allowance
9.11	Navigation Aids - Lights	0	ea.	\$20,000	\$0	on dock only
9.12	Navigation Aids - Range Targets	0	ea.	\$100,000	\$0	relocated existing
9.13	Oil Spill Boom Brackets	0	I.s.	\$20,000	\$0	
9.14	Oil Spill Boom	0	I.s.	\$50,000	\$0	basic lightweight only
9.15	Caisson Keys	0	cu.m.	\$2,500	\$0	fabricated on site
9.16	Miscellaneous Precast Concrete Footings	0	I.s.	\$100,000	\$0	
9.17	Shore Bollards Footings	0	cu.m.	\$1,500	\$0	cast-in-place
9.18	Scour Protection Mats	0	I.s.	\$1,500,000	\$0	precast in south
9.19	Dock Office, Lunch Room, Washroom Facilities (~5m x 15m)	1	I.s.	\$500,000	\$500,000	
9.20	Fencing	1	I.s.	\$200,000	\$200,000	
9.21	Shoreline and Other Barriers	1	I.s.	\$50,000	\$50,000	
<b>Piping</b>						
9.22	New Fuel Manifold	0	I.s.	\$200,000	\$0	
9.23	Demolish Old Fuel Manifold	0	I.s.	\$50,000	\$0	
9.24	Demolish Old Fuel Line	0	I.s.	\$50,000	\$0	
9.25	Extend New Fuel Line to Dock and Fuel Manifold	0	I.s.	\$500,000	\$0	
9.26	Water Supply	1	I.s.	\$0	\$0	no allowance
	<b>Subtotal</b>				<b>\$1,000,000</b>	assumes seawater system based on well
9.27	Fire Protection	1	I.s.	\$1,000,000	\$1,000,000	and pre-fab container
9.28	Allowance for Temporary Tanker Berth	0	I.s.	\$0	\$0	no allowance
<b>Electrical and Lighting</b>						
9.29	Wharf Lighting and Electrical	0	I.s.	\$500,000	\$0	
9.30	Yard Lighting (Dock Back-up Lands)	1	I.s.	\$1,000,000	\$1,000,000	
9.31	Yard Lighting (Dock Secondary Yard/Parking Area)	1	I.s.	\$1,000,000	\$1,000,000	
9.32	Poles to Wharf	1	I.s.	\$500,000	\$500,000	
9.31	Delivering Power to the Site	1	I.s.	\$0	\$0	assumes existing is about 12kV and enough for all services
	<b>Subtotal</b>				<b>\$4,250,000</b>	
	<b>Subtotal</b>				<b>\$23,724,200</b>	
<b>10.00</b>	<b>General Indirects</b>					
10.01	Contingency and Escalation Allowance (allow 15%)	1	I.s.	\$3,600,000	\$3,600,000	
10.02	Engineering and Project Management (allow 8%)	1	I.s.	\$2,200,000	\$2,200,000	
	<b>Subtotal</b>				<b>\$5,800,000</b>	
	<b>Total</b>				<b>\$29,524,200</b>	

**Iqaluit Port Development**

Project 09120

Quantity and Capital Cost Estimation						
Item	Description	Quantity	Unit	Unit Rate	Total	Remarks
<b>Option A - Small Craft Dock at the Existing Causeway</b>						
<b>GENERAL</b>						
1.00	<b>Mobilization</b>	1	l.s.	\$0.0	\$0	assumes combined with other work
	<b>Subtotal</b>				<b>\$0</b>	
2.00	<b>Demobilization</b>	1	l.s.	\$0.0	\$0	assumes combined with other work
	<b>Subtotal</b>				<b>\$0</b>	
<b>DREDGING</b>						
3.00	<b>Dredging and Offshore Disposal</b>					
3.01	Dredge to EI -5.0	0	cu.m	\$75.0	\$0	rate from CR
3.02	Dredge to EI -1.0	14,500	cu.m	\$75.0	\$1,087,500	rate from CR
3.03	Dredge for causeway	0	cu.m	\$75.0	\$0	rate from CR
3.04	Sediment treatment / silt curtain (allowance)	0	l.s.	\$0.0	\$0	
	<b>Subtotal</b>	<b>14,500</b>			<b>\$1,087,500</b>	
<b>EARTHWORKS</b>						
4.00	<b>Rock Excavation</b>					
4.01	Drill and Blast rock (total volume required based on the total volume of fill and rip rap. Add 30% void for volume after blasting)	115,000	cu.m	\$19	\$2,185,000	rate by Kudlik
	<b>Subtotal</b>	<b>115,000</b>			<b>\$2,185,000</b>	
5.00	<b>Fill (onshore and offshore) Production of Material</b>					
5.01	Stockpile general fill (600mm minus) (causeway and landing beach)	117,000	cu.m	\$0.0	\$0	included in Drill and Blast
5.02	Break and sort riprap (1,200mm to 300mm) (causeway and landing beach)	30,000	cu.m	\$10.0	\$300,000	rate by Kudlik
5.03	Crushing and Stockpiling road sub-base (crushing - 150mm minus)	0	cu.m	\$20.0	\$0	rate by Kudlik
5.04	Crushing and Stockpiling road base (crushing - 25mm minus)	0	cu.m	\$20.0	\$0	rate by Kudlik
	<b>Subtotal</b>	<b>147,000</b>			<b>\$300,000</b>	
6.00	<b>Fill (onshore and offshore) Installation</b>					
6.01	Causeway lower Fill (general fill), hauling and placing	117,000	cu.m	\$35.0	\$4,095,000	rate by Kudlik
6.02	Causeway top fill (sub-base 450 mm thick and base courses 150 mm thick), hauling, placing, and compacting	0	cu.m	\$21.0	\$0	Included in 6.01
6.03	Riprap Shoreline Protection, hauling, placing and shaping	30,000	cu.m	\$31.0	\$930,000	rate by Kudlik
	<b>Subtotal</b>				<b>\$5,025,000</b>	
7.00	<b>Roadway</b>					
7.01	Place and compact road base/sub-base	0	cu.m	\$21.0	\$0	rate by Kudlik
	<b>Subtotal</b>				<b>\$0</b>	
<b>WHARF</b>						
8.00	<b>Small Craft Floating Wharf</b>					
8.01	Floating wharf - supply	1	l.s.	\$3,500,000	\$3,500,000	from Groupe Ocean
8.02	Transportation to the site	1	l.s.	\$400,000	\$400,000	
8.03	Temp onshore storage	1	l.s.	\$0	\$0	
8.04	Installation	1	l.s.	\$200,000	\$200,000	with Groupe Ocean
8.05	Access Ramp (Gangway)	1	l.s.	\$350,000	\$350,000	
	<b>Subtotal</b>				<b>\$4,450,000</b>	
9.00	<b>Wharf Hardware, Utilities, and Equipment</b>					
<b>General</b>						
9.01	Fencing	1	l.s.	\$0	\$0	no allowance
9.02	Shoreline and other barriers	1	l.s.	\$0	\$0	included in riprap
<b>Electrical</b>						
9.03	Seawater Fire Protection on Floats	1	l.s.	\$100,000	\$100,000	
9.04	Floats and Roadway lighting (allowance)	1	l.s.	\$250,000	\$250,000	
9.05	Delivering power to the site (allowance)	1	l.s.	\$0	\$0	
	<b>Subtotal</b>				<b>\$350,000</b>	
	<b>Subtotal</b>				<b>\$13,397,500</b>	
	Contingency and Engineering (20%)				<b>\$2,700,000</b>	
	<b>Total</b>				<b>\$16,097,500</b>	

**Iqaluit Port Development**

Project 09120

Quantity and Capital Cost Estimation						
Item	Description	Quantity	Unit	Unit Rate	Total	Remarks
<b>Option B - Municipal Breakwater Expansion</b>						
<b>GENERAL</b>						
1.00	Mobilization	1	l.s.	\$0.0	\$0	assumes combined with other work
	<b>Subtotal</b>				<b>\$0</b>	
2.00	Demobilization	1	l.s.	\$0.0	\$0	assumes combined with other work
	<b>Subtotal</b>				<b>\$0</b>	
<b>DREDGING</b>						
3.00	<b>Dredging and Offshore Disposal</b>					
3.01	Dredge to EI -5.0	0	cu.m	\$75.0	\$0	adjusted DB rate
3.02	Dredge to EI -1.0	62,800	cu.m	\$75.0	\$4,710,000	adjusted DB rate
3.03	Dredge for causeway	30,000	cu.m	\$60.0	\$1,800,000	adjusted DB rate
3.04	Sediment treatment / silt curtain (allowance)	0	l.s.	\$0.0	\$0	
	<b>Subtotal</b>	<b>92,800</b>			<b>\$6,510,000</b>	
<b>EARTHWORKS</b>						
4.00	<b>Rock Excavation</b>					
4.01	Drill and Blast rock (total volume required based on the total volume of fill and rip rap. Add 30% void for volume after blasting)	120,000	cu.m	\$19	\$2,280,000	from Kudlik
	<b>Subtotal</b>	<b>120,000</b>			<b>\$2,280,000</b>	
5.00	<b>Fill (onshore and offshore) Production of Material</b>					
5.01	Stockpile general fill (600mm minus) (causeway and landing beach)	120,600	cu.m	\$0.0	\$0	included in Drill and Blast
5.02	Break and sort riprap (1,200mm to 300mm) (causeway and landing beach)	33,000	cu.m	\$10.0	\$330,000	from Kudlik
5.03	Crushing and Stockpiling road sub-base (crushing - 150mm minus)	500	cu.m	\$20.0	\$10,000	from Kudlik
5.04	Crushing and Stockpiling road base (crushing - 25mm minus)	500	cu.m	\$20.0	\$10,000	from Kudlik
	<b>Subtotal</b>	<b>154,600</b>			<b>\$350,000</b>	
6.00	<b>Fill (onshore and offshore) Installation</b>					
6.01	Causeway lower Fill (general fill), hauling and placing	120,600	cu.m	\$35.0	\$4,221,000	from Kudlik
6.02	Causeway top fill (sub-base 450 mm thick and base courses 150 mm thick), hauling, placing, and compacting	0	cu.m	\$27.0	\$0	Included in 6.01 rate by Kudlik
6.03	Riprap Shoreline Protection, hauling, placing and shaping	33,000	cu.m	\$40.0	\$1,320,000	from Kudlik
	<b>Subtotal</b>				<b>\$5,541,000</b>	
7.00	<b>Roadway</b>					
7.01	Place and compact road base/sub-base	1,000	cu.m	\$27.0	\$27,000	from Kudlik
	<b>Subtotal</b>				<b>\$27,000</b>	
<b>WHARF</b>						
8.00	<b>Small Craft Floating Wharf</b>					
8.01	Floating wharf - supply	1	l.s.	\$3,500,000	\$3,500,000	from Groupe Ocean
8.02	Transportation to the site	1	l.s.	\$400,000	\$400,000	
8.03	Temp onshore storage	1	l.s.	\$0	\$0	
8.04	Installation	1	l.s.	\$200,000	\$200,000	with Groupe Ocean
8.05	Access Ramp (Gangway)	1	l.s.	\$350,000	\$350,000	
	<b>Subtotal</b>				<b>\$4,450,000</b>	
9.00	<b>Wharf Hardware, Utilities, and Equipment</b>					
<b>General</b>						
9.01	Fencing	1	l.s.	\$0	\$0	no allowance
9.02	Shoreline and other barriers	1	l.s.	\$0	\$0	included in riprap
<b>Electrical</b>						
9.03	Seawater Fire Protection on Floats	1	l.s.	\$100,000	\$100,000	
9.04	Float and Breakwater Lighting	1	l.s.	\$250,000	\$250,000	assumes power at the breakwater
9.05	Delivering power to the site (allowance)	1	l.s.	\$0	\$0	
	<b>Subtotal</b>				<b>\$350,000</b>	
	<b>Subtotal</b>				<b>\$19,508,000</b>	
	Contingency and Engineering (20%)				<b>\$3,900,000</b>	
	<b>Total</b>				<b>\$23,408,000</b>	

**Iqaluit Port Development**

Project 09120

Quantity and Capital Cost Estimation						
Item	Description	Quantity	Unit	Unit Rate	Total	Remarks
<b>Option C - Municipal Breakwater Upgrades</b>						
<b>GENERAL</b>						
1.00	<b>Mobilization</b>	1	l.s.	\$0.0	\$0	assumes combined with other work
	<b>Subtotal</b>				<b>\$0</b>	
2.00	<b>Demobilization</b>	1	l.s.	\$0.0	\$0	assumes combined with other work
	<b>Subtotal</b>				<b>\$0</b>	
<b>DREDGING</b>						
3.00	<b>Dredging and Offshore Disposal</b>					
3.01	Dredge to EI +3.5	11,400	cu.m	\$35.0	\$399,000	assume 50% of material reused as fill
3.02	Dredge to EI +6.0	1,400	cu.m	\$35.0	\$49,000	assume 50% of material reused as fill
3.03	Dredge for causeway	0	cu.m	\$35.0	\$0	
3.04	Sediment treatment / silt curtain (allowance)	0	l.s.	\$0.0	\$0	
3.05	Disposal (50% of dredge material)	6,400	cu.m	\$10.0	\$64,000	
	<b>Subtotal</b>	<b>12,800</b>			<b>\$512,000</b>	
<b>EARTHWORKS</b>						
4.00	<b>Rock Excavation</b>					
4.01	Drill and Blast rock (total volume required based on the total volume of fill and rip rap. Add 30% void for volume after blasting)	15,000	cu.m	\$19	\$285,000	from Kudlik
	<b>Subtotal</b>	<b>15,000</b>			<b>\$285,000</b>	
5.00	<b>Fill (onshore and offshore) Production of Material</b>					
5.01	Stockpile general fill (600mm minus) (shoreline fill and boat ramps)	16,600	cu.m	\$0.0	\$0	included in Drill and Blast
5.02	Break and sort riprap (1,200mm to 300mm) (shoreline fill and boat ramps)	1,600	cu.m	\$10.0	\$16,000	from Kudlik
5.03	Crushing and Stockpiling road sub-base (crushing - 150mm minus)	0	cu.m	\$20.0	\$0	from Kudlik
5.04	Crushing and Stockpiling road base (crushing - 25mm minus)	0	cu.m	\$20.0	\$0	from Kudlik
	<b>Subtotal</b>	<b>18,200</b>			<b>\$16,000</b>	
6.00	<b>Fill (onshore and offshore) Installation</b>					
6.01	Shoreline fill and boat ramps (general fill), hauling and placing	16,600	cu.m	\$27.0	\$448,200	from Kudlik
6.02	Allowance for placing salvaged fill (50% of dredge material)	6,400	cu.m	\$10.0	\$64,000	
6.03	Shoreline top fill (sub-base 450 mm thick and base courses 150 mm thick), hauling, placing, and compacting	0	cu.m	\$27.0	\$0	Included in 6.01 rate by Kudlik
6.04	Riprap Shoreline Protection, hauling, placing and shaping	1,600	cu.m	\$40.0	\$64,000	from Kudlik
	<b>Subtotal</b>	<b>24,600</b>			<b>\$576,200</b>	
7.00	<b>Roadway</b>					
7.01	Place and compact road base/sub-base	0	cu.m	\$27.0	\$0	from Kudlik
	<b>Subtotal</b>				<b>\$0</b>	
<b>WHARF</b>						
8.00	<b>Wharf Hardware, Utilities, and Equipment</b>					
8.01	Concrete Access Stairs	1	l.s.	\$200,000	\$200,000	
8.02	Curb Barrier	1	l.s.	\$100,000	\$100,000	
8.03	Mooring Eyes	1	l.s.	\$100,000	\$100,000	
8.04	Electric Hoist Davit	2	ea.	\$150,000	\$300,000	
8.05	Dock Ladder	2	ea.	\$10,000	\$20,000	
8.06	Storage area lighting	1	l.s.	\$250,000	\$250,000	
8.07	Fencing	1	l.s.	\$0	\$0	no allowance
8.08	Shoreline and other barriers	1	l.s.	\$0	\$0	no allowance
	<b>Subtotal</b>				<b>\$970,000</b>	
9.00	<b>Small Craft Float System</b>					
9.01	5m x 10 m Three-Tube Pontoon Float	3	ea.	\$150,000	\$450,000	
9.02	Four Sets of Chain Anchors and Concrete Blocks for each Float	3	ea.	\$20,000	\$60,000	
9.03	20m Long Gangway x 1.2 m Wide	3	ea.	\$50,000	\$150,000	
9.04	Transportation to Site	3	ea.	\$80,000	\$240,000	
9.05	Abutment	3	ea.	\$20,000	\$60,000	
9.06	Location Transportation and Installation at Site	3	ea.	\$100,000	\$300,000	
	<b>Subtotal</b>				<b>\$1,260,000</b>	
	<b>Subtotal</b>				<b>\$3,619,200</b>	
	Contingency and Engineering (25%)				<b>\$900,000</b>	
	<b>Total</b>				<b>\$4,519,200</b>	



GOVERNMENT OF NUNAVUT  
IQALUIT PORT DEVELOPMENT

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## Appendix F Economic Analysis

**Iqaluit**
**Capital Cost**

Deep Sea Dock	68,759,700
Causeway with ramps	21,121,437

**Percentage of Capital Cost Remaining in Iqaluit**

Deep Sea Dock	30%
Causeway with ramps and new tanker moorings	80%

**Deep Sea Dock Annual Operating Costs**

Position fenders start of season	20,000
Remove fenders end of season	20,000
Place standing Lines start of Season	5,000
Remove Standing Lines end of season	5,000
Check standing lines, re-certify as necessary	5,000
Lighting, water, telephone, sewage	20,000
Re-grade apron	10,000
Re-grade laydown area	25,000
Re-grade access road	15,000
Harbourmaster	65,000
Communications	15,000
Security	100,000
<b>Total operating Costs</b>	<b>305,000</b>

**Causeway with ramps and new tanker moorings annual operating costs**

Re-grade ramps	60,000
Re-grade laydown area	25,000
Re-Grade Access road	5,000
Lighting, water, telephone, sewage	10,000
<b>Total Operating Costs</b>	<b>100,000.00</b>

**Annual Repair and Maintenance Costs**
**Deep Sea Dock**

Fencing and gates	5,000
Fendering	10,000
Dock Cope and Mooring	5,000
Standing Line Replacement	5,000
<b>Total Repair and Maintenance Costs</b>	<b>25,000.00</b>

**Causeway**

Fencing and gates	5,000.00
Lighting	3,000.00
Tanker moorings	15,000.00
<b>Total Repair and Maintenance Costs</b>	<b>23,000.00</b>

<b>Population, base year 2009</b>	<b>7,400</b>
% per annum growth rate	2.5%

<b>Dry Cargo demand per person,cubic metres</b>	<b>8.00</b>
---	-------------

Bulk Petroleum Product Demand, cubic metres	% Growth Rate	Base Year Demand
Jet A1	0.5%	23,473
Diesel	4.2%	30,867
Mogas	2.3%	4,987

**Dry Cargo Handling Rates, cubic metres per day**

Beach	830
At Causeway	1,650
At Deep sea dock	2,500

**Tanker handling rates cubic metres per hour**

At Anchorage	3,300
At Deep sea dock	10,000

<b>Dry cargo ship daily cost in port</b>	<b>27,500</b>
<b>Lighterage System cost per day</b>	<b>5,800</b>
<b>Tanker daily cost in port</b>	<b>27,500</b>

<b>Extra Trucking Costs</b>	<b>0</b> \$ per revenue ton
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The causeway capital cost excludes tanker moorings and small craft dock

**Iqaluit**
**Forecast**

Year	Population	Dry Cargo Volume	Petroleum Product Volume				Days to Discharge Dry Cargo			Days to Discharge Petroleum Products	
			Jet A1	Diesel	Mogas	Total	Beach	Causeway	Dock	Anchorage	Dock
2009	7,400	59,200	23,590	32,163	5,102	60,855	71	36	24	18	6
2010	7,585	60,680	23,708	33,514	5,219	62,442	73	37	24	19	6
2011	7,775	62,197	23,827	34,922	5,339	64,088	75	38	25	19	6
1 2012	7,969	63,752	23,946	36,389	5,462	65,796	77	39	26	20	7
2 2013	8,168	65,346	24,066	37,917	5,588	67,570	79	40	26	20	7
3 2014	8,372	66,979	24,186	39,509	5,716	69,411	81	41	27	21	7
4 2015	8,582	68,654	24,307	41,169	5,847	71,323	83	42	27	22	7
5 2016	8,796	70,370	24,429	42,898	5,982	73,308	85	43	28	22	7
6 2017	9,016	72,129	24,551	44,700	6,120	75,370	87	44	29	23	8
7 2018	9,242	73,933	24,673	46,577	6,260	77,511	89	45	30	23	8
8 2019	9,473	75,781	24,797	48,533	6,404	79,734	91	46	30	24	8
9 2020	9,709	77,676	24,921	50,572	6,552	82,044	94	47	31	25	8
10 2021	9,952	79,617	25,045	52,696	6,702	84,443	96	48	32	26	8
11 2022	10,201	81,608	25,171	54,909	6,856	86,936	98	49	33	26	9
12 2023	10,456	83,648	25,296	57,215	7,014	89,526	101	51	33	27	9
13 2024	10,717	85,739	25,423	59,618	7,175	92,216	103	52	34	28	9
14 2025	10,985	87,883	25,550	62,122	7,340	95,013	106	53	35	29	10
15 2026	11,260	90,080	25,678	64,731	7,509	97,918	109	55	36	30	10
16 2027	11,541	92,332	25,806	67,450	7,682	100,938	111	56	37	31	10
17 2028	11,830	94,640	25,935	70,283	7,859	104,077	114	57	38	32	10
18 2029	12,126	97,006	26,065	73,235	8,039	107,339	117	59	39	33	11
19 2030	12,429	99,431	26,195	76,310	8,224	110,730	120	60	40	34	11
20 2031	12,740	101,917	26,326	79,516	8,414	114,255	123	62	41	35	11

## Iqaluit

## Deep Sea Dock

IRR

-1%

Percentage of cost increase

2.5%

Year	Cost					Benefit				Cumulative Benefit	Discount Rate	NPV
	Deep Sea Dock	Operating costs	Extra Trucking Cost	Repair and maint.	Total Cost	Portion of Capital Cost Retained	Dock	Total Benefits	Net Benefits			
1 2012	68,759,700	305,000	0	25,000	69,089,700	20,627,910	2,075,946	22,703,856	-46,385,844	-46,385,844	1.0%	(\$17,092,468.43)
2 2013		312,625	0	25,625	338,250		2,128,563	2,128,563	1,790,313	-44,595,531	2.0%	(\$23,745,895.49)
3 2014		320,441	0	26,266	346,706		2,182,627	2,182,627	1,835,921	3,626,234	3.0%	(\$29,346,564.85)
4 2015		328,452	0	26,922	355,374		2,238,178	2,238,178	1,882,804	3,718,725	4.0%	(\$34,062,084.34)
5 2016		336,663	0	27,595	364,258		2,295,260	2,295,260	1,931,002	3,813,806	5.0%	(\$38,031,438.53)
6 2017		345,080	0	28,285	373,365		2,353,919	2,353,919	1,980,554	3,911,556	6.0%	(\$41,370,201.03)
7 2018		353,706	0	28,992	382,699		2,414,200	2,414,200	2,031,501	4,012,055	7.0%	(\$44,174,744.08)
8 2019		362,549	0	29,717	392,266		2,476,151	2,476,151	2,083,884	4,115,386	8.0%	(\$46,525,647.78)
9 2020		371,613	0	30,460	402,073		2,539,821	2,539,821	2,137,748	4,221,632	9.0%	(\$48,490,468.66)
10 2021		380,903	0	31,222	412,125		2,605,260	2,605,260	2,193,135	4,330,883	10.0%	(\$50,125,993.93)
11 2022		390,426	0	32,002	422,428		2,672,522	2,672,522	2,250,094	4,443,229	11.0%	(\$51,480,081.97)
12 2023		400,186	0	32,802	432,989		2,741,659	2,741,659	2,308,671	4,558,765	12.0%	(\$52,593,168.88)
13 2024		410,191	0	33,622	443,813		2,812,728	2,812,728	2,368,915	4,677,586	13.0%	(\$53,499,504.81)
14 2025		420,446	0	34,463	454,909		2,885,786	2,885,786	2,430,878	4,799,793	14.0%	(\$54,228,171.32)
15 2026		430,957	0	35,324	466,281		2,960,892	2,960,892	2,494,611	4,925,489	15.0%	(\$54,803,920.43)
16 2027		441,731	0	36,207	477,938		3,038,108	3,038,108	2,560,169	5,054,780	20.0%	(\$56,030,358.64)
17 2028		452,774	0	37,113	489,887		3,117,495	3,117,495	2,627,608	5,187,777	25.0%	(\$55,596,456.75)
18 2029		464,094	0	38,040	502,134		3,199,119	3,199,119	2,696,985	5,324,594	30.0%	(\$54,356,690.92)
19 2030		475,696	0	38,991	514,687		3,283,048	3,283,048	2,768,361	5,465,346	35.0%	(\$52,737,962.43)
20 2031		487,588	0	39,966	527,555		3,369,351	3,369,351	2,841,796	5,610,157	40.0%	(\$50,961,444.41)

Iqaluit

Causeway with Ramps and new Tanker IRR

41%

Percentage of cost increase

2.5%

Year	Cost					Benefit				Cumulative Benefit	Discount Rate	NPV
	Causeway with ramps and new tanker	Operating costs	Extra Trucking Cost	Repair and maint.	Total Cost	Portion of Capital Cost Retained	Lighterage Benefit	Total Benefits	Net Benefits			
1 2012	21,121,437	100,000	0	23,000	21,244,437	16,897,150	1,271,128	18,168,278	-3,076,159	-3,076,159	1.0%	\$42,422,599.46
2 2013		102,500	0	23,575	126,075		1,302,906	1,302,906	1,176,831	-1,899,328	2.0%	\$37,309,052.37
3 2014		105,063	0	24,164	129,227		1,335,479	1,335,479	1,206,252	2,383,084	3.0%	\$32,900,020.52
4 2015		107,689	0	24,768	132,458		1,368,866	1,368,866	1,236,408	2,442,661	4.0%	\$29,085,923.43
5 2016		110,381	0	25,388	135,769		1,403,088	1,403,088	1,267,319	2,503,727	5.0%	\$25,775,791.42
6 2017		113,141	0	26,022	139,163		1,438,165	1,438,165	1,299,002	2,566,320	6.0%	\$22,893,882.50
7 2018		115,969	0	26,673	142,642		1,474,119	1,474,119	1,331,477	2,630,478	7.0%	\$20,376,949.49
8 2019		118,869	0	27,340	146,208		1,510,972	1,510,972	1,364,764	2,696,240	8.0%	\$18,172,026.39
9 2020		121,840	0	28,023	149,864		1,548,746	1,548,746	1,398,883	2,763,646	9.0%	\$16,234,630.38
10 2021		124,886	0	28,724	153,610		1,587,465	1,587,465	1,433,855	2,832,738	10.0%	\$14,527,297.41
11 2022		128,008	0	29,442	157,450		1,627,152	1,627,152	1,469,701	2,903,556	11.0%	\$13,018,386.39
12 2023		131,209	0	30,178	161,387		1,667,830	1,667,830	1,506,444	2,976,145	12.0%	\$11,681,100.09
13 2024		134,489	0	30,932	165,421		1,709,526	1,709,526	1,544,105	3,050,548	13.0%	\$10,492,681.29
14 2025		137,851	0	31,706	169,557		1,752,264	1,752,264	1,582,707	3,126,812	14.0%	\$9,433,751.29
15 2026		141,297	0	32,498	173,796		1,796,071	1,796,071	1,622,275	3,204,982	15.0%	\$8,487,764.05
16 2027		144,830	0	33,311	178,141		1,840,973	1,840,973	1,662,832	3,285,107	20.0%	\$5,020,242.20
17 2028		148,451	0	34,144	182,594		1,886,997	1,886,997	1,704,403	3,367,235	25.0%	\$2,911,599.47
18 2029		152,162	0	34,997	187,159		1,934,172	1,934,172	1,747,013	3,451,416	30.0%	\$1,566,412.54
19 2030		155,966	0	35,872	191,838		1,982,526	1,982,526	1,790,688	3,537,701	35.0%	\$674,275.08
20 2031		159,865	0	36,769	196,634		2,032,089	2,032,089	1,835,455	3,626,144	40.0%	\$64,143.08



GOVERNMENT OF NUNAVUT  
IQALUIT PORT DEVELOPMENT

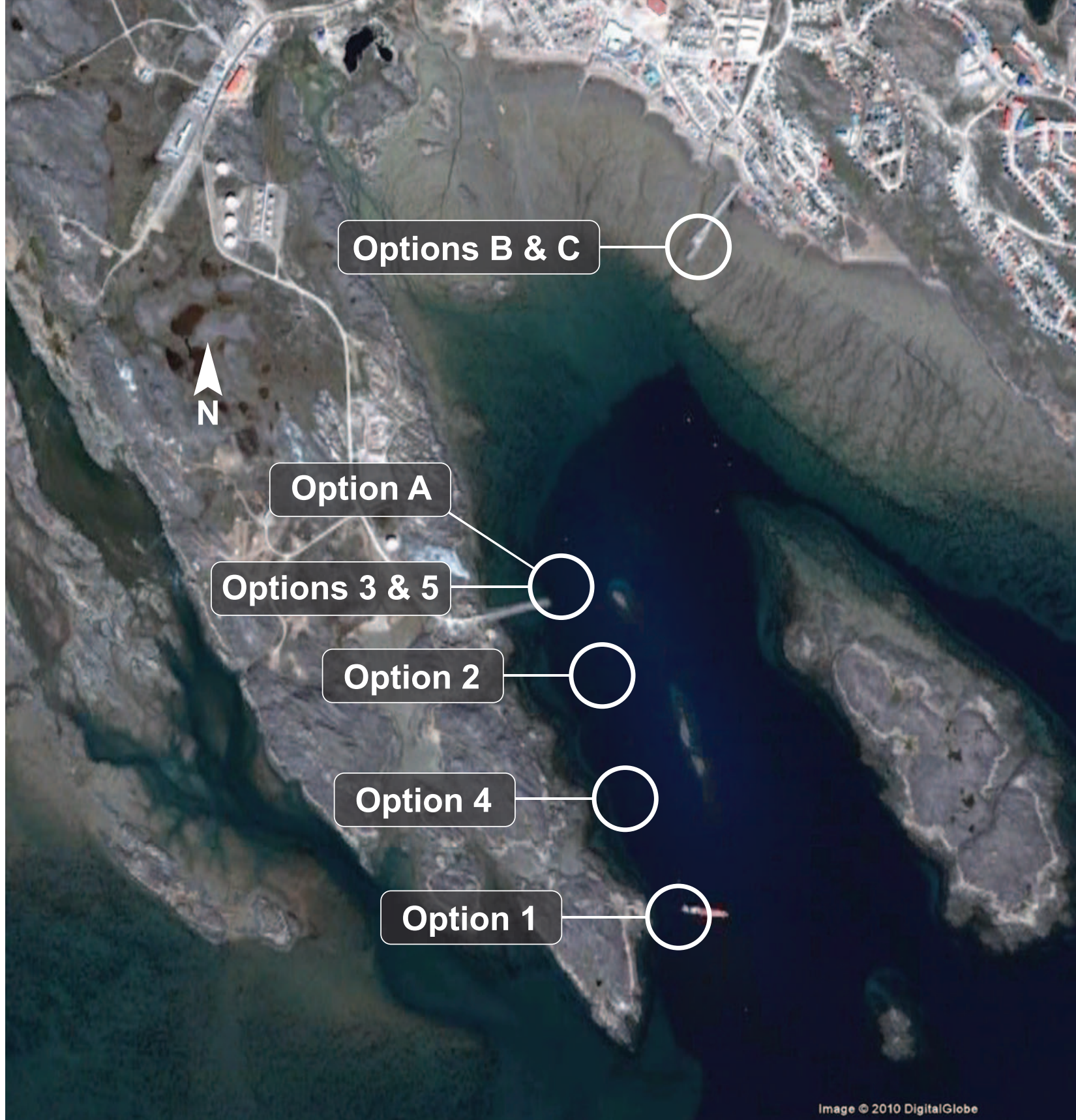
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## **Appendix G Open House Display Boards, June 21, 2010**

# IQALUIT PORT DEVELOPMENT



**WorleyParsons**  
resources & energy



- Four deep sea dock options are considered, < located between Innuit Head and the old causeway
- Fifth cargo handling option is based on twin < ramps and an upgrade to the old causeway
- Three small craft harbour options are < considered, including at the old causeway and municipal breakwater
- General improvements to municipal breakwater < facilities

## ADDITIONAL WORK COMPLETED

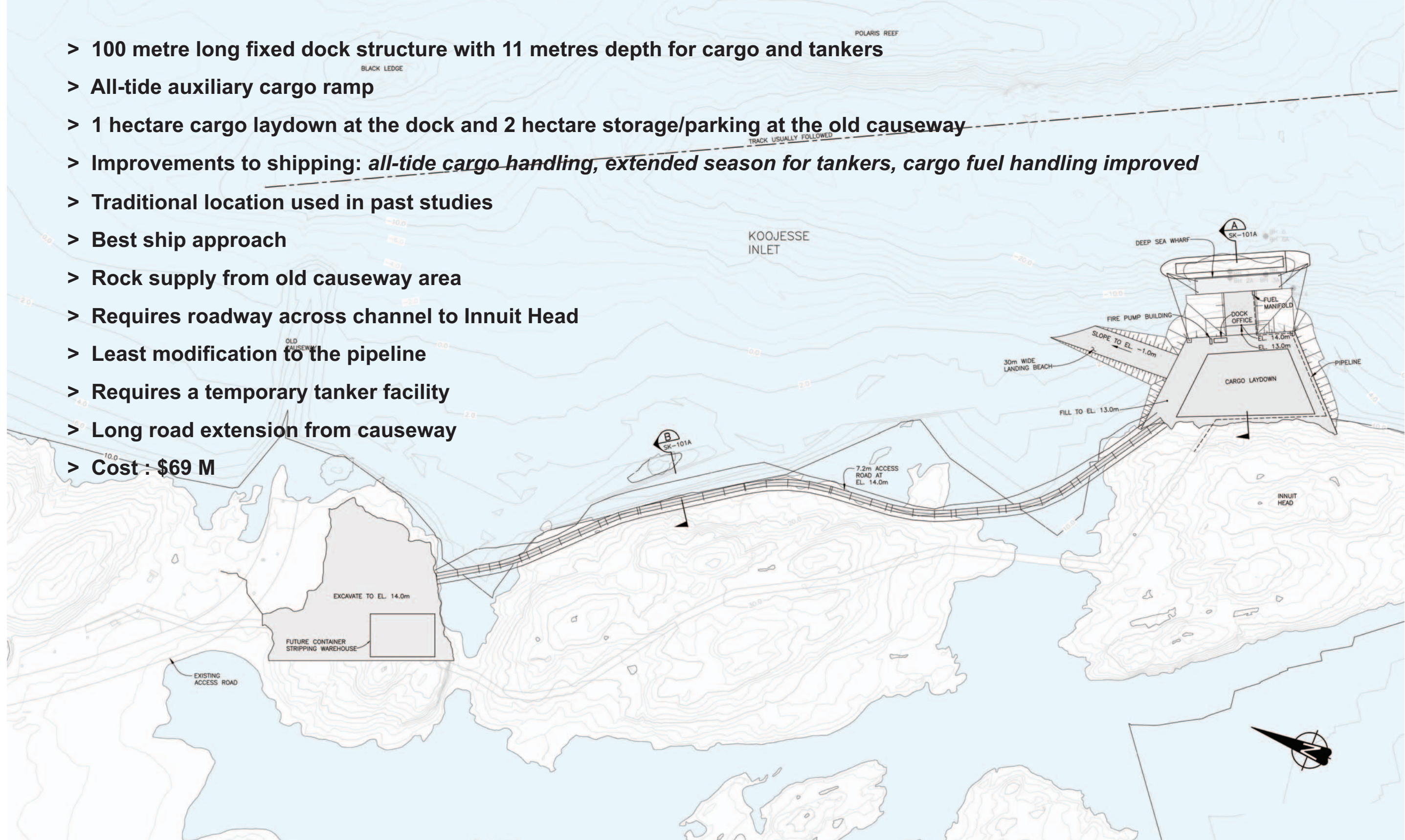
- Topographic survey in the tidal zone <
- Fish habitat assessment <
- Geophysical survey (acoustic sub-bottom profiling) <
- Assessment of environmental conditions (wind, < waves, ice)
- Desktop geotechnical study (based on historic < geotechnical work and latest geophysical)

# OPTION 1 - INNUIT HEAD



**WorleyParsons**  
resources & energy

- > 100 metre long fixed dock structure with 11 metres depth for cargo and tankers
- > All-tide auxiliary cargo ramp
- > 1 hectare cargo laydown at the dock and 2 hectare storage/parking at the old causeway
- > Improvements to shipping: *all-tide cargo handling, extended season for tankers, cargo fuel handling improved*
- > Traditional location used in past studies
- > Best ship approach
- > Rock supply from old causeway area
- > Requires roadway across channel to Inuit Head
- > Least modification to the pipeline
- > Requires a temporary tanker facility
- > Long road extension from causeway
- > Cost : \$69 M

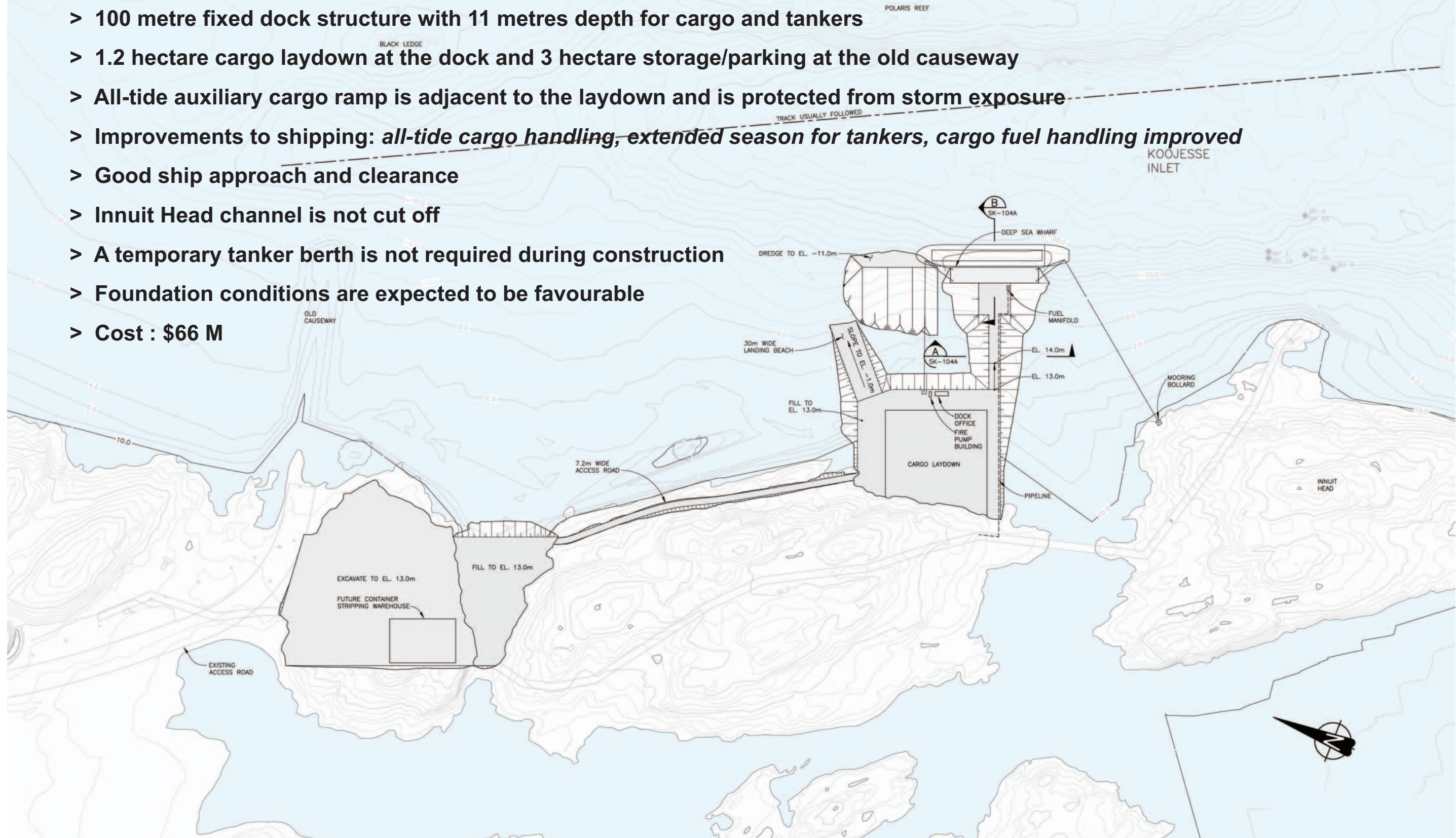


# OPTION 4 - SOUTH POLARIS REEF



**WorleyParsons**  
resources & energy

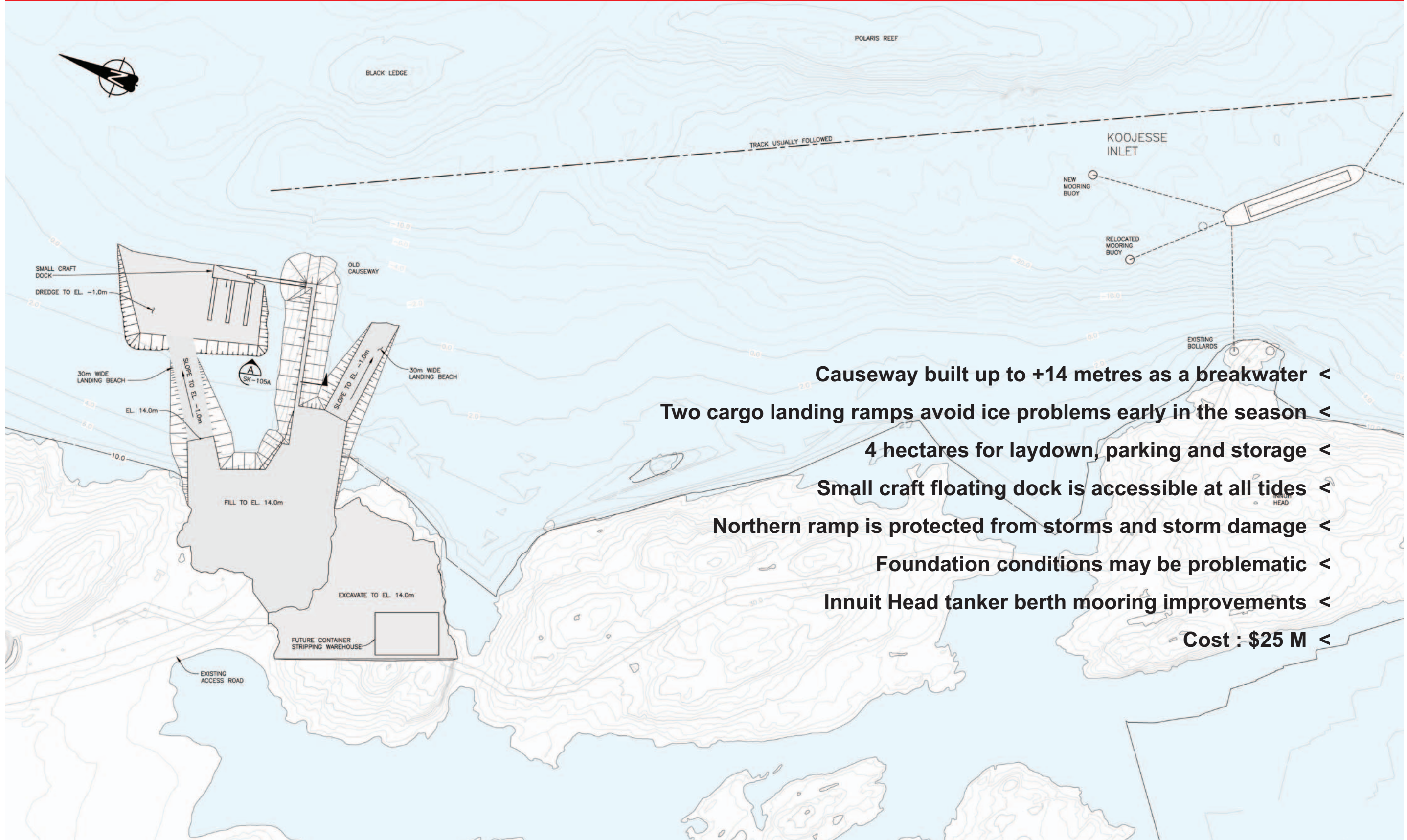
- > 100 metre fixed dock structure with 11 metres depth for cargo and tankers
- > 1.2 hectare cargo laydown at the dock and 3 hectare storage/parking at the old causeway
- > All-tide auxiliary cargo ramp is adjacent to the laydown and is protected from storm exposure
- > Improvements to shipping: *all-tide cargo handling, extended season for tankers, cargo fuel handling improved*
- > Good ship approach and clearance
- > Innuit Head channel is not cut off
- > A temporary tanker berth is not required during construction
- > Foundation conditions are expected to be favourable
- > Cost : \$66 M



# OPTION 5 - Twin Ramps at Old Causeway

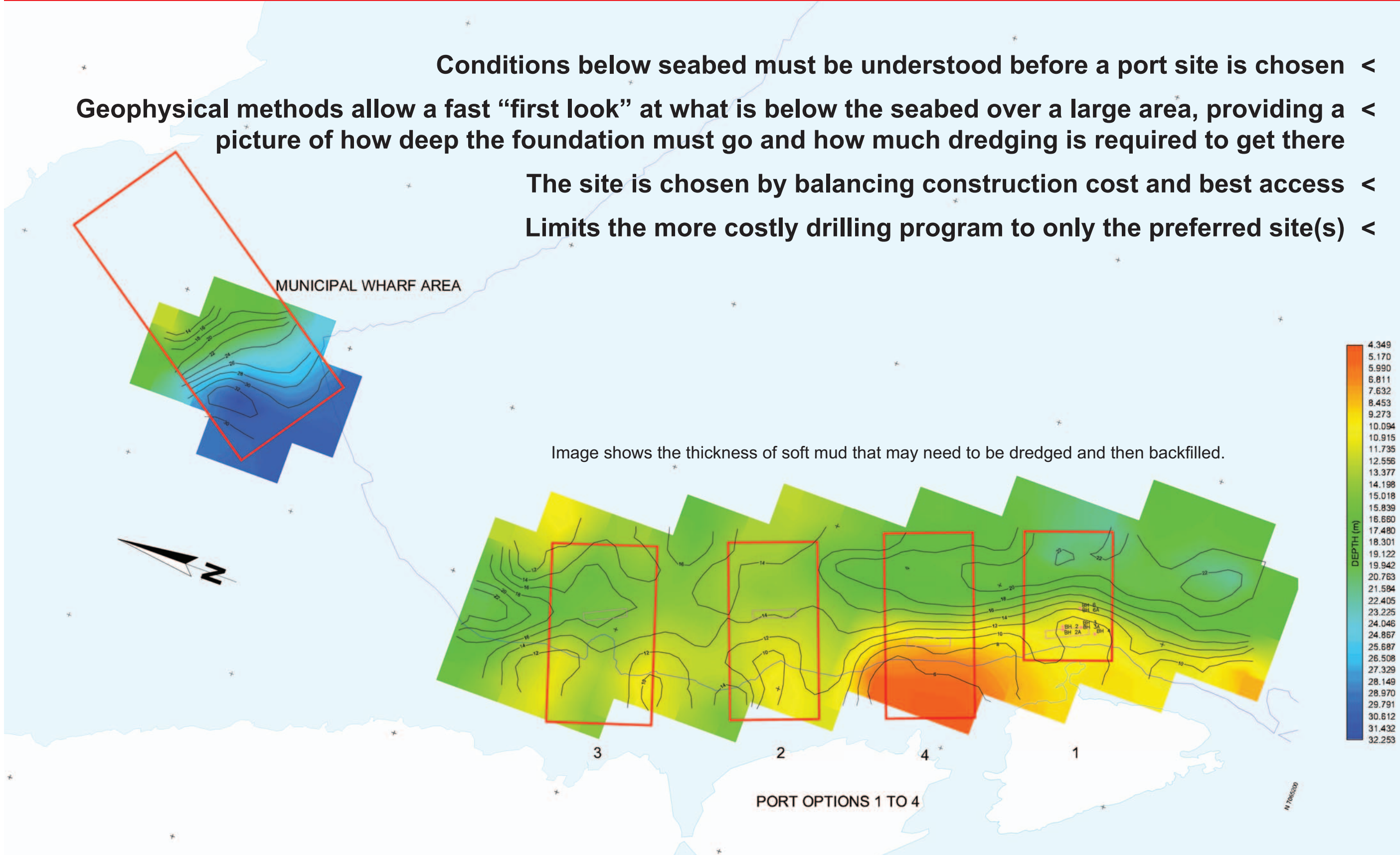


**WorleyParsons**  
resources & energy

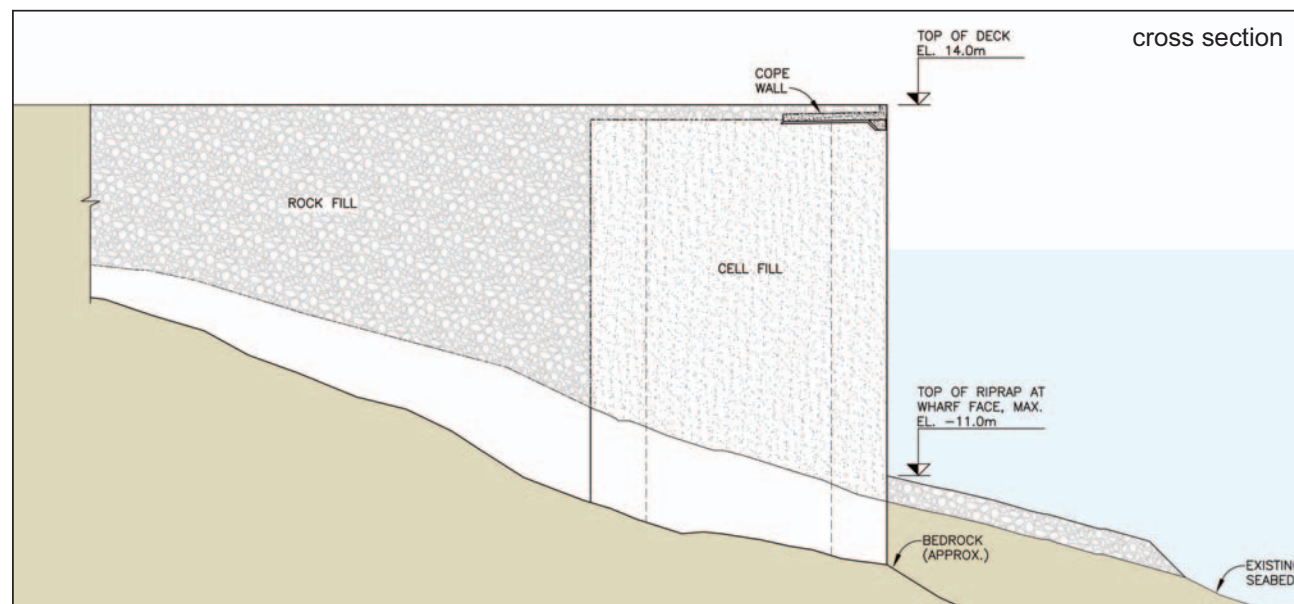
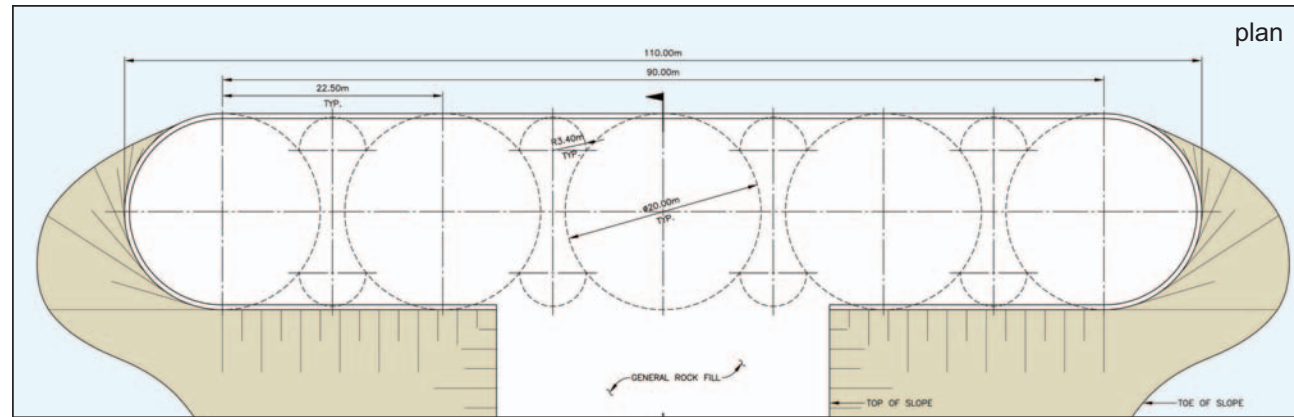


- Causeway built up to +14 metres as a breakwater <
- Two cargo landing ramps avoid ice problems early in the season <
- 4 hectares for laydown, parking and storage <
- Small craft floating dock is accessible at all tides <
- Northern ramp is protected from storms and storm damage <
- Foundation conditions may be problematic <
- InnuIt Head tanker berth mooring improvements <
- Cost : \$25 M <

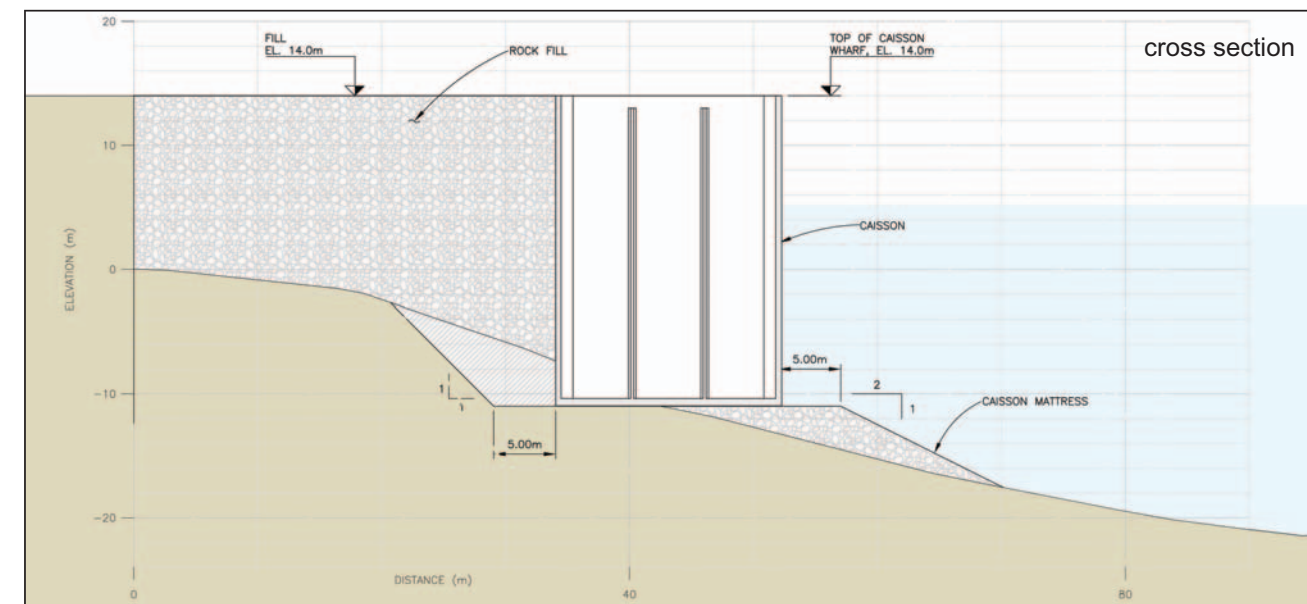
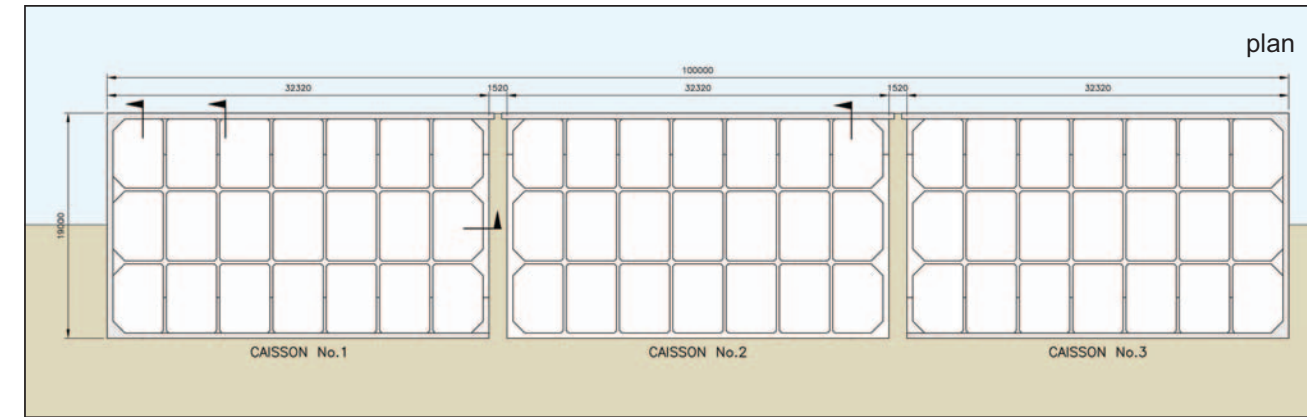
- Conditions below seabed must be understood before a port site is chosen <
- Geophysical methods allow a fast “first look” at what is below the seabed over a large area, providing a picture of how deep the foundation must go and how much dredging is required to get there <
- The site is chosen by balancing construction cost and best access <
- Limits the more costly drilling program to only the preferred site(s) <



## SHEET PILE CELLS



## CAISSONS



- > 100 metres long by 19 metres wide wharfhead
- > 11 metres depth alongside
- > Deck at +14 metres
- > Two structure options; concrete caissons like Deception Bay or steel sheet piles like Voisey's Bay, Polaris and Nanisivik
- > Concrete caissons likely the economical choice for Iqaluit



New Caisson Wharf Structure at Deception Bay Prior to Filling with Gravel



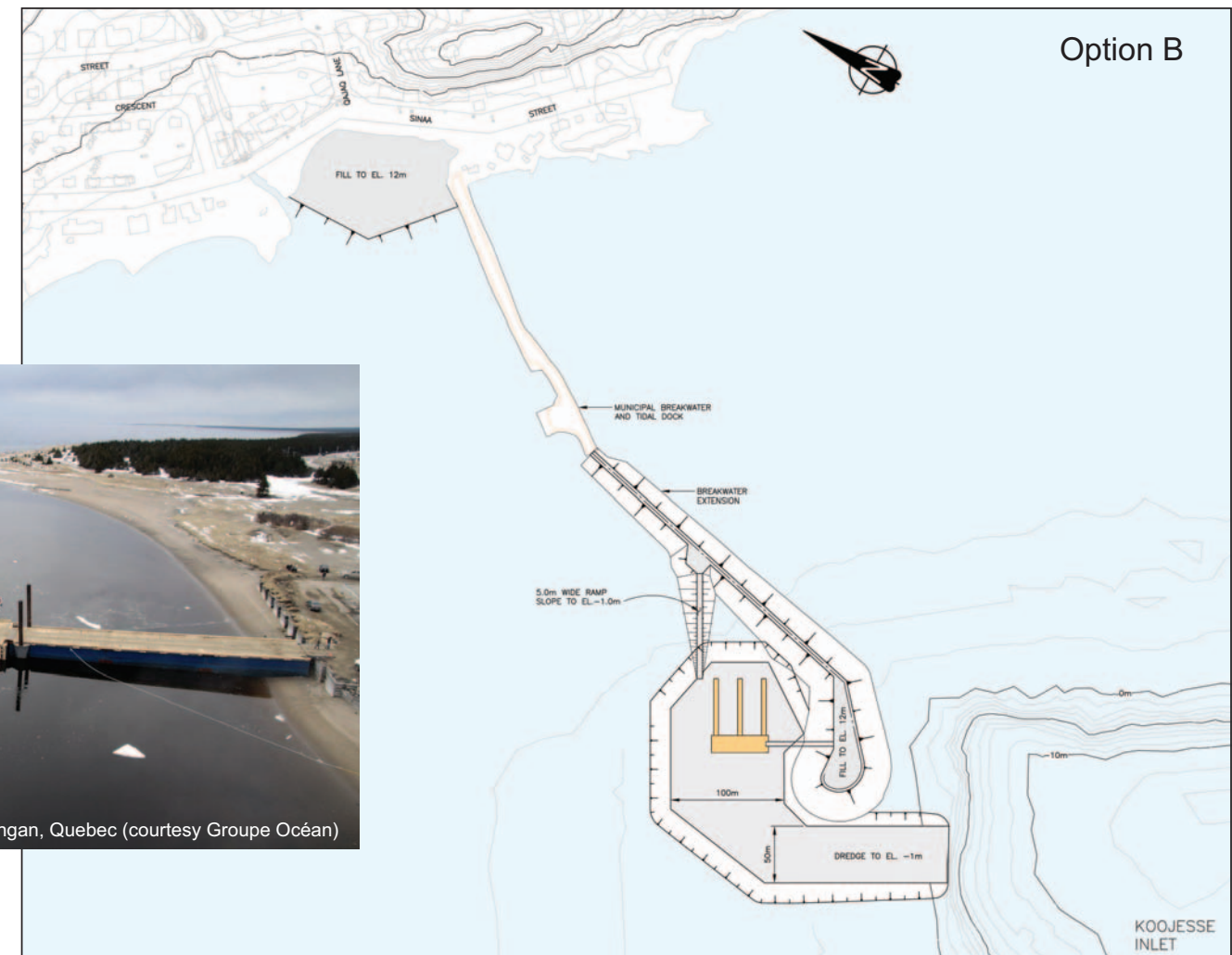
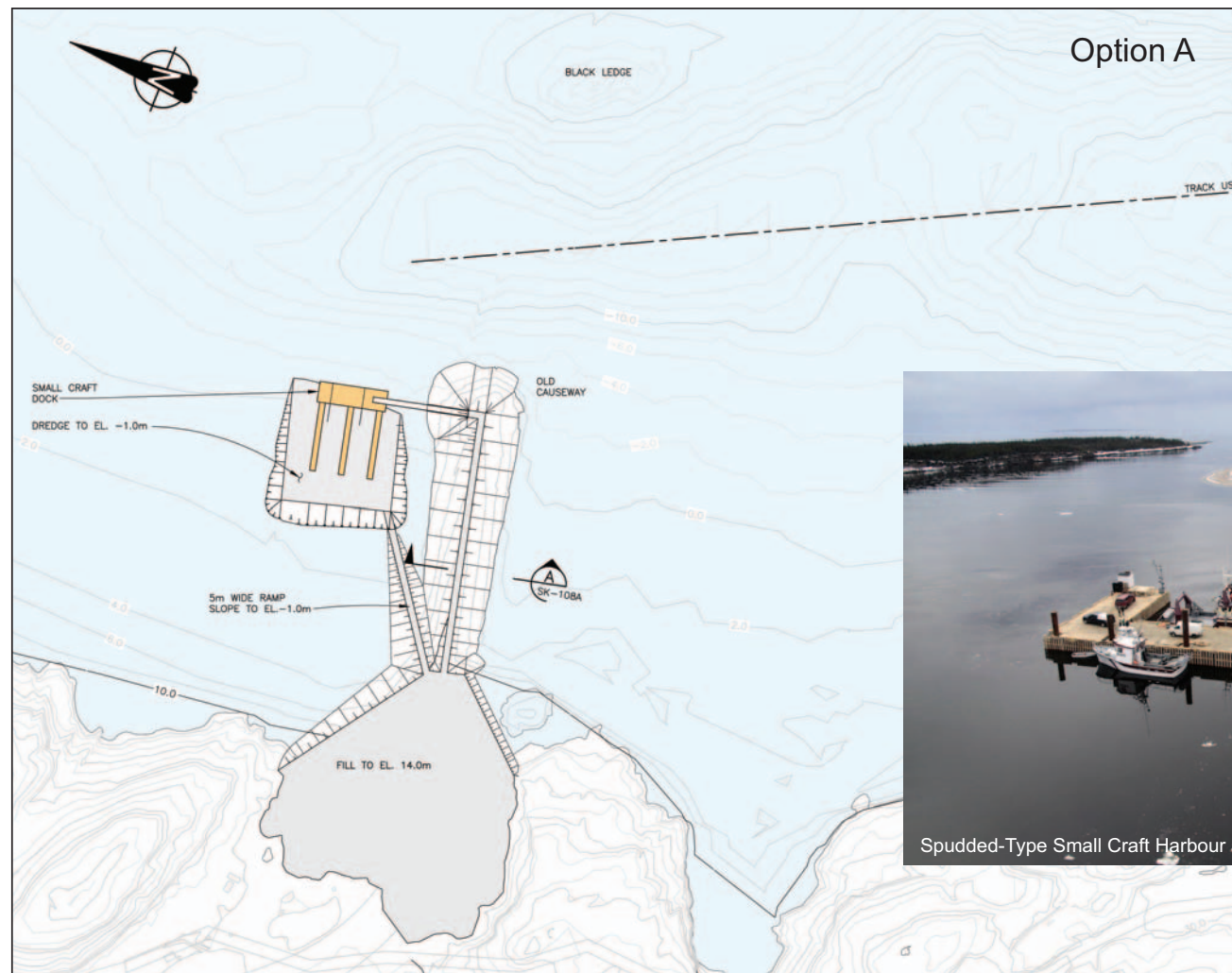
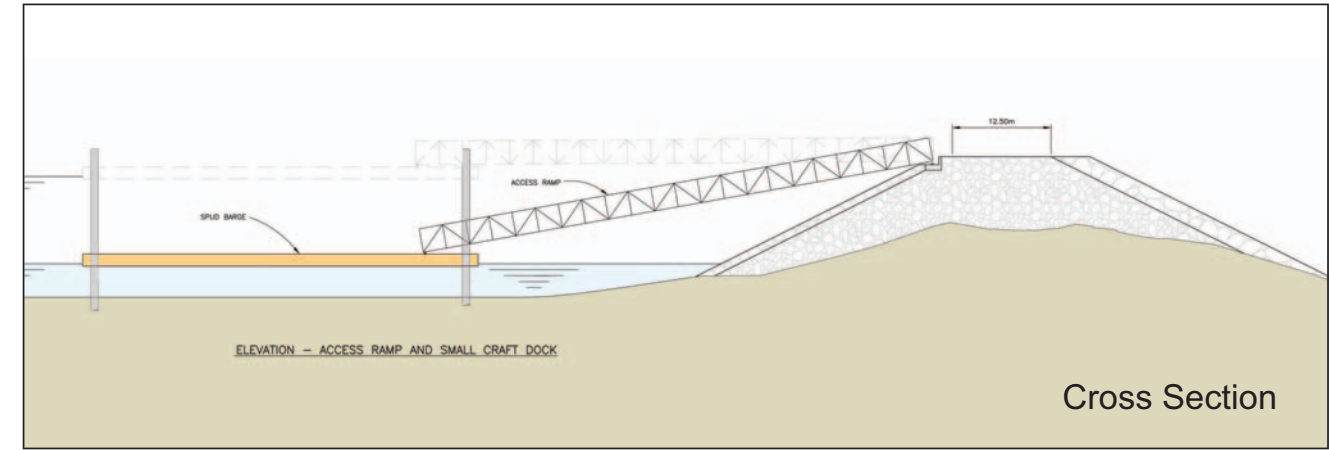
New Steel Sheet Pile Wharf Under Construction at Voisey's Bay

# SMALL CRAFT HARBOUR



**WorleyParsons**  
resources & energy

- > Location A – upgrade of old causeway
- > Location B – extension to municipal breakwater
- > Features : all-tide accessible boat launching ramp and docks, 15m x 50m main dock with ATV access, optional three 4m x 50m finger floats
- > Spud-barge-type concept as conceived by Groupe Océan is removed and beached for the winter
- > Cost estimate : Option A - \$15 M    Option B - \$21 M

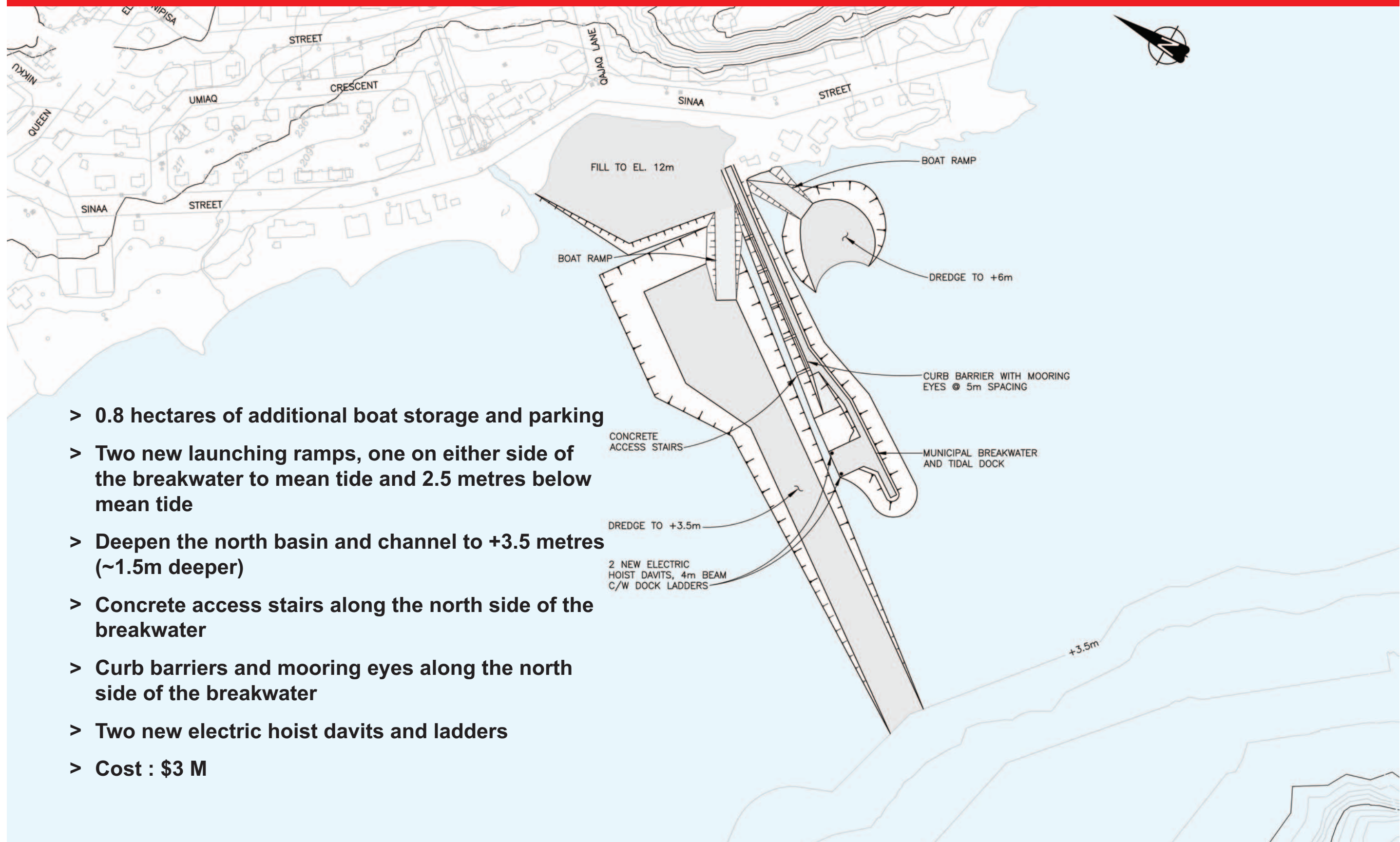


Spudded-Type Small Craft Harbour at Mingan, Quebec (courtesy Groupe Océan)

# MUNICIPAL BREAKWATER IMPROVEMENTS



**WorleyParsons**  
resources & energy



- > 0.8 hectares of additional boat storage and parking
- > Two new launching ramps, one on either side of the breakwater to mean tide and 2.5 metres below mean tide
- > Deepen the north basin and channel to +3.5 metres (~1.5m deeper)
- > Concrete access stairs along the north side of the breakwater
- > Curb barriers and mooring eyes along the north side of the breakwater
- > Two new electric hoist davits and ladders
- > Cost : \$3 M