Sanirajak

Marine Infrastructure Planning Study

Municipality of Sanirajak

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1 Introduction

1.1 Background

Advisian has been engaged by the Hamlet of Sanirajak (Hall Beach) to undertake a planning study for the development of marine infrastructure at Sanirajak, Nunavut.

The intent of this study is to assess the marine infrastructure needs in Sanirajak while exploring the key issues and goals of the Project. Aspects of the study span various elements, including environmental, geotechnical, cost, and engineering factors. The goal of the construction is to facilitate improved marine access for hunters, fishers, outfitters, and emergency response, while protecting the marine equipment owned by community residents. As most residents rely on country food as their primary food source, a key goal is to have infrastructure that supports local harvesting activities. The study also assesses the socio-economic benefits of improved marine infrastructure and provides initial concepts for the required marine infrastructure.

Sanirajak has been identified as a community that would benefit significantly from investment in marine infrastructure based on local community development plans as well as the Nunavut Transportation Strategy. The marine infrastructure being proposed is intended to achieve the following benefits:

- Support safe access to the land and sea in the context of rapid environmental changes in the Arctic and in support of community fish harvesting and marine mammal harvest.
- Support the future development of an anticipated inshore commercial fishery, ensuring that local fishing operations have access to a safe harbour and landing facilities.

The planning study, when successfully completed, is the first step in achieving the above goals and will better position the Hamlet for upcoming marine infrastructure funding opportunities.

1.2 Scope of Study

The scope of work includes:

- Review of available existing information and data.
- Geological desktop assessment and geophysical survey.
- Basic assessment of coastal processes.
- Engagement with relevant stakeholders such as residents, Hamlet council, the Sanirajak Hunters' and Trappers' Association (HTA), the Government of Nunavut's (GN) Department of Community and Government Services (GN-CGS) and the GN's Department of Economic Development and Transportation (GN-EDT) to define project needs. Consultations within the community include three visits:
  - The first involving an initial reconnaissance meeting with key community members and stakeholders to understand needs, preferences and understanding how users' interface with the marine environment.

- The second, during open water season, to further evaluate community marine use, assess sealift operations, and to present options developed that are based on the feedback from the first visit.
- And the third to present the report findings.

- Site reconnaissance completed together with the first and second community consultations.
- Initial concept development, involving three options.
- Class D cost estimate.
- Draft and Final reports including a socio-economic benefits assessment.

1.3 Approach to Consultation

A critical component to the Study was the engagement and collaboration of community leaders, hunters, fishers, other key users and stakeholders. Early dialogue allowed the Study team to learn from the local community and understand their needs and priorities while communicating the objectives, constraints, and realities of marine infrastructure development in Sanirajak. Such dialogue supports building a mutually beneficial, trusting relationship and nearly always results in better project delivery through designs and plans that address local conditions and manage communities' expectations and concerns.

Consultation for the study included meetings with the Hamlet and design workshops with the HTA. Information booths were set at up at both the Co-op store and the Northern store to obtain feedback from residents. Additional ad-hoc meetings with the Chief Administrative Officer (CAO) and community service providers were conducted by community researcher, Solomon Allurut, to support the socio-economic baseline. Local interpreters were hired to facilitate discussions as required.

1.4 Past Studies

The following previous studies and information are available in support of the planning study report:

- "Breakup of Limestone Bedrock by Frost Shattering and Chemical Weathering, Eastern Canadian Arctic", L.A. Dredge, 1992.
- "Erosion Cost Benefit Analysis", exp Services Inc., November 2016.
- "From Science to Policy in the Eastern Canadian Arctic, Chapter 8", ArcticNet, 2018.
- "Hall Beach Coastal Protection Assessment – Conceptual Design Options", W.F. Baird & Associates Coastal Engineers Ltd., November 2016.
- "Hall Beach Nunavut – Climate Change Adaptation Action Plan", Hemmera and Compass Resource Management, March 2008.
- "Infrastructure for a Sustainable Hall Beach Vol.1 Community Priorities", Aarluk Consulting Inc., March 2011.
- "Infrastructure for a Sustainable Hall Beach Vol.2 Consultation Report", Aarluk Consulting Inc., September 2010.
- "Overwater Acoustic Profiling and Marine Seismic Refraction Survey Report Harbour Project – Sanirajak, NU", Frontier Geosciences Inc., January 2022.

- “Preliminary Design Report – Floating Dock 14.4 m x 3.6 m for Installation in Nunavut Communities”, Jivko Engineering, January 2008.
- “Quaternary Geology of Northern Melville Peninsula, District of Franklin, Northwest Territories”, L.A. Dredge, 1995.
- “The Geology of the Igloolik Island Area, and Sea Level Changes”, L.A. Dredge, 1992.

2 Site Description

2.1 General

Nunavut is the northernmost territory of Canada's 13 provinces and territories and officially became a territory in 1999 with the capital located at Iqaluit on Baffin Island. Nunavut consists of 1,936,113 km^2 of land area which comprises approximately 21% of the total Canadian land area, the largest of any province or territory. According to 2021 census data, the total population of Nunavut is 36,858, which is approximately 0.1% of Canada's population (Statistics Canada 2022).

This report focuses on marine infrastructure development in the Hamlet of Sanirajak, Nunavut (68°47′25″N 081°14′15″W). Sanirajak is within the Qikiqtaaluk Region of Nunavut and is approximately 69 km south of Igloolik, as shown in Figure 2-1.

Figure 2-1 Nunavut Communities

Sanirajak is 245 km north of the Arctic Circle and has a tundra climate, with no month having an average temperature above 10 °C. The community was first formally recognized during the Cold War era, during which a string of Distant Early Warning (DEW) radar sites was built along the 70th parallel in 1957 to monitor northern Canadian air space. The DEW station in Sanirajak was decommissioned a few years later when new technologies made half of the DEW radar stations obsolete. It has since been replaced with a more technologically advanced North Warning System (NWS) radar site.

The community of 891 (Statistics Canada 2022) is supplied via sealift several times throughout the shipping season and is accessible by airline service from Iqaluit, Nunavut. The community has a mixed economy, combining various wage-based positions with traditional subsistence activities such as hunting, fishing, and gathering.

The community has recently seen investments in municipal projects, including:

- $10.0 million for the upgrade to the airport runway, taxiway, and lighting;
- $5.2 million for a Community Hall expansion;
- $3.1 million for the construction of a new Fire Hall; and
- $2.7 million for the construction of a new parking garage.

2.2 Marine Infrastructure and Operations

2.2.1 Marine Infrastructure

Most marine activities, including dry cargo sealift and boating, occur on the waterfront adjacent to the main part of the Hamlet between the tank farm and residential houses. At the start of each season, a loader from the first sealift ship clears the beach of accumulated gravel, down to the bedrock. Figure 2-2 and Figure 2-3 below show typical sealift operations.

Figure 2-2 Sealift barge with tug at beach with loader installing ramp (courtesy of CBC's High Arctic Haulers series)

Figure 2-3 Front end loaders removing ramp after unloading operations, tank farm in background (courtesy of CBC's High Arctic Haulers series)

In 2008, the GN-EDT designed a floating dock system to be built for various Nunavut communities. Sanirajak was selected as one of these communities, and the dock was later constructed in 2009. The dock is located 3.5 km north of the community, in a semi-protected cove that dries at low tide. The structure is comprised of a 14.4 m by 3.6 m floating platform, with two access ramps each 2.4 m wide, as shown in Figure 2-4 below.

Figure 2-4 Sanirajak floating dock

The dock uses steel pipe pontoons for flotation that allow it to move with the tide, and has a davit installed on the offshore end. It is only used by a few residents due to the distance from the rest of the community and is only useable at high tide as the area dries at low tide.

Approximately 3.5 km south of the community, the remains of an old military jetty constructed from round caissons (large diameter corrugated culvert pipes) can be seen on the waterfront in a satellite image from 2004, as shown in Figure 2-5. The jetty suffered significantly from exposure to storm waves and ice action and fell into disrepair. It was demolished in the 2010s. It is assumed that this wharf was used by the large NTCL barges that used to supply cargo from Churchill, MB.

Figure 2-5 DEW Line Jetty in 2004 (Google Earth)

The tanker moorings and fuel manifolds for fuel resupply are located at the shoreline approximately 800 m southeast of the Sanirajak airport, adjacent to the site of the old DEW Line Jetty and is shown in Figure 2-6 below.

Figure 2-6 Sanirajak fuel manifolds

2.2.2 Vessel Traffic

Based on information received from NORDREG, a summary of 2014 to 2019 Eastern Arctic passenger vessel activity, including the Northwest Passages is presented in Table 2-1. Table 2-1 provides a sense of how much passenger related traffic there was in the Eastern Arctic in each year.

Table 2-1 Eastern Arctic Passenger Related Vessel Activity

Vessel Type	2014	2015	2016	2017	2018	2019
Cruise Ships	8	9	11	12	11	15
Mega Yachts (30 m in length or greater)	2	3	5	3	4	6
Adventurers (Less than 30 m in length).	29	20	17	29	14	13

Sanirajak does not currently receive any cruise/passenger ship calls but does occasionally get adventurers (usually sailboats) as a result of the nearby Fury and Hecla Strait, which provides a shortened route to and from the Northwest Passage. Dry cargo and fuel ship calls for 2020 and 2021 are summarized in Table 2-2.

Table 2-2 Sanirajak Dry Cargo and Fuel 2020/2021 Ship Calls

2020 Ship Calls				2021 Ship Calls			
Type	Ship Name	Arrival Date	Departure Date	Type	Ship Name	Arrival Date	Departure Date
Dry Cargo	M/V Nunalik	21-Aug	22-Aug	Dry Cargo	M/V Mitiq	3-Sep	4-Sep
Dry Cargo	Sedna Desgagnés	31-Aug	1-Sep	Fuel	Tuvaq W	20-Sep	25-Sep
Dry Cargo	Sedna Desgagnés	3-Sep	6-Sep	Dry Cargo	Zélada Desgagnés	18-Sep	22-Sep
Fuel	Tuvaq W	17-Sep	22-Sep	Dry Cargo	Rosaire A. Desgagnés	8-Oct	10-Oct

Based on a visual survey in September 2021, the number of small craft vessels in the community are listed as follows:

- There are an estimated 46 boats in the community (18 aluminum, 15 canoes, 11 fibreglass, and 2 wooden skiffs). Some of these boats may no longer be in use.
- The HTA has one of the largest boats in Sanirajak with a Silver Dolphin 24.
- There are approximately 13 boat trailers in the community. Thus, most boat owners pull their boats up along the shoreline at high tide.
- Most of the boats on trailers are located at the owners' residences.
- Boats at the shoreline are usually pulled up to above high water using a pickup truck or ATV and pulling over timber sleepers.

2.2.3 Fuel

The figures provided are indicative volumes from the GN's Petroleum Products Division (PPD) for annual fuel purchases from the 2017/18 season. They are not actual quantities delivered. Because of the size of the community, and very slow population changes, these are not expected to materially change into the future.

- Diesel: 2,800 m^3
- Mogas: 300 m^3
- Jet A1: 540 m^3

The marine infrastructure associated with fuel receiving comprises of three onshore receiving manifolds and four bollards distributed along the shoreline. The manifolds are located 800 m southeast from the airport on a flat gravelly area approximately 50 m from shore. The north manifold is dedicated to the community tank farm, while the south set of manifolds serve the Department of National Defense.

In 2017, there were upgrades to the fuel storage facility in Sanirajak due to code deficiencies resulting from Environment Canada's new codes under the Canadian Environmental Protection Act (CEPA). Since then, the facility has been upgraded and is now code compliant.

2.2.4 Cargo Handling

Cargo shipping operations are provided by Nunavut Eastern Arctic Shipping (NEAS) and Nunavut Sealink and Supply Inc. (NSSI). NSSI won the GN dry cargo contract for the community in 2012 and has had it since. The data reported by the carriers excludes private cargo, particularly anything for the Co-op and Northern Stores. In all years reported, both carriers will also call with private cargo. A summary of the cargo quantities is provided in Table 2-3.

In Sanirajak, the Co-op is served by NSSI and the Northern store is served by NEAS. Their quantities are not provided in Table 2-3.

*Table 2-3 NSSI Community Dry Cargo Data**

Cargo Volumes	2016	2017	2018	2019	2020
Cube	3,150	450	340	1,800	6,770
Tonnes	780	90	65	600	1,525
Rev. Tonnes	1,250	160	115	425	2,180
Cube/Tonnes	4.0	4.9	5.3	4.5	4.4

**Excludes private cargo and store deliveries by NEAS/NSSI.*

Dry cargo is lightered to shore in the conventional manner using small tugs and barges that are carried on board the arriving ship. Generally, the sealift carriers are contractually required to deliver the cargo to the high-water mark, where it is usually taken by a local cartage company (in this case the Hamlet) or the owner from the temporary stored location into the community. The sealift beach is cleared at the start of each season of any accumulated sediments, gravel, and boulders by loader.

Figure 2-7 Barge lightering operations at Sanirajak sealift beach (2021). Supply ship is shown anchored in the background.

2.3 Population and Forecasts

2.3.1 Population Forecasts

The 2021 Census reported the total population of Sanirajak to be 891, representing an increase of 5.1% since 2016, a comparable level of growth to other communities in Nunavut.

The Nunavut Community Population projections for 2014-2035 prepared by the Nunavut Bureau of Statistics in 2014 are presented in Table 2-4.

Table 2-4 Nunavut Bureau of Statistics Forecast 2014

Description	2021 (Forecast)	2021 (Actual)*	2025	2030	2035
Population	1,044	891	1,122	1,215	1,311

**2021 actual is Census Population. Population estimates take into account net under coverage determined from postcensal coverage studies.*

2.3.2 Cargo Forecasts

Population has been found to provide a good indication of both current and future dry cargo demand. Because formal data is not readily available, dry cargo demands are estimated[1] based on population. Average annual forecasts are shown in Table 2-5. This excludes large community infrastructure projects that will occur occasionally.

Table 2-5 Sanirajak Dry Cargo Forecast

Year	Dry Cargo (tonnes)	POL (tonnes)
2021	2,300	3,300
2025	2,500	3,600
2030	2,700	3,900
2035	2,900	4,200

In reviewing these estimates, the following should be noted:

- Fuel does not account for unique requirements such as major airport re-fuelling needs, Military, NWS, mining or exploration demands.
- A community heavily dependent on country food will have lower dry cargo needs.

2.4 Climate Change and Implications on Marine Infrastructure

The Earth's climate is changing. The average annual temperature in Canada has risen 1.7 deg. C. from 1948 to 2016, approximately double the global rate (Environment and Climate Change Canada 2017). Northern regions of Canada have experienced a more significant temperature increase of 2.3 deg. C over the same period- triple the global rate. Warming of the Arctic can translate to a longer open water season, increased marine shipping traffic, coastal erosion, permafrost melting, higher density of icebergs etc. which can influence infrastructure designs (see Figure 2-8).

[1] Based on 2.2 t per capita as an average dry cargo and 3.2 t per capita for fuel. Additional cargo is moved by air, mainly produce and other perishables. Capital expenditure in the community for housing, public buildings, etc. will increase the quantity shipped by sea.

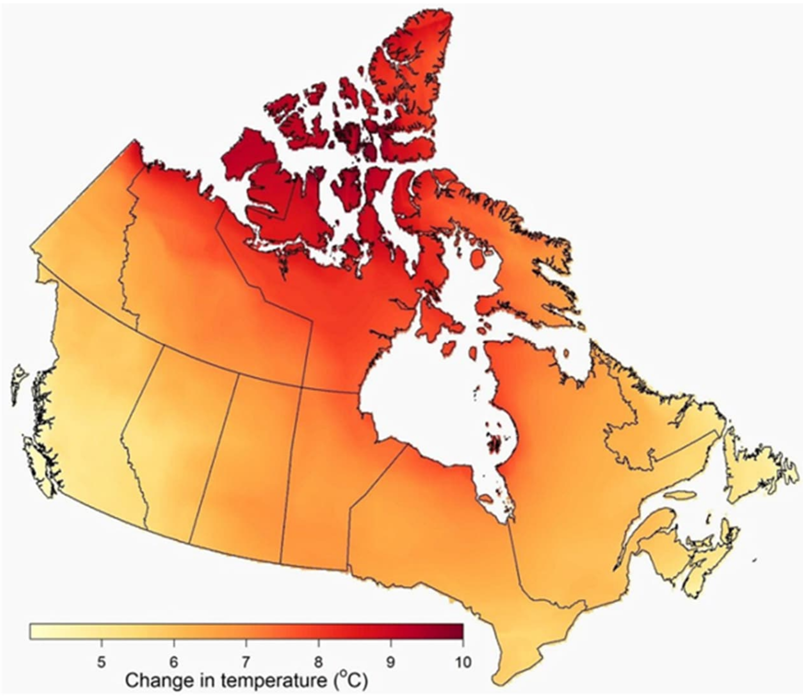


Figure 2-8 Projected Temperature Change, Based on 1986 to 2005 Average Temperatures

Warming in the Canadian Arctic has communities facing coastal erosion, sea-level rise, flooding, water supply issues, sea-ice cover decline and infrastructure instability due to permafrost melt.

When designing marine infrastructure, the influence of climate change such as increases in storm intensity, changes to water level, ice concentrations, and combinations thereof are of main concern. These topics are discussed in the following sections.

2.4.1 Ice Concentrations and Thickness

One of the major environmental forces against marine infrastructure in the Arctic is the formation, breakup, and movement of ice. There are four distinct cyclical icing conditions throughout the year: ice break-up, ice-free, freeze-up, and frozen. Based on the 30-year average from 1981-2010, the typical break-up date for Sanirajak is the week of June 18 (Figure 2-9) while freeze up occurs the week of October 22nd (Figure 2-10).

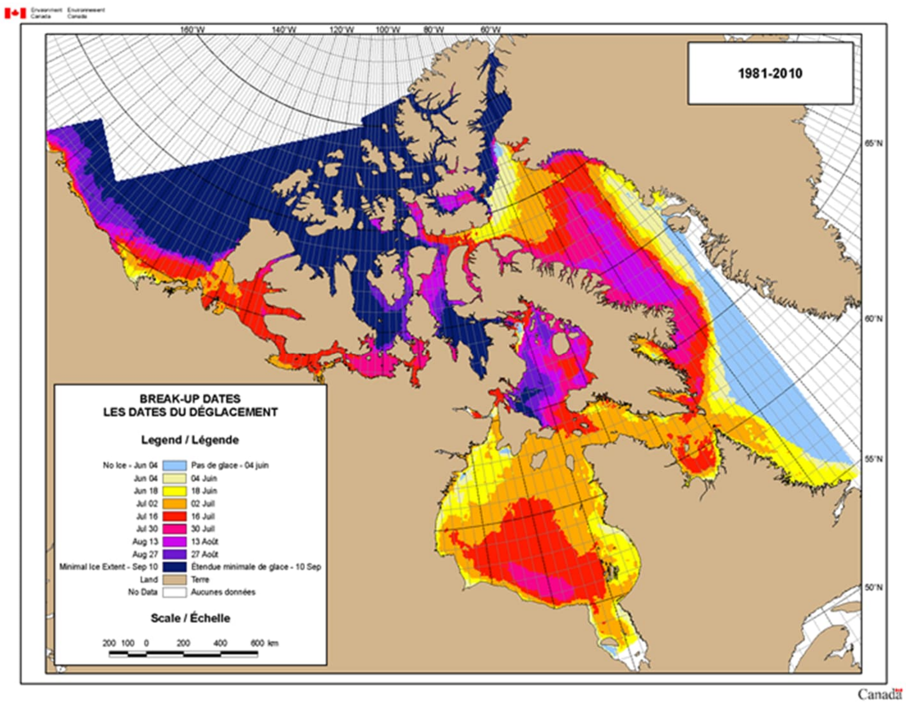


Figure 2-9 30-Year Ice Break-Up Dates (Canadian Ice Service)

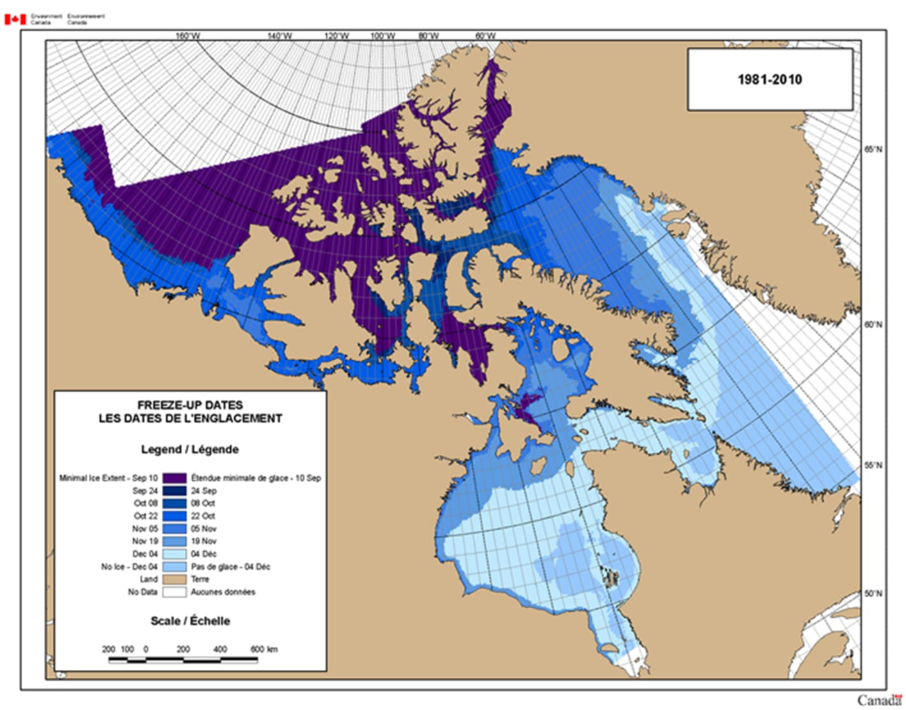


Figure 2-10 30-Year Ice Freeze-Up Dates (Canadian Ice Service)

Recent years are seeing the effects of climate change and the 30-year averages are not necessarily applicable. Ice charts and satellite images are presented in Appendix 4 for the most recent 10 years to provide a better indication of the annual variability. Due to Sanirajak's exposed location to Foxe Basin, ice floes are often blown towards the community from both the north and the south throughout the summer. The ice in Foxe Basin remains mobile throughout the winter with open leads frequently close to Sanirajak. This results in periodic break-up winter events close to shore. Ice charts and satellite imagery analysed in Appendix 4 categorize icing conditions as follows:

- Ice Break-Up: Ice along the community decreases to less than 1 km in width.
- Ice-Free: No visible ice along community and within a 5 km offshore radius of the community in satellite imagery.
- Freeze-up: Ice chart total concentrations of 7/10+ along the community (The Egg Code, Government of Canada).

Overall, the Arctic Ocean has been experiencing a significant reduction in multiyear sea ice (MYI). Currently approximately 70% of the Arctic sea ice is first year ice (FYI) and melts seasonally (Mersmann and NASA, 2018). This thin ice melts faster and breaks up easier than MYI and can be moved more easily by wind (Kwok 2018). Large sheets of ice floating into a marine structure can have higher impact forces than normal berthing energy, therefore the ice thickness is considered a crucial aspect in the design of marine infrastructure.

Yearly ice thicknesses and snow depth data is available for two time periods, from January 1959 to February 2000, and again from January 2003 to May 2018. The combined ice thickness and snow cover data for these two data sets is provided in Figure 2-11.

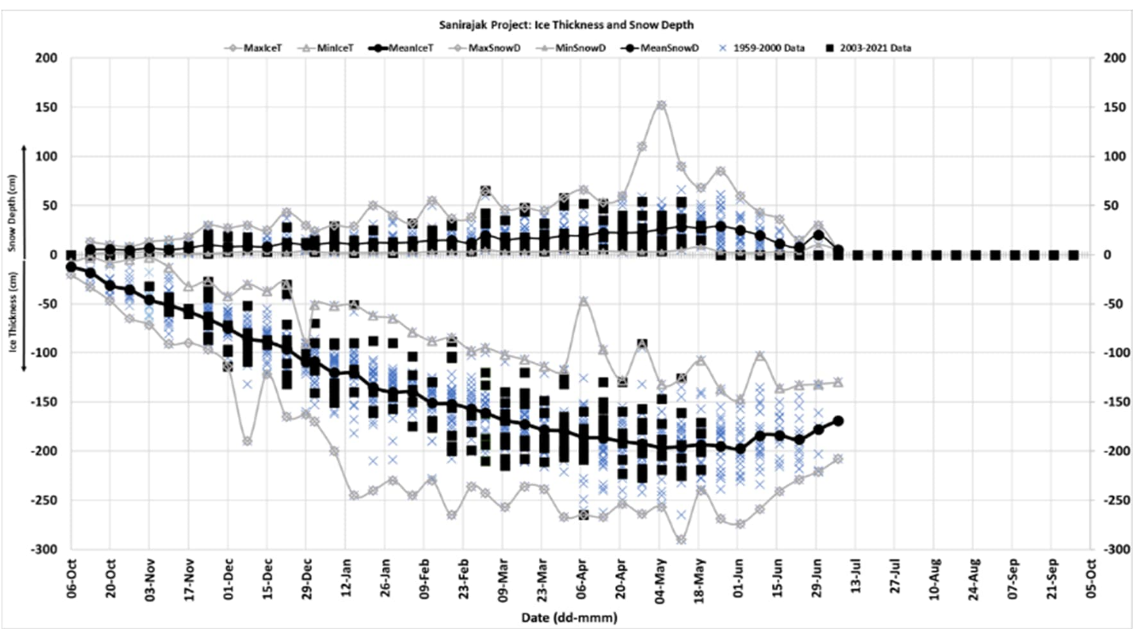


Figure 2-11 Combined ice thickness and snow depth data sets of 1959 to 2000 and 2003 to 2018 (Environment and Climate Change Canada)

The average of the individual data sets shows unexpected similar results in ice thickness, with the latest data set showing a shorter time from the start to the end of recordings, as provided in Figure 2-12.

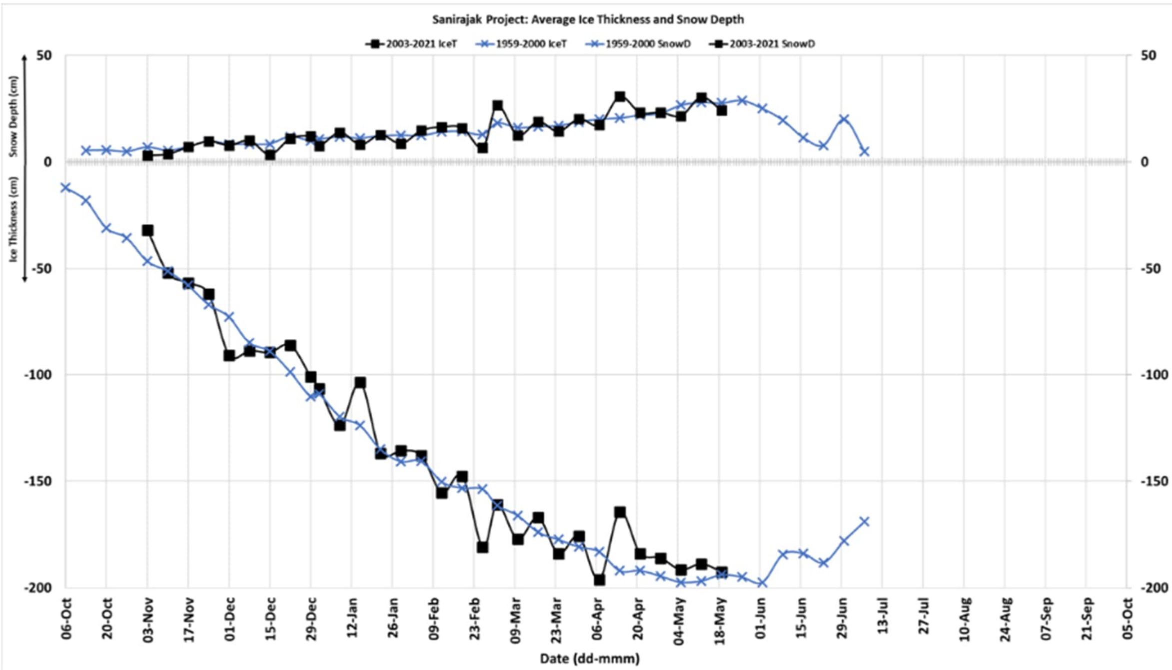


Figure 2-12 Average ice thickness and snow depth for data sets of 1959 to 2000 and 2003 to 2018 (Environment and Climate Change Canada)

The results do not show a trend towards thinner ice as predicted by others (Dumas et al, 2006; Hu et al, 2016), and the data shown in Figure 2-11 and Figure 2-12 indicate that thicker ice could actually be encountered before freeze-up and after break-up, in which case larger armour rock may be required in the breakwaters than allowed for herein, and this will need to be addressed in the next level of design.

Further ice studies using satellite imagery, ice charts and discussions with personnel involved in obtaining the data, should be done for detailed design, but for the purposes of this study the following is used for sizing the armour rock and calculating the forces on vertical sided structures:

- At freeze-up, it is assumed that large diameter cold ice floes with a thickness of 0.6 m could impact the breakwaters.
- At break-up, it is assumed that the ice is warm due to thermal radiation and warm air temperatures and could be present in large floes with a thickness of 1.5 m, which could impact the breakwaters.

Sanirajak is particularly susceptible to high impact forces from large sheets of floating ice, as the community is located on a shoreline exposed to Foxe Basin. Residents have reported ice pile-up events up to the second story, as close as 100 m from the homes of residents. These pile-up events can be extremely damaging to shorefront infrastructure and pose a safety risk. Figure 2-13 below shows a photo of a pile-up event in December 2005.

Figure 2-13 Sanirajak ice pile-up event in December 2005. Photograph provided by Manson and Forbes (personal communications 2016, source unknown)

An in-depth analysis has been conducted for the design of the breakwater with consideration of ice loads, specifically the crushing loads during periods of freeze-up and break-up. The analysis indicates that the largest loads are due to ice crushing loads during break-up.

Details on ice loads can be found in section 6.4.2 for breakwater design.

2.4.2 Sea Level Rise

As climate change is having increasing effects on sea level rise, consideration must be given to the potential impacts on coastal design.

Climate models developed by the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report (2021) indicate global sea level increases of 0.28 m (very low GHG emissions scenario) to 1.01m (very high GHG emissions scenario) by 2100. Relative sea-level change is a combination of sea-level change and any vertical land motion (rebound or subsidence). The reviewed literature does not provide specific subsidence or uplift data for Sanirajak, but Figure 2-14 provided by National Resources Canada indicates that Igloolik, a community 69km north of Sanirajak, is estimated to have almost a metre of vertical rebound between 2000 and 2100 based on median high-emission projections. It is expected that

Sanirajak will experience a negative relative sea level rise similar to Igloolik, primarily due to glacial isostatic rebound – a phenomenon that occurs at the end of each glacial period where the retreat of massive glacier weights leads to an uplift of the land and the flow of viscoelastic mantle back under deglaciated areas.

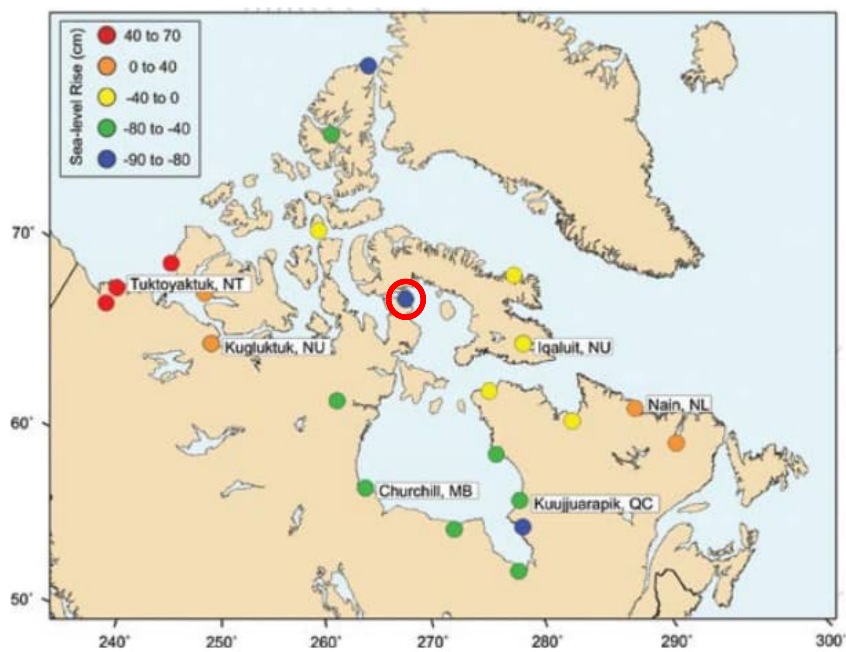


Figure 2-14 Selected Northern Communities with Predicted Net Sea Level Rise in 2100 (Source: Canada's Marine Coasts in a Changing Climate)

Figure 2-15 shows the predicted relative sea level change for Igloolik under various emission scenarios. Assuming a 75-year design life, the estimated net sea level rise is approximately -1.0 m by the year 2100 (i.e., the net is rebound of the land). Previous predictions have generally been well underestimated and on that basis, it is Advisian's practice to base the estimate on the 95% percentile curve. However, in Sanirajak's case, the local geology indicates that bedrock is very shallow and predictions of this much rebound must be carefully considered, especially if the estimated rebound is realized. To accommodate for current and future conditions, a relative sea level rise allowance of -0.5 m was used (95th percentile) to determine the minimum harbour depth. However, for the breakwater crest elevation, sea level rise (rebound) is not relevant.

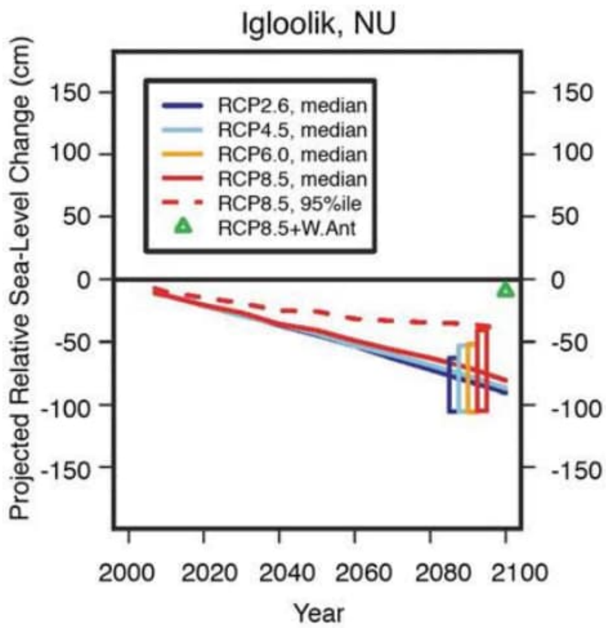


Figure 2-15 Selected Northern Communities with Predicted Net Sea Level Rise (Source: Canada's Marine Coasts In a Changing Climate)

Figure 2-16, produced by the Geological Survey of Canada, shows the sensitivity of Canada's coastlines to change in various factors. The sensitivity index shown was obtained by assigning scores of 1 to 5 attributed to each of six variables: decadal mean wave height, change in relative sea level, ground ice, coastal materials, backshore slope, and tide range. Sensitivity levels are not a measure of the additional water height due to sea level changes but rather the effect sea level change, as well as the other listed variables above, will have on an area. For example, a rocky shoreline with infrastructure built at a higher elevation will have a low sensitivity to sea level rise whereas a sandy shore with flatter upland will have a higher sensitivity. Sanirajak is considered to have high coastal sensitivity, as can be seen in Figure 2-16.

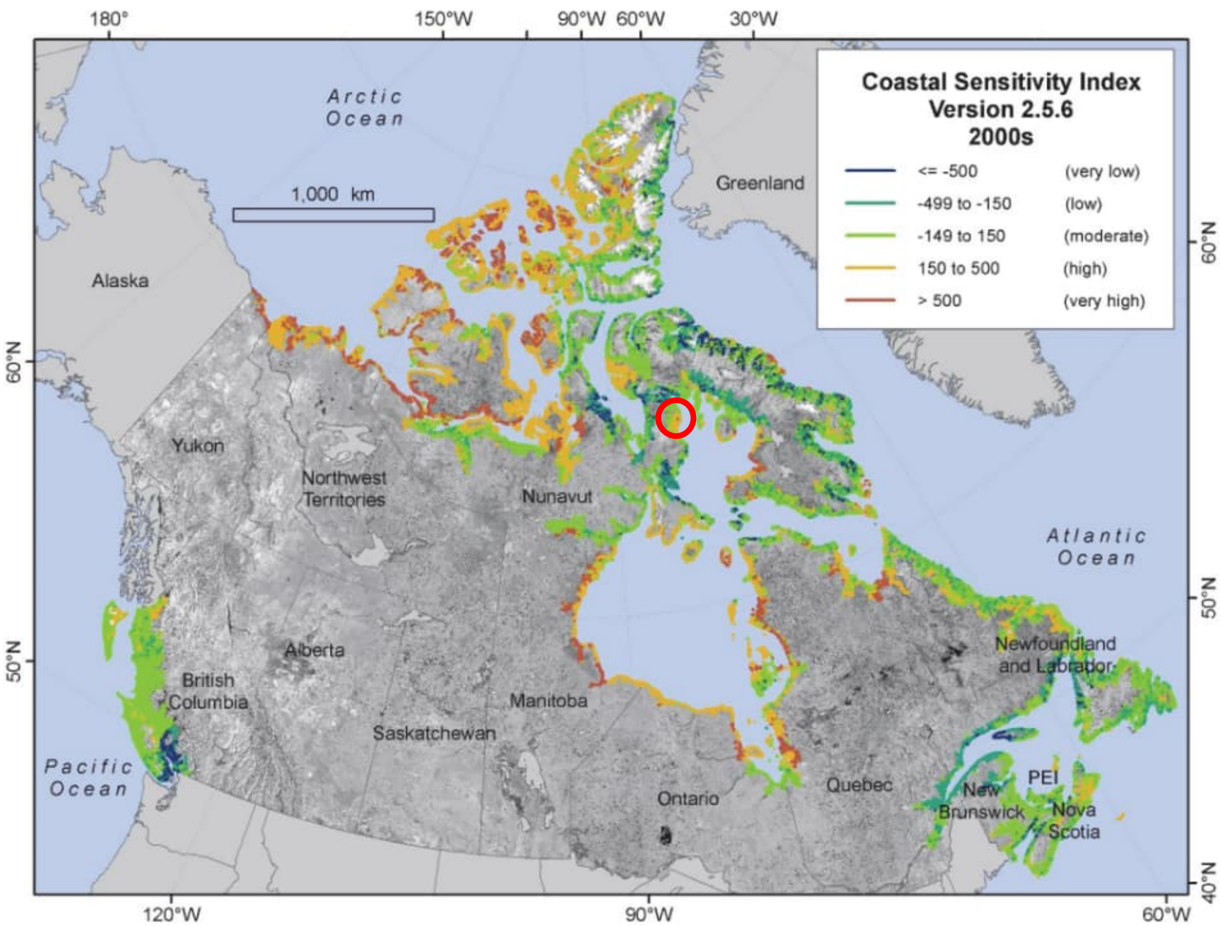


Figure 2-16 Coastal Sensitivity to Sea-Level Rise (Geological Survey of Canada 2019)

2.4.3 Shoreline Erosion

Sanirajak is situated on a raised gravel beach, with many of the houses built close to the shoreline in the 1980s. The community is highly exposed to strong wind waves, and the warming oceanwaters along with longer open water seasons will allow for greater storm surge and shoreline erosion. Reduced land-fast ice, which normally provides protection from erosion, will expose new areas to erosion and possible flooding.

Figure 2-17 shows eleven of the houses (#98 to #110) situated in the middle of the community that were indicated by the GN-CGS as high risk of being threatened by shoreline erosion. In the late 1990s and 2000, the footings of multiple houses were at risk of failing due to erosion caused primarily by large, infrequent storm events, and additional fill was required to be placed on multiple occasions to stabilize the houses (Oliver, Mangione, McCalla & Associates, 2001).

Figure 2-17 High risk houses #98 to #110 threatened by shoreline erosion (Google Earth)

To mitigate further erosion, a concrete block seawall was constructed in 2002 in front of six of the houses, however, the structure was severely damaged soon after construction (Baird, 2016), as seen in Figure 2-18.

Figure 2-18 Damaged concrete block seawall in front of houses #105 to #110 (2021)

In 2016, GN-CGS commissioned a study by EXP Services Inc. to perform a coastal protection assessment and provide options for managing the erosion. Together with W.F. Baird & Associates Coastal Engineers Ltd. (Baird), an erosion cost benefit analysis was conducted, and three solutions for the protection of houses #98 to #110 was proposed – beach nourishment, beach nourishment with groynes, and rubble mound revetment. Relocating high-risk houses was also suggested as an alternative. Thus far, no action has been taken regarding the solutions.

Surveys completed as part of the Baird study indicated accretion of sediments in the shallow subtidal areas fronting these houses, with the possibility that the area is currently in a state of deposition, rather than erosion. During a site visit in 2021 by Advisian, it was observed that the beach area fronting these houses is accumulating sediments that may be protecting these houses and the adjacent revetment from further erosion as seen by the berm feature above the high water mark in Figure 2-18. It appears that the general accretion zone immediately south of these houses is making its way north. This, combined with land rebound, suggests that the area may have stabilized over the past decade from erosion based on current sediment migration.

2.4.4 Permafrost

Melting permafrost can result in changes to ecosystems as well as infrastructure. This effect is most pronounced over land, where melting permafrost can cause slope instabilities, softening foundations under infrastructure, and a shortened season for land transportation over winter roadways. In addition, melting permafrost releases gases into the atmosphere and will affect the local ecosystem while exacerbating the progression of permafrost melting.

Columbia University Graduate School of Architecture, Planning and Preservation conducted research on air-borne pollution in the Arctic in 2020, targeting chemicals knows as Persistent Organic Pollutants (POPs) in Sanirajak. The study suggests that warming waters and the loss of sea ice around Foxe Basin creates accumulating POPs and are intensified by the melting permafrost.

It is not known if subsea permafrost exists at Sanirajak. Subsea permafrost is known to exist deep below the seabed at Nanisivik and Milne Inlet (at least 50 m deep), but these project sites are significantly further north. While melting permafrost could affect the structures, it is unlikely in this case since melting subsea permafrost is a relatively slow process, and it is typically located well below the seabed surface. The potential for affecting the structure will also be dictated by the type of ground conditions at the site (such as clay versus bedrock versus gravel, as some materials are not sensitive to thaw), which are currently unknown but can be determined by geotechnical drilling. Nevertheless, subsea permafrost, if it exists, will be deep, likely within bedrock and is unlikely to affect the marine infrastructure at Sanirajak.

3 Consultation

A key component to the Study and design process was the engagement and collaboration of the community and external stakeholders.

The following provides objectives of the consultation program:

- To develop an informed understanding of site(s) limitations based on relevant information and available local knowledge.
- To gain an understanding of the perspectives and needs of the community and various users to support the development of harbour concepts.
- Provide meaningful opportunities for community members and stakeholders to review the proposed harbour concepts, ask questions, and provide input.
- Discuss technical issues including the pros and cons of the harbour layout options, the impact of ice break-up and flushing, potential for sedimentation, boat sizes and number of boats, opportunities for expanding the harbour in the future, and the mooring/float concept(s), including removal and reinstallation procedures (if applicable).
- Discuss construction related issues such as the ability of the communities to accommodate the contractor's work force (room and board, fuel, and other community services), local equipment availability for construction and/or maintenance, and the availability of local labour or contractors to assist in the construction of the harbour or execute the work as the general contractor.
- Follow up on previous meetings (in particular with the Hamlet and HTA) by verifying that the interests, inputs, and needs expressed were heard and understood while addressing any outstanding issues, questions, or information requests.

Two consultation trips were conducted during key stages of the study: the first to understand the community's uses of the marine environment, their needs and preferences for the marine infrastructure, to workshop ideas for infrastructure that address the community's needs. The second was to present high level concepts for harbour options based on the information gathered from the first consultation, hold a workshop with the HTA to refine the concepts and obtain additional feedback to assess if alternative locations warrant consideration, and to develop a further understanding of the community's marine environment use during open water season.

Two virtual meetings were conducted jointly with the Hamlet and HTA following submission of the draft report. These meetings provided an opportunity for key community leaders to review the findings and cost estimates for construction of various options, and discuss next steps, should funding be available to advance the project.

The first round of consultations was conducted in March of 2021 and included meetings with the Hamlet (Hamlet staff, mayor and councillors) and HTA board members. These meetings provided the design team with an understanding of the community's needs and expectations, local knowledge of site conditions, and community resources critical to the development of the harbour concepts.

The second round of consultations was conducted in September of 2021 to present the Hamlet and HTA with the harbour layout concepts developed based on the local knowledge and feedback received during the first round of consultations. The third and fourth consultations were virtual meetings conducted in August 2022 and February 2023 following submission of the draft report. A report summarizing the consultation conducted and the feedback received is provided in Appendix 2.

Consultation materials were provided in both English and Inuktitut and included: presentations; engineering design drawings; photographs; and maps. Local interpreters were hired to support the consultations, as required.

4 Socio-Economic Benefits

A detailed description of existing socio-economic conditions in Sanirajak is provided in Appendix 6 including topics such as: demographics; education; health services; community infrastructure; workforce and economic activity; transportation and land and resource use.

As with most communities in Nunavut, Sanirajak's economy is characterized by a mix of wage-based and harvesting activities (hunting, fishing, gathering, etc.). The availability of traditionally harvested foods in Sanirajak is critical to food security by lowering the demand for imported food which is expensive and most often less nutritious. Additionally, the harvesting, preparation, and sharing of meat and skins offers important opportunities for community members to maintain Inuit cultural practices, provide in-kind income, and opportunities for commercial arts and crafts activities.

The lack of adequate marine infrastructure requires most hunters in Sanirajak to pull their boats up on the shoreline above high water over timber sleepers using a pickup truck, ATV, or manually to protect their boats and equipment.

> *"Most people need to pull their boats up along the shoreline in the community. Canoes need to be pulled up high – they otherwise get washed away with waves and the current."*
> HTA member, March 2021 Joint Meeting

> *"We need a protected harbour – secure from waves and winds."*
> Hamlet Councilor, March 2021 Joint Meeting

A dock located 3.5 km from the community is only useable at high tide and is used by few residents due to the distance from the rest of the community.

> *"The majority of hunters don't have access to the floating dock, it's too far and too small."*
> HTA member, March 2021 Joint Meeting

> "*Most hunters only have a boat, no other form of transportation…"*
> Hamlet Councilor, March 2021 Meeting

> *"The floating dock is too small. There are never more than about 10 boats there at a time. Not enough room for more. Only 4 boats can be tied up at once and the rest are landed."*
> HTA member, March 2021 Joint Meeting

Due to increasing shallowness and bedrock very near to the surface, hunters are unable to anchor close to shore and must navigate very carefully when coming in so as not to damage boats and equipment.

> *"In the 80s we would have whales within meters from shore, but the last 5 years or so whales haven't come close at all because it's getting shallower."*
> Hamlet Councilor, March 2021 Joint Meeting

> *"Hunters need to be very careful now and slow down when coming in to land to avoid shallow areas."*
> HTA member, March 2021 Joint Meeting

"We can't anchor close to shore at all because of all the bedrock near the coastline."
HTA member, March 2021 Joint Meeting

"*The community requires a dock to be constructed to facilitate the loading and unloading of community boats and for a safe place for boat owners to tie their boats to during storms. As the majority of the community relies on country food as their main food source, infrastructure that supports harvesting activities is required."* – Hamlet's 2022/2023 Infrastructure Plan

Ice changes in recent years observed in Sanirajak also threaten damage to boats and equipment.

"Sea ice is thinner now and large ice is being rafted in. We lost two boats because of ice rafting."
HTA member, Design Workshop September 2021

Sanirajak experiences lower participation rates and higher unemployment rates compared to Nunavut and Canada as a whole. According to the 2021 census, Sanirajak has a 41.1% participate rate in the labour force compared to 58.6% for Nunavut and 63.7% for Canada (Statistics Canada 2023). The unemployment rate in Sanirajak was reported as 18.2%, just over the 17.4% for Nunavut, but nearly twice the rate for Canada (10.3%) (Statistics Canada 2023). According to Nunavut's Inuit Labour Force Analysis Report (2018), a lack of wage-based opportunities and food insecurity are among the many challenges to labour force development across the territory.

In order to create jobs, diversify the economy and address food insecurity, the community, through the HTA has recently partnered with the Qikiqtaaluk Corporation (QC) to conduct inshore test fisheries to assess the potential in developing a viable fishing industry in Sanirajak (Qikiqtaaluk Corporation 2021). Research on a potential inshore fishery for Sanirajak began in September 2022 with the newly built RV Ludy Pudluk research vessel conducting sea bottom mapping and inshore fisheries surveys in collaboration with the HTA (ArcticNet 2021). Further, the Hamlet of Sanirajak has included the construction of a fish plant in their 2022/2023 Infrastructure Plan's priority list to support a commercial fishery as there is also an abundance of fish near the community and the fish plant *"would generate much needed employment".*

Although Sanirajak doesn't currently receive large passenger or cruise ships, the community reports an increase in visits from adventurers and private leisure boats (mostly sailboats) in recent years. There are several hunters from Igloolik that also pass through Sanirajak on their way caribou hunting (HTA board member. pers. comm. March 2021). Additionally, walrus and bowhead tours by Eagle Eye Tours have recently begun operating out of Sanirajak using local guides and their aluminum boats to bring visitors out to explore nearby islands and local wildlife, especially marine mammals (Eagle Eye Tours 2023).

Given the context provided above, a small craft harbour development in Sanirajak is expected to benefit the community by:

- Providing safe and reliable access for local harvesters, outfitters, search and rescue, and visitors.
- Serving as a platform for economic development in the community - ensuring that future commercial inshore fisheries have access to a safe harbour and landing facilities.
- Improving congestion and addressing risks to public safety.
- Creating local employment, business, and capacity building opportunities.

- Lowering the risk of expensive boat and equipment loss and damage.

5 Site Conditions

5.1 Daylight and Temperatures

Sanirajak is 245 km north of the Arctic Circle and experiences 24 hr sunlight during portions of the year, as well as dark periods where no daylight is available, similar to other communities in Nunavut. The shortest day (December 21) experiences no daylight with just under 5 hours of civil twilight, while from late May to late July the community experiences 24 hrs of sunlight. It is generally recognized that daylight and civil twilight provide enough light for ordinary outdoor occupations, such as construction. Figure 5-1 illustrates hours of night, astronomical twilight, nautical twilight, civil twilight, and daylight over the course of a year, with a summary of hours for the shortest day, December 21.

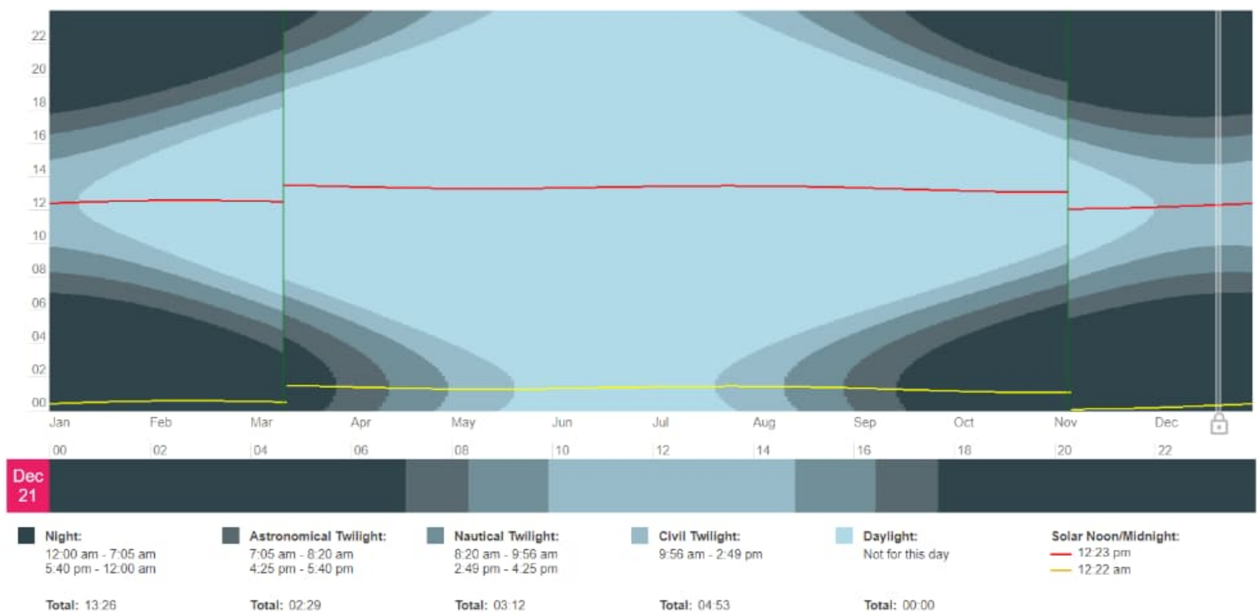


Figure 5-1 Night, Astronomical Twilight, Nautical Twilight, Civil Twilight, and Daylight Time for Sanirajak

During the summer months temperatures can reach an average of around 9 deg. C with the warmest recorded temperature being 24.8 deg. C which occurred in August 1991. The coldest time in Sanirajak is in February when the daily mean temperature is -31.0 deg. C, with the coldest record temperature being -54.1 deg. C which occurred in February 1979. This information comes from the Canadian Climate Normals Station Data. A monthly breakdown of average temperatures between 1957 to 2007 is provided in Figure 5-2.

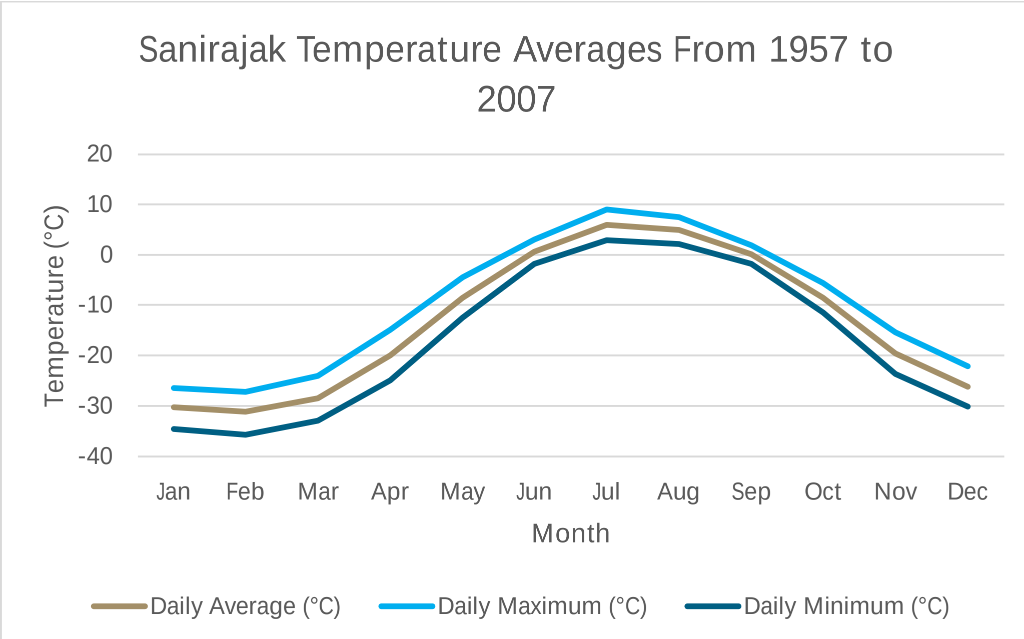


Figure 5-2 Average Temperatures for Sanirajak from 1957 to 2007

5.1.1 Precipitation

Average rainfall, snowfall, and snow depth in Sanirajak were obtained from the Canadian Climate Normals station data from 1981-2010 and are presented in Table 5-1.

Table 5-1 Precipitation Averages in Sanirajak (Environment and Climate Change Canada)

Month	Rainfall (mm)	Snowfall (cm)	Average Snow Depth (cm)
Jan	0	7.9	34.0
Feb	0	7.0	34.3
Mar	0.1	10.3	39.8
Apr	0.2	12.9	43.5
May	1.4	15.2	34.7
Jun	10.6	6.6	3.7
Jul	28.5	0.3	0.1
Aug	39.6	2.6	0.2
Sep	15.9	12.2	3.0
Oct	1.0	22.8	15.6

Month	Rainfall (mm)	Snowfall (cm)	Average Snow Depth (cm)
Nov	0.3	18.9	26.9
Dec	0.2	9.9	30.8
Yearly Total	97.8	126.6	N/A

5.1.2 Tides

Tide levels for Sanirajak station were obtained from Canadian Tide and Current Tables, Volume 4 (Canadian Hydrographic Service 2022) and are provided in Table 5-2.

Table 5-2 Tide Levels at Sanirajak

Tide	Elevation (m, CD)
Extreme High Water Level (EHWL)	2.4*
Higher High Water Level, Large Tide (HHWL)	1.4
Higher High Water Level, Mean Tide (HWL)	1.2
Mean Water Level (MWL)	0.7
Lower Low Water Level, Mean Tide (LWL)	0.3
Lower Low Water Level, Large Tide (LLWL)	0.0
Extreme Low Water Level (ELWL)	-0.5*

** EHWL and ELWL, which reflects high and low storm surges that coincide with high and low tide levels, respectively, are not provided in the Tide and Current Tables for Sanirajak. Storm surge is determined with a Mike21 wave and is provided in the following subsection 5.1.6.*

5.1.3 Currents

Currents in front of Sanirajak were measured by the Geological Survey of Canada in September and October of 2008. A wave instrument was deployed in 10 m of water, and tidal current speeds were measured to be around 1 m/s. This is generally consistent with speeds noted on CHS navigation chart 7485 (0.5 m/s to 2 m/s).

For the conceptual design of the harbours, surface currents of 3% of the winds were used.

5.1.4 Wind

Hourly wind data recorded at Sanirajak airport were obtained from Environment Canada's online climate database (https://climate.weather.gc.ca/historical_data/search_historic_data_stations_e.html?searchType=stnName&timeframe=1&txtStationName=hall+beach&searchMethod=contains&optLimit=yearRange&StartYear=1840&EndYear=2023&Year=2023&Month=3&Day=26&selRowPerPage=25). The data covered a period of 66 years (January 1, 1956 – April 10, 2022) and is a combination of data recorded at two stations.

The monthly distribution of storms is analyzed and provided in Table 5-3 by considering the wind speed of 15.2 m/s (55 kph) as a storm threshold (defined by WMO (2011)). The table also shows the percent of storm with respect to total data length and recorded maximum wind speed on monthly basis. The analysis shows that the greatest number of storms occur in October and November. Such a distribution is a warning for potentially severe weather conditions in the future context of global warming, which may result in a longer open water season extending beyond the month of November. The maximum wind speed also occurred in an October storm. The second maximum wind speed was observed in February.

Table 5-3 Monthly Storm Statistics for Sanirajak (Environment and Climate Change Canada)

Month	Distribution of Storms per Month in Percent	Percent of Storms w.r.t Total Data Length	Peak Storm	
			Maximum Wind Speed (km/h)	Direction
January	9.56%	0.082	86	NW
February	6.41%	0.055	98	NW
March	8.92%	0.077	90	NW
April	4.18%	0.036	76	NW
May	5.21%	0.045	90	NW
June	2.77%	0.024	86	W
July	1.22%	0.010	71	NW
August	3.88%	0.033	86	NW
September	11.43%	0.098	90	NW
October	22.06%	0.189	107	W
November	15.73%	0.135	86	E
December	8.64%	0.074	86	S
Total	100	---	---	---

Historical records of storm are presented in Figure 5-3 below.

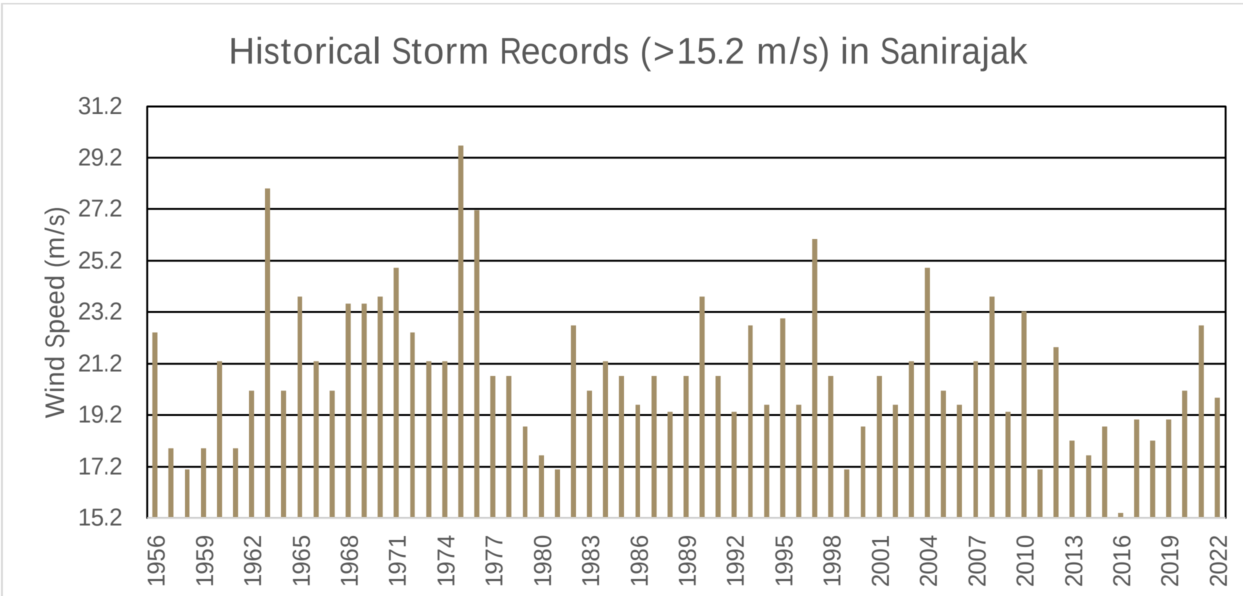


Figure 5-3 Historical Storm Records (>15.2 m/s) in Sanirajak

The wind data were further analyzed to determine the design wind condition, and subsequently used to analyze waves and storm surge at the Study site. Hence, data recorded only during the open water season were used for the analysis. The extent of the open water season was determined by examining the historical ice cover data and considering the effect of global warming. As there is no recent information on the trend in the change of open water season length beyond Dumas et al, 2006 (Future Projections of Landfast Ice Thickness and Duration in the Canadian Arctic), it was assumed that the freeze-up date would be delayed by a maximum 60 days during the life of the harbour. Hence, the extent of the open water season for Sanirajak was considered to be from May 15 to the December 31 for North sector directions, from June 1 to December 31 for the East sector directions, and from July 1 to December 31 for the South sector directions. Accordingly, wind data were filtered for the metocean analysis and the subsequent design criteria development.

Figure 5-4 presents the wind rose illustrating the annual wind climate in Sanirajak. For demonstrating the directional dominance of wind with its variation in intensity, a wind frequency table was prepared (Table 5-4). This analysis shows that while the highest directional frequency of winds in July are southerly, and northerly winds are most prevalent during the months of August and September, northwesterly winds are the most dominant throughout the remainder of the year.

Monthly wind roses and frequency tables for Sanirajak were also prepared and are provided in Appendix 3.

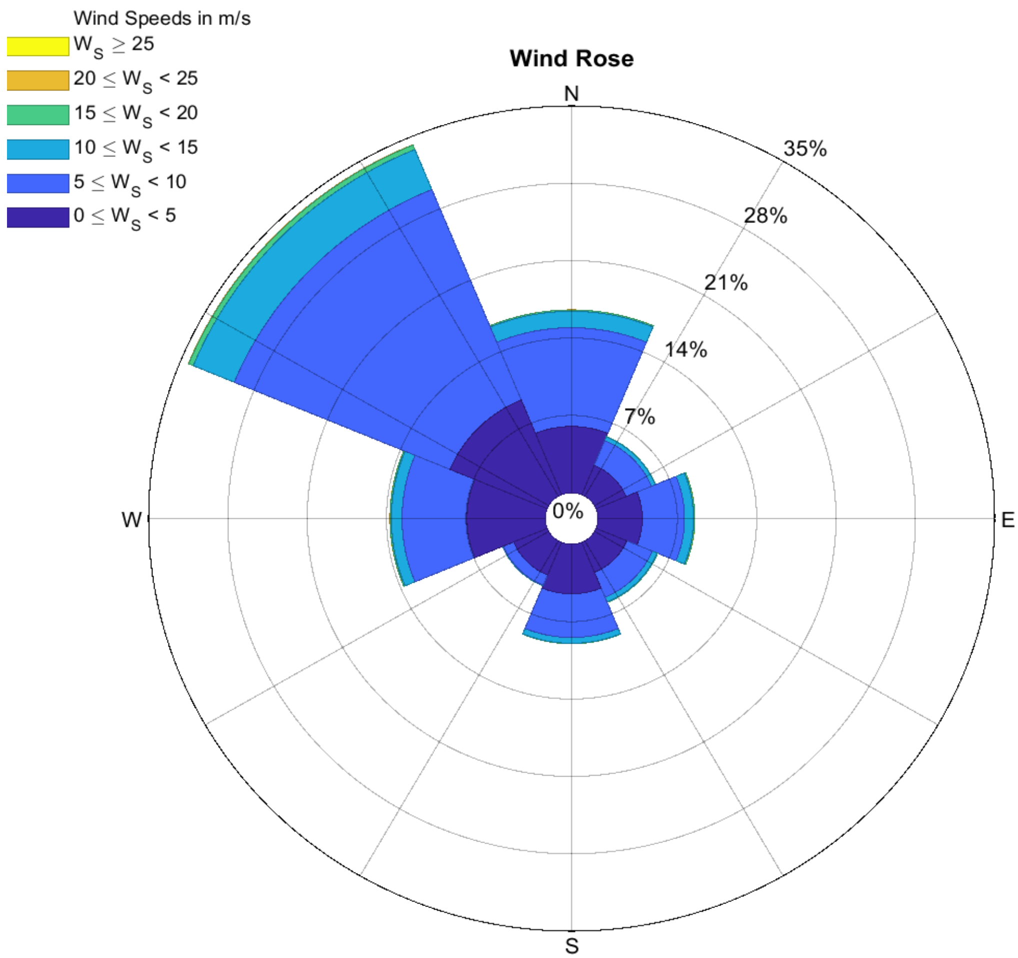


Figure 5-4 Yearly wind rose for Sanirajak

Table 5-4 Frequency of Wind Occurrence from Different Directions for Sanirajak

Speed (m/s)	N	NE	E	SE	S	SW	W	NW	Total
0-3	2.137	1.304	1.928	1.384	1.893	1.809	3.108	2.433	15.996
3-6	6.965	2.617	3.342	2.605	4.225	2.116	5.989	13.147	41.005
6-9	5.321	1.425	2.226	1.397	2.263	0.496	3.326	12.559	29.012
9-12	1.692	0.443	0.861	0.517	0.645	0.090	1.045	4.271	9.564
12-15	0.563	0.139	0.331	0.196	0.192	0.018	0.367	1.662	3.467
15-18	0.113	0.026	0.094	0.044	0.029	0.000	0.099	0.380	0.787
18-21	0.012	0.000	0.020	0.000	0.000	0.000	0.020	0.070	0.133

Speed (m/s)	N	NE	E	SE	S	SW	W	NW	Total
21-24	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.031
24-27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27-30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	16.800	5.950	8.800	6.140	9.250	4.530	13.950	34.540	100.000

Extreme analysis was performed using Gumbel method for all directions for four design periods. The results of extreme wind analysis are provided in Table 5-5.

Table 5-5 Extreme Wind Speeds for all directions in Sanirajak

Return Period (Years)	Speed (m/s)							
	N	NE	E	SE	S	SW	W	NW
1	14.6	11.4	13.9	12.9	11.9	9.0	12.9	15.6
10	19.5	18.4	21.3	19.2	18.3	14.7	22.1	22.9
50	21.7	21.4	24.6	22.0	21.1	17.2	26.1	26.1
100	22.6	22.6	25.9	23.1	22.3	18.2	27.8	27.5

5.1.5 Waves

Winds recorded by Environment and Climate Change (ECCC) at the local airport, which is located about 1 km southwest of the community, are used to model wind generated waves during open water periods. A state-of-the-art hydrodynamic wave model, Mike 21, was used to augment a previous study by EXP Services Inc. and Baird, 2016.

The open water for generating waves is influenced by climate change and direction, as follows:

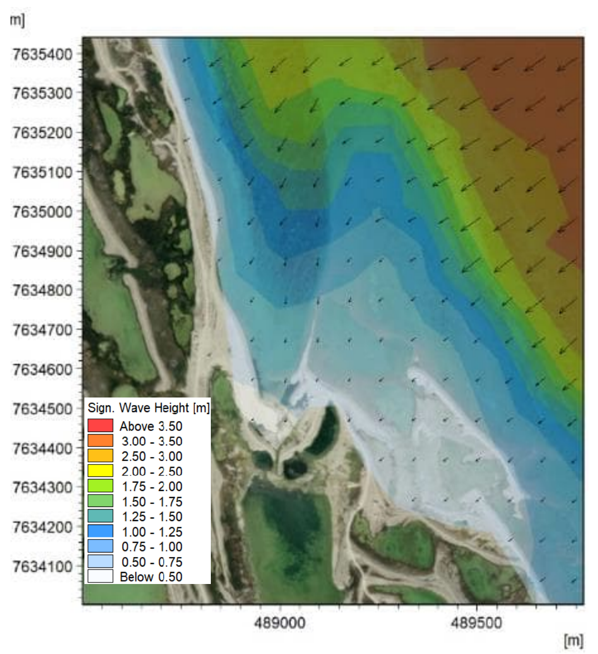
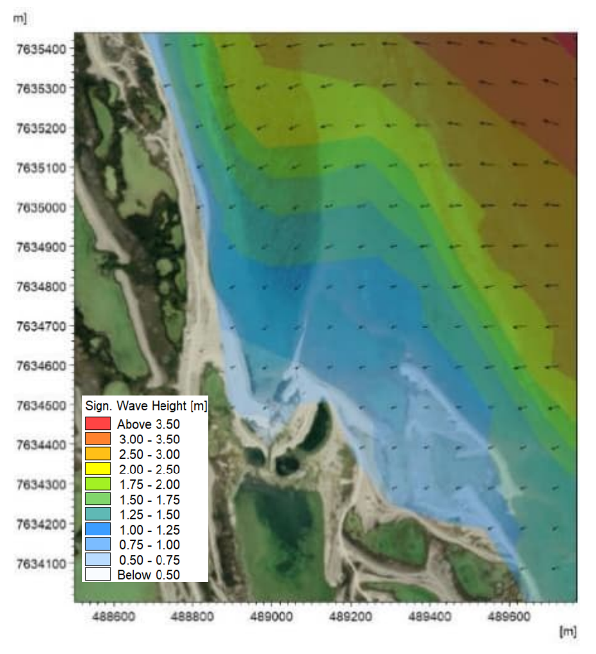
- Climate change – global warming is thought to result in thinner ice and longer periods of open water (Dumas et al, 2006; Hu et al, 2016), and an increase in sea level rise (which at this site is smaller than the vertical upward movement of the land, and results in a negative sea level rise).
- Direction – the north end of Foxe Basin around Sanirajak opens earlier than the rest of the Basin, and as a result the fetches to the north (N) open sooner than the fetches to the east (E) and south (S) sector directions.
  - Open water at the end of the design life at 2100 is proposed for conceptual design, as follows:
    - N sector open water is from May 15 to December 31.
    - E sector open water is from June 1 to December 31.
    - S sector open water is from July 1 to December 31.

5.1.5.1 Storm Generated Waves

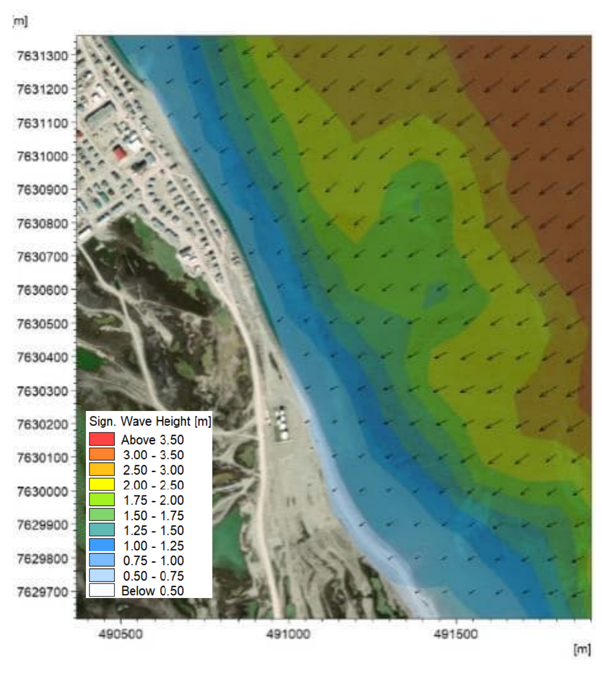
Design wave conditions were derived by employing the MIKE 21 SW model. The model bathymetry was set up using data from the following sources:

- non-navigational (NONNA) bathymetric data, Canadian Hydrographic Service (CHS)
- regional data from NOAA (https://www.ngdc.noaa.gov/mgg/global/)
- local bathymetry survey conducted by Frontier Geosciences Inc. in 2021

Waves were simulated for the extreme winds from northeast and southeast directions. Figure 5-5 shows simulated distribution of 50-year waves generated by the northeast and southeast direction storms. Wave parameters were extracted from two locations near the project site and provided in Table 5-6.

Site 1 and 2 – NE Storm	Site 1 and 2 – SE Storm
	

Site 3 – NE Storm	Site 3 – SE Storm



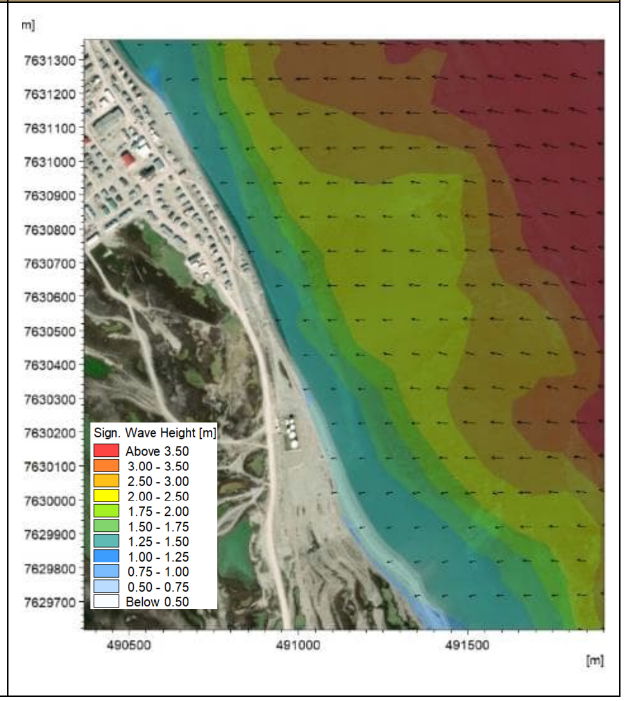


Figure 5-5 Simulated 50-year waves at Sites 1, 2, 3, and 4 for NE and SE storms

Table 5-6 Tide simulated wave parameters for Sites 1, 2, 3, and 4 at Sanirajak

Return Period (Years)	Site 1 and 2			Site 3 and 4		
	H_s (m)	T_P (s)	MWD (dir)	H_s (m)	T_P (s)	MWD (dir)
North Storms						
1 Year	1.58	6.3	25	1.72	6.3	32
10 Year	1.95	7.6	25	1.92	7.6	40
50 Year	1.95	8.0	25	1.93	8.2	45
100 Year	1.95	8.3	26	1.94	8.4	45
Northeast Storms						
1 Year	1.46	5.7	43	1.44	5.7	48
10 Year	1.90	7.8	25	1.95	7.8	52
50 Year	2.00	8.6	25	1.84	8.6	55
100 Year	2.00	9.0	28	1.90	9.2	55

Return Period (Years)	Site 1 and 2			Site 3 and 4		
	H_s (m)	T_P (s)	MWD (dir)	H_s (m)	T_P (s)	MWD (dir)
East Storms						
1 Year	1.60	6.6	51	1.88	6.6	78
10 Year	1.60	8.4	39	2.24	8.4	75
50 Year	1.60	9.3	39	2.12	9.3	75
100 Year	1.60	9.4	39	2.14	9.4	75
Southeast Storms						
1 Year	0.96	6.2	82	1.42	6.4	108
10 Year	1.80	8.4	68	2.60	8.6	96
50 Year	1.95	9.2	60	2.75	9.8	94
100 Year	1.95	9.9	60	2.82	10.1	92

From these results, it is apparent that despite the predominate northerly storm winds, the south easterly storms produce by far the largest wave height due to the very long fetch.

5.1.5.2 Wave Agitation in Harbour

The design of the breakwater will provide a relatively calm harbour. Table 5-7 and Table 5-8 below are various guidelines that determine wave agitation for which the Sanirajak harbour will be designed to.

Table 5-7 Harbour Agitation Guidelines, Fisheries and Oceans Canada (DFO), 2015

Location	STACAC Vessel Class	Vessel Length (m)	Vessel Length (ft)	Threshold Significant Wave Height (m)	Frequency of Occurrence
Service/Offloading	1	0 to 10.7	0 to 35	0.3	1.0% to 2.5%
	2	10.7 to 13.7	35 to 45	0.4	
	3	13.7 to 19.8	45 to 65	0.4	
Mooring Basin	1, 2 & 3	0 to 19.8	0 to 65	0.5	1.0% to 2.5%

Table 5-8 Planning and Design Guidelines for Small Craft Harbours, American Society of Civil Engineers (ASCE), 3rd Edition, 2019

Wave Period and Craft Heading	*Significant Wave Height, Hs	
	50 Year Wave Event	Yearly Maximum Wave Event
Less than 2 seconds in head seas	-	Less than 0.3 m wave height
Greater than 2 seconds in head seas	Less than 0.6 m wave height	Less than 0.3 m wave height
Less than 2 seconds in beam seas	-	Less than 0.3 m wave height
Greater than 2 seconds in beam seas	Less than 0.25 m wave height	Less than 0.15 m wave height

**To develop criteria for an "excellent" wave climate, multiply wave heights by 0.75. For "moderate" wave climate, multiply wave heights by 1.25. For oblique seas refer to the noted guideline above.*

The final design criteria will be confirmed at detailed design stage.

5.1.5.3 Wave Loads and Armour Rock Size

Wave loads on vertical sided elements such as caissons will be calculated using methods in the Coastal Engineering Manual, 2011.

Armour rock will be sized using the Hudson Formula in the Coastal Engineering Manual, 1984.

5.1.6 Storm Surge

Storm surge is an abnormal rise of water (in addition to normal tides) generated during a storm. Large storm surges are typically generated due to the combined effect of atmospheric pressure fall and wind drag. These components were separately estimated and combined below to arrive at the total storm surge, as shown in Table 5-9 below.

Table 5-9 Estimated wind and pressure induced storm surges at Sanirajak

Return Period (Years)	Pressure Fall (hPa)	Surge by Pressure Fall (m)	Surge by Wind (m)	Total Surge by South Sector Storms (m)
1	30.5	0.31	0.20	0.51
10	38.7	0.39	0.41	0.80
50	42.3	0.43	0.60	1.03
100	43.8	0.44	0.65	1.09

5.2 Geology and Rock Sources

The community of Sanirajak is located on the eastern lowland area of the Melville Peninsula. The main topographic features in the lowlands are gravelly or flaggy raised beaches commonly underlain at shallow depth by stepped limestone outcrop, and bedrock buttes capped by resistant dolomites.

Based on the current stage of the desktop study conducted by Advisian, there is no suitable site for a rock quarry at or near Sanirajak for producing armour rock. Further, the upland is essentially flat and low lying which will make quarrying for other uses difficult, as it is expected that controlling water will be difficult.

5.2.1 Site Geology

5.2.1.1 Surficial Geology

Surface soils around Sanirajak are made of quaternary deposits, including littoral deposits made up of gravel, boulder, or flaggy deposits that are 2 to 6 m thick and derived from shattered limestone. Further inland, the soil is comprised of glaciomarine deposits that are 1 to 5 m thick and made up of stony sand silt or stony clay.

Ice flow indicators and glacial transported erratics associated with the Melville Peninsula can be used to reconstruct glacial events. Figure 5-6 below shows that ice flow moved from Hall Lake towards the Sanirajak area. Figure 5-7 indicates that glacial erratics in the Sanirajak area are likely to be limestone.

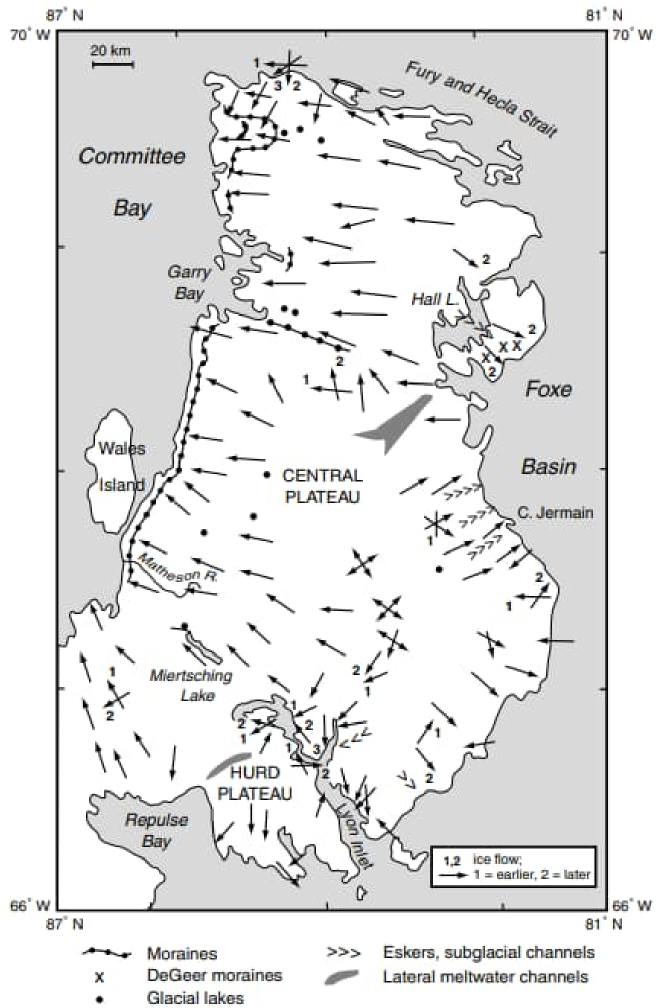


Figure 5-6 Ice flow indicators used to reconstruct glacial events (Geological Survey of Canada, 1995)

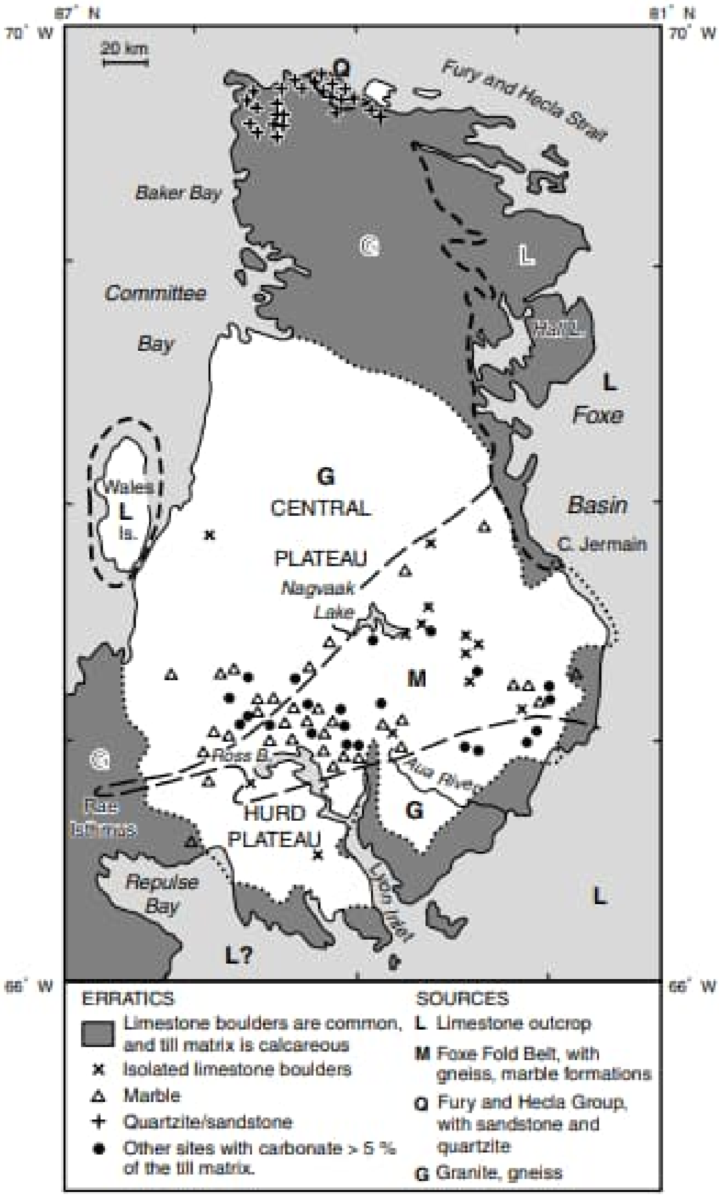


Figure 5-7 Glacially transported erractics, with bedrock source areas. Regional-scale dispersal trains of calcareous till on northern Melvill Peninsula and Rae Isthmus are shaded. The dashed lines are geological contacts (Geological Survey of Canada, 1995)

Based on the available information on the shoreline east of the community, the shoreline is likely comprised of variable thicknesses of littoral deposits and active beach deposits comprised of predominantly gravel, cobbles and boulders of limestone and dolomite. The thickness of the deposits will vary, but based on the surficial geology, may be up to 6 m thick.

5.2.1.2 Bedrock Geology

Flat lying Ordovician carbonate rocks underlie the eastern part of the peninsula. The rocks are predominantly sandy dolomite of the Ship Point Formation (lmOs) and shown in Figure 5-8. Bedrock is generally not far below the land surface.

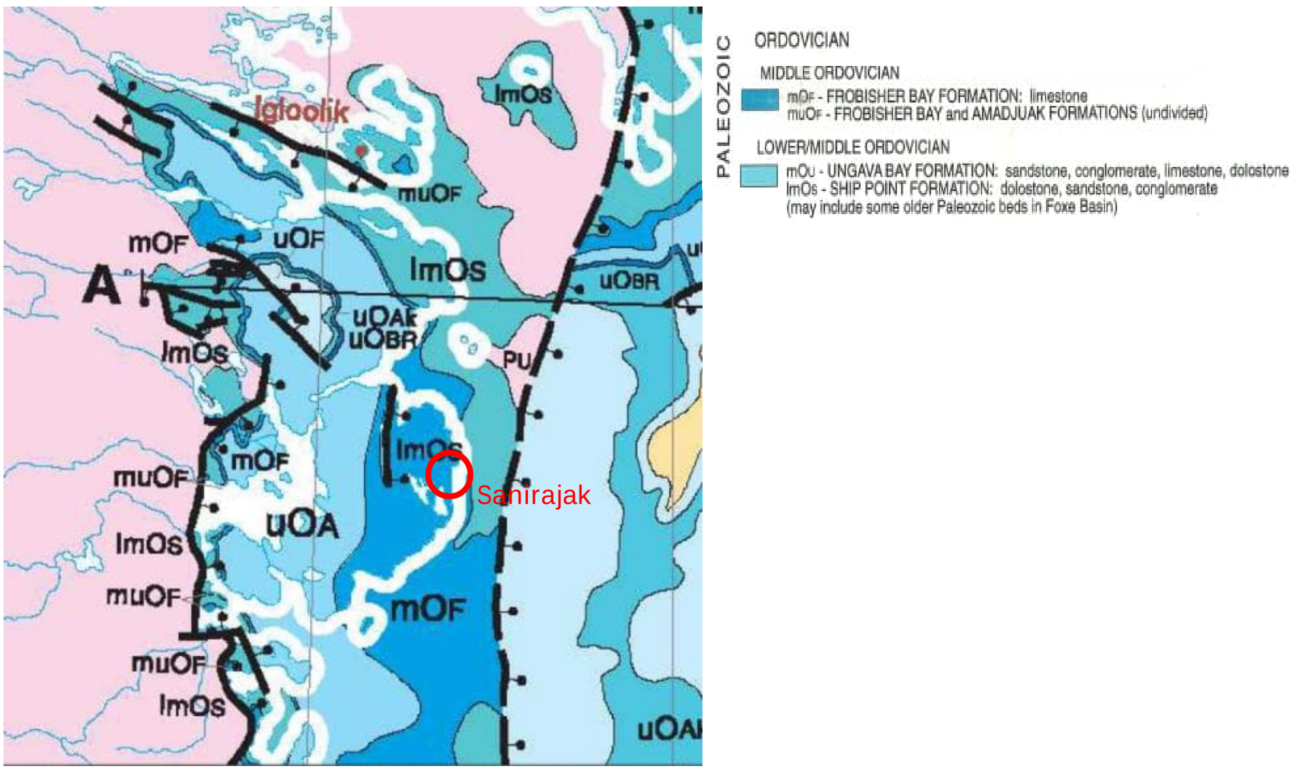


Figure 5-8 Geology of Igloolik Island area, and sea level changes (L.A. Dredge, 1992)

Fresh Paleozoic outcrop is limited to one area on Igloolik Island and to small scarp faces. Photos such as Figure 5-9 and Figure 5-10 show the flat thinly bedded limestone. Limestone beds generally range from 10 to 20 cm thick. The upper beds can comprise hard and resistant caprocks with weaker less resistant limestone or dolomite below. There are interbeds and partings of relatively weak shale and sandstone.

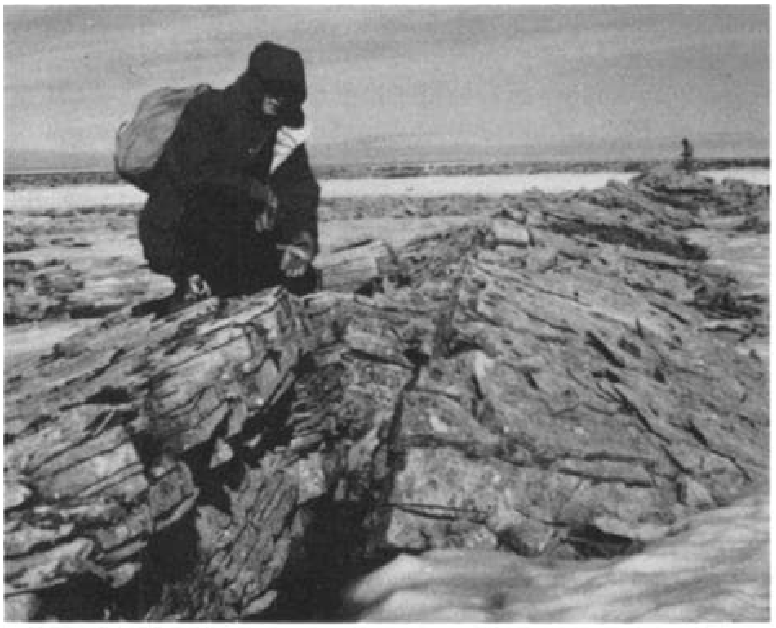


Figure 5-9 Bent and broken limestone flexures, with massive ice at the bottom of joint fissures. Loosened plates have slid down the arch incline. Taken June 26, 1988 (L.A. Dredge, 1992)

Figure 5-10 Toppled blocks and broken fragments on Cemetery Hill, Igloolik Island. Joints determine block size and geometry (L.A. Dredge, 1992)

5.2.2 Quarry

Depth to bedrock is expected to be variable near the community of Sanirajak. There is no obvious quarry source based on the reports, journals and geological maps assessed. The bedrock is likely to comprise highly variable limestone and dolostone, variable in strength and block size. Figure 5-9 and Figure 5-10 show frost shattering. Large blocks of rock can be seen in Igloolik in Figure 5-10, which is the same rock type as at Sanirajak. It should be noted however that frost shattering is evident along bedding planes and that obtaining large blocks for rip rap is unlikely, either in the Sanirajak area or at Igloolik.

At this stage there does not appear to be a suitable target for a rock quarry in or near Sanirajak for producing armour rock. The geological map in Figure 5-11 below shows Paleozoic bedrock extending across the entire eastern lowlands, possibly 60km away from granitic rock to the west. Such a distance is impractical for supporting a single project, especially given that no roads currently exist and the terrain is difficult with numerous ponds, lakes and drainage channels between.

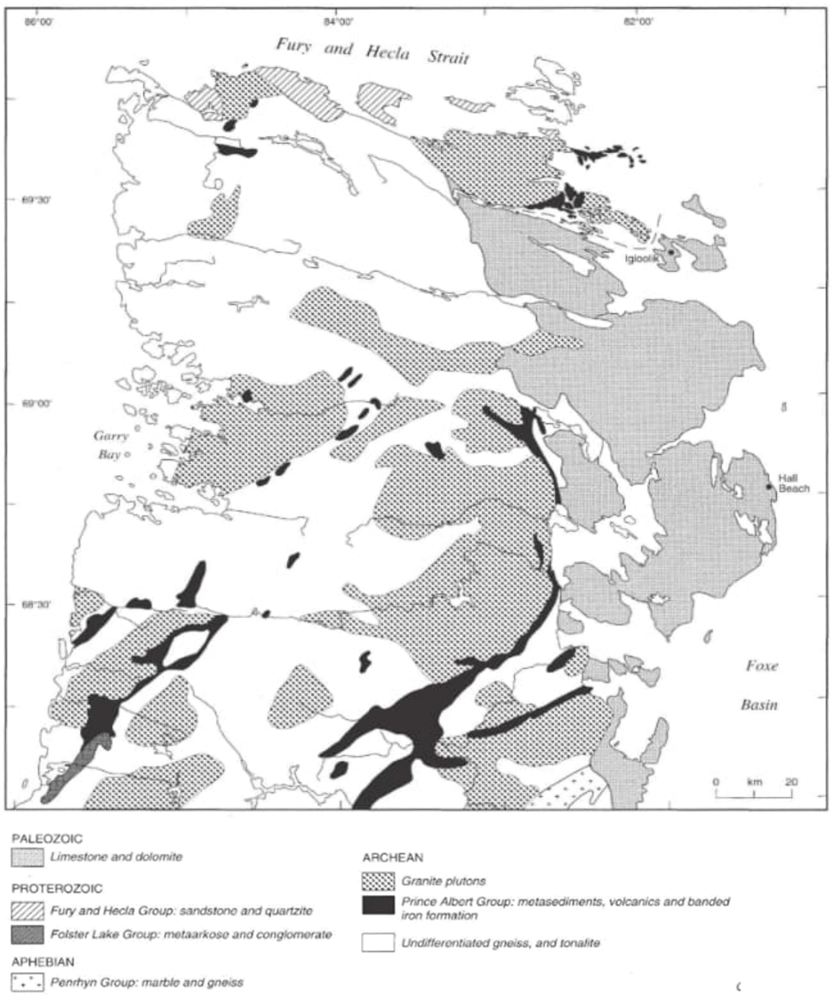


Figure 5-11 Paleozoic and Mesozoic geology of the Hudson and southeast arctic platforms (B.V. Sandford and A.C. Grant, 1998)

At this level of study and given that import of rock appears to be necessary, the most practical location for the supply of armour stone is Rankin Inlet. There is an existing rock quarry adjacent to the shoreline at Itivia - the primary sealift beach and industrial area of Rankin Inlet. This quarry is known to be capable of producing large blocks as seen by the port development work completed by Agnico Eagle Mines for their nearby Meliadine Mine. There is a rock quarry at Naujaat, however the yield ratio is expected to be much lower for armour protection than at Rankin Inlet, hauling would require trucks to drive through the main part of Naujaat, and the tide range at Naujaat is notably higher, making Rankin Inlet more conducive to barge loading, as neither community has a dock.

For the purpose of this study and the costs estimates produced, it is assumed that the heavy armour rock will be obtained from Rankin Inlet. At the next stage of study, an optimization assessment should be made to confirm if other, closer, sources of rock can be economical. Armour stone would be produced in Rankin Inlet and transported by tug and barge to Sanirajak. Typical aggregates required for breakwater, parking area core material, and surfacing material is expected to be able to be produced in Sanirajak by blasting locations of shallow bedrock.

5.2.3 Geophysical Assessment

In 2021, Frontier Geosciences Inc., under contract to Advisian, completed a geophysical assessment of the sea floor surrounding Sanirajak. The goal of the assessment was to provide bathymetric data, depth to bedrock, and material velocity classification information. Bathymetric and sub-bottom acoustic profiling surveys were carried out at six locations along the shore, as shown in Figure 5-12. Additional information on survey procedures, methodology, and results can be found in Appendix 5.

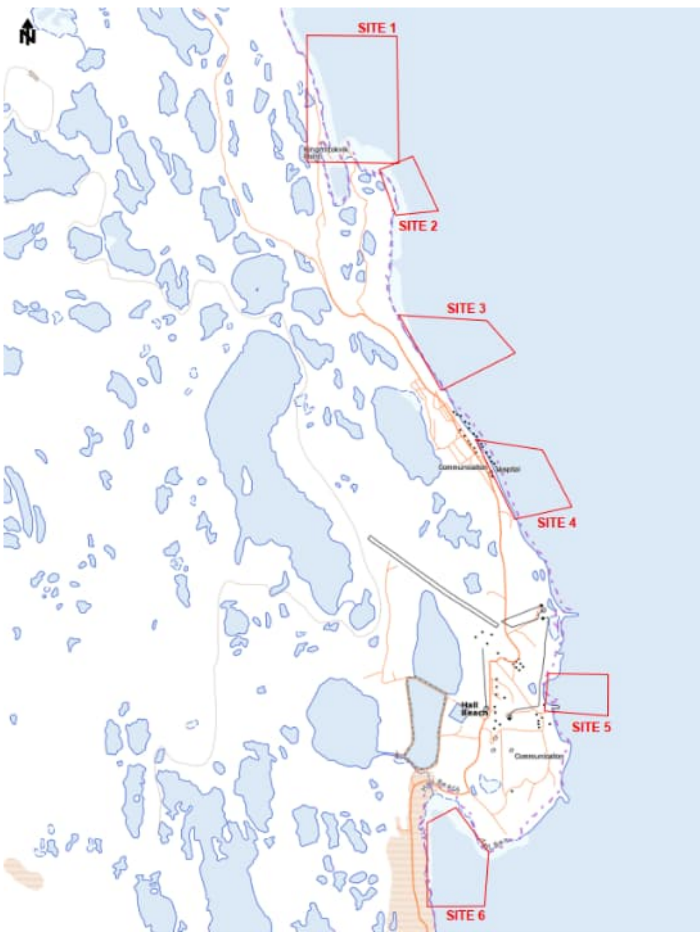


Figure 5-12 Frontier Geosciences offshore survey locations along the coast of Sanirajak

Results indicated extremely shallow depths along most of the shoreline, with the bedrock near the surface of the seabed.

The combination of shallow water fronting the community, bedrock at or near the surface and continued sea-level drop requires very careful consideration in siting the harbour options and is discussed in greater detail in Section 6.3.1.

5.3 Seismicity

Sanirajak is located in an area of low seismicity. The Natural Resources Canada Seismic Hazard Calculator (https://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/nbc2020-cnb2020-en.php) was used to determine a site-specific seismic hazard. Seismic Hazard is presented in Figure 5-13.

Table 5-10 Seismic Hazard

Probability of Exceedance in 50 Years	40% (1 in 100)	10% (1 in 475)	5% (1 in 1,000)	2% (1 in 2,475)
Sa (0.05)	0.008	0.02	0.029	0.046
Sa (0.1)	0.014	0.031	0.043	0.066
Sa (0.2)	0.018	0.036	0.048	0.068
Sa (0.3)	0.017	0.035	0.046	0.063
Sa (0.5)	0.016	0.033	0.043	0.059
Sa (1.0)	0.01	0.022	0.03	0.041
Sa (2.0)	0.004	0.012	0.016	0.023
Sa (5.0)	0.001	0.003	0.004	0.005
Sa (10.0)	0.001	0.001	0.002	0.003
PGA (g)	0.008	0.018	0.026	0.038
PGV (m/s)	0.01	0.025	0.034	0.049

Figure 5-13 shows an excerpt from the 2015 Seismic Hazard Map National Resources Canada. Sanirajak is in the lowest seismic zone. Seismicity at Sanirajak is not expected to govern the design of any of the components and for the purposes of this study has been excluded.

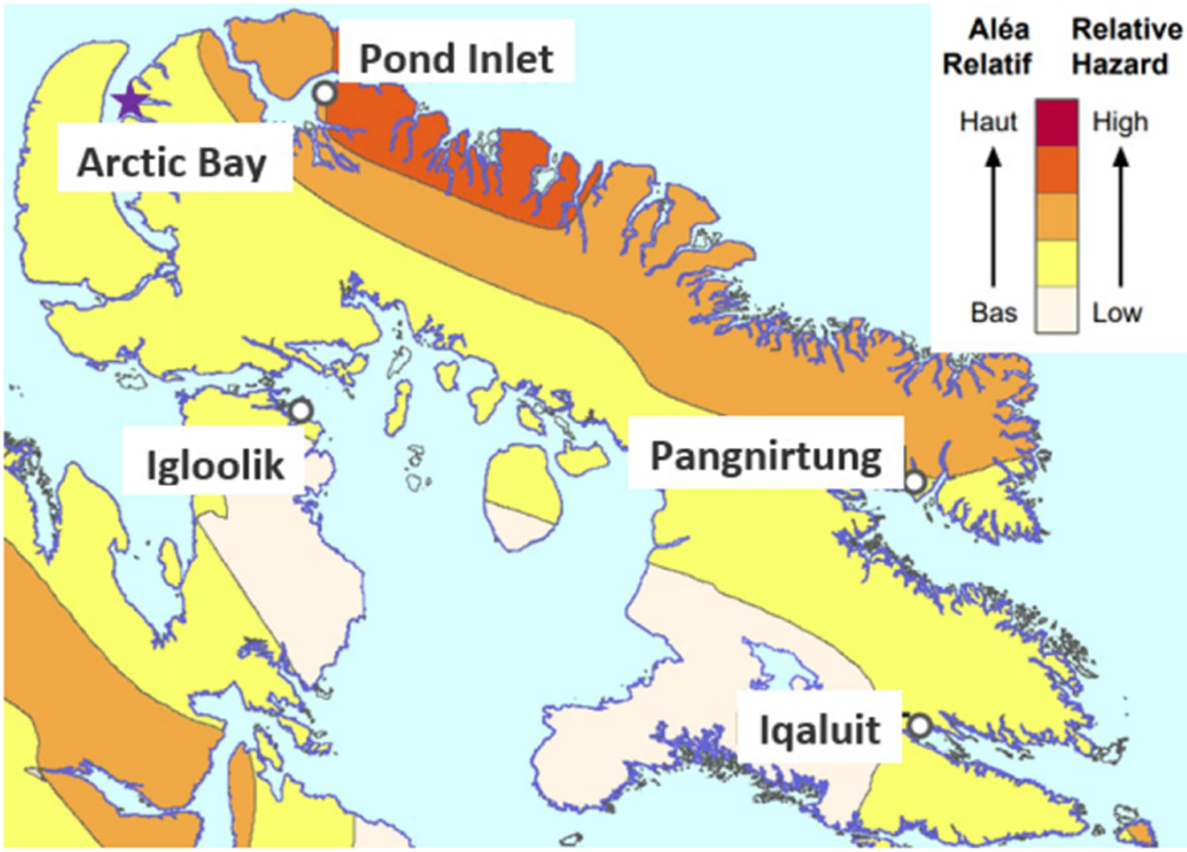


Figure 5-13 2015 Seismic Hazard Map for Baffin Island (Source: National Resource Canada)

5.4 Sedimentation

The Sanirajak shoreline is particularly prone to sedimentation and littoral drift due to the exposed nature of the community waterfront combined with the available sediments as a source. The effect of wind and wave forces on shoreline change can be seen from the Government of Nunavut's satellite imagery, as shown in Figure 5-14 and Figure 5-15 below. The shoreline alignment has gone from a relatively straight and uniform beach to significant zones of steady accretion and erosion.

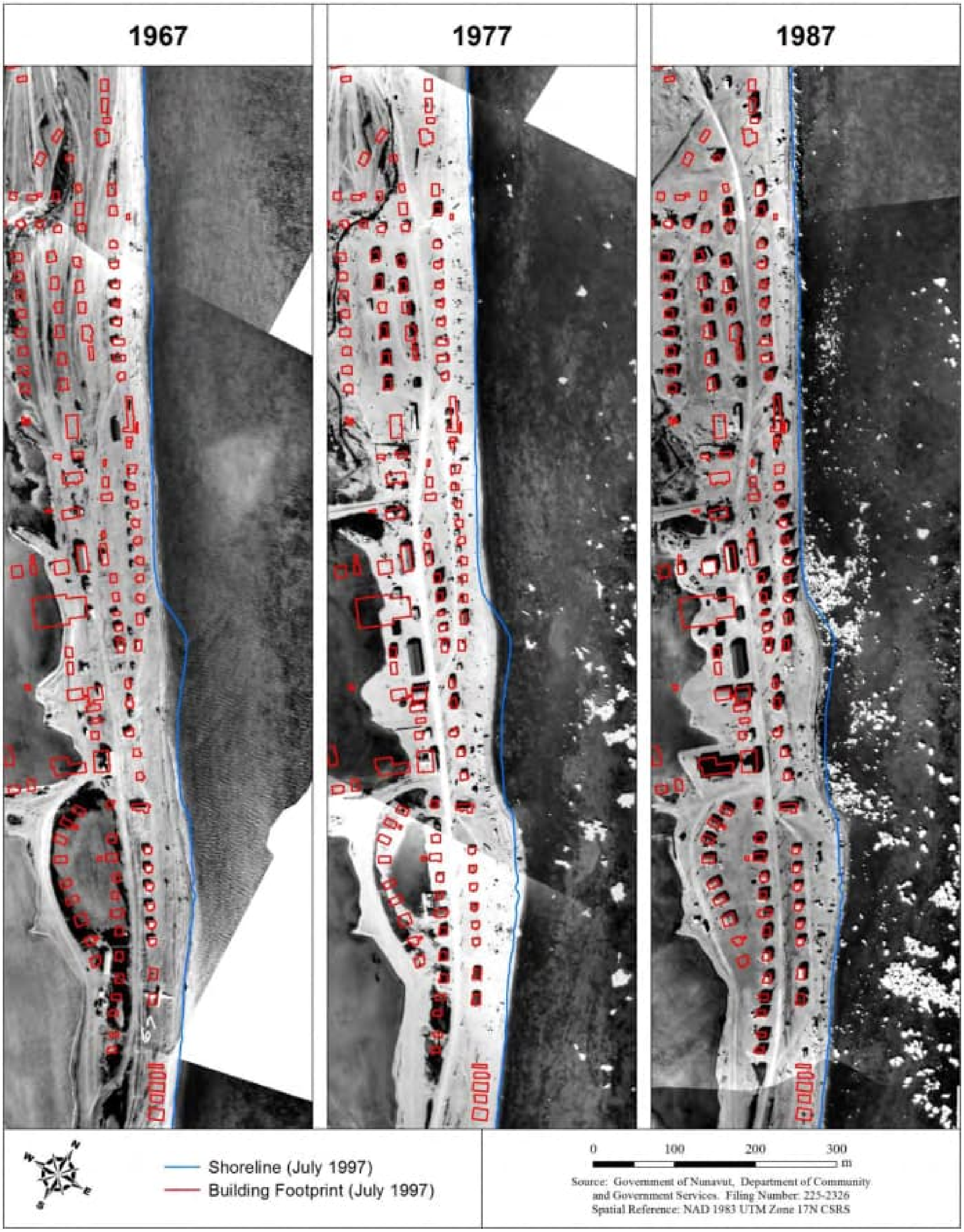


Figure 5-14 Building footprint and shoreline comparison from 1967 to 1987 (Government of Nunavut)

Figure 5-15 Building footprint and shoreline comparison from 1997 to 2015 (Government of Nunavut)

Baird. conducted a study on Sanirajak coastal protection options in 2015 and drew similar conclusions on sediment transport and littoral drift. Historical satellite images show significant beach evolution along the shoreline, though highly inconsistent in rate, as can be seen in Figure 5-16 below. This suggests that the storms that alter the coastline from the southeast are infrequent.

Figure 5-16 Shoreline evolution from 1987 to 2015 (Source: Baird, 2015)

The design of the harbour will need to consider the impact of interrupting any littoral transportation of sediments, as this is likely to have a dramatic impact on the current regime.

6 Small Craft Harbour

6.1 Design Life

A design life of 75 years and a return period of 100 years for design events is proposed for the conceptual design. It is important to note that design life does not imply that maintenance on the structure will not be required during that period. Due to harsh conditions in the Arctic and the lack of experience with structures with an age approaching 75 years, considerable variability in the amount of maintenance required should be expected. The floating docks are expected to have a substantially lower service life before complete replacement is required. The service life in the south for these floating docks is expected to be in the order of 25 to 30 years but because floating docks in Sanirajak will require annual removal and reinstallation, the handling is likely to be the greatest cause of wear and tear. The Pangnirtung floating docks, which are the basis of the dock system here, have been in service for 10 years and are performing well.

Maintenance of the facility will include the following:

- Regular comprehensive inspections, both above and below water.
- Replacement of anodes for corrosion resistance (if so equipped).
- Replacement of timbers and flotation billets on the floating docks.
- Replacement of anchor chains and float connections.
- Re-grading of gravel driving surfaces, including the breakwater surfacing, parking/storage area and approach roads.
- Repair of riprap slopes from ice action, especially impacts from large ice floes from storm events during breakup, and potentially ice plucking.
- Repair and regrading of landing/launching ramps.
- Sounding surveys and/or sweeping to check for boulders where vessel underkeel clearance can be an issue at low tide.
- Dredging, if sensitive to littoral drift or deposition from point sources such as creeks.

6.2 Operability

The facility is intended to be operational during the open water season only. Floating docks will need to be removed from the water for the winter. The operating season for small craft facilities will be dictated by essentially zero ice conditions allowing deployment and recovery activities of the floating docks at a nearby landing beach. It is important to note that the harbour will freeze up earlier than the surrounding open water, being largely calm waters with little ability to breakup during windstorms.

Ice access with skidoos and qamutiks is required for hunters and fishers. It is understood that access onto the ice is generally available in multiple locations to the extent that if the harbour development affects the quality of the adjacent ice, access is available at other locations or around the harbour site.

6.3 Design Vessels

6.3.1 Small Craft Harbour (SCH)

There are approximately 46 small vessels in Sanirajak based on a boat count in September 2021, with makes consisting of aluminum, fiberglass, and wood. Approximately half of these boats were located along the beach ready for deployment. However, a few boats appeared to have been abandoned and are no longer in use.

The SCH concepts are based on initial moorage of 56 boats, providing 10 slips over the present count of small vessels. All options allow for future expansion of at least double this number of slips.

Due to the nearshore shallow water at Sanirajak and the hard bottom conditions, a target depth of 1.5 m below lowest tide is selected for initial conditions. Following 75 years of net land rebound, the harbour will have an estimated minimum depth of 1.0 m. This depth is adequate for all local boats that will typically draw approximately 0.3 m. Some options will have considerable portions of the basin with depths up to 2 m initially. However, this will be a limitation of the harbour, as most fishing trawlers in the 12 m to 15 m length range will draw around 1.5 m. Some can draw considerably more, while a few specialized are around 1.2 m.

For comparison with some of the larger "Nunavut-based" boats, the following are noted:

- Nuliajuk (GN fishery research vessel): 18.3 m length overall (LOA) x 2.6 m draft
- Ludy Pudluk (QIA fishery research vessel): 12 m LOA x 0.95 m draft
- Arctic Focus':
  - William Kennedy – 20 m LOA x 4.1 m draft (currently operates in Hudson Bay)
  - Martin Bergman – 18.4 m LOA x 3.4 m draft (currently operates from Cambridge Bay)
- Baffin Fishery Coalition and Arctic Fishery Alliance trawlers (smaller, non-factory ships):
  - 30 m LOA x ~3.5 m draft loaded, ~2.4 m light w/ fuel (based on AFA fleet)

6.4 Breakwaters

Breakwaters will be required for most of the options to provide protected waters. It is expected that a rubble mound breakwater is the most appropriate and economical structure, despite the lack of local rock available. Figure 6-1 shows an example of a rubble mound breakwater at Pond Inlet.

An overtopping analysis was performed for the breakwaters to suit the exposure of the specific option. To determine the crest elevation, overtopping analyses were performed using the design waves and water levels provided in sections 5.1.2 and 5.1.5. The following three methods were used for estimating overtopping for rock breakwater, and the maximum value was used for selecting the crest elevation:

- EurOtop (Environment Agency, UK et al., 2018)
- HR Wallingford (HR Wallingford, 1999)
- Pederson & Burchart (1992)

It is recommended to limit the overtopping discharge to less than 0.05 m^3/s (CIRIA 2007) to avoid damage to the road on the crest of the breakwater.

The analysis was performed by changing the crest elevation and subsequently, the elevation that met the discharge criteria was selected for the design. Specific elevations are described in Section 7.

Figure 6-1 Breakwater, Pond Inlet

6.4.1 Armour Rock Sizing for Ice Loads

As proposed in section 2.4.1, the thickness of ice that could impact the rubble mound breakwater is 0.6 m at freeze-up, and 1.5 m at break-up. These ice thicknesses indicate that the armour rock should have a mean cubic rock size of D50 = 1,500 mm (D50 is the average rock size in the gradation) for a 1 Vertical to 2 Horizontal (1V:2H), for the outer and more exposed sections of the breakwater.

The following conclusions are provided for the armour rock of D50 = 1,500 mm:

- The specified dimension is for a cubic size rock, and so the weight of this mean size rock is the density of rock times $(D50)^3$.
- The armour rock is stable at break-up when the maximum ice thickness is no greater than 1.5 m.
- The armour rock is stable at freeze-up when the ice thickness is less than about 0.8 m, which satisfies an early winter breakup criterion of 0.6 m.
- The armour rock is stable when the ice grows to a maximum thickness of up to 2.5 m, due to the presence of an active zone adjacent to the breakwater, where a tidal crack separates the ice adhering to the breakwater, and the fast ice further offshore or in the interior of the harbour.

- The presence of glacial ice and multi-year ice is not known at this time and will be the subject of further study during detailed design; however, due to the unknowns at this time, a conservative selection of armour rock size and quality is appropriate.

6.4.2 Ice Crushing Loads on Vertical Sided Breakwater Elements

For the option of using vertical sided elements, such as caissons or sheet pile cells, drifting ice floes could impact against the vertical sides and could generate crushing loads.

The crushing strength of ice is calculated using the methods in ISO 19906 (2019) for three periods as follows:

- Freeze-up: The ice is growing in thickness, but it can be broken up during storms and be highly mobile; it is cold and hence of high strength.
- Mid-winter, stable ice (landfast): During this period the ice attains maximum thickness, but strain rates are usually limited to the creep regime giving lower effective strength.
- Break-up: The ice becomes mobile again; it can be close to maximum thickness but is often thinner due warmer temperatures which also weakens the ice.

Calculated ice loads indicate that the largest loads are due to ice crushing loads during break-up. At this time, the calculations are considered appropriate for a conceptual level of design, and further ice studies should be performed to refine these loads for detailed design.

Due to the large cost of constructing breakwaters of this type, this option was not pursued further.

6.5 Harbour Classification

The SCH concepts have been laid out to meet the 2015 Department of Fisheries and Oceans (DFO) Harbour Accommodation Manual (HAM) using engineering judgement, based on the work completed to date. Preliminary layouts have also been reviewed with the Hamlet and the HTA. Design with respect of wave heights in the mooring area and at the entrance to the harbour will be provided for the 0.3 m to 0.5 m H_s levels to ensure that the broad level of exceedance of those wave heights for no more than 1% to 2.5% of the time are met. It is expected that some refinement to the layout of the harbour will be required at the next stage of the project.

6.6 Harbour Navigation

With reference to the HAM and the design trawler, the main entrance to the harbour must conform to the following geometric constraints:

- For turns of 30 degrees, the minimum radius of curvature will be 5 times the ship length.
- For turns in excess of 30 degrees, the minimum radius of curvature will be 10 times the ship length.
- For bends where the minimum radius of curvature cannot be provided, the channel should be widened at a rate of 3 m for each degree of deflection from the straight line.

- Where possible, it is ideal to have the channel run straight into a protected area or at least into the lee of the breakwater before the vessel must turn.
- Based on Section 5.2.3 of the HAM, the entrance channel for one-way traffic is 3 times the beam of the design vessel, or a minimum of 30 m. For these options the minimum width of 30 m governs the design.
- The entrance channel width and depth criteria as provided in the HAM is proposed for the purposes of conceptual design. Boat dimension, wind loaded areas, sheltering between rows of boats, berth widths, fairway dimensions, and other details will be based on the local fleet and information in Marinas and Small Craft Harbours, Tobiasson and Kollmeyer, 2000. For accommodating the local small craft, the dimensions are provided in section 6.7 below.

6.7 Floating Docks

Small craft floating docks associated with fishing harbours are usually pile or chain anchored systems with floating dockage. Pile anchors are typically used in shallow waters (less than 15 m) where sediments permit while chain anchored arrangements are typically used in deeper waters or where soil conditions are rocky. Pile anchors must be used with extreme care in cold climates with water elevation changes as ice jacking can occur as well as ice fracturing near the shoreline where lateral loads can occur. Ice jacking is the freezing of ice around a pile and the subsequent lifting of the pile as the water elevation fluctuates. Due to the extreme temperatures experienced in the region, pile anchors are not a viable design selection in areas that could be affected by moving ice. Therefore, floating dockage with chain anchoring systems is most appropriate for Arctic SCHs. The harbour in Pangnirtung uses a combination of onshore piles and a proprietary mooring system called Seaflex, which uses elastic cables in place of chains to accommodate the very large tidal fluctuation that is combined with very shallow water depth at low tide.

The following has been considered in developing the layout and concept for the floating dock system:

- The system needs to be easily disassembled, hauled, and easily reassembled for reinstallation.
- It is preferred to align the system with the prevailing winds to minimize loads on the system.
- Wave conditions expected within the harbour.
- Anchors to be left in over winter need to be robust and avoid contact with ice.
- Number of vessels desired to be moored at any one time.

The shore transition is based on a 5H:1V gravel slope where the inshore floats ground at low tide.

The dockage will be removed annually before freeze-up to prevent damage to the floats.

The floating dock system shown in the SCH concepts has the following characteristics which are based on DFO standard docks and are similar to the Pangnirtung arrangement (Figure 6-2):

- 6.1 m long finger floats
- 1.2 m wide finger floats
- 2.4 m wide main floats comprised of 6.7 m long modules

- 5.6 m double berth widths
- 20 m fairway width (this is set wider than required by various standards and guidelines due to the windy climate at the site)

Figure 6-2 Pangnirtung Floating Docks

Floating docks similar to Pond Inlet can also be considered. These docks are wider and have no fingers and thus, boats moor parallel to the main floats.

Figure 6-3 Pond Inlet Floating Docks

6.8 Boat Launch Ramp

The boat launch ramp will be sloped at 1:10. While many boat launching ramps in Nunavut are 1:10, a slightly shallower slope, say 1:12, may be preferred depending on the typical vehicles and traction used for launching and recovery.

The ramp surfacing will be a compacted coarse gravel.

It is important to note that few boat owners have trailers and pull their boat up onto the shoreline for daily and winter storage. While moorage is available at the floating docks, the shoreline inside the harbour will not be suitable for boats up above the high water mark, as it will be higher and steeper. Unless special provision is made inside the harbour, such users will need to pull there boats up at existing shorelines outside of the harbour. Alternatively, some communities offer the service of pulling boats out using the hamlet's loader and placing on blocking. This can be done in the harbour, using the launching ramp.

6.9 Parking and Storage Areas

Parking and storage areas will have modest slopes for drainage, of 1 to 2%. The surfacing will be compact gravel.

These areas will be constructed to an elevation that has a minimum elevation equal to extreme high water plus a nominal freeboard to account for wave chop inside the harbour. Where the parking areas will be constructed against to existing lands that are high, appropriate transitions or adjustments in elevation will be made.

6.10 Lighting and Navigation Aids

All access roads, including those on breakwaters, and the parking and storage areas will have standard QEC lighting comprised of LED streetlights and/or flood lights.

Navigation aids will ultimately be determined by Transport Canada based on consultation with the Canadian Coast Guard (CCG) as part of the Navigation Protection Program process. In general, standard CCG navigation lights on masts will be installed on the ends of breakwaters. CCG is trending toward 4 nautical mile lights. These lights will be prominent for several miles within the backdrop of the community street lights. Leading lights will be required for any options that have entrance channels of some length.

6.11 Fixed Dock

In consideration of local site conditions, a fixed dock has not been specifically allowed for as it is considered cost prohibitive, and given the problems with depth, it is of limited benefit. The provision of such a structure needs to be made in the context of the anticipated depth required alongside. As examples, the minimum depth alongside the fixed dock, together with the tide range, is presented below for those harbours constructed or planned:

- Pangnirtung: 4.4 m deep, 7.7 m tide range.
- Pond Inlet: 3.5 m deep, 2.5 m tide range.

- Clyde River: 5.0 m deep, 1.6 m tide range.
- Arctic Bay: 5.0 m deep, 3.0 m tide range.

The shallow water, hard (bedrock) bottom, and net land rebound make it difficult to construct a fixed dock in the harbour without in-water blasting, for both the entrance channel and the berth alongside the dock. While in-water blasting does occur on rare occasions in the south, it is viewed with increased resistance from regulators due to its perceived effects on marine life. The only alternative would be to construct the facility further offshore, resulting in a much larger harbour structure at a substantially larger cost which is considered cost prohibitive for Sanirajak.

Figure 6-4 shows an example of a fixed dock at the harbour in Pond Inlet.

Figure 6-4 Fixed Dock, Pond Inlet

For the above reasons, a fixed dock structure has not been allowed for in the conceptual options presented.

6.12 Surface Water Drainage

Runoff from local waters will, in general, be diverted through ditches and culverts, from the harbour to avoid sedimentation that would otherwise require maintenance dredging in the harbour basin.

7 Marine Infrastructure Layout Concepts

Based on meetings with Hamlet council and design workshops with the HTA , the most practical locations for small craft harbour facilities are the beach area, in between the community housing and the tank farm to the south (Options 3 and 4) and the location of the existing floating dock, in a small cove approximately 3.5 km north of the community (Options 1 and 2) (Figure 7-1).

A further location (Option No. 5) was also initially considered south of the airport in a small bay due to the protection it afforded from the prevailing northerly winds.

At the workshop with the HTA during the second consultation, an additional location (Option No. 6) was suggested that utilized a sand/gravel bar between the community and the north location. Local knowledge suggested that an offshore sandbar is steadily growing, becoming more pronounced at low tide, and is extending to the south toward the community. This location was also supported by several residents that stopped at information booths set up at the Northern and Co-op stores.

Figure 7-1 Proposed Harbour Development Locations

A total of six options were developed including Option No. 1 and 2 at the northern location, Options 3 and 4 at the beach immediately south of the community, Option No. 5 at the cove south of the airport, and Option No. 6 at the additional location immediately north of the community.

The options are described in the following sections. Of the six options, the fully developed concepts are presented in Appendix 1.

7.1 Option No. 1 – North Cove Site, Offshore

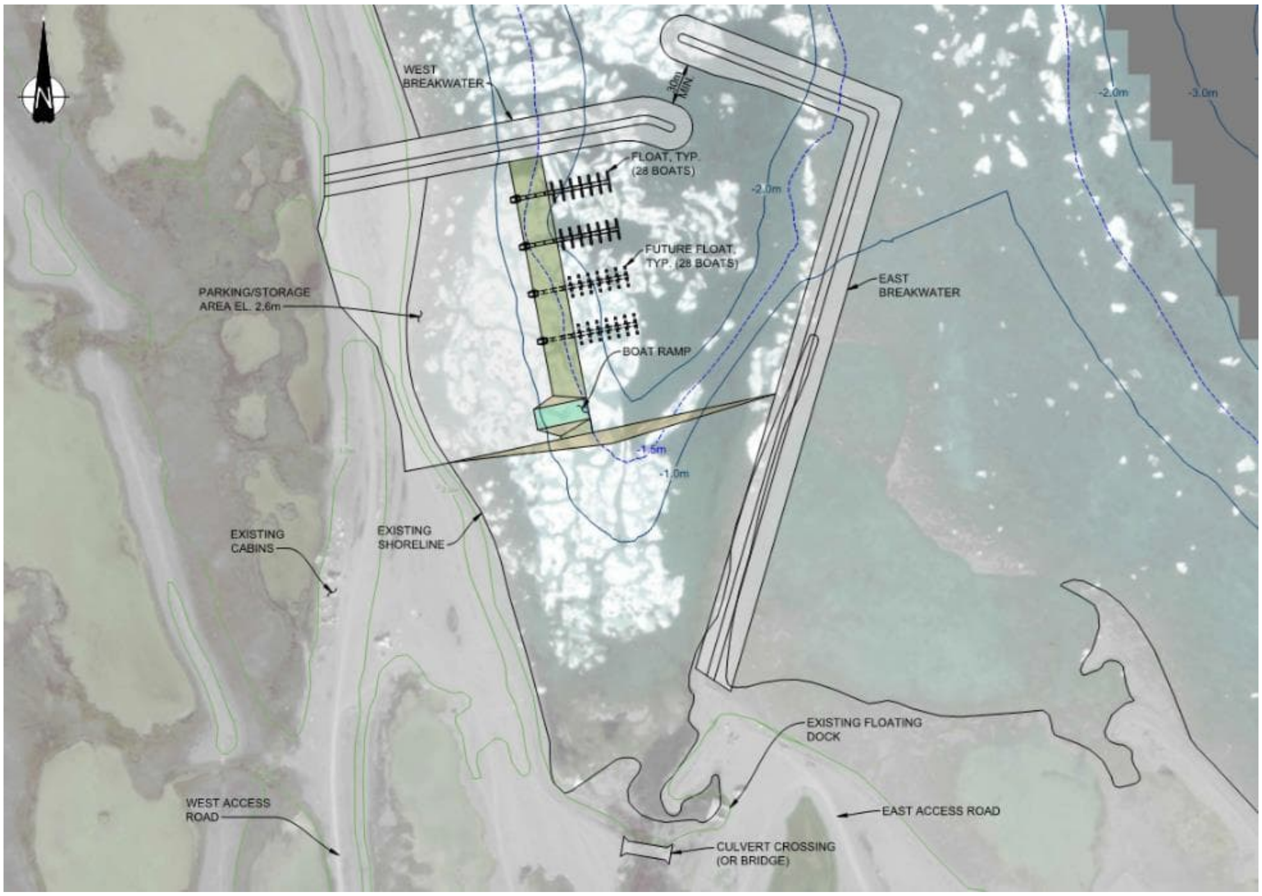


Figure 7-2 Sanirajak Harbour Option No. 1

Option No. 1 is located approximately 3.5 km north of the community at the north cove adjacent to the existing floating dock, with two existing access roads leading to the harbour location from either side of the waste dump, as shown at the bottom of Figure 7-2. The harbour is adjacent to several cabins. A large culvert crossing over the stream that empties into the harbour from the south would provide access from the east road to the harbour which is primarily situated on the western shoreline of the cove. A future bridge could be considered if stream discharge proves to be problematic for maintenance of a culvert crossing.

Option No. 1 consists of two breakwaters that create a protected harbour with approximately 3 hectares at -1.5 m CD or deeper. The breakwaters have a crest elevation of +3.5 m CD, and the west breakwater extends 200 m perpendicularly off the west shore. The east breakwater extends from the south shore along an existing gravel bar towards the northeast for 430 m, with a 150 m hook at the north end, forming a 30 m entrance with the end of the west breakwater. The breakwaters are constructed with a core of local blasted rock and a layer of armour rock protecting the slopes. The inshore armour rock is 1.6 m thick, while the offshore armour rock is 3 m thick and has a 3 m thick toe, to protect from southeastern waves. Both breakwaters are designed to be available for access by pedestrians, with a 7 m wide section of gravel along the top. Navigation lights on masts are installed at the end of each breakwater.

The parking and storage area is approximately 2.7 hectares in size, which is driven by filling from the west shoreline to the 1.5 m depth contour. This area is intended for parking of vehicles, trailers and boats, as well as shacks for users to store loose equipment. The floating docks, that will need to be removed for the winter, will be stored in this area. A 15 m wide boat launch ramp is located at the south end of the parking area.

The southern end of the harbour will be untouched, the west shoreline of which is available for residents without trailers to pull their boats up above high water for the winter. This area will remain lower and has a flatter slope than that on the developed, northern side of the harbour making manual boat handling easier.

Two strings of floating docks extend perpendicularly offshore from the north end of the pullout area, with each of the floating docks able to accommodate 28 boats, for a total of 56 slips. The harbour is designed with the consideration of increasing float capacity in the future, for a total of 112 slips. The floating docks can be lengthened in the future to add more boat moorage. The storage area for the strings of floating docks in the winter is to be +2.6 m CD.

The following pros and cons are noted in reviewing the Option No. 1 concept:

- Pros:
  - Well protected from southern storm waves
  - Does not interrupt the littoral drift processes that could otherwise lead to high maintenance costs (i.e., dredging)
  - Has water depth inside the harbour in excess of 2 m initially
- Cons:
  - North cove site is considered too far for many residents, especially those without vehicles or only ATVs.
  - Requires import of significant armour rock from remote locations

7.2 Option No. 2 – North Cove Site, Inshore

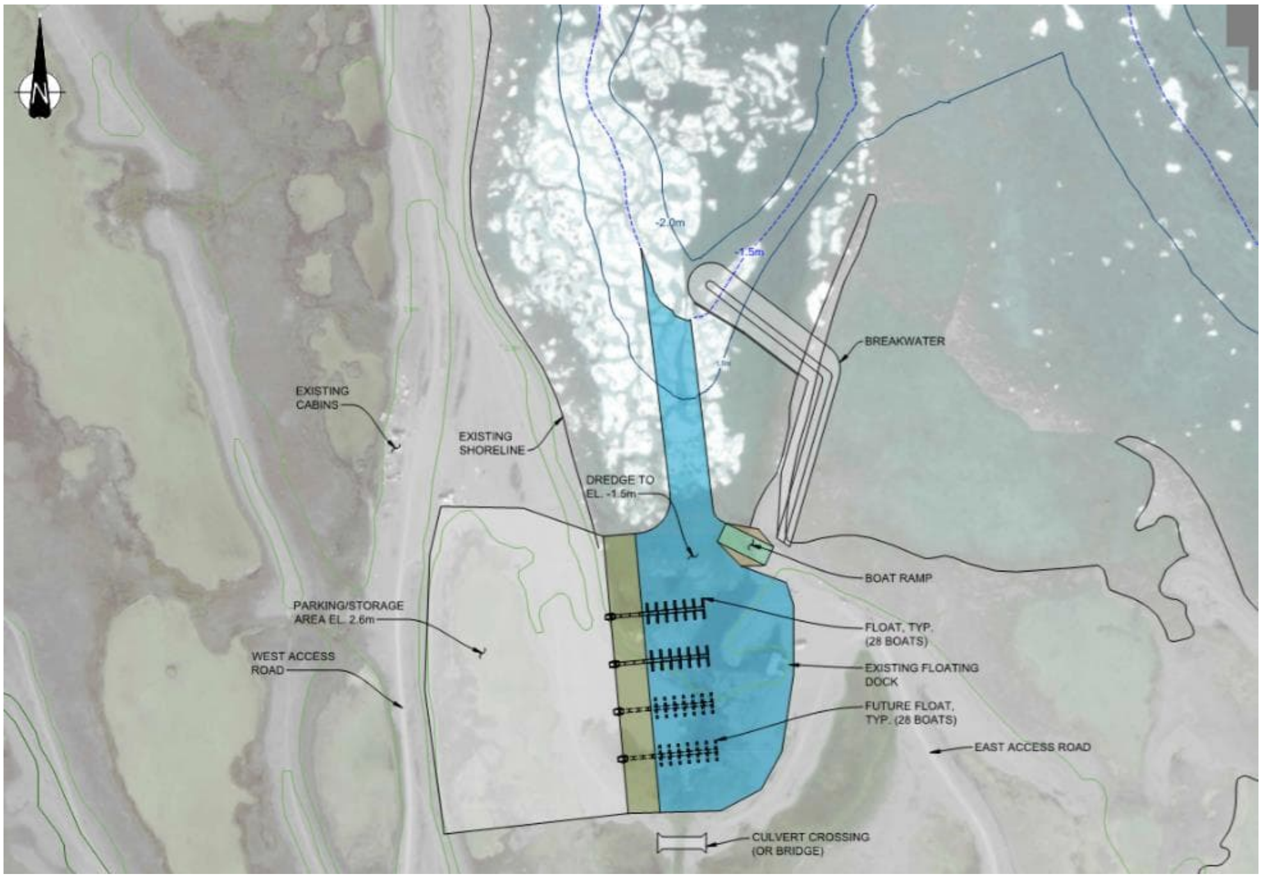


Figure 7-3 Sanirajak Harbour Option No. 2

Option No. 2, shown in Figure 7-3, is located at the same north cove site as Option No. 1. Option No. 2 is well inshore of Option No. 1.

This option has one breakwater on the east side, utilizing the same gravel bar as Option No. 1 but is only 130 m long, with a 110 m hook. The breakwater is constructed similar to Option No. 1 except that the crest elevation is 0.5 m lower at 3.0 m CD, being more sheltered than Option No. 1. It may be practical to construct the breakwater with very flat slopes using the available local rock, rather than importing.

The northwest end of the harbour is largely protected by the existing seabed bathymetry. The entrance channel shown would be 30 m wide.

Much of the harbour basin is likely to be bedrock and is expected to be constructed in the springtime by drilling and blasting when the area is frozen. The layout and position of the basin will require careful consideration to confirm all areas will be frozen to the seabed in case secondary blasting is required to remove any remaining high spots after initial blasting is completed, as flooding at high tide will make secondary blasting more problematic.

The parking and storage area is located on the west shore of the harbour along with the floating docks as in Option No. 1 and is approximately the same area. The capacity for floating docks is the same as Option No. 1. A 15 m wide boat ramp is located on the east side of the harbour. The creek crossing is located just south of the harbour, connecting the east and west access roads while also allowing for a natural route between the parking area and the boat launch ramp.

The following pros and cons are noted in reviewing the Option No. 2 concept:

- Pros:
  - Well protected from southern storm waves
  - Does not interrupt the littoral drift processes that could otherwise lead to high maintenance costs (i.e., dredging)
  - Lower cost than Option No. 1, due mainly to the reduced rock requirements for the breakwater. It may be practical to further economize on the breakwater, using local rock only.
- Cons:
  - North cove site is considered too far for many residents, especially those without vehicles or only ATVs.
  - The position of the harbour basin may require adjustment to suit the extent of freezing of the seawater to practically construct the breakwater in springtime.
  - The entrance channel may be difficult to dredge with an excavator. Geophysics data suggests that the areas approaching the shoreline have more sediment and/or weathered bedrock. If the rock is too competent it may be necessary to use a hydraulic breaker to complete the channel.

7.3 Option No. 3 – South Community Site - Offshore

Option No. 3 is located offshore, immediately south of the community, between the southernmost houses and the tank farm. This location is the community's primary boat launching area and is also the beach used for receiving sealift barges. This location is particularly desirable for the sealift companies and their barging operations as it has the deepest water adjacent to the community's shoreline and the slope is well suited for their barges and ramps. The sealift companies in turn doze the accumulated gravel from the previous months down to bedrock making the surface better for vehicle traction, especially for launching the community's boats off trailers.

Because the location is at the sealift beach and is an offshore position, it will interrupt the local sediment transport regime. This option is expected to result in beach formation on both the north and south sides of the harbour, affecting the usability of this beach for sealift. Therefore, sealift must be located inside the harbour where sediments will not accumulate.

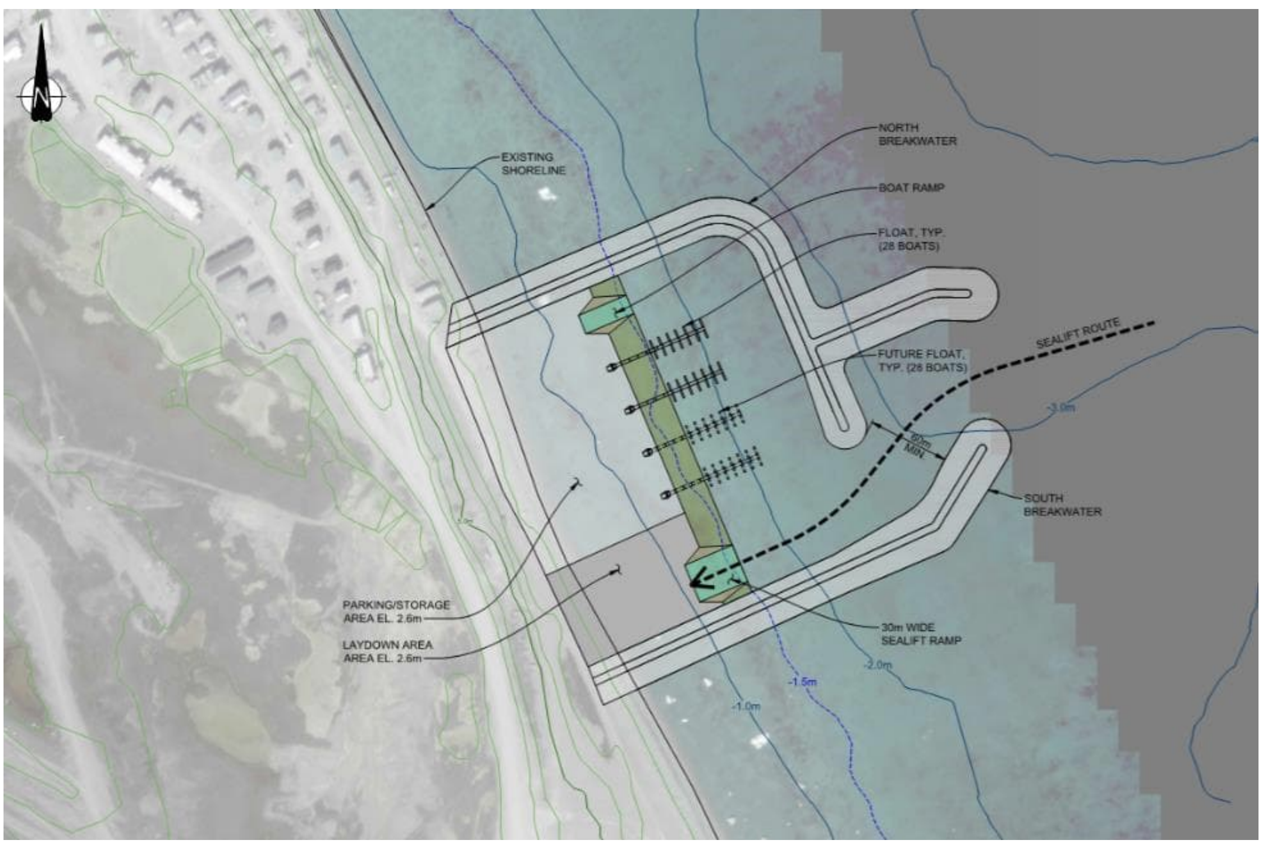


Figure 7-4 Sanirajak Harbour Option No. 3

Option No. 3 is shown in Figure 7-4 and has two breakwaters that extend perpendicularly from the shore. The south breakwater extends for 280 m northeast, before curving towards the north for another 80 m. The north breakwater extends out from the shore for 200 m northeast, then turns 90^{o} towards the southeast for another 180 m to enclose the harbour. This creates a basin area of 2.4 hectares and forms a minimum entrance width of 60 m, which is considered the minimum for sealift barges. To provide additional wave protection to the harbour entrance, an additional 120 m of breakwater (groyne) extends perpendicularly offshore, 70 m from the end of the southeast portion of the north breakwater. This groyne is designed to reduce waves in the entrance. The tops of the breakwaters are at an elevation of +4.0 m CD.

The parking and storage area is located on the northwest end of the harbour with a total area of 2.2 hectares, which is mostly created by filling offshore to the -1.5 m contour. The boat launch ramp is located at the north end of the parking area. South of the boat ramp, two floating dock strings extend from the shore, each with a capacity of 28 boats, for a total of 56 boats. As with the other options, the harbour area is sized for the addition of two more floating docks in the future, increasing the total capacity to 112 boats. In addition, there is the ability to lengthen the string to add even more dock space.

At the south end of the harbour, a 30 m wide sealift ramp is positioned in front of the harbour entrance and allows for barges to offload from a straight path after entering the harbour. Sealift laydown will include approximately 1 hectare of new laydown, created by filling to the -1.5 m contour, to be combined with the existing lands fronting the existing beach. This forces substantially more public access for boats to be combined with the industrial activities of sealift. Separation, in the form of barriers, will be required to separate the two.

As stated earlier, this option will interrupt the active sediment transport that exists on this shoreline. It is expected that a significant volume of sediment moves south from the prevailing northerly windstorms. However, the beach formation that has been occurring over the past decades in front of the community houses suggests that more sediment is moving from the much larger but more infrequent waves from the southeast. It is expected that there will be significant beach formation on both the north side of the harbour from the northerly storms and the south side of the harbour from the southeasterly storms. It is probable that cutting off the sediment from migrating from the south will result in starvation and subsequent erosion of the shoreline further north. Detailed modeling will be required to understand what will happen on the shoreline fronting the community.

The following pros and cons are noted in reviewing the Option No. 3 concept:

- Pros:
  - This option was identified by many as the preferred option. It is the most accessible location for the community
  - A substantial portion of the harbour has a depth between 2 m and 2.5 m.
- Cons:
  - Interrupts littoral drift and may lead to increased erosion further north.
  - Combines the heavy equipment of sealift activities with the public accessing the boat harbour
  - Very high cost due mainly to the large quantity of imported rock.

7.4 Option No. 4 – South Community Site – Inshore

Option No. 4 is in the same general location as Option No. 3, between the southern most houses and the community tank farm, as shown in Figure 7-5.

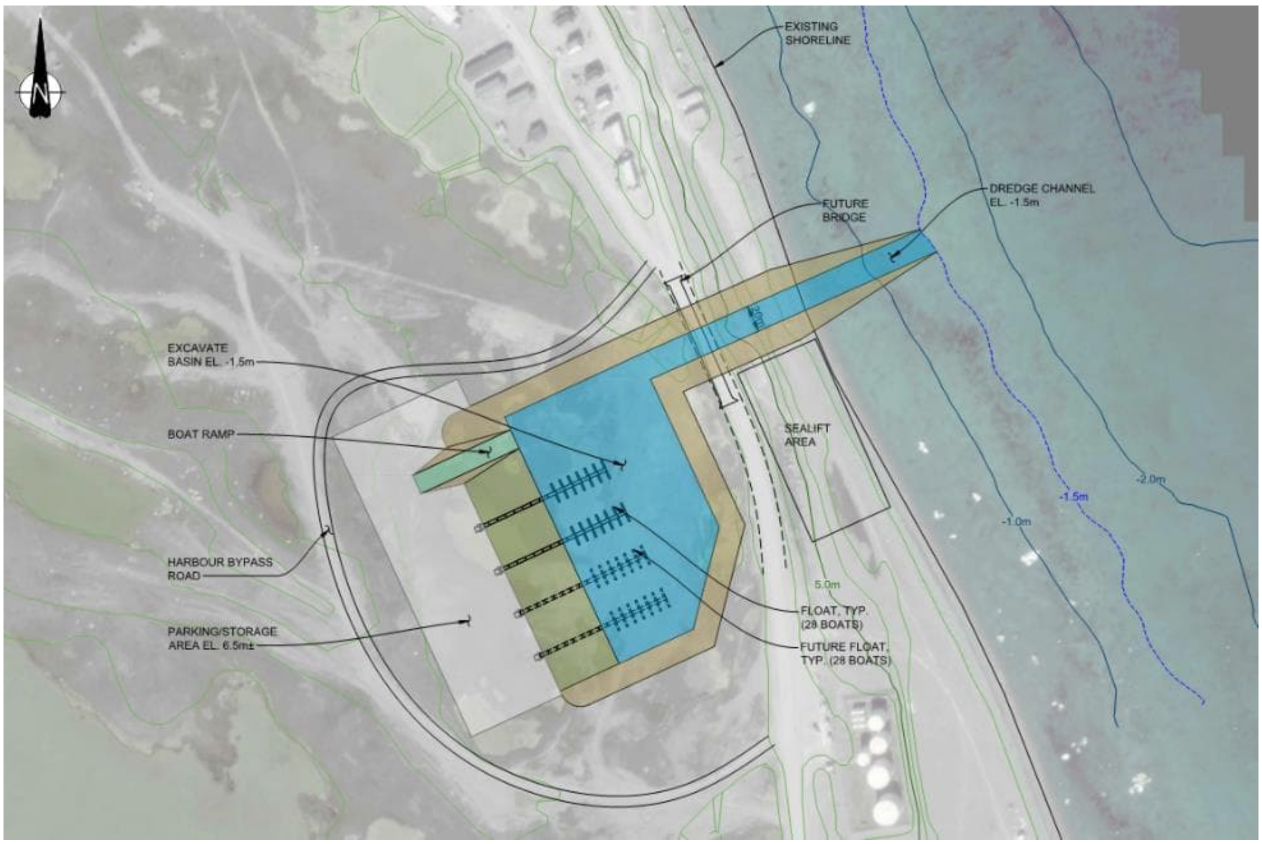


Figure 7-5 Sanirajak Harbour Option No. 4

This option is dredged into the land and is located immediately west of Option No. 3. It is assumed that bedrock is at or just below the surface of the local topography. Thus, the rock will be required to be blasted and it is expected that the best approach will be during the springtime while the ground is still frozen and adjacent ponds will not drain into the blasted hole. The basin would be blasted first followed by the entrance channel.

The harbour is located roughly equidistant from the southern most houses and the tank farm. In discussions with blasting specialists, it was confirmed that the proximity is feasible with reasonable efficiency. It is expected that blast mats will be required to avoid fly rock damaging local infrastructure. The perimeter harbour slopes are, for the purposes of this study, assumed to be cut at roughly a 1:1 slope (45-degree angle). While deterioration of these slopes will occur over time, this is expected to be a very slow process. The entrance channel will be removed last and be blasted deeper at the entrance to act as a sediment collection basin as discussed below, with the final blast being at the shoreline at a low tide to open the channel and flood the basin slowly while water seeps in from below the grounded ice.

The basin is shown at 2.5 hectares and with a depth of 1.5 m below lowest tide. The additional cost to construct a larger and deeper basin is relatively low and it may therefore be desirable for this option to enlarge the basin. The adjacent parking and storage area will be filled using the blasted rock to create approximately 2.2 hectares of space at an elevation to match the surrounding roads and building sites of approximately +6.5 m CD. Two strings of floating docks, each with a capacity of 28 boats, are built from the west end of the harbour basin, and future accommodation for two additional strings, allowing for a total capacity of 112 boats, have been designed into the current harbour size. A boat launch ramp is situated on the northwest side of the harbour.

The entrance channel is shown at 20 m wide. Detailed modelling will be required to confirm the ideal slope and width of the channel to ensure that the north easterly waves are sufficiently cut down to meet the requirements of the basin design criteria while still providing a width adequate for users.

The harbour entrance will be at the shoreline where sediments will continue to migrate both north and south. It is expected that the entrance will need to be dredged, within the sediment collection basin, likely once a year, with a long-reach excavator. It is proposed that dredging is completed at the most appropriate time (likely at mid season when southeast storms increase) and be placed on the shoreline on the north side of the beach, to replenish sediments that will continue to migrate north.

This option will produce some 250,000 cubic metres of bulked rock from the basin excavation. This rock is proposed to be stockpiled near the harbour for use in community expansion plans. Much of the planned community expansion is south into the airport lands, due to the large number of shallow ponds further west. Such a stockpile of rock and gravel is well positioned for such future expansion of the community.

There is a significant drainage culvert, roughly on the alignment of the entrance channel. It is proposed that a new culvert will be installed to the north of the existing culvert to allow drainage to be discharged into the sea, north of the entrance.

The following pros and cons are noted in reviewing the Option No. 4 concept:

- Pros:
  - This option is the lowest cost option and avoids import of any rock for armour.
  - The location is in the area preferred by the community.
  - The excess excavated material is usable for other community development plans
- Cons:
  - Bedrock blasting in close proximity to the community and the tank farm
  - Regular dredging of the entrance is required
  - A bypass road is required for traffic to travel around the harbour

7.5 Option No. 5 – South Airport Site

Option No. 5 is located approximately 2 km south of the airport in a bay immediately south of the Hall Beach NWS site, as shown in Figure 7-6. The location was investigated because of its protection from all northern winds. This option was generally rejected in meetings during the second consultation based on its distance from the community. The concept is shown here but was not developed further.

Figure 7-6 Sanirajak Harbour Option No. 5

7.6 Option No. 6 – North Gravel Bar Site

Option No. 6 is located approximately 1 km north of the community, opposite the waste dump and lagoon, as shown in Figure 7-7. This location is adjacent to a large developing gravel bar that extends from the north cove site and is reportedly growing in height and length toward the community. The concept is based on constructing the main breakwater on the gravel bar. This option was suggested at a meeting with the HTA in September 2021 and received considerable favourable support at public drop-in information booths at the Northern and Co-op stores.

While it was too late to expand the efforts of Frontier Geosciences to include that area, as Frontier had already completed their target locations and demobilized, Frontier was able to complete some geophysics close to the entrance of this option. The results of their data highlight two important factors:

1. The depth of water at the entrance is very shallow, requiring extensive dredging of both the basin and an entrance channel; and

2. Bedrock is at or very near the surface.

Therefore, this option would require offshore blast dredging to be realized and is rejected on the basis on the magnitude of cost and the regulatory hurdles to overcome.

Figure 7-7 Sanirajak Harbour Option No. 6

8 Construction Execution

8.1 Regulatory

The regulatory regime in Nunavut is complex, especially for marine infrastructure, involving several territorial and federal agencies. Territorial agencies include:

- Nunavut Planning Commission (NPC)
- Nunavut Impact Review Board (NIRB)
- Nunavut Water Board (NWB)
- Nunavut Wildlife Management Board (NWB)
- Nunavut Marine Council (NMC)

There are several territorial processes that will require consultation as part of a project development but do not specifically issue permits. These include Culture and Heritage (CH), NTI, and QIA, to name a few.

Federal agencies that will have direct impact to permit marine infrastructure projects in Nunavut include:

- Fisheries and Oceans Canada (DFO), Fisheries Act.
- Transport Canada (TC), Navigable Waters Protection Act.
- Environment and Climate Change Canada (ECCC), Disposal at Sea (DAS) permit if required.
- Crown-Indigenous Relations and Northern Affairs Canada (may have jurisdiction below the high water mark).
- Natural Resources Canada (NRCan), for explosives regulation (for a quarry)
- It is important to point out that the issue of construction related in-water noise is gaining attention. This is related to two factors: research on the west coast by the Port of Vancouver on ship noise and shipping noise in Eclipse Sound as a result of Baffinland ore carriers. Similarly, ship noise has been cited as affecting marine life in Chesterfield Inlet as a result of Meadowbank mine traffic. Construction related noise is now increasingly being highlighted as a concern, especially blasting.

8.1.1 Methodology

Most projects in the south seek interim funding to complete most field programs, reducing execution risk, before funding is approved for construction. This includes field work such as geotechnical drilling and baseline investigations for environmental related impact assessments. Such field work in Nunavut is costly and therefore usually included in the construction funding unless the entire project is owned by the federal government. Thus, funding for such projects in Nunavut are usually secured prior to completing the bulk of the fieldwork, which adds some risk to project cost control.

The following generalized execution is envisioned:

Year 1/2

- Confirm the preferred option with the community, hold public consultation session(s) to gather information from residents and, based on feedback, agree on the final option to be developed.
- Engage with regulatory agencies to confirm the scope of field work required to support permit applications.
- Complete the required field programs, including any remaining topographic and legal surveys, bathymetric surveys, geotechnical drilling, both at the site and selected local quarry. Field programs would be intended to be sufficient for permitting purposes, though supplemental field work may be required.
- If a remote quarry is also required, complete trade-off study to confirm the optimum quarry location. Based on the selected quarry, complete any additional required field program to allow permits to be obtained, if any.
- Complete detailed design, producing plans and specifications in support of construction tendering.

Year 3

- Receipt of final permits.
- Tender the construction.
- Mobilize for construction, including accommodation camp, office, earthworks equipment, maintenance facilities.
- Prepare site, quarry and site for temporary facilities and contractor’s laydown area. This includes remote quarry if part of the project.

Year 4/5

- Harbour construction.

Year 6

- Contingency year.

8.2 Cost Estimate

The Class D estimates for the Study consist of the full scope of work to construct the facilities including quarrying facilities, on land civil works, dredging, marine facilities and on land infrastructure. Operation and maintenance costs are not included. A detailed breakdown of the material quantities and costs are provided in Appendix 7.

A summary of the total estimated costs is presented in Table 8-1.

Table 8-1 Summary of the Total Estimated Costs

Description	Option No. 1	Option No. 2	Option No. 3	Option No. 4
General	$30,300,000	$24,106,000	$41,538,000	$25,253,000
Quarrying	$33,508,000	$9,266,000	$43,348,000	-
Dredging/Excavation	$206,000	$4,396,000	-	$20,390,000
Primary Breakwater	$2,518,000	$651,000	$3,447,000	-
Secondary Breakwater	$896,000	-	$1,937,000	-
Boat Storage and Parking	$1,478,000	$1,472,000	$1,359,000	$2,444,000
Small Craft Floats	$1,067,000	$1,067,000	$1,067,000	$1,067,000
Electrical	$660,000	$605,000	$220,000	$330,000
Subtotal	$70,600,000	$41,600,000	$92,900,000	$49,500,000
Contingency and Engineering	$24,300,000	$16,500,000	$29,900,000	$17,900,000
Total	$94,900,000	$58,100,000	$122,800,000	$67,400,000

In reviewing the cost estimate, it is important to note the following:

- The estimates, including contingency, are to a Class D level with an accuracy of approximately ±25%.
- There is no allowance for escalation. The estimate is based on early 2022 costs and not based on the inflated market conditions that currently exist in Nunavut and to a lesser degree in southern Canada. At the time that the Hamlet decides to secure funding for the project, market conditions need to be assessed. Based on discussions with GN-CGS, most projects tendered by the GN in Q2 2022 have been over the estimated cost by 30 to 100%. Recently tendered marine construction by the federal government for projects in Nunavut have seen very high risk-pricing applied to projects and very few bidders. Some general contractors that have bid such work in the past are finding their crews are fully utilized and not interested in riskier marine construction. The estimates above are not based on such inflated pricing. It is important to note also, the federal government is presently applying 6-7% inflation pricing, per annum, to projects. Inflation and risk cost allowances need to be considered and added when applying for funding.
- Taxes are excluded.

- The contingency allowance is intended to cover those items/costs that have not been expressly quantified or allowed for due to the level of engineering completed but are expected to be spent. The contingency is not intended to be an accuracy allowance, which is very important and is not included in the estimate.
- There is no allowance for marine habitat compensation measures. It is assumed that the constructed works will be self-compensating for marine habitat impacts and will not require additional efforts.
- The estimate is based on similar work from past experience.
- Prices during tender are expected to vary widely, due to the few projects that have been executed in the north of this type in the last decade and the unique nature of the Sanirajak site conditions. Marine construction is not the core business of most contractors that have experience executing work in the north. Therefore, the accuracy is notably lower than might normally be considered as Class D.
- There is no allowance for COVID-19 or related virus impacts to the project. It is assumed that this will not impact the project schedule or costs. COVID-19 had profound impacts to schedule and cost on the harbour construction projects in Pond Inlet and Iqaluit.
- It is assumed armour stone would be produced in Rankin Inlet and transported by tug and barge to Sanirajak. Smaller processed aggregates required for breakwater and parking area is assumed to be produced in Sanirajak.
- There is no allowance for road improvements for Option No. 1 and 2. Consideration should be made to widen, level and to some degree straight one of the two access roads. The value will depend on the magnitude of the improvements, but $1-2M is suggested.

8.3 Operations and Maintenance

Operations and maintenance costs have not been included here. Such costs will be strongly dependent on the approach to management of the facility, especially who ultimately will own and be responsible for the facility. If the GN will own and maintain the facility, they will most likely combine efforts with their existing commitments at Iqaluit for the large port and the recently opened harbour in Pond Inlet, which will be followed in a few years by the harbours in Grise Fiord and Resolute Bay.

It is also important to point out that the cost of maintenance should not be viewed as an annual allowance, but rather as an average annual allowance. Minor issues will often be deferred for years and combined with more significant cost items that will be more infrequent, such as maintenance dredging which is usually periodic if at all (except for the modest amounts needed for Option No. 4). Therefore, moneys not spent annually should be assumed to be required in later years.

The types of regular operations and maintenance include:

- Inspections and documentation
- Grading and compacting gravel surfaces (including top-up)
- Grading and compacting launching ramp
- Removal and reinstatement of floating docks.
- Repairs/replacement to floating dock components
- Power costs

More infrequent maintenance would include:

- Maintenance dredging
- Repairs to armour rock
- Replacement of floating docks
- Damage from extreme events, especially from large ice pile-up events

Depending on the operations approach and priorities of the community, the hamlet may prefer to have dedicated security to control access to the docks and private equipment. It is expected that after the community becomes used to new facilities, priorities are likely to change.

9 Further Work

The following work/studies should be considered in further developing the designs presented in this feasibility study:

- In advance of applying for funding and given the high cost projections for any harbour development in Sanirajak, it is suggested to complete some optimization and refinement of any preferred options, as all are unique to the Arctic. Some additional fieldwork and consultations will be beneficial to cost refinement.
- Consultation:
  - While preferences have been communicated from the Hamlet and the HTA, a public open house is recommended.
  - It is recommended that consultations continue through the development of the project. Consultations are also a mandatory requirement of the regulatory process, especially with projects that involve federal regulators such as Transport Canada and Fisheries and Oceans Canada, both of which apply to Sanirajak's harbour project.
- Detailed wave modelling and geomorphology to finalize and optimize breakwater configuration and design to accommodate littoral transportation.
- Surveying
- Geotechnical: Drilling and sampling is normally required to verify conditions assumed in desktop analyses and geophysics assessments. In the case of Sanirajak, where conditions appear to be weathered bedrock at or near the surface, drilling may not be a requirement and will be a judgement made by the engineer that will be responsible for the detailed design of the harbour.
- Quarry Assessment:
  - Trade-off study to confirm quarry location, if required.
  - While it may be desirable to drill and sample at the proposed quarry, a drilling program is not strictly necessary. It is advisable to complete a geological assessment of the rock face for the proposed quarry to confirm fracture structure and confirm if the desired rock size is likely available. If using rock from Rankin Inlet at Itivia, drilling will not be required as the proposed location is already an operating quarry. However, geological assessment and laboratory testing of the rock would still be required to confirm durability for the purpose of producing armour stone.
  - Further consultations should include confirmation of the proposed location of the quarry.
- Regulatory:
  - With complex regulatory processes in Nunavut that involve both territorial processes as well as federal, further studies should include the work associated with baseline studies that are expected to be required for permitting needs.
  - Marine baseline work is likely required for the offshore options, but may not be required for inshore options, given the modest shoreline impact. Environmental baseline studies should be deferred until such time as the work is fully funded to avoid regulators deeming such study work as stale due to age.

10 Summary

The Study has developed four options for consideration by the community of Sanirajak. Two of these options are located some 3.5 km north of the community at the existing floating dock. The other two options are located immediately south of the community's current residential limit. A further two options in two other locations were considered and are briefly discussed in this report but have been rejected as either not practical or not supported by the community.

The majority of the support by the community is for the options immediately south of the community. There was limited support for a harbour location at the existing floating dock north of the community due mainly to the concern that the distance would be too far for many residents and the issue of equipment security being so far from the community, though it is noted that more support was being generated for the more remote northern sites/options by the final consultation.

The Study investigated the site conditions at Sanirajak. There are six significant factors of the site conditions that make the development of a small craft harbour at Sanirajak difficult when compared to other harbours developed or studied in Nunavut. These factors are:

1. Shallow water fronting the shoreline of the community
2. Bedrock at or very near the seabed surface
3. Low tide range (which does not allow depth to be notably improved at high tide)
4. Relatively high net land rebound
5. Severe exposure to wind generated waves (little natural shelter from the worst waves except for locations far from the community)
6. No local rock capable of producing armour stone for breakwater construction.

The first four factors make it difficult to construct a harbour that has a generous water depth. It is not practical to blast dredge, especially in the quantities that would otherwise be required. The last two factors make traditional harbours at Sanirajak costly. The combination of these makes it impractical to construct a harbour with sufficient water depth that will allow for fishing trawlers at a fixed dock, the type of which is comparable to other harbours constructed/planned in Nunavut. Comparable depth adjacent to the community is approximately 0.8 kilometres offshore. The options, therefore, do not include a fixed dock.

The option most preferred during consultation meetings was Option No. 3, the traditional offshore harbour immediately south of the community. The harbour concept is of similar size as other harbour layouts in Nunavut but has an average depth inside limited to approximately 2.0 m, which after 75 years is estimated to be reduced to 1.5 m due to net land rebound. The deepest part of the harbour has a depth of approximately 2.5 m but is limited to the inshore edge of one of the breakwaters. Option No. 3 is based on importing rock from Rankin Inlet.

Option No. 4 received some favourable feedback, though notably less than Option No. 3. Option No. 4 is at the same shoreline location as Option No. 3 but is based on building the harbour into the land rather than the traditional offshore arrangement. Given that bedrock is at or very near the surface, this means that the majority of the earth to be removed to create an inshore basin will be by drilling and blasting.

During the last consultation meeting in February 2023, there was increasing favourable feedback on Option 2, located 4 km north of the community. The interest in Option 2 was largely in recognition that the cost was the lowest and more likely to be funded.

The estimated project cost to develop a harbour at Sanirajak for the preferred location for the three primary options are:

- Option No. 2 (North, Inshore): $58.1 million
- Option No. 3 (Offshore): $122.8 million
- Option No. 4 (Inshore): $67.4 million

It is important to note that these costs do not consider escalation or the current heated market conditions. The risk dollars applied by contractors currently and the escalation allowances that are being recommended will add significantly to the project budgets and this should be considered in preparation for a funding campaign.

All options are also unique and have never been executed or conceived for a project in Nunavut. Option No. 3 requires importing of rock using tugs and barges which adds an element of risk to the project. Option Nos. 2 and 4 require blasting inshore and below the water table, with Option No. 4 being near community infrastructure. All options would benefit greatly from optimization and more in-depth assessment of risks and subsequent costs. While it is not common to seek project funding from the federal government in stages for such infrastructure projects, this should be considered in refining the cost estimates, given the unique concepts being put forward here.

Given the very wide ranging costs of the options, it is recommended that when engaging funding agencies, if there is an opportunity confirmed, the community should review the options and confirm which option to proceed with based on the agency’s capacity.

These projects are estimated to be 5-year projects, including two years of planning, design and regulatory approval work and three years of construction.

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Appendix 1
Drawings

SITE PLAN
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SITE PLAN

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NOTES:

1. ELEVATIONS AND CONTOURS ARE IN METRES AND DECIMALS THEROF TO HYDROGRAPHIC (CHART) DATUM.
2. EXISTING SHORELINE IS DERIVED FROM GOVERNMENT OF NUNAVUT COMMUNITY AND GOVERNMENT SERVICES PLANNING AND LANDS DIVISION.

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WORLEY PROJECT No 317086-32238

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SANIRAJAK
OPTION 1
GENERAL ARRANGEMENT

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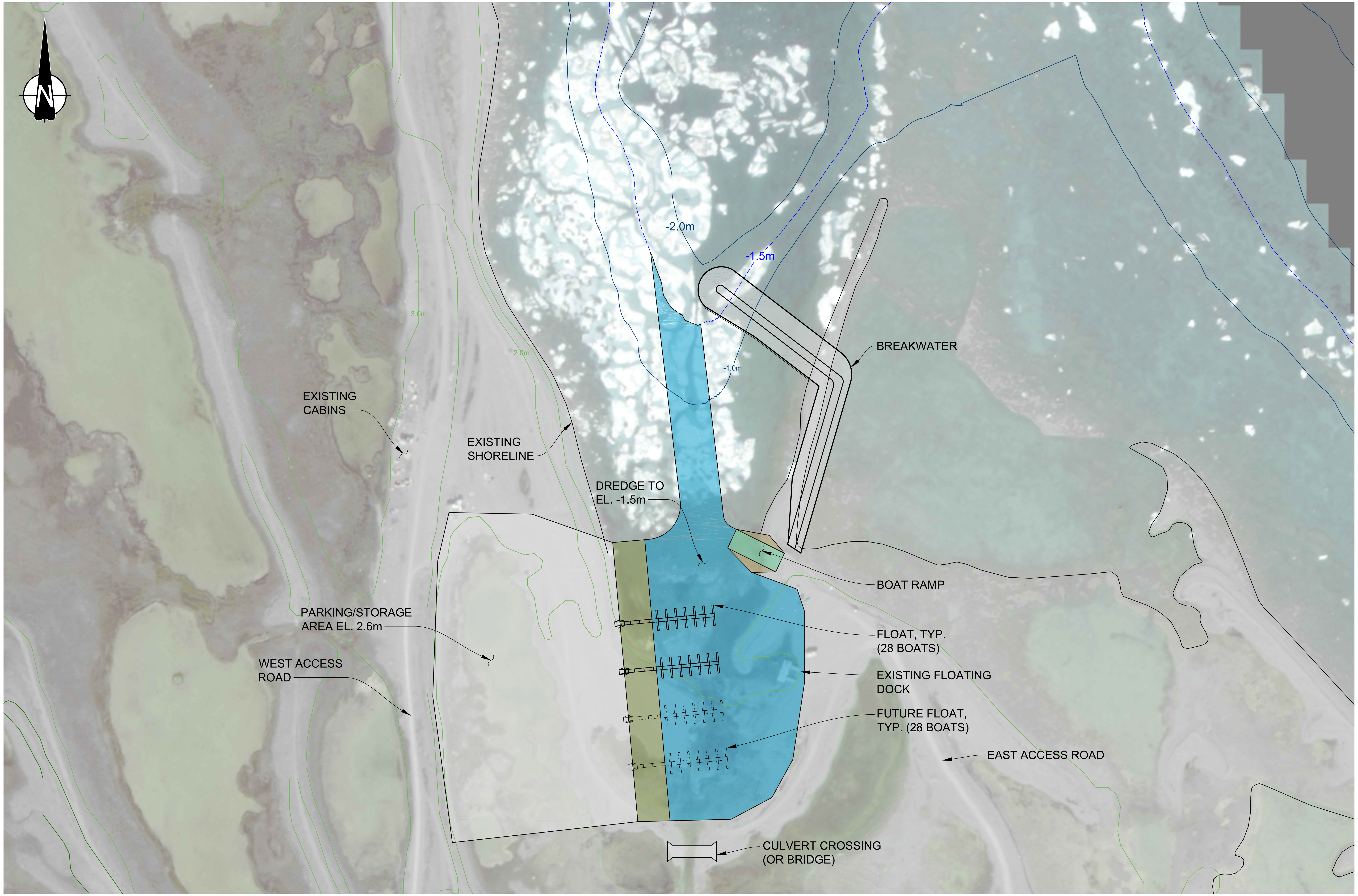

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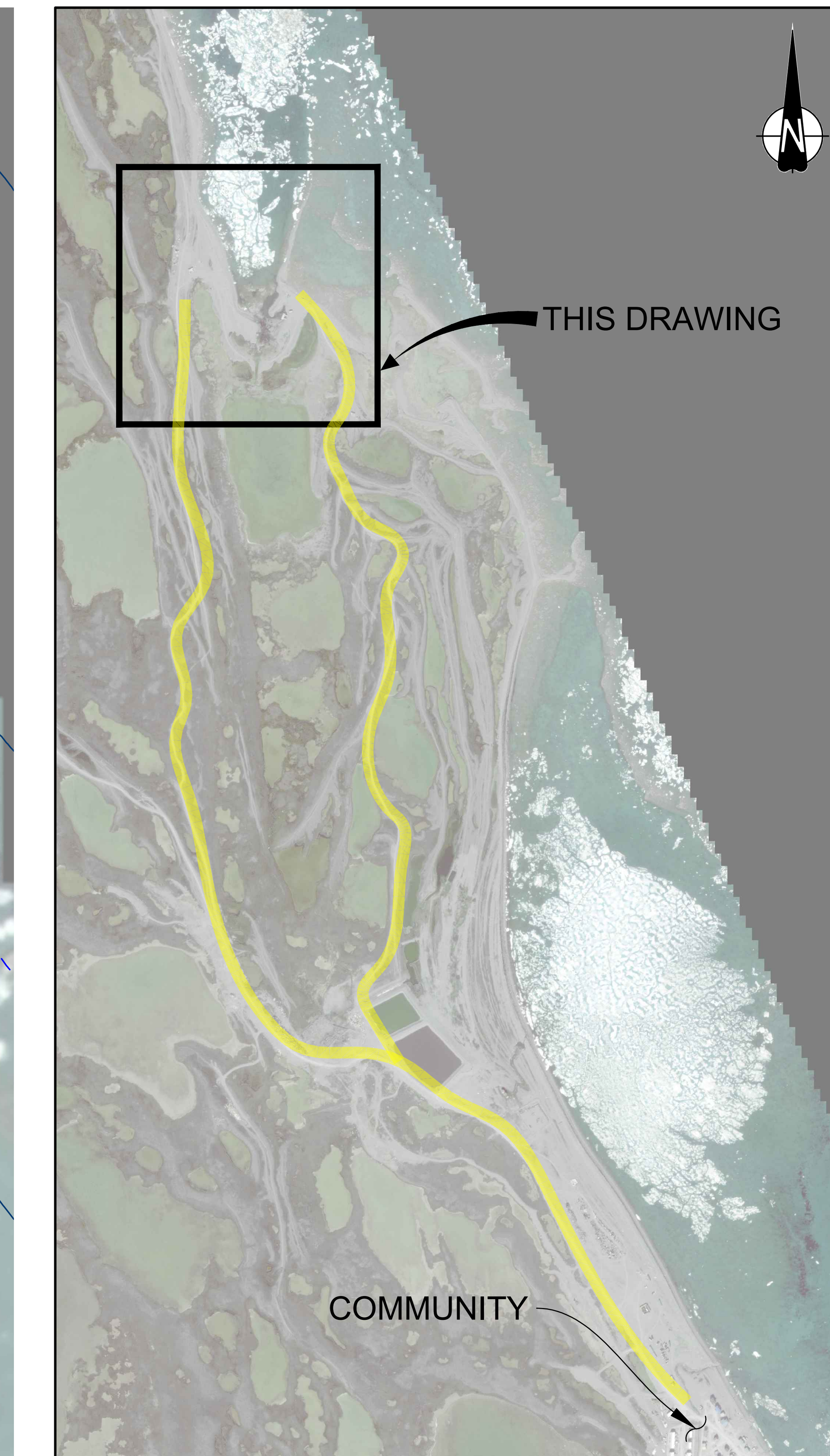

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OPTION 2
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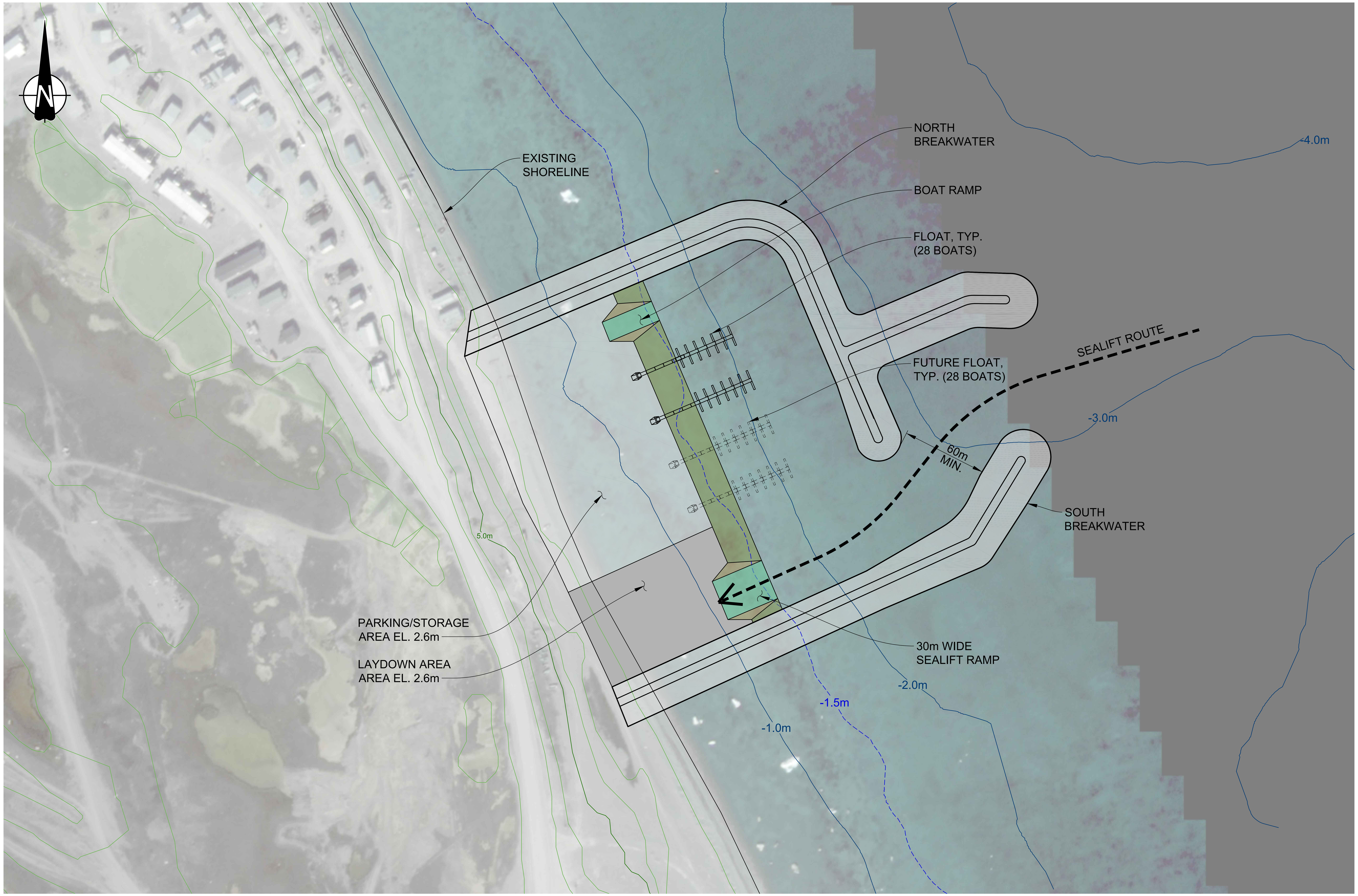

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SITE PLAN

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OPTION 3
GENERAL ARRANGEMENT

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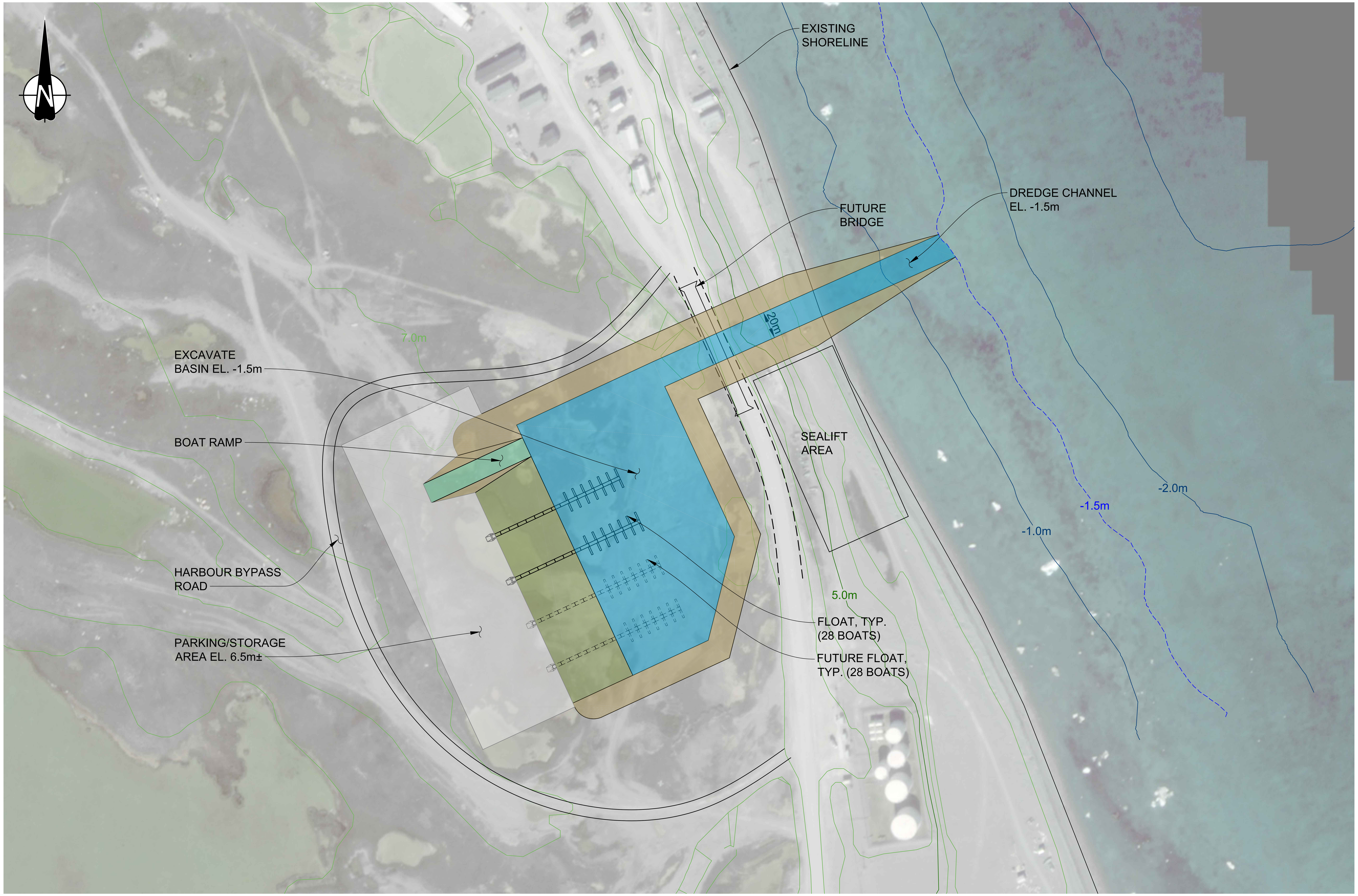

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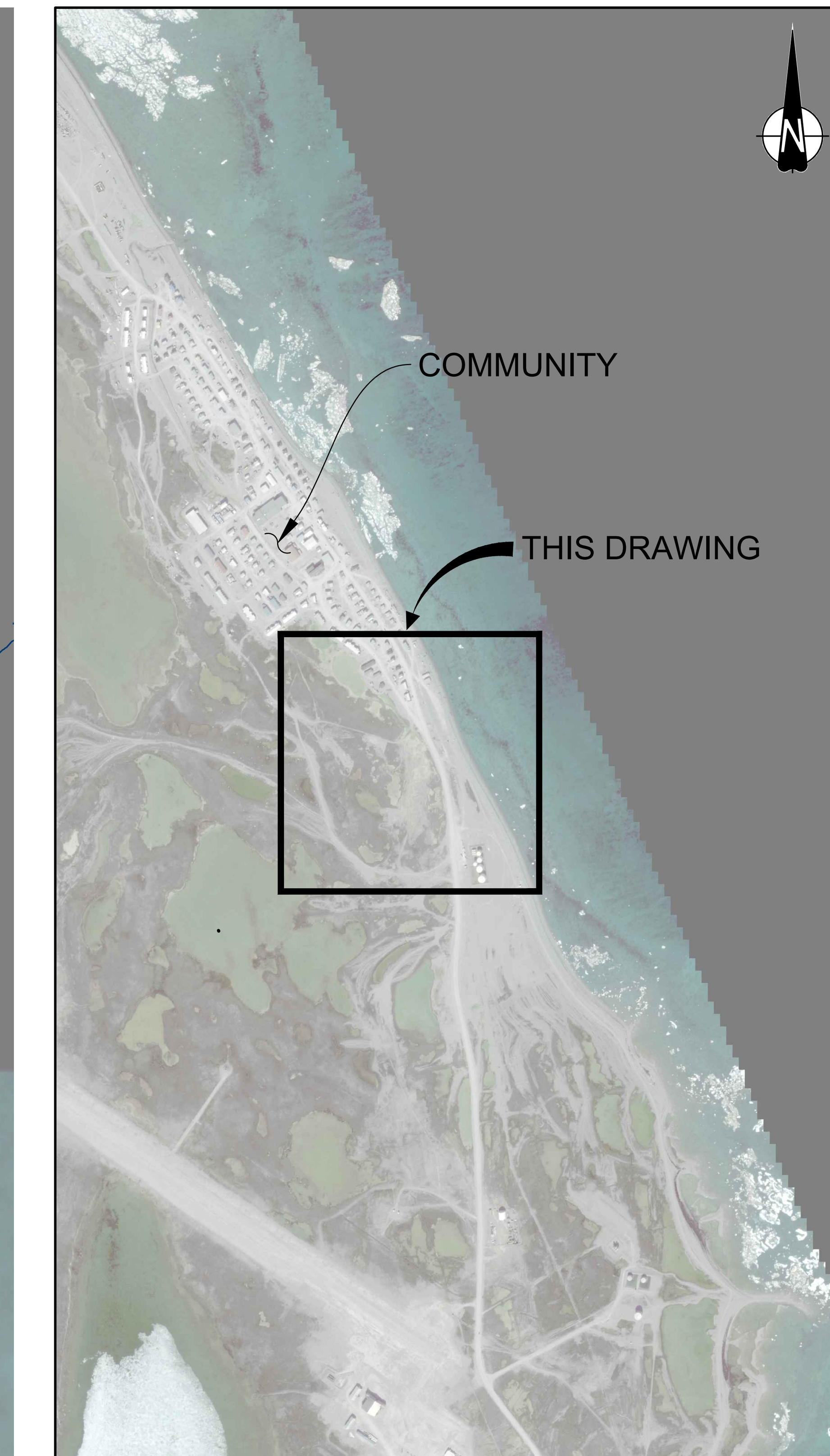

SITE PLAN

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NOTES:

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SANIRAJAK
OPTION 4
GENERAL ARRANGEMENT

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Appendix 2
Consultation Summary

Appendix 2 - Consultation Summary

A2.1 Introduction

This report summarizes the community feedback received during consultations conducted for the Sanirajak Marine Infrastructure Planning Study (the Study).

Two consultation trips were conducted during key stages of the Study.

On the first trip, Harald Kullmann (Project Manager and Marine Infrastructure Engineer, Advisian) and Diane Pinto (Consultation Lead, Advisian) travelled to Sanirajak in March 2021 to meet jointly with the Hamlet council and the Hunters and Trappers' Association (HTA) to understand the community's uses of the marine environment, the needs, preferences, and priorities for marine infrastructure, and to begin workshopping infrastructure ideas that address the community's needs.

Harald and Diane travelled to Sanirajak again in September 2021 to conduct a second round of consultations. The second trip was to: present the Hamlet and the HTA with concepts for harbour options based on the local knowledge and feedback received from the first consultation; conduct a design workshop with the HTA to refine the concepts and obtain additional feedback to assess if alternative locations warranted consideration, and to develop a further understanding of the community's marine environment use during open water season. Harald and Diane also hosted information booths at both the Co-op and Northern Stores during their second trip to gather feedback from residents on the community's needs for marine infrastructure and current challenges with boating. The information booths were advertised on Sanirajak's community Facebook page and on local radio.

Joint Hamlet and HTA meetings began with Advisian presenting a detailed overview of the Study and results using a slide deck followed by open discussion. A list of questions was used to guide the dialogue, but information was allowed to flow in a manner that was natural for participants and not restricted or bound to any strict process. Copies of the presentations are provided in Attachment 1.

The separate meeting with the HTA during the second consultation visit followed a design workshop format. An open dialogue between HTA board members and Advisian was facilitated using maps, surveys, photographs and large-scale drawings of the harbour concepts. Land use information and design ideas were marked directly on the drawings and maps during discussions.

Following submission of the draft report, two virtual meetings were conducted jointly with the Hamlet and HTA in August 2022 and February 2023. An in-person meeting, at the request of council, was attempted in late November 2022 but a storm forced the cancellation of flights and schedules did not allow a follow attempt before the end of the study. The final virtual meeting in February 2023 used the same slide deck as the August meeting as the basis of the call. These meetings provided an opportunity for key community leaders to review the various findings and cost estimates for construction of the various harbour options, and discuss next steps, should funding be available to advance the project.

Consultation materials were provided in both English and Inuktitut and included: presentations; engineering design drawings; charts/surveys; photographs; and maps. Local interpreters were hired to support the consultations.

We are grateful to the residents of Sanirajak who graciously provided their time, knowledge, and unique insights during meetings.

A2.2 Consultation Activities

Table A2.2-1 Consultation Activities

Group	Method	Date
Sanirajak HTA	Joint Meeting – Presentation followed by open discussion at the Community Hall	March 6, 2021
	Design Workshop at the HTA office	September 21, 2021
	Virtual joint Meeting – Presentation followed by open discussion	August 29, 2022
	Virtual joint Meeting – Presentation followed by open discussion	February 20, 2023
Hamlet Council	Joint Meeting - Presentation followed by open discussion at the Community Hall	March 6, 2021
	Meeting in Hamlet Chambers	September 20, 2021
	Virtual joint Meeting – Presentation followed by open discussion	February 20, 2023
	Virtual joint Meeting – Presentation followed by open discussion	February 20, 2023
Community members	Information booths at the Northern and Co-op Stores	September 21 and 22, 2021

Table A2.2-2 Participants at Meetings

Organization	Participant
Hamlet	Jaypetee Audlakiak (Mayor) Stacey Kadlutsiak (Deputy Mayor) David Irqittuq (councilor) Danny Arvaluk (councilor) Mary Kuppaq (councilor) Timothy Kuppaq (councilor)

Organization	Participant
	Isaac Issigaitork (councilor) Louis Primeau (Chief Administrative Officer) Roger Beaudry (Economic Development Officer) Loreen Issigaitok (Executive Secretary) Jayko Simonie (Interpreter)
HTA	Paul Nagmalik Sam Arnardjuak Abraham Qammaniq Deborah Qanatsiak (also on Hamlet council) Solomon Allurut (Interpreter)

A2.3 Summary of Community of Feedback

A2.3.1 Joint Hamlet and HTA Meeting – March 2021

- Winds are coming from all directions now – climate is changing. Prevailing winds are changing.
- Last storm in Nov came from the southeast area. This is important for the coastline as well.
- Not much for NW winds, mostly south winds now. South more prevailing than north.
- Nowadays it has changed. Southern winds give us a lot of high waves. South or eastern winds give us big waves that's why the shoreline is starting to erode, prevailing winds come from the sea for quite a while now.
- We used to get strong west wind, but now easterly is stronger.
- The weather has changed a lot. Lots of rough weather coming from Foxe Basin around Christmas time.
- No more NW prevailing winds nowadays.
- The old ice is no longer here, the ice melts down completely now – no old ice.
- Late September winds pick up more from the sea.
- Fast ice goes around July 1 but this is changing and is variable from year to year.
- Freeze up was usually October but now it can go into November (last several years it has been November).
- The ice doesn't stick to the coastal area – it comes and goes. Land fast ice takes a long time to form.
- Ice pile up – around the #200 houses – there was an extreme event with a major ice pile that was over 2 storeys high. This isn't common but it does happen.
- Happens during lunar tide/super moon, with strong currents – ice could easily pile up to the height of the community hall building.
- Marine life changes also observed – in the 80s we would have whales within meters from shore, but the last 5 years or so whales haven't come close at all because it's getting shallower.

- Whales in the fall are now much further out because the coastline is getting shallower.
- It has been getting shallower for years – even the lakes are getting shallower.
- Boulders are now more noticeable in the water – definitely more shallow.
- Hunters need to be very careful now and slow down when coming in to land to avoid shallow areas.
- Sealift has had to move because of shallowness as well.
- Many more white caps now observed – a long line of white caps north of the community.
- A few places along the shoreline have bedrock – all the way down to the gas bar.
- Sealift only has problems anchoring in really strong winds.
- We can't anchor close to shore at all because of all the bedrock near the coastline.
- There are two areas for boat launching – the floating dock area is only for big boats. It's very far away from the community also. Most canoes just pull up along the shoreline.
- ~10% of boaters have trailers
- ~100+ boats in the community
- Fibreglass and aluminum boats generally have trailers.
- There are more canoes than boats in the community.
- There are not too many fiberglass boats in the community (~<10%) because of high maintenance required.
- The biggest boats are about 33' (fiberglass)
- No anchoring – boats are pulled up.
- Pipes or wood boards are placed on the shore for boats to be pulled up by ATV, trucks, or manpower.
- The best location for any boat is in front of the owners' house. Boaters want to be able to see their boat and make sure it's safe.
- Canoes need to be pulled up high – they otherwise get washed away with waves and the current.
- The sealift area is for people with aluminum boats – the ground is more solid there.
- The floating dock is only used at high tide – too shallow at any other time.
- If it's too rough, with too many waves, boaters go straight to the floating dock - it's a calm area, safe from waves and passing ice.
- The floating dock is way too small though, we need a bigger dock.
- Hunters from Igloolik are often passing through also to go caribou hunting.
- On an average, good weather, Saturday there could be ~50 boats going out.
- The fuel hose and tanker is not a problem. There are good anchor points and bollards to tie up to on shore.
- Boats don't cross the fuel lines – they place buoys so it's easy to navigate and boaters go around the tanker.
- The fuel operation itself is not easy at times – in hard strong currents they have problems trying to tie the hose / connect it. They have to often wait until weaker winds/waves to connect.

- Fuel tanker is in for ~3-4 days.
- The floating dock is too small. There are never more than about 10 boats there at a time. Not enough room for more. Only 4 boats can be tied up at once and the rest are landed.
- Would be a benefit to have the floating dock area improved. Dredged to make it bigger and so you can launch at any time. Make it an all tides launch area.
- Combining sealift and harbour in the community would be a benefit to more residents.
- It's more secure to have a harbour right in the community. Vandalism is easy if it's out of the community at the floating dock – boats would be targeted because no one is watching.
- Hunters need to be able to see their boat.
- Vandalism seems to be increasing every year.
- Sealift beach is where people with trailers launch – it's a nice level slope, compacted. Everywhere else it's loose gravel, not compacted.
- Majority of hunters don't have access to the floating dock, it's too far and too small.
- It's better to have a brand new harbour in town accessible to all hunters.
- The sealift area is the deepest area along the shoreline.
- Sealift carriers would be happy to have a protected area as well to land their barges.
- Most hunters only have a boat, no other form of transportation so it would be better where all hunters can access.
- Any harbour that can be built earlier is the best option though.
- We need a protected harbour – secure from waves and winds near the sealift.
- Consider high currents causing ice damage on any design concepts.
- Improvements to sealift area – engage with the carriers for this. Hamlet does not grade the area for their barges. The carriers do this yearly maintenance for their operations.
- Dredge the floating dock area and provide a new harbour in the community would be the best.

A2.3.2 Hamlet Meeting – September 2021

- Our shoreline is getting shallower every year.
- Suggest extending the beach out to where it gets deeper. Placing gravel along the shoreline area will help.
  - Harald replied that in some areas you have the gravel disappearing and in others you have it accumulating because of wave and wind action.
- In some areas for sure the gravel will wash away but if you put gravel on the clay/mud area it will stick and stay.
- We have a big erosion issue here in the community, which is why we're asking for gravel to build it back up.
- Option No. 1: Big aluminum boats with trailers use the floating dock, but the lighter canoes and those without trailers wouldn't want to go for Option No. 1 because it's too far from the community.

- The Baffinland mine means more money in the community. We have quite a few people working there. More money means bigger and better boats, and more of them.
- Hunters will buy more expensive stuff that is better quality and more durable if they have a good income.
- Option No. 1: There's potential for seaweed to collect and get trapped in the area of Option No. 1, something to consider in the design.
- Option No. 1: the shoreline in that area doesn't have as much movement as our shoreline, there isn't the issue as much with sediment deposition and erosion there.
- When there is a storm, boaters often go to the area of Option No. 1 but it's not ideal in some winds.
- Suggest that the breakwater be designed so the inside wall is smooth so the propellers don't get stuck on big rocks.
- What about the use of sheet piles? The DEW line has these metal culvert looking things filled with gravel for their wharf, I think they're called sheet piles. They worked very well.
  - Harald replied that yes, this could be done but would worry about ice impacts and building anything that would be damaged or in need of repair in a few years.
- What about sandbags?
  - Harald replied that he has looked into them for Gjoa Haven but concluded that the ice would very likely rip them apart.
- Option No. 2: if blasting is fast and in the winter, that would be best. We could make it as deep as we want.
- In the area of Option No. 2, during low tide, it's very hard to get in to shore. Must navigate many shallow areas, if we could improve that area, remove the gravel and dredge the shallow high spots that would be a big benefit.
  - Harald replied that the Hamlet could apply for CTIP funding for marine improvements for a very modest amount of maintenance dredging to improve the area.
- Lighting would be very helpful for coming in at night. Will there be lighting?
  - Harald replied, that yes, all options include lighting.
- Option No. 3: entrance looks too small. Can you add another entrance or widen the channel? This location is the worst place. The current is very strong, the north wind would probably bring ice in and break the breakwater
  - Harald replied that the designs consider the impacts of ice, currents, winds, and waves. Pond Inlet is designed to withstand impact from 5 km ice floes. It will be worse here.
- In the 1990s there was a big ice pile up and the ice got very, very high. The sea current here is much stronger than in Arctic Bay and Pond Inlet, those communities are both in fjords. The ice pile reached the height of a two storey building, it was massive.
- We have no more old ice now. It's completely different now. The mud and shallowness also is getting worse. Need to look into potential impacts from ice very closely for the designs.
- Option No. 5 would probably get the most ice impact and would need the biggest breakwater.

- Option No. 5: to get to that area you have to maneuver through very shallow bedrock areas to get to that dock. I don't see how that Option No. 5 is feasible for bigger boats.
- Option No. 1 is in a much better area. It's easier for canoes to pull up fast during storms, but not for the big boats.
- Option No. 2: Only during lunar high tide times can we go into the dock at lower tide.
- A stronger sea current goes around the point right near that breakwater in Option No. 2, not in the entrance so it's very well laid out.
- Option No. 2: suggest blasting it deep in the right corner for bigger boats.
  - Harald replied that the idea would be to have it 5 ft deep in the whole harbour at low tide
- Blasting in the winter is a great idea, Option No. 2 is good.
- The options in the community could become a safety hazard for kids.
- Option No. 3 is good, but a good point was made that it's a safety hazard as we have a lot of young kids who like to explore on their own.
- Option No. 4 would be preferable and work on the sealift area a bit more to improve it also but there's no breakwater needed for them.
- There are about 5-6 boaters on a daily basis using the sealift beach.
- Option No. 3 is also good, especially if properly planned. Not everyone can travel the 4 kms to go boating – very few have trailers.
- There's not enough information yet to decide as there is no data yet for Option No. 5 and only partial data for Option No. 3.
- The entrance in Option No. 3 also needs some work – consider the needs of the barge and the currents.
- Would be good to engage with other communities to understand how they deal with the public safety hazard aspect of these facilities.
- The floating docks is a good idea for Option No. 3.

A2.3.3 HTA Design Workshop – September 2021

- Are estimated maintenance costs included because the hamlet won't be able to pay to maintain any of these options.
  - Harald replied that DFO owns Pangnirtung and they hire the Hamlet to maintain the facility which is mostly dealing with the floats. Pond Inlet is owned by the GN-EDT and they haven't yet figured out the operating model but the GN-EDT is responsible for paying for the maintenance costs.
- Does Option No. 3 require blasting? It's right near the fuel tanks.
  - Harald replied that blasting so near to residences and the fuel tanks is not ideal but that it can be done safely with proper planning and careful mitigations.
- It's fine by us if you block the sediment movement on the outside of the breakwater – we have too much seaweed as it is.

- Have you considered using cement?
  - Harald replied that he thinks it would be cheaper to get rock from Rankin Inlet compared to using cement. The cement structures required are very expensive and you have to build them in the south.
- What about steel culverts like the DEW line or Nanisivik?
  - Harald replied the Study is looking in to steel options but they would need to be much stronger than what the DEW line had and that they would likely get damaged by ice and need lots of repairs.
- We have good rock, but it's very far from here ~40-50 miles away.
- Option No. 5 is too far from town – if kids start playing over there who's going to be able to watch them?
- Sea ice is thinner now and large ice is being rafted in. We lost two boats because of ice rafting.
- There is a natural sandbar since the 70s that's not going anywhere. Location marked on map. You could use it as part of the infrastructure for a harbour. Fill it all in up to the depth line and it becomes a natural breakwater – it's becoming very shallow.
- It would be best to design into a natural feature already or to at least look at the possibility of doing so.
- Th location is also well protected from ice and strong currents don't hit that area.
- It eroded very close to the houses for many years, but that sandbar never eroded.
- Our beach gravel is always moving, but not there.
- Could there be an option looked at for this location - suggest filling it, let it freeze, then blast it.
  - Harald replied that the Study team will have a look at that area and develop a new concept at that site - Option No. 6.
- The most feasible option always means the cheapest because nothing will get built here if it's too expensive.
- Waves and ice area going to destroy the Option No. 3 / sealift breakwater.
- The low tide and high tide currents are really strong.

A2.3.4 Virtual Joint Hamlet and HTA Meeting – August 2022

- Do currents affect harbour entrance in Option No. 4?
  - Harald replied that we don't have data on local currents but don't expect currents to be a significant factor in designing the harbours.

- Suggestion that the old DEW Line dock which used culverts worked for many years and did not require big rock.
  - Harald replied that we will have difficulty making that system work. We don't know how it got damaged over time. However, we could do something similar, but if there is significant damage in, say, 5 years, would people think that this was a success? I think not, especially after spending such a significant amount of money. All sites have a hard bottom, so we would expect that rock fill would leak out of the bottom.
- What about pinning the culverts to hold them down? Would drilling offshore be doable?
  - Harald replied that yes we could do that, but we would not use culverts, it would need to be something more robust. Such an idea was considered, but the cost would be even higher.
- Harald asked about blasting close to shore when the floe edge is some 1 km or 2 km offshore, would there be an impact to marine life?
  - An elder replied that there are not many seals or walrus around at the ice edge at that time.
- CAO noted that escalation adds a significant cost to the project if we add just the lower end. He thinks something should be carried.
  - Harald agreed but used Pond Inlet and Iqaluit as examples. Since there is little in way of materials purchase for these projects (most is rock) and much of the equipment is already owned (not rented), there was not a material escalation between the 2010 studies, the 2015 application to the feds and the 2018 tender for the construction. So while current escalation is high, we need to consider how much do you want to ask for? A high ask will be more difficult to justify.
- Inquiry about maintenance cost and especially in regards Option No. 4. If this one needs annual dredging, we need to allow for the operating costs.
  - Harald replied that Pangnirtung was operated for the several years with very little budget, less than $100k. The new harbours (Lancaster) had a commitment of $1.5M per annum each to operate the facilities. Annual dredging will not be that high. While you may not have the equipment currently, that would not be significant add. Also, if reach is an issue, the approach taken in Pond Inlet would work quite well – gravel berm placed to get out as far as you need and then you dredge and pull back the berm. Definitely, you need to carry an operating/maintenance budget. If the GN delivers/owns the facility, they will add some operating as well.
- CAO noted the comment about further study, especially Option No. 3. What sort of magnitude of effort? Similar to present study?
  - Harald replied, yes, but will depend on what sort of field data is required.
- What about icing up of the harbour?
  - Harald noted that the harbour will freeze up early. The calm waters inside the harbour will freeze much earlier than the waters surrounding Sanirajak. The floats will need to be removed before freeze-up. People that still expect to be active in the water, will need to keep their boats outside the harbour and launch on the rest of the shoreline. For the early season, the sealift beach has a culvert. If we were to direct that spring runoff into the harbour, we could thaw the ice early, get the floats in early. Need to be careful with sedimentation from this discharging water.

- Why was Option No. 6 not discussed in more detail like the others?
  - Harald replied that although Option No. 6 was considered, it is even shallower at the entrance compared to the others and like the others, bedrock is at the surface. This option became impractical to develop further because there is just not enough depth to make it useful.
- When will be the next in person meeting?
  - Harald replied that the visit was currently planned for second half of October 2022 or later. Want to combine with other travel where possible.

A2.3.5 Virtual Joint Hamlet and HTA Meeting - February 2023

- Option No. 3: since the sealift is located in that same area, what would happen to the sealift operations?
  - Harald replied that we're adding more space for the sealift area. We added a sealift ramp inside the harbour and we've added space for cargo. There's lots of space in this option to also store boats, ATVs, trailers, trucks etc.
- Option No. 4 – Just FYI, this year, in Oct and Nov – we had the biggest waves we've ever had. You would see now that the sealift area is much different, it's nearly completely gone and the area is way shallower. Nowadays it's too shallow for belugas and other whales to come near like they used to. The sediment is moving up along the shoreline.
- The fuel tanks would cause a major safety risk for one of the options.
  - Harald replied that blasting would be done close to the tanks and to a house. Explotech was engaged and they think it can be done and it can be done safely.
- You also need to know that kids will go to the harbour and vandalize boats and equipment if the harbour is close by. If the harbour is farther, they wouldn't vandalize or go play at the harbour as much. We need to find ways to save the people's boats, protect the boats, to store them. We need a floating dock soon and definitely before we need any kind of improvements to the sealift area.
  - Harald replied that regarding vandalism, Pangnirtung had the same concerns about vandalism so they only built floating docks for 30 boats. A lot of people said they would just anchor their boats but didn't want to tie up their boats. Within 2 years, they added another 30 slips and another 2 years later they built another 20. So right now, they can tie up 80 boats inside the harbour and it's not enough. They now need to make the harbour bigger. I think it's a combination of awareness and people keeping an eye on kids, they added cameras at the floating dock also. Option No. 3 or 4 also have a lot of space for anchoring if people still wish to do that.
- Harald requested pictures of the storm and what the shoreline looks like now.
  - Councillor Kuppaq replied that you'll have to wait until the snow melts to see the shoreline so that they can take pictures.

- QIA is exploring the possibility of a fishery here. Having worked in Pangnirtung, do you have an idea what kind of boats would be able to use any of these options, in terms of research or fisheries.
  - Harald replied that in order to accommodate those larger ships you would have to extend Option No. 4 into deeper water and that would increase the cost. But for the fish packing plant boats, like they have in Pangnirtung, I don't think they use those big ships, and I think you would be ok to accommodate those boats.
- Option No. 2: lots of seaweed to deal with in that option even though the cost seems better.
- Option No. 5 and 6 – thank you for clarifying that they're not feasible. The HTA was very interested in those locations as potential harbours but if it's not feasible because it's too shallow and the bedrock is right at the surface than we accept that.
- Hamlet is in the process of getting an excavator to deal with the seaweed that overwhelms our floating dock.
- If we were to use Option No. 1, would the Hamlet be able to get financial assistance to deal with maintenance dredging?
  - Harald replied that CTIP or CANOR may be able to fund maintenance dredging.
- CAO noted that CTIP funds quite a few different initiatives and we obtained funding from CANOR, in part, for this feasibility study.
- Option No. 2 – probably the easiest one to get done: it's the smallest project.
- In the fall time, the waves are getting stronger every year, and it's moving all the gravel. Do you know about this?
  - Harald replied I think the gravel mostly moves from the south to the north? Is that the question?
- In the fall, the winds, currents, waves etc. are much stronger and there's a lot of movement of gravel and changes to the shoreline, just so you know what you're up against.
  - Harald replied: I think in the fall, you get storms out of the south moving north pushing a lot in that direction, more moving from the south to the north. In the summer, your storms are mainly from the north, so gravel moves from the north to the south but not as strong.
- Yes, that's the question, do you know what the forces are that you need to deal with from the south-easterly storms for the design?
  - Harald replied that yes, we are able to calculate the forces.
- Was a winter road considered to the granite? – I'm not understanding this. Getting the machinery is the big cost.
  - Harald replied that you would need big rock haul trucks to be able to do that. That could be an option but you would need to study an ice road. I don't think it would be an easy execution. I don't see it being a lot cheaper, it might be a bit, but not a lot cheaper. Option No. 4 for 60M hardly has any trucking. If it's trucking 80 km and on ice, I don't see it being much cheaper.

- That's why we should choose Option No. 2.
  - Harald replied, yes, keeping the project as tight as possible, with all the components close and minimal trucking is the easiest and usually the cheapest way to go. I also, should say, that in the current market/ climate, building anything is crazy expensive right now. Pond that was built for 40M would be 60 if not 80M today. It's a very hard time to get anything funded right now because everything is so expensive.
- Harald asked if the GN cancelled any projects in Sanirajak?
  - CAO replied that none he was aware of, but they do know of many projects across the territory that have been put on hold because of the costs.
- Option No. 2 would save a lot of money and it wouldn't cost that much to build comparatively.
- Option No. 2 is preferred because it could likely be built sooner and wouldn't cost that much. We in Sanirajak, we are in a flat place, we can go far and access places year around. Option No. 2 would be acceptable.
- Option No. 4 is preferred by HTA member Issigaitork, the waves in the fall time wouldn't impact the harbour compared to Option No. 2 and since the blasting has been confirmed to be able to be done safely and wouldn't impact the community or residents, it's my preferred.
- Would blasting be done in the winter?
  - Harald replied that yes, most of the blasting would be done during the winter months.
- Option No. 2 is preferred by councillor Kuppaq since it will be cheaper and could likely be built sooner.
- What is going to be done to improve the area of the floating dock in the meantime?
  - CAO replied that the floating dock issue is not in the scope of the Study. The Study team are consultants and do not fund anything.
- Harald shared that he gets the sense that transport has quite a bit of interest in Sanirajak, so it may be worth sending Matt Bowler at GN-EDT a proposal within $200K to improve your floating dock area, if that's using Hamlet equipment to be able to make it a bit deeper.
- Why is Option No. 2 so expensive? Is it blasting?
  - Harald replied that yes, it's blasting, in the wintertime, but also there's a fair bit of rock in that option as well.
- Can you come back to us with more details on Option No. 2 once the report is finalized? We would really appreciate that.

  Harald replied that we won't be able to come back to Sanirajak before the end of the project (end of March). There isn't enough time, but if the Hamlet can make it work after March, we could look into that.
- In Sanirajak, we have an MLA that is willing to help the community and will for sure help the Hamlet with pushing this issue of getting the harbour realized

Attachment 1
Presentation Slides

Sanirajak Marine Infrastructure Feasibility Study

March 6, 2021

Diane Pinto
Harald Kullmann

Advisian
Worley Group

Introduction and Study Timelines
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Advisian contracted by the Hamlet of Sanirajak

1st Consultation visit ᓯᕗᓪᓕᖅᐹᖅ ᕿᒥᕐᕈᐊᖅᑎᓖᑦᓗᑎᒃ ᐅᖅᑲᖅᑎᓖᑦᓗᑎᒃ ᐳᓛᖅᓗᒋᑦ	March 2021
Coastal Overview and Develop concepts ᓯᓪᔭᖕᒐ ᖃᓄᐃᓕᖕᒐᓂᐊᕐᓂᖕᒐ ᐊᒻᒪᓗ ᓴᓇᓯᒪᓂᐊᖅᑐᑦ ᑕᖕᒋᖕᒋᑦ	March to June 2021
2nd Consultation Visit and Site Reconnaissance ᐱᖅᑖ ᕿᒥᕐᕈᐊᖅᑎᓖᑦᓗᑎᒃ ᐅᖅᑲᖅᑎᓖᑦᓗᑎᒃ ᐳᓛᖅᓗᒋᑦ ᐊᒻᒪᓗ ᐃᓂᖕᒐ ᖃᐅᔨᓴᖅᓗᒍ	Early August 2021
Geophysical Assessment	Mid August 2021 (subject to ice)

Introduction and Study Timelines
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• Draft Report	October 21, 2021
• Third Community Consultation	End of October, 2021
• Socio-Economic Assessment	November 2021
• Final Report	December 6, 2021

Background Information ᖃᐅᔨᓂᕆᓯᒪᔭᖓ ᑐᓴᕐᑎᑦᑎᔾᔪᑎᒋᓗᒍ

- Information from GN (EDT and CGS)
  - EDT assess document with some old concepts
  - GN study on shoreline erosion at House #98-110 (2015)
  - NRCan study on climate change
- Does the Hamlet have any previous data/studies?
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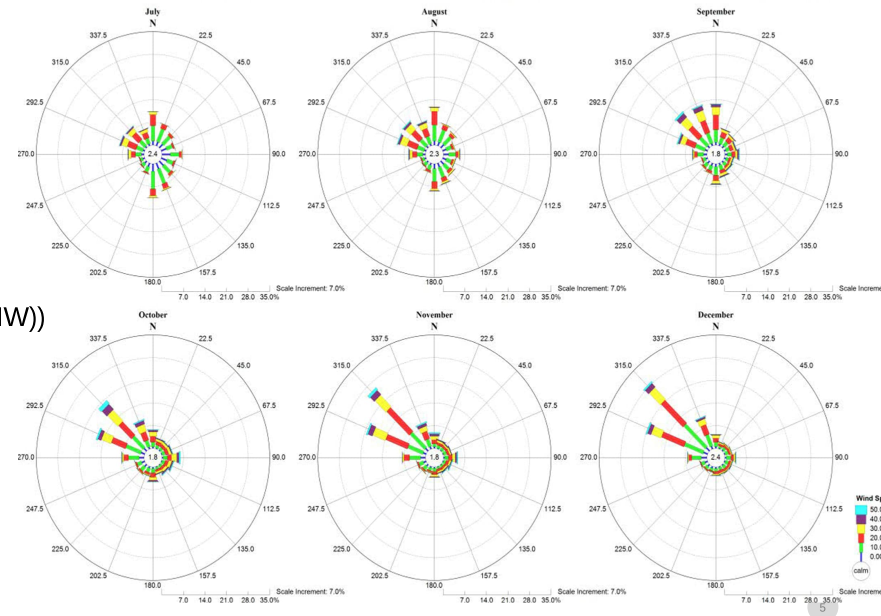
Background Information ᖃᓄᐃᓐᓂᕆᓯᒪᔭᖓ ᑐᓴᕐᑎᑦᑎᔾᔪᑎᒋᓗᒍ

- Existing conditions:
  - Tide range –
    - 1.4 metres (“yearly max”)
    - 0.9 metres (“every day”)
- Winds:
  - Prevailing winds from NW?
  - Storm winds from NW?
- Waves? (fetches: 500km SE, 100km N-NW, 30km NW))



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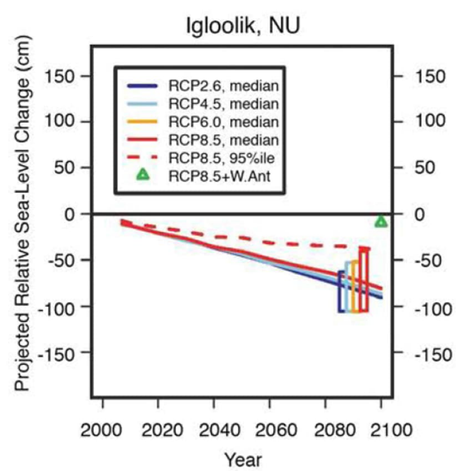
- Ice:
  - Local breakup in early/mid June?
  - Regional (Foxe) in late July
  - Freeze-up in mid-October
  - Ice pile-up events? (2nd floor window report?)
- Sea-level change
  - Almost 1 metres drop by 2100
- What are people seeing/noticing?
  - Ice changes
  - Winds
  - Waves
  - Sand movement
  - Water depth
  - bedrock



Existing Facilities

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Understanding Marine Activities

- Boats – storage, launching, etc
- Sealift
- Fuel resupply
- Other?

Existing Facilities ᒫᓐᓇᐅᔪᖅ ᐊᑐᖅᑕᐅᔪᑦ ᓇᐸᔪᑦ

Boaters ᒫᓐᓇᐅᔪᖅ ᐊᑐᖅᑕᐅᔪᑦ ᓇᐸᔪᑦ

- How many boats? Size? Type? Trailers?
- How are boats dragged up the beach/launched?
- Community freezer?
- Significant creeks/drainage?

- Any problems with sealift barges?
- Any problems with tankers/hoses?

- Quality of road to the floating dock?

- Are there many Igloolik boats visiting?

Existing Facilities

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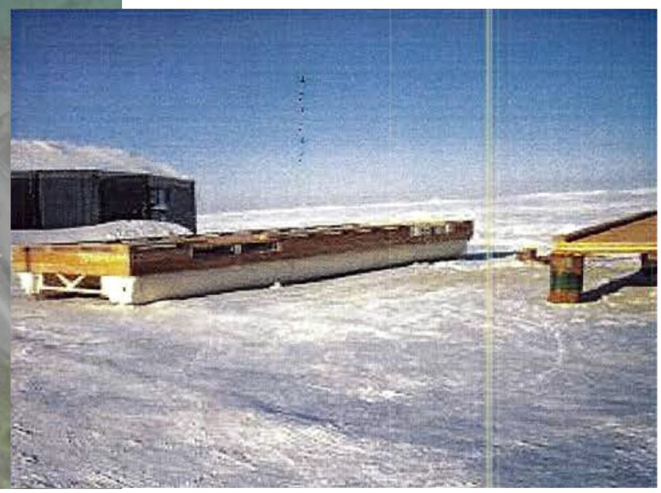
- Float dock ~4km north of hamlet
  - How is it used?
  - Issues?



Past Facilities

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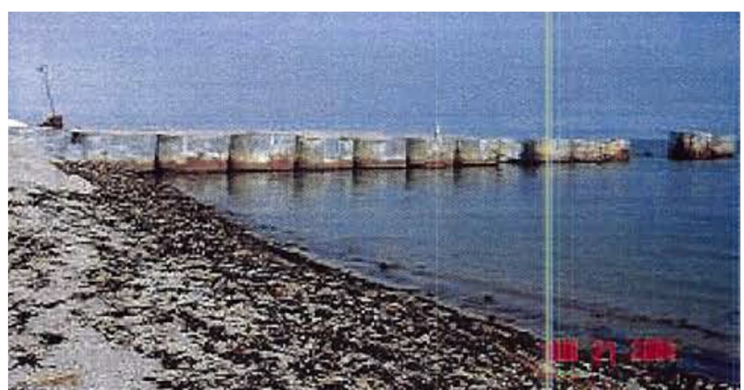
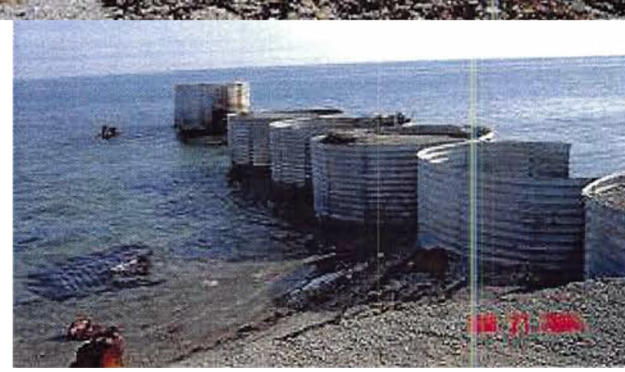
- Old Dew Line Dock
  - What was it used for?
  - How did the damage occur?
  - Is there anything left on the seabed?





Past Concepts

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Harbour Ideas

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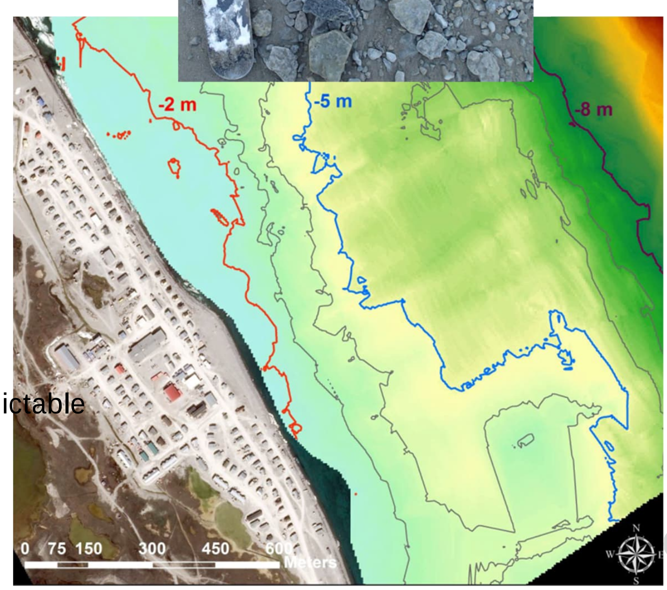
- Where does the community/hamlet want to see a harbour?
  - Old concepts:
    - Old concepts at old DEW Line dock
    - In front of community
    - South of tank farm
- How was floating dock decided?
  - $1.5M dredging plan – was this done? Documents?
- Be careful of sea level drop and future dredging
  - Bedrock, if shallow, means costly blast dredging
  - Geophysics may help guide, but careful of accuracy
  - Is bedrock known anywhere (exposed at south beach area)
- Be careful of shoreline sediments – Sanirajak is very unpredictable
- What are plans for sealift in the future?
- What are plans for fuel resupply in the future?



Coastal Issues

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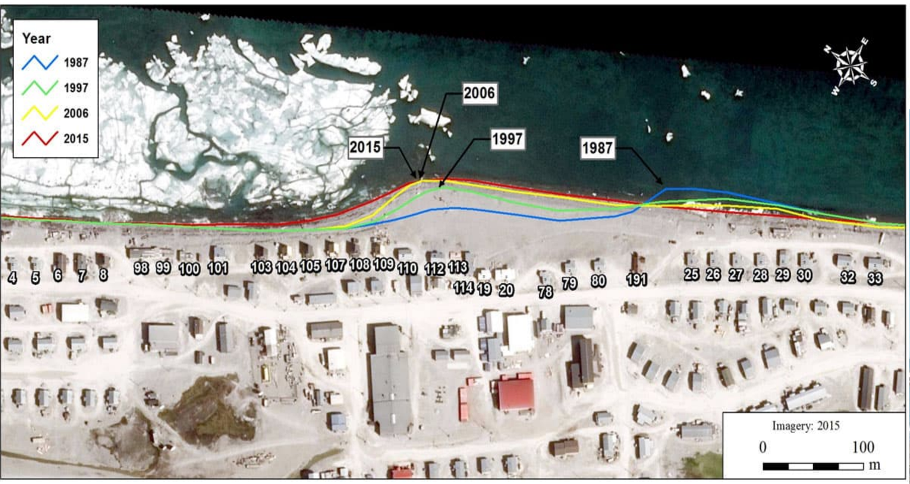
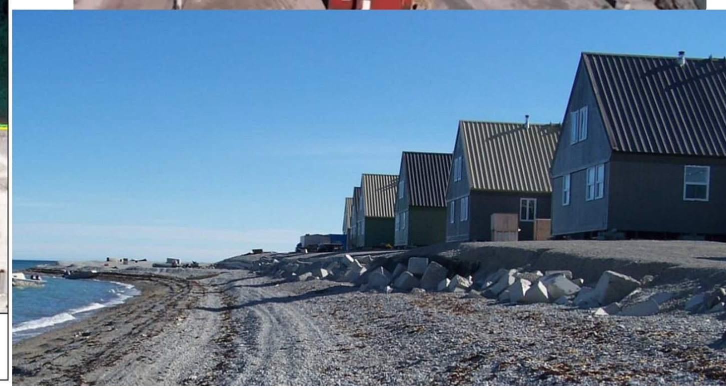
- Describe what is happening (daily winds, storms)
- What are people seeing over the years?





Quarry

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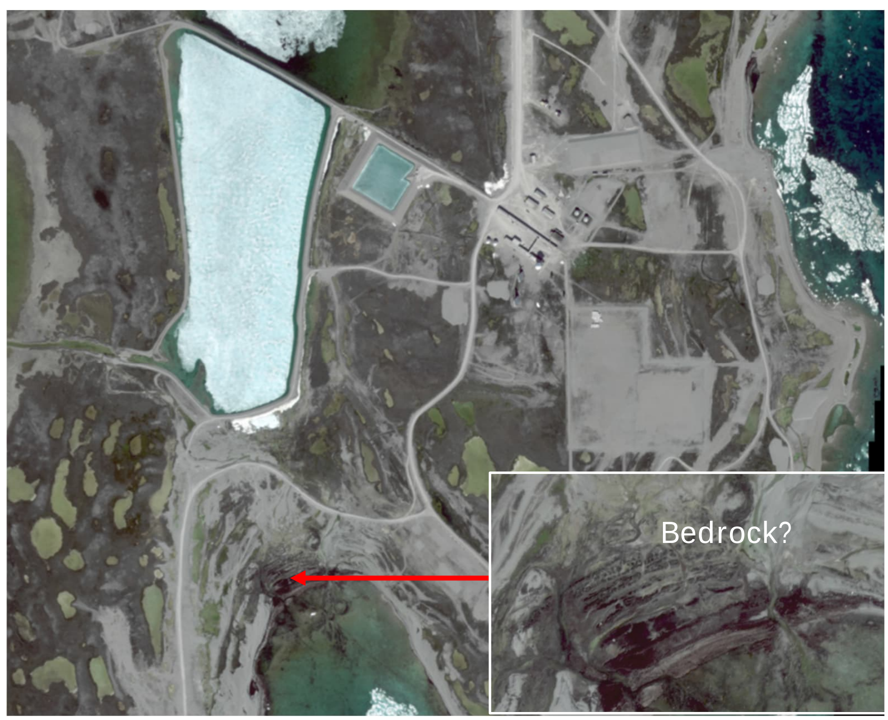
- Desktop geological study:
  - Poor quality limestone in the area
  - Better granite further west
  - Overlying sediment/soil ~2-6 metres
- Exposed bedrock locations?
- How deep in bedrock?
- Field boulders?



Geophysical Survey Work
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- Sub-bottom Profiling
  - Electrical acoustic source (signals received by hydrophones towed behind a boat)
  - Source is a pulser system – 142 dB (at standard reference)
  - Equivalent noise to an outboard motor
  - ~4 hours (during 1 day)
  - Compared to offshore seismic survey
    - ~ 1/1000 noise level

Type of Sounds	In Air (dB re 20μPa @ 20m) unless otherwise stated	In Water (dB re 1μPa @ 1m)
Threshold of Hearing	0 dB	62 dB
Whisper at 1 Meter	20 dB	82 dB
Normal Conversation in Restaurant	60 dB	122 dB
Ambient sea noise	--	100 dB
Blue Whale	--	190 dB
Live Rock Music	110 dB	172 dB
Thunderclap or Chainsaw	120 dB	182 dB
Large Ship	--	200 dB
Earthquake	--	210 dB
Seismic Array at 1 Meter	158 - 178 dB	220 - 240 dB
Bottlenose Dolphin	--	225 dB
Sperm Whale Click	--	236 dB
Jet Engine Take-off at 1 Meter	180 dB	242 dB
Volcanic Eruption	--	255 dB

Geophysical Survey Work
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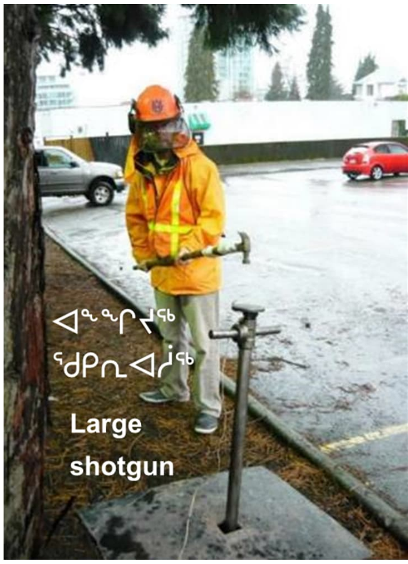

Refraction survey
- 2 or 3 lines extending offshore from the beach
- 8ga (500 grain) blank shotgun shells fired from heavy-wall tubes (shotguns)
- Receivers are submersible hydro-phone cable
- 5 to 6 fired offshore, within 1 and 10m deep, (small shotgun)
- 2 fired onshore, within 30m of the beach (large shotgun)

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- 2 ᐅᒡᕙᓘᓐᓃᑦ 3 ᑐᑭᓕᐅᖅᑐᑦ ᐃᒪᕙᖓᓂᑦ ᓯᒡᔭᖓᓄᑦ
- 8ᖄᓲᖅ (500 ᒍᓚᐃᓐ) ᓱᓇᒐᖃᓐᖏᑦᑐᖅ ᐆᖅ ᖁᑭᓇᐊᖅᑎᑕᐅᒍᓂ ᐅᖃᒪᐃᑦᑐᓂᒃ ᓱᓪᓗᓕᖕᓂᑦ (ᖁᑭᐅᑎᑦ)
- ᑏᓵᔅᔪᑎᑦ ᐃᖃᖓᓄ ᐃᒫᕈᓐᓇᖅᑐᑦ ᐅᖃᓘᑎᓯᐅᑎᑦ ᐅᐊᔭᖏᑦᑎᒍᑦ
- 5 ᑎᑭᓪᓗᒍ 6 ᖁᑭᓇᐊᖅᑎᑕᐅᓗᓂ ᐃᒪᕙᖏ, ᐃᓗᐊᓂ 1 ᐊᒻᒪᓗ 10 ᒦᑕ ᐃᑎᑎᒋᔪᒥ, (ᒥᑭᔪᖅ ᖁᑭᐅᑎᖏᑦ)
- 2 ᖁᑭᓇᐊᖅᑎᑕᐅᓗᑎᒃ, ᐃᓗᐊᓂ 30 ᒦᑕ ᓯᒡᔭᒥ (ᐊᖕᖏᔪᒧᑦ ᖁᑭᐅᑎᒧᑦ)

Sealift

ᒫᓐᓇᐅᔪᖅ ᐊᑐᖅᑕᐅᔪᑦ ᓇᐸᔪᑦ

- Any issues/conflict with sealift?
- ICSP 2010 talks about sealift access improvements. Complete?
- Does the hamlet need to grade beach for sealift?
- Community expansion plans onto airport lands? How far is the hamlet expecting to develop over the next 10 or 20 years?

Thank you!

ᖁᔭᓐᓇᒦᒃᖁᔭ

Contact information:
ᐅᖃᖃᑎᒋᔪᑦ ᐅᑯᐊ:

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- diane.pinto@advisian.com
- Cell: 647-829-8531

Sanirajak Marine Infrastructure Feasibility Study

September 2021

Diane Pinto
Harald Kullmann

Advisian
Worley Group

Introduction and Study Timelines
ᐱᒋᐊᕐᕕᖓ ᐊᒻᒪᓗ ᐃᓕᑕᐅᓇᓱᖕᓂᐊᖅᑐᖅ ᐊᑯᓂᐅᑎᒋᓂᖓ

Advisian contracted by the Hamlet of Sanirajak

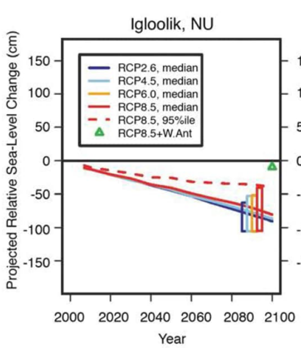
1st Consultation visit ᓱᕗᓪᓕᖅᐹᖅ ᕿᒥᕐᕈᐊᖃᑎᒌᓪᓗᑎᒃ ᐅᖃᖃᑎᒌᓪᖢᑎᒃ ᐳᓛᖅᓗᒋᑦ	March 2021
Coastal Overview and Develop concepts ᓱᒻᔫᖓ ᖃᓄᐃᓕᖓᓂᐊᕐᓂᖓ ᐊᒻᒪᓗ ᓴᓇᓯᒪᓂᐊᖅᑐᑦ ᑕᖏᖏᑦ	March to June 2021
Geophysical Assessment	September 2021
2nd Consultation Visit and Site Reconnaissance ᐱᖃᑖ ᕿᒥᕐᕈᐊᖃᑎᒌᓪᓗᑎᒃ ᐅᖃᖃᑎᒌᓪᖢᑎᒃ ᐳᓛᖅᓗᒋᑦ ᐊᒻᒪᓗ ᐃᓂᖓ ᖃᐅᔨᓴᖅᓗᒍ	September 2021

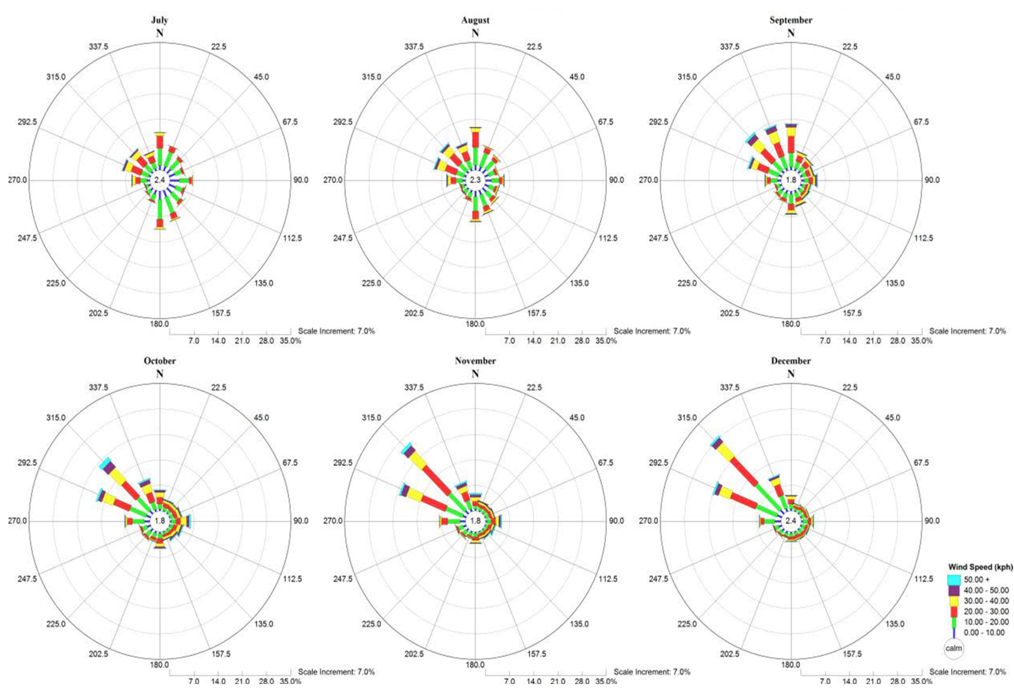
Introduction and Study Timelines
ᐱᒋᐊᕐᕕᖕᒐ ᐊᒻᒪᓗ ᐃᓕᑕᐅᓇᓱᖕᓂᐊᖅᑐᖅ ᐊᑯᓂᐅᑎᒋᓂᖕᒐ

• Preliminary Socio-Economic Assessment	December 2021
• Draft Report	Dec/Jan 2021
• Third Community Consultation	February 2021
• Final Report	March 2021

Background Information ᖃᓄᐃᓐᓂᕆᓯᒪᔭᖕᒐ ᑐᓴᕐᑎᑦᑎᔾᔪᑎᒋᓗᒍ

- Existing conditions:
  - Tide range –
    - 1.4 metres (“yearly max”)
    - 0.9 metres (“every day”)
- Sea-level change
  - Almost 1 metre drop by 2100





Existing Facilities

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Existing Facilities

ᒫᓐᓇᐅᔪᖅ ᐊᑐᖅᑕᐅᔪᑦ ᓇᐸᔪᑦ

Sealift

ᒫᓐᓇᐅᔪᖅ ᐊᑐᖅᑕᐅᔪᑦ ᓇᐸᔪᑦ

- Community expansion plans onto airport lands? How far is the hamlet expecting to develop over the next 10 or 20 years?

- When does the gravel come into the sealift beach area? End of season storms?

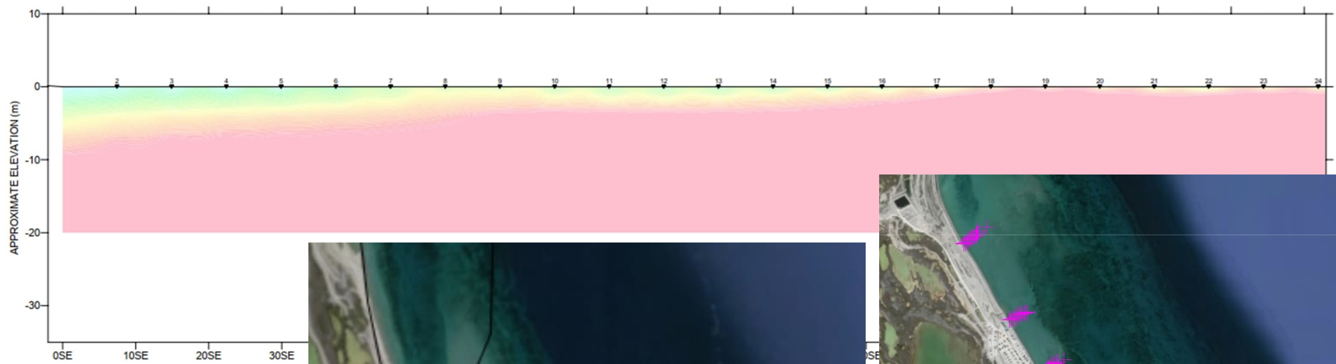
Boaters

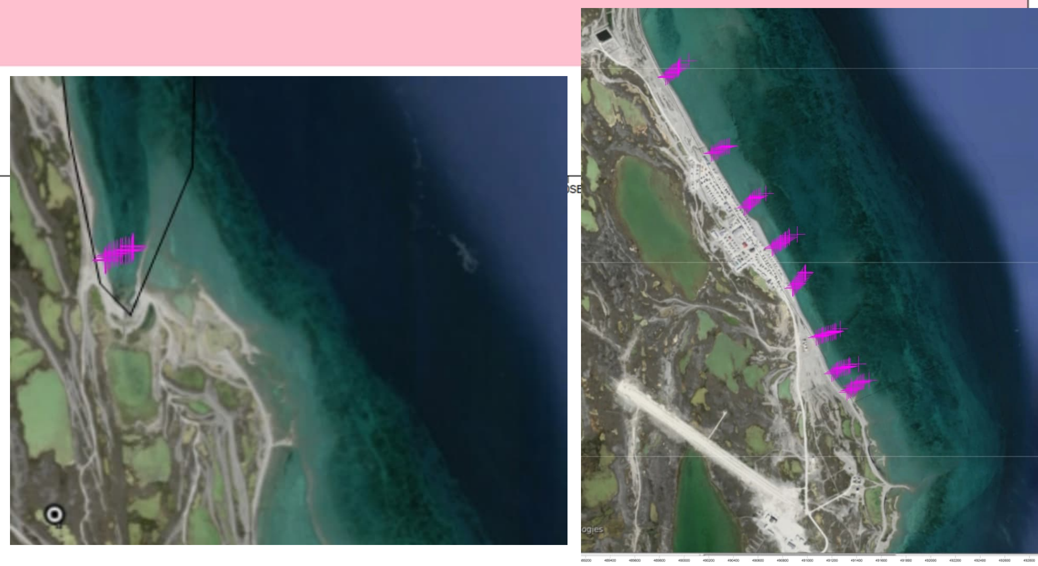
ᒫᓐᓇᐅᔪᖅ ᐊᑐᖅᑕᐅᔪᑦ ᓇᐸᔪᑦ

- How many boats? Size? Type? Trailers?
- How are boats dragged up the beach/launched?
- Community freezer?
- Significant creeks/drainage?

- Quality of road to the floating dock?

Geophysical Survey Work
ᓄᓇᖓ ᖃᓄᓂᓚᑑᓂᖓ ᖃᐅᔨᓴᐅᓇᓱᒡᒍᑎᒃ ᓴᓇᒍᑎᒃ



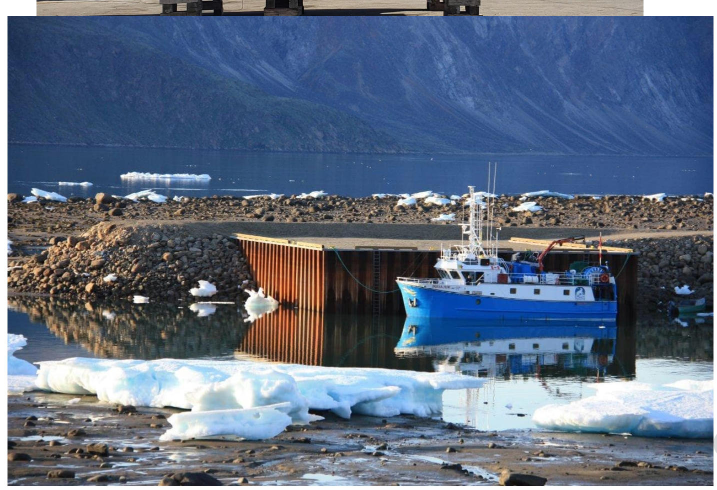


Refraction survey

- Very shallow bedrock

Inshore Fishery
ᐅᒃᑯᓯᒃᓴᓚᒃ

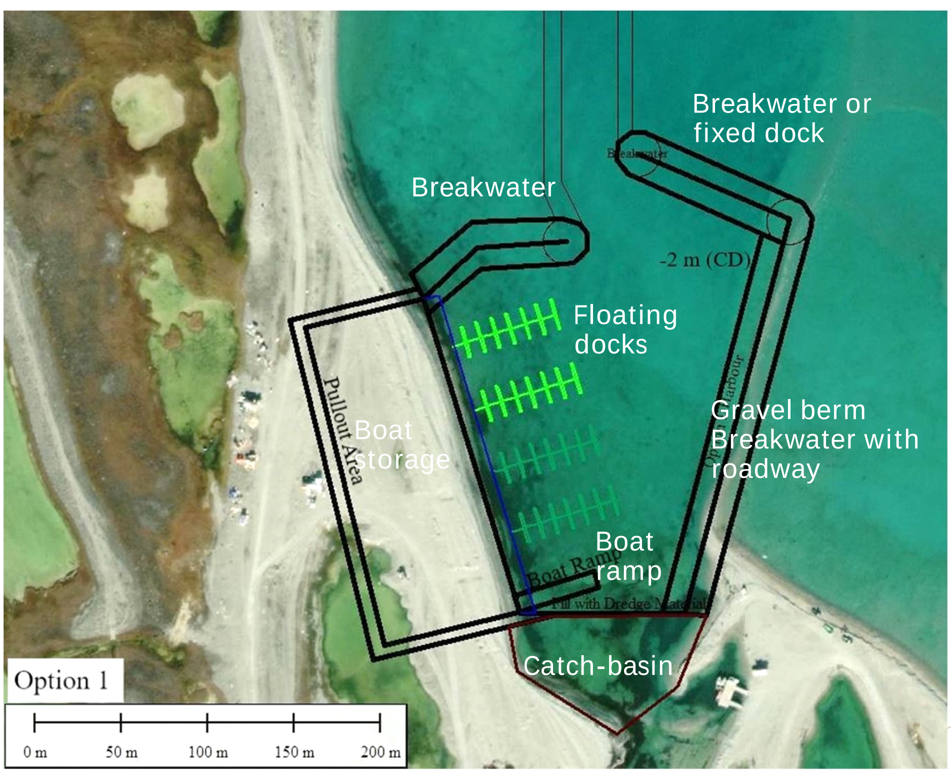
- QIA test fishery planned for 2022
- Size of trawlers to be considered?
- Fixed wharf for receiving catch
  - Will have limited depth
- Freezer/packing plant location?



Option Locations - ᓇᓖᕌᕈᑎᒃᓴᖅ 1

- Options 1 & 2:
  - Kingmitokvik Point
  - At floating dock
- Options 3 & 4:
  - At sealift beach
- Option 5:
  - South of North Warning/Airport Site
  - Near Hall Point

Option 1 - ᓇᓖᕌᕈᑎᒃᓴᖅ 1 (Kingmitokvik Point)



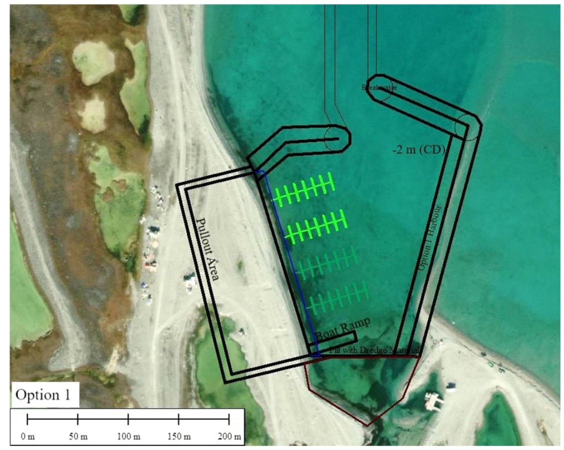
- Catch-basin for catching sediment from upland drainage channels (dredge annually?)
- Large area for boat storage
- Depths?

Option 1 - ᓇᓵᖀᐳᑎᒃᓴᖅ 1 (Kingmitokvik Point)

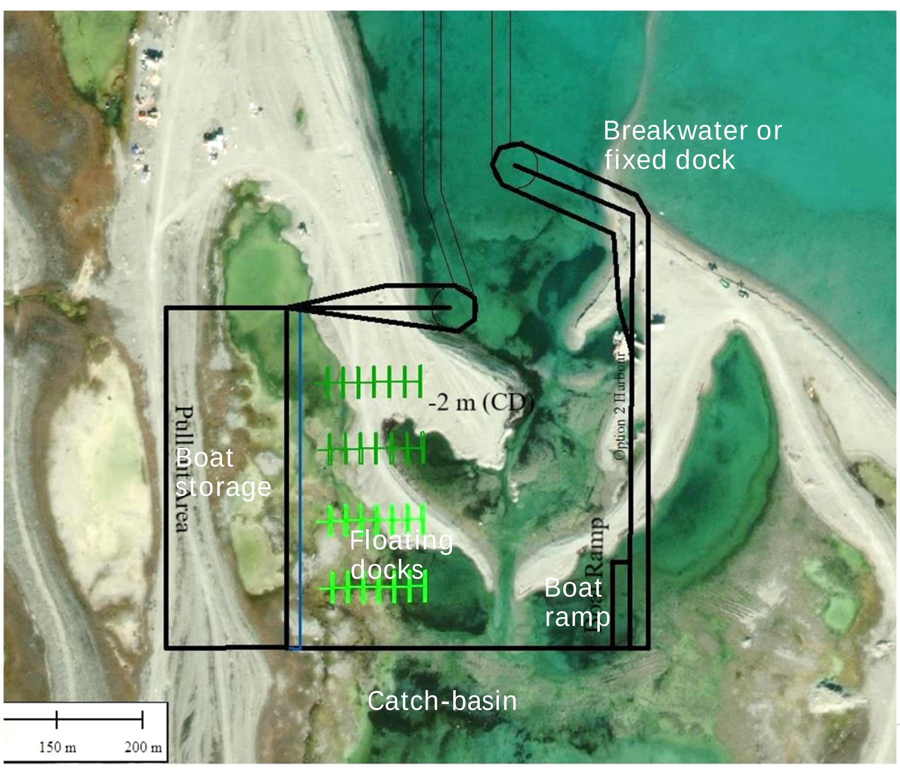
- Advantages:
  - Some people prefer the location
  - Makes use of existing sandbars
  - Likely minimum of sediment interruption

- Disadvantages:
  - 4km from town (security?)
  - Depth not known (local knowledge?)
  - Likely need some import rock
  - Drainage into harbour needs to be addressed

- Like medium cost



Option 2 - ᓇᓵᖀᐳᑎᒃᓴᖅ 2 (Kingmitokvik Point)



- Excavate basin rock by blasting in winter
- Same size
- Minimal rock is needed
- Breakwater could be fixed dock
- Depths unknown
- Relatively unlimited space in the area
- Could divert drainage into harbour or build catch-basin
- Expandable inshore into the future
- Blast deeper for future and bigger boats (work tides)?

Point Roberts Example

- Point Roberts Marina excavated into shoreline
- For Sanirajak:
  - Excavate basin rock by blasting in winter
  - Blasted edges might need maintenance
  - Might get some big rocks, geology suggests probably not
  - Produce 100,000+ cubic metres of blast rock available for land development

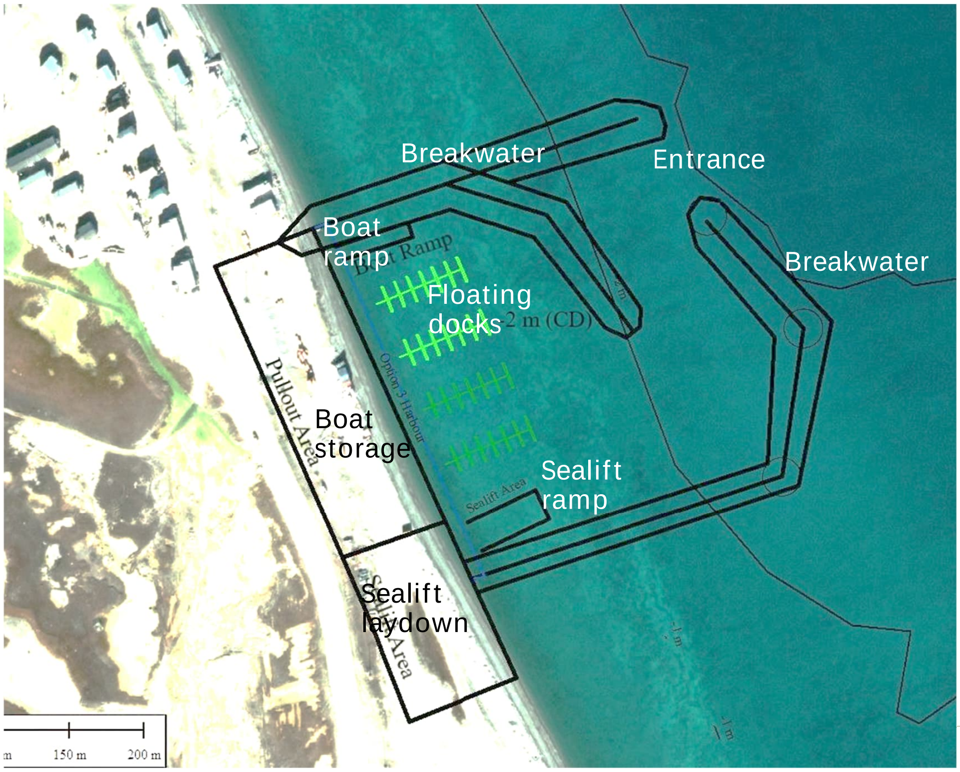
Option 2 - ᓇᓖᖀᕈᑎᒃᓴᖅ 2 (Kingmitokvik Point)

- Advantages:
  - Some people prefer the location
  - Makes use of existing sandbars
  - No interruption of sediment movement
  - Minimum of big rock needed
  - Produce lots of supply rock

- Disadvantages:
  - 4km from town (security?)
  - Depth not known (local knowledge?)
  - Depth likely shallower than Option 1?
  - Drainage into harbour needs to be addressed

- Likely lowest cost to build and lowest maintenance cost

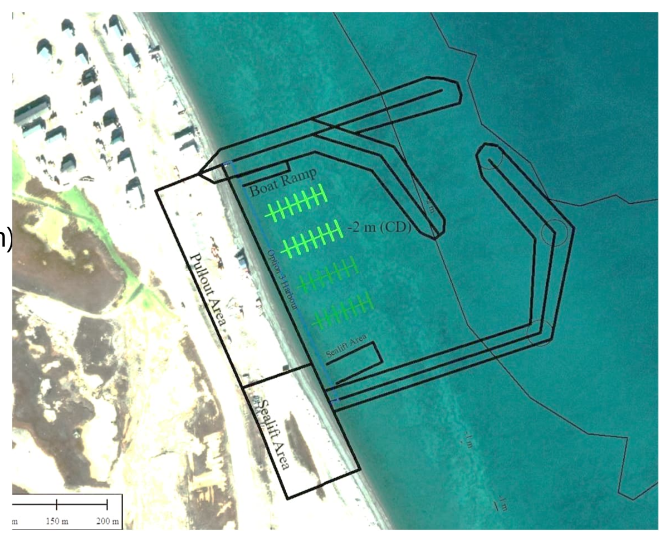
Option 3 - ᓇᓛᖀᕈᑎᒃᓴᖅ 3 (Sealift Beach)



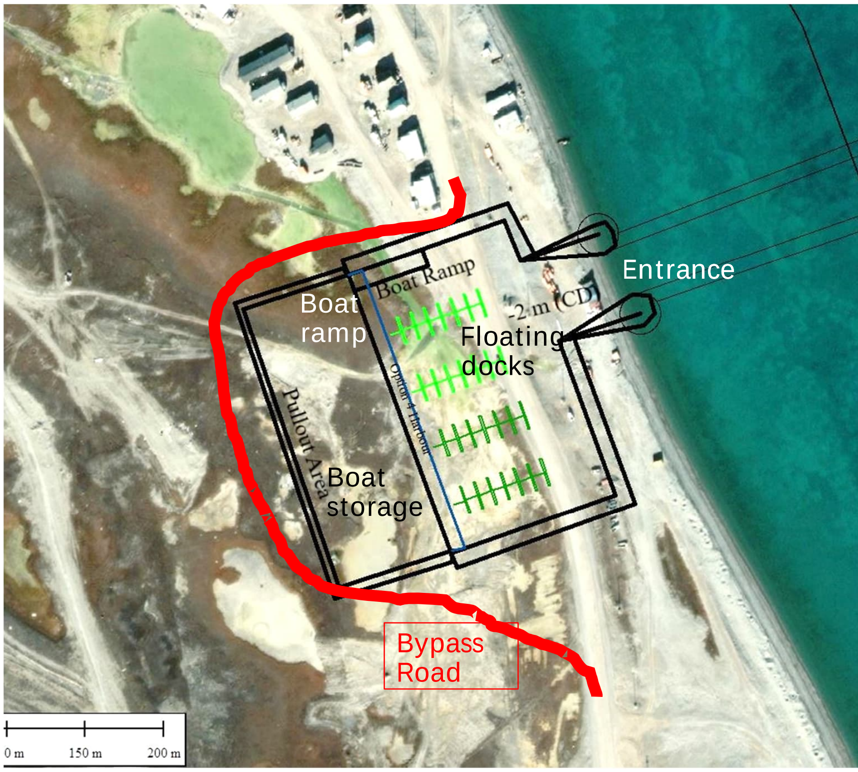
- Location preferred by many
- Sealift comes into harbour
- Entrance width important for sealift barges
- Largest amount of rock needed
- Breakwaters might be better as sheet pile structure
- Ice loads will be complex and very larger
- Likely much higher cost than other harbours in Nunavut

Option 3 - ᓇᓛᖀᕈᑎᒃᓴᖅ 3 (Sealift Beach)

- Advantages:
  - Preferred location by many
- Disadvantages:
  - Lots of import rock need
  - Breakwaters will be difficult to design (cost could be very high)
  - Conflict with sealift will increase cost
  - Interrupts sediment movement; erosion to north may happen
- Likely highest cost, including maintenance



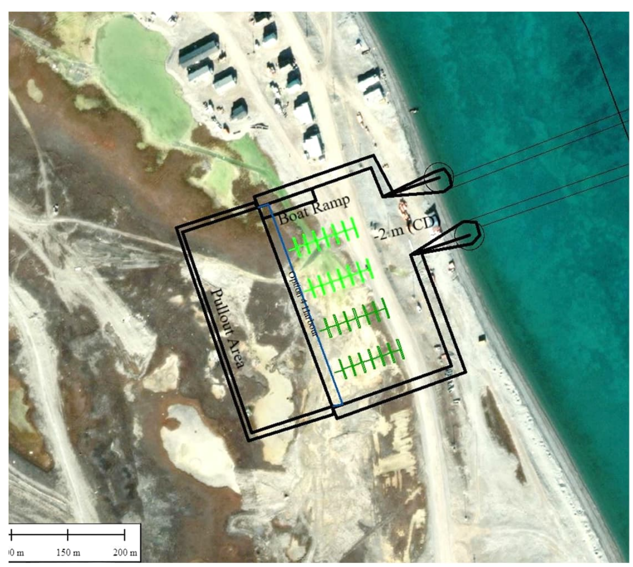
Option 4 - ᓇᓖᕿᕈᑎᒃᓴᖅ 4 (Sealift Beach)



- Basin cut into land
- Probably annual dredging needed at the entrance (like the sealift beach clearing)
- Needs refinement for waves
- Bypass road around the harbour
- Expand into land into the future
- Minimal/no big rock needed
- Large stockpile of rock
- Blasting near houses, runway, tank farm – probably need blast mats

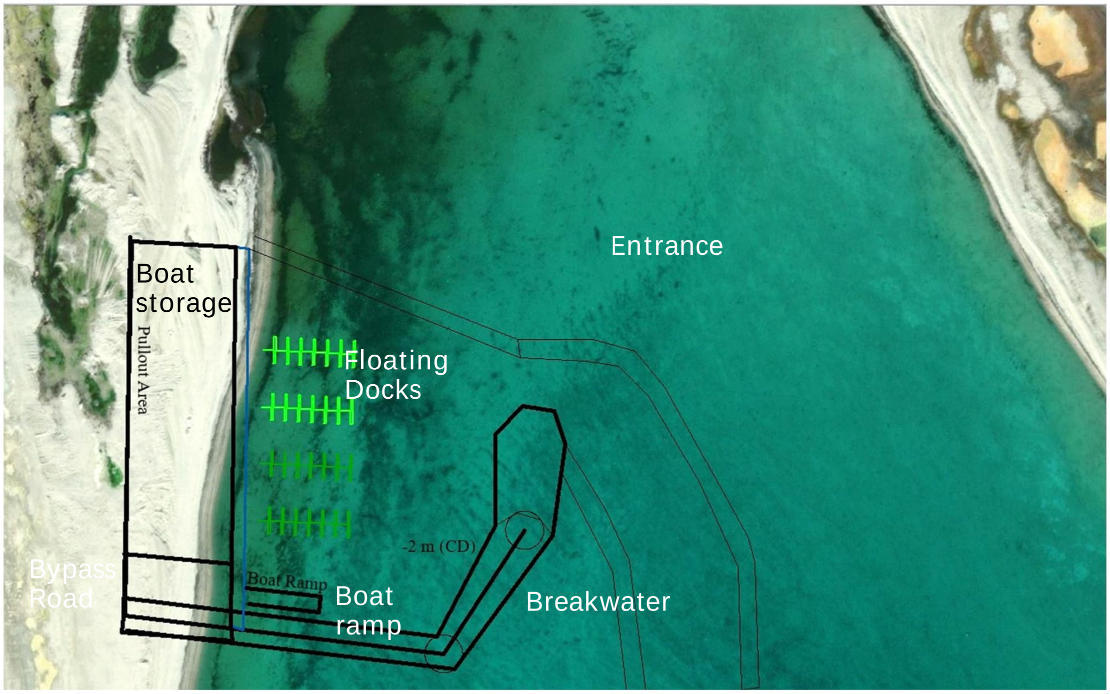
Option 4 - ᓇᓖᕿᕈᑎᒃᓴᖅ 4 (Sealift Beach)

- Advantages:
  - Preferred location by many
  - Very close to the community
  - Lowest (if any) amount of big rock needed
  - Produces a lot of useable rock
- Disadvantages:
  - Blasting close to houses and tank farm
  - Will need annual maintenance dredging
  - Conflict with sealift needs to be worked out
  - Needs a bypass road for fuel/airport/NWS



- Likely medium-low cost to build, maintenance cost medium

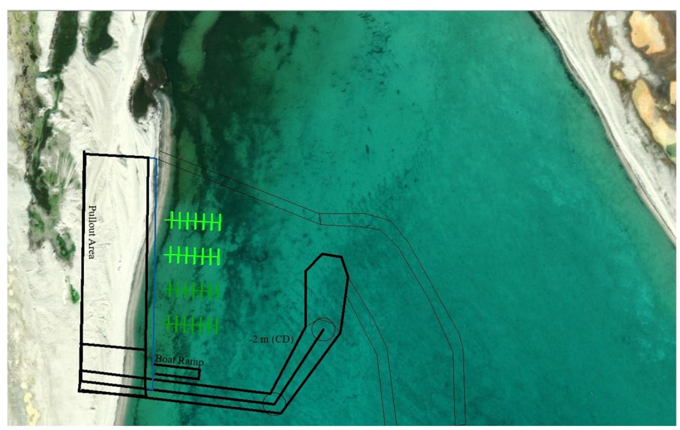
Option 5 - ᓇᓛᖀᕈᑎᒃᓴᖅ 5 (Hall Point)



- South of North Warning
- Depths unknown (no surveys)
- Ice could be a problem in early and late season
- Biggest boulders needed

Option 6 - ᓇᓛᖀᕈᑎᒃᓴᖅ 6 (Hall Point)

- Advantages:
  - Less breakwater than Option 3
  - Likely no significant impact to sediment movement
  - No constricted entrance
- Disadvantages:
  - Farthest from the community
  - Depths unknown but believed to be shallow, which may make this option impractical
  - Main access passes through NWS



- Likely high cost to build, maintenance cost medium

Considerations

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- Will an inshore fishery need a fixed dock?
  - Deep water will cost a lot
- Floating docks:
  - Pang 8’ mains, 4’ finger floats
  - Pond 12’ mains (no finger floats)
- Blasting near houses/tank farm
- All sites have problems with depth
  - Future deepening
  - Deepen inshore harbours?
- Importing rock is very costly
- Apply for CTIP funds for improvements at floating dock for short term

Remaining Work

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- Finalize concepts based on feedback here
- Update concepts for full geophysical results
- Develop cost estimates
- Document preferred option(s)
- Socio-economic assessment
- Prepare draft report
- 3rd consultation
- Finalize report

Thank you! ᖁᔭᓐᓇᒦᒃᖁᔭ

Contact information:
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- diane.pinto@advisian.com
- Cell: 647-829-8531

Sanirajak Marine Infrastructure Feasibility Study
ᓴᓂᕋᔭᒃ ᑕᕆᐅᙱᓂ ᐱᖁᑎᖅᔪᐊᑦ ᐱᔭᒃᓴᐅᓂᖏᓐᓂᒃ ᖃᐅᔨᓴᕐᓂᖅ

ᐊᒋᔨ August 2022

ᕼᐊᕈᑦ ᑲᓪᒪᓐ Harald Kullmann

Background ᖃᓄᐃᓕᖓᓂᖓ

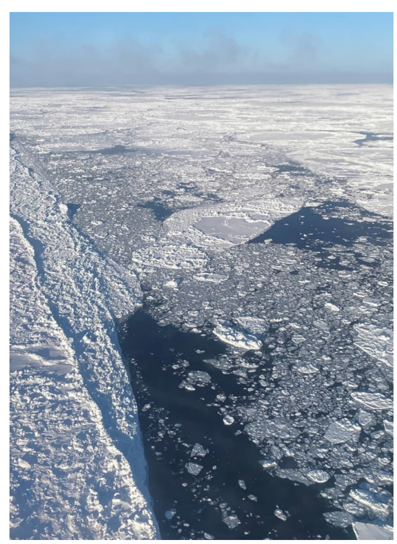
- Previous Consultations and Site reconnaissance:
- ᑭᖑᓂᑦᑎᓐᓂ ᖃᐅᔨᒋᐊᕐᕕᐅᓯᒪᓂᖓ ᐊᒻᒪᓗ ᓄᓇᖓ ᖃᐅᔨᓴᖅᑕᐅᓪᓗᓂ:

  - March 2021 – Joint Hamlet Council and HTA meeting
  - ᒪᔾ 2021 – ᑲᑎᙵᓪᓗᑎᒃ ᕼᐊᒻᓚᒃᑯᑦ ᐊᒻᒪᓗ ᐅᒪᔪᕐᓂᐊᖅᑎᒃᑯᑦ ᑲᑎᒪᔩᖏᑦ

  - September 2021 – Geophysics survey
  - ᓯᑎᐱᕆ 2021 – ᐅᔭᕋᙱᓂᒃ ᖃᐅᔨᓴᕐᓂᖅ

  - September 2021 – Separate council and HTA meetings
  - ᓯᑎᐱᕆ 2021 – ᐊᑐᓂ ᕼᐊᒻᓚᒃᑯᑦ ᐊᒻᒪᓗ ᐅᒪᔪᕐᓂᐊᖅᑎᒃᑯᑦ ᑲᑎᒪᖃᑎᒌᔭᐅᓪᓗᑎᒃ

  - September 2021 – General marine information booth at Co-op and Northern Stores
  - ᓯᑎᐱᕆ 2021 – ᑕᕆᐅᙱᓂᒃ ᖃᐅᔨᓇᓱᒃᑐᑦ ᐅᖃᖅᑕᕐᕕᐅᓪᓗᓂ ᑯᐊᐸᒃᑯᓐᓂ ᓂᐅᕕᕐᕕᖕᒥᓗ



Key Feedback ᐱᓗᐊᕐᓂᖏᑦ ᐅᖃᐅᓯᐅᓯᒪᔪᑦ

- Sealift beach area is the primary area for boating and preferred location for a harbour
- ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᓂᐅᕋᐃᕕᒃ ᐃᓂᒋᔭᐅᓪᓗᐊᑕᕐᒪᑦ ᐅᒥᐊᓄᑦ ᐊᒻᒪᓗ ᐃᓂᒋᔭᐅᔪᒪᓂᕐᓴᐅᓪᓗᓂ ᐅᒥᐊᒃᑯᕕᖕᐅᓗᓂ

- Limited support for a harbour at Kingmitokvik Point (too far away, only for those with trailers/vehicles)
- ᐃᑲᔪᕐᑐᕐᑕᐅᖏᓐᓂᕐᓴᐅᔪᖅ ᕿᖕᒥᕐᑐᖅᕕᒃ ᓄᕗᐊᕐᔪᒃ (ᐅᖓᓯᓗᐊᕐᓂᖓᓄᑦ, ᑲᓚᕕᓚᖕᓄᑐᐊᖅ/ᓄᓇᓯᐅᑎᖃᕐᑐᑐᐊᓄᕐ)

- Bottom is hard offshore
- ᐃᕐᑲᖓ ᑎᓯᓗᐊᕐᑐᖅ ᓴᒃᕙᓯᒃᑐᒥ

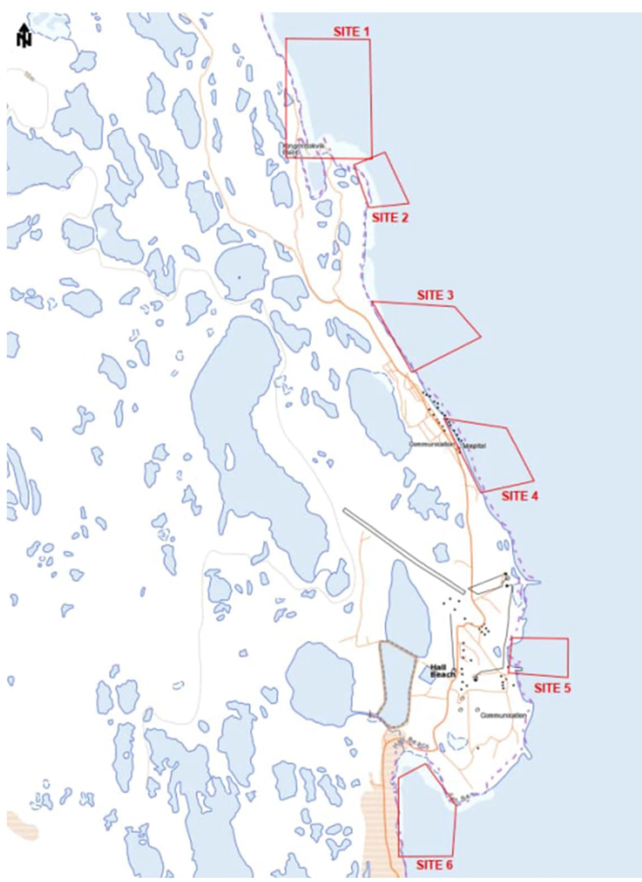
- Consider using the sand bar south of Kingmitokvik Point
- ᐃᓱᒪᒋᔭᐅᓗᓂ ᐊᑐᕐᑕᐅᓗᓂ ᓯᐅᕋᐅᓂᖓ ᕿᖕᒥᕐᑐᖅᕕᒃ ᓄᕗᐊᕐᔪᖓᓂ

- Water is becoming shallower – boulders are becoming exposed
- ᐃᒃᑲᒃᓚᕙᓪᓚᐊᔪᖅ – ᐅᔭᕋᓱᒃᔪᐃᑦ ᓴᕿᐸᓪᓚᐊᔪᑦ

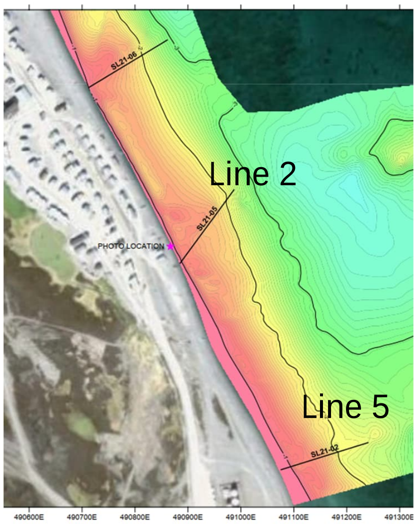
- There is stronger/more wind and a shift in directions
- ᐊᓄᓇᕐᑲᕐᓂᖅᓴᐅᓪᓗᓂ/ᐊᓄᕋᒐᔪᖕᓂᖅᓴᐅᓪᓗᓂ ᐊᒻᒪᓗ ᓴᕿᖅᑲᑦᑕᕐᓗᓂ

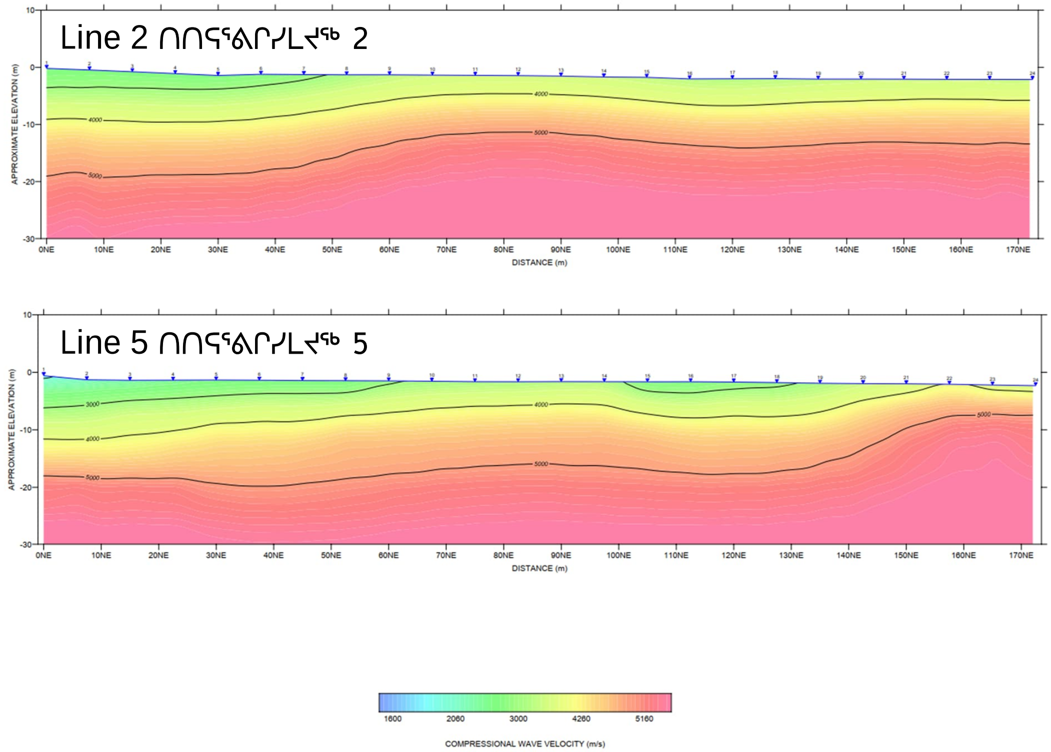
- Open water season is longer now (ice gone sooner and breaking up faster)
- ᐃᒪᐅᓱᔭᖅᑲᑦᑕᕐᓂᖅᓴᐅᓚᕐᑐᖅ (ᓯᑯᐃᖅᓴᖅᑲᑦᑕᕐᓗᓂᓗ)

Geophysics Work ᐅᔭᕋᓕᕆᓂᕐᒥᒃ ᓴᓇᔪᑦ

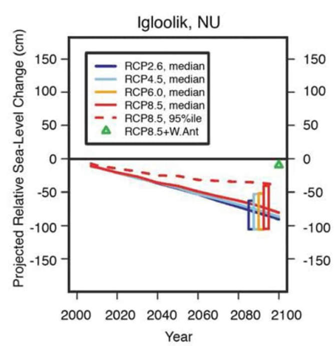


Geophysics Work ᐅᔭᕋᓕᕆᓂᕐᒥᒃ ᓴᓇᔪᑦ

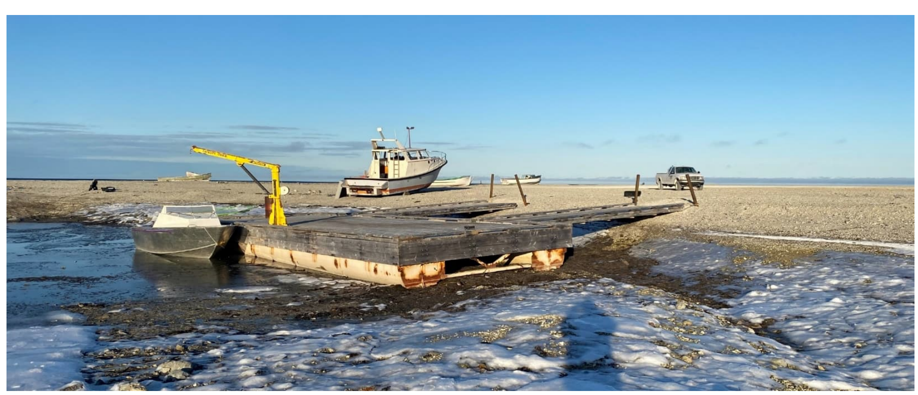




Sanirajak Challenges ᓴᓂᕋᔭᖕᒥ ᐊᔪᕐᓇᐅᑕᐅᔪᑦ



- Shallow water close to shore
- ᐃᑲᖕᓂᖓ ᖃᓂᒍᐊᕐᑐᖅ ᓯᒃᔭᒧᑦ
- Bedrock is at or near the surface
- ᖃᐃᕐᓯᓂᖓ ᓴᕿᔭᕐᑐᖅ ᐅᕙᓗᓐᓂᑦ ᓴᕿᓚᒐᔪᖅ
- Low tide range
- ᑎᓂᑦᑕᕐᓂᖓ
- Land is coming up (no sea level rise)
- ᓄᓇ ᖁᕙᕐᐸᑦᑕᐊᔪᖅ (ᑕᕆᐅᖅ ᐃᒪᕐᑐᓯᕙᑦᑕᐊᖕᒋᑦᑐᖅ)
- Very exposed shoreline
- ᓴᕿᔭᒍᐊᕐᑐᖅ ᓯᒃᔭᖓ
- No local rock to build breakwaters
- ᓄᓇᑕᖕᓂ ᐅᔭᕋᒃᑕᕐᑲᖕᒋᑦᑐᖅ ᑐᑕᒃᑕᕐᕕᑕᐅᕈᑎᒃᓴᓂᒃ



Option Locations - ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᑦ

- Options 1 & 2: ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᑦ 1 ᐊᒻᒪ 2
  - Kingmitokvik Point
  - ᑭᖕᒥᑦᑐᖅᕕᒃ ᓄᕗᐊᕐᔪᐊᓂ
  - At floating dock
  - ᐃᐱᕐᕕᖕᒥ

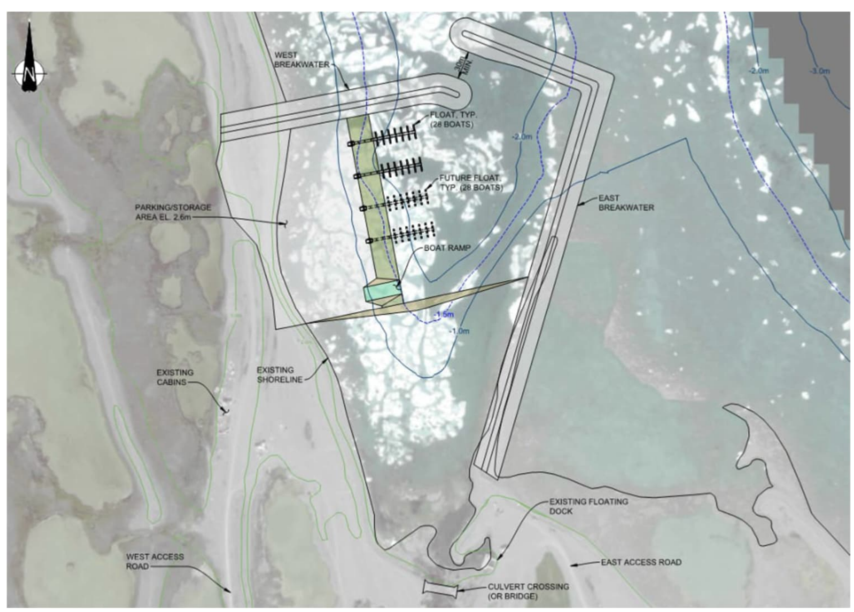
  Options 3 & 4: ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᑦ 3 ᐊᒻᒪ 4
  - At sealift beach
  - ᐅᒥᐊᕐᔪᐊᓄᑦ ᓂᐅᕋᐃᕕᖕᒥ

  Option 5: ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 5
  - South of North Warning/Airport Site
  - ᓂᒋᐊᓂ ᐅᓇᑕᕐᑐᒃᓴᖃᕐᕕᐅᑉ/ᒥᑦᑕᕐᕕᐅᑦ
  - Near Hall Point
  - ᖃᓂᒋᔭᖓᓂ ᓴᓂᕋᔭᐅᑉ ᓄᕗᐊᕐᔪᐊ
- Option 6: ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 6
  - North Sand Bar
  - ᐅᐊᖕᓇᖓᓂ ᓯᐅᕋᐅᓂᖓ

Option 1 - ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 1 (ᑭᖕᒥᑦᑐᖅᕕᒃ ᓄᕗᐊᕐᔪᐊ Kingmitokvik Point)

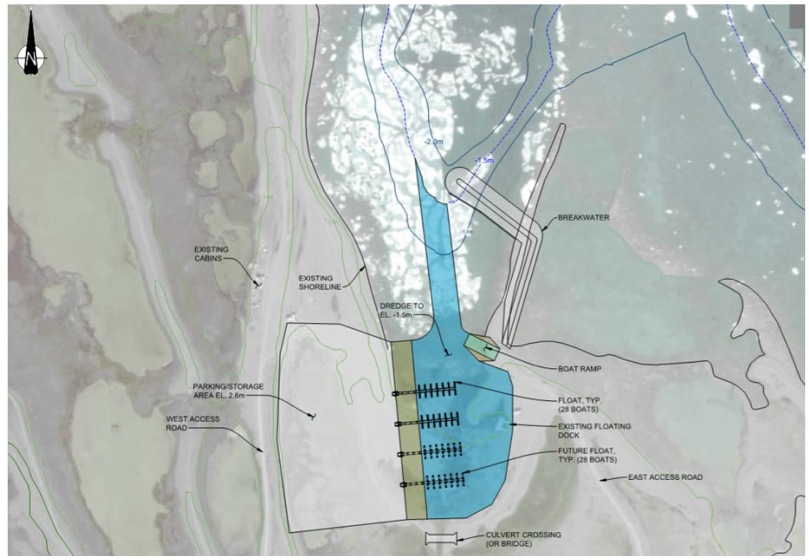
- Advantages ᐱᐅᓂᖓ:
  - Makes use of existing sandbars
  - ᓯᐅᕋᖓ ᐱᑕᖅᑲᕐᐸᒋᕐᑐᖅ ᐊᑐᕐᓗᒍ
  - Likely to affect sediment movement
  - ᐃᖅᑲᖕᒪᓂᖕᒪᕐᑐᑦ ᐊᐅᓚᑲᑕᑐᐃᓐᓇᑎᐊᓕᑦ

- Disadvantages ᐱᐅᖕᒋᓐᓂᖓ:
  - 4km from town, few people like location
  - 4 ᑭᓚᒥᑕ ᓄᓇᓕᖕᓂᑦ, ᐅᓄᖕᒋᑦᑐᑦ ᑕᕿᓂᕐᑯᔪᑦ
  - Likely need some import rock
  - ᐅᔭᕋᓕᒃᑲᓐᓂᑎᐊᕐᑲᕋᔭᕐᑐᖅ ᓯᓚᑕᓂᑦ
  - Location is well offshore due to depth
  - ᐃᓂᖓ ᓴᑦᑎᒃᑐᒥᑦᑐᖅ ᐃᒃᑲᓐᓂᖓᓄᑦ
  - Lots of heavy rock needed
  - ᐅᔭᕋᖕᓂᒃ ᐅᖁᕐᑐᓂᒃ ᐱᔭᑎᐊᓕᒃ
  - No deep water close by
  - ᐃᒪᖓ ᐃᑎᓂᕐᑲᖕᒋᑦᑐᖅ ᖃᓂᒋᔭᖓᓂ



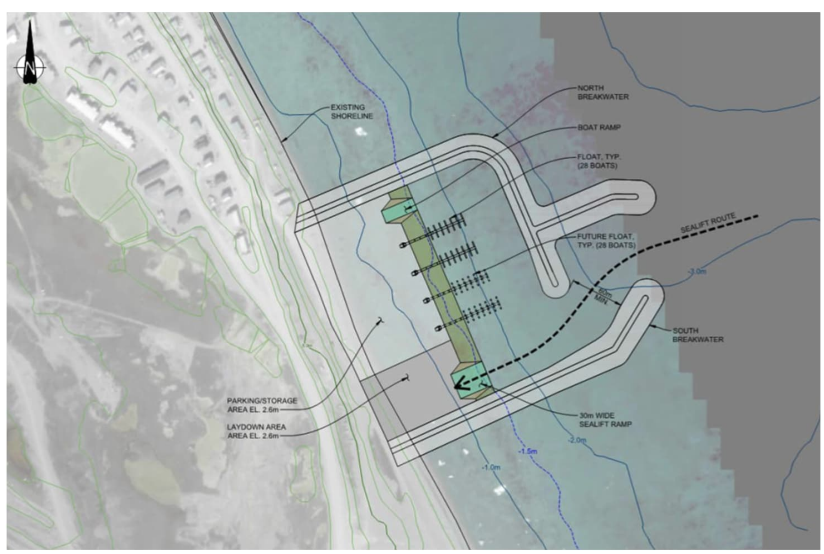
Option 2 - ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 2 (ᑭᖕᒥᒃᑐᖅᕕᒃ ᓄᕗᐊᕐᔪᐊ Kingmitokvik Point)

- Advantages ᐱᐅᓂᖓ:
  - Makes use of existing sandbars
  - ᓱᐅᕋᖕᒪ ᐱᑕᖃᕐᐸᒋᕐᑐᖅ ᐊᑐᕐᓗᒍ
  - No interruption of sediment movement
  - ᐃᖃᖕᒪ ᐃᖕᒋᕋᕙᓪᓚᐊᖕᒋᑦᑐᖅ
  - Minimum of big rock needed
  - ᐊᖏᓗᐊᖕᒋᑦᑐᒥᒃ ᐅᔭᕋᖕᓂᒃ ᐱᔭᕆᐊᓕᒃ
  - Produce lots of supply rock
  - ᐅᔭᕋᒃᑕᕐᕕᐅᔪᓐᓇᕐᑐᖅ
  - Can easily make harbour basin deeper
  - ᐅᒥᐊᒃᑯᕕᒃ ᐱᔭᐃᕕᐅᔪᓐᓇᕐᑐᖅ ᐃᑎᒃᓕᒋᐊᕐᑕᐅᓗᓂ
- Disadvantages ᐱᐅᖏᓐᓂᖓ:
  - 4km from town, few people like location
  - 4 ᑭᓚᒥᑕ ᓄᓇᓕᖕᓂᑦ, ᐅᓄᖏᑦᑐᑦ ᑕᕙᓂᕐᒍᔪᑦ
  - Depth likely shallower than Option 1?
  - ᐃᒃᑲᓐᓂᕐᓴᐅᑐᐃᓐᓇᓇᐊᓕᒃ ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 1-ᒥᑦ
  - Entrance channel will be difficult
  - ᐃᓯᓇᐊᕐᕕᖕᒪ ᓱᓪᓗᖕᒪ ᐱᔭᕐᓂᔾᔮᐊᖕᒋᑦᑐᖅ
  - No deep water close by
  - ᐃᒪᖕᒪ ᐃᑎᔪᒥ ᖃᓂᒋᔭᖃᖕᒋᑦᑐᖅ



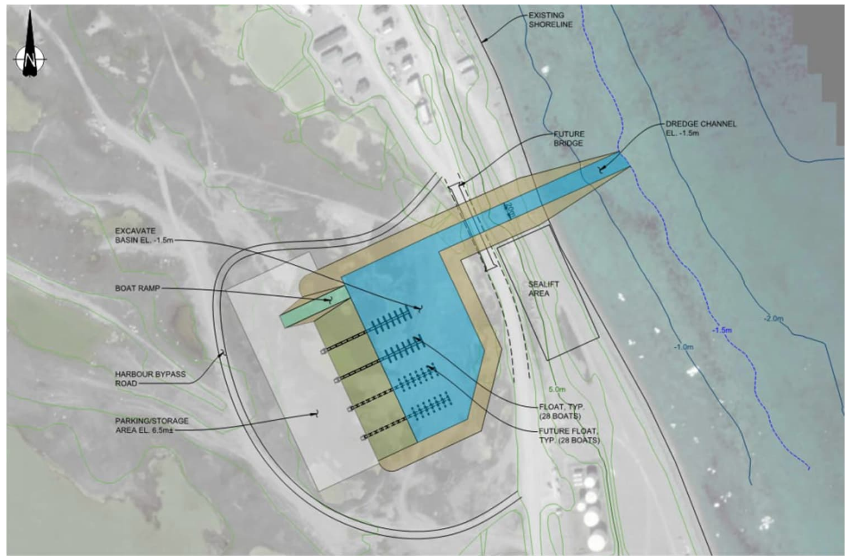
Option 3 - ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 3 (ᓂᐅᕋᐃᕕᒃ ᐅᒥᐊᕐᔪᐊᒃᑯᑦ Sealift Beach)

- Advantages ᐱᐅᓂᖓ:
  - Preferred location by many, close to hamlet
  - ᐃᓂᒋᔭᐅᒪᓂᕐᓴᖅ ᐅᓄᕐᓂᖅᓴᓄᑦ, ᓄᓇᓕᖕᓄᑦᓗ ᖃᓂᑦᑐᓂ
- Disadvantages ᐱᐅᖏᓐᓂᖓ:
  - Lots of import rock need
  - ᐅᔭᕋᓕᕐᓯᓇᐊᖃᕐᑐᖅ ᐅᓄᕐᑐᓂᒃ
  - Conflict with sealift
  - ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᓂᐅᕋᐃᑎᓪᓗᒋᑦ ᐊᒃᕕᐊᕐᑐᖅ
  - Interrupts sediment movement
  - ᐃᖃᖕᒪᓂᒃ ᐊᐅᓚᔪᓐᓂᕐᑎᑦᑎᒐᔭᕐᑐᖅ
  - No deep water close by
  - ᐃᑎᔪᒥᒃ ᖃᓂᒋᔭᖃᖕᒋᑦᑐᖅ



Option 4 - ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 4 (ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᓂᐅᕋᐃᕖᒃ Sealift Beach)

- Advantages ᐱᐅᓂᖓ:
  - Preferred location by many, close to hamlet
  - ᐃᓂᒋᔭᐅᔭᒪᓂᕐᓴᖅ ᐅᓄᕐᓂᖅᓴᓄᑦ, ᓄᓇᓕᖕᓄᑦ ᖃᓂᑦᑐᓂ
  - Least import rock ᐅᓄᖏᓚᓂᒃ ᐅᔭᕋᒃᑕᕆᐊᓕᒃ
  - Produces a lot of useable rock
  - ᐅᔭᕋᒃᑕᕕᐅᔪᓐᓇᕐᑐᖅ ᐊᑐᕈᓐᓇᕐᑐᓂᒃ
  - Harbour can be any size, any depth
  - ᐅᒥᐊᒃᑯᕖᒃ ᖃᓄᐃᑐᐃᓐᓇᖅ ᐊᖏᑎᒋᔪᓐᓇᕐᑐᖅ
- Disadvantages ᐱᐅᖏᓐᓂᖓ:
  - Blasting close to houses and tank farm
  - ᖃᕐᑎᕐᑎᑲᑕᒃᑐᑎᒃ ᐃᒡᓗᐃᑦ ᖃᓂᒋᔭᖓᓂ ᐊᒻᒪᓗ ᐅᕐᓱᕐᑕᕕᖕᒥ
  - Annual dredging at entrance
  - ᐊᕋᒍᑕᒪᑦ ᐃᖅᑲᖓ ᐱᔭᕐᑕᐅᖅᑕᕐᕋᔭᕐᑐᖅ
  - Sealift conflict ᓂᐅᕋᐃᕖᖑᑦ ᐊᒃᕕᐊᕐᑐᖅ
  - Needs a bypass road ᐊᖅᑯᑎᑕᕆᐊᓕᒃ
  - No deep water close by ᐃᑎᔪᒥᒃ ᖃᓂᒋᔭᖃᖏᑦᑐᖅ



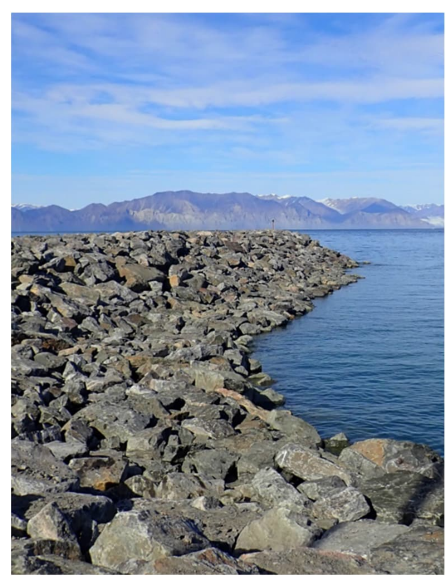
Costs ᐊᑭᖏᑦ

- Option 1 - Kingmitokvik Point (offshore) $94.9 million
- ᐃᓂᒃᓴᐅᔪᓐᓇᕐᑐᖅ 1 - ᑭᖑᒥᒃᑐᖅᕕᒃ ᓄᕗᐊ(ᓴᑦᑎᒃᑐᒥ)

- Option 2 - Kingmitokvik Point (inshore) $58.1 million
- ᐃᓂᒃᓴᐅᔪᓐᓇᕐᑐᖅ 2 - ᑭᖑᒥᒃᑐᖅᕕᒃ ᓄᕗᐊ (ᓯᒃᔭᕐᐸᓯᒃ)

- Option 3 – Sealift Beach (offshore) $123 million
- ᐃᓂᒃᓴᐅᔪᓐᓇᕐᑐᖅ 3 – ᐅᒥᐊᕐᔪᐊᓄᑦ ᓂᐅᕋᐃᕖᒃ (ᓴᑦᑎᒃᑐᒥ)

- Option 4 – Sealift Beach (inshore) $67.4 million
- ᐃᓂᒃᓴᐅᔪᓐᓇᕐᑐᖅ 4 – ᐅᒥᐊᕐᔪᐊᓄᑦ ᓂᐅᕋᐃᕖᒃ (ᓯᒃᔭᕐᐸᓯᖕᒥ)



Estimate Considerations ᐊᑭᖏᓐᓄᑦ ᐃᓱᒪᒋᔭᐅᔪᑦ

- Does not include escalation (feds currently allowing 6-7%)
- ᐱᖃᓱᐅᑎᖏᑦᑐᖅ ᐊᑭᑦᑐᕆᐊᕐᐸᓪᓕᐊᓂᖓ (ᒐᕙᒪᒃᑯᑦ ᐱᕕᖃᕐᑎᑦᑎᔪᑦ 6-7 ᐳᓴᓐᑦ)

- Current market conditions are very hot. Estimates may not be enough if this continues.
- ᒫᓐᓇ ᓂᐅᕕᕐᑕᐅᓂᒃᑯᑦ ᐱᔭᐅᔪᒪᓪᓚᕆᒃᑐᑦ. ᐊᑭᖏᑦ ᐊᒥᒐᑐᐃᓐᓇᕆᐊᓕᑦ ᐊᑭᑦᑐᕆᐊᕐᐸᓪᓕᐊᖏᓐᓇᕐᐸᑕ.

- All options have never been done – adds risk and cost
- ᑕᒪᕐᒥᒃ ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᑦ ᓴᓇᔭᐅᓚᐅᕐᓯᒪᖏᒻᒪᑕ – ᐅᓗᕆᐊᓇᕐᑐᖅᑐᐃᓐᓴᕆᐊᓕᒃ ᐊᒻᒪ ᐊᑭᖓ

- Other Nunavut harbours have been ~$40M
- ᓄᓇᕗᒻᒥ ᐅᒥᐊᒃᑯᕕᑦ ᐃᒪᓐᓇᖅᑲᕐᓯᒪᔪᑦ ~$40M

Next Steps ᖃᓄᐃᓕᖓᓂᐊᕐᓂᖓ

- Confirm which option to seek funding
- ᓇᓗᓇᐃᕐᑕᐅᓗᓂ ᐃᓂᒋᔪᓐᓇᕐᑕᖓ ᓂᕈᐊᕐᑕᐅᓗᓂ ᑮᓇᐅᔭᓂᒃ ᕿᓂᕈᑕᐅᓕᕐᓗᓂ
- Decide if harbour depth is ok
- ᐊᕐᑭᒃᑕᐅᓗᓂ ᐅᒥᐊᒃᑯᕕᒃ ᐃᑎᓂᖓ ᓇᒻᒪᖕᒪᖔᑦ
- Consider further study, especially for Option 3
- ᐃᓱᒪᒋᔭᐅᓗᓂ ᖃᐅᔨᓴᕐᑕᐅᒃᑲᓐᓂᕆᐊᖃᕐᓂᖓ, ᐱᓗᐊᕐᑐᒥ ᐃᓂᒋᔪᓐᓇᕐᑕᖓ 3
- Decide if blasting close to shore in spring important
- ᐊᕐᑭᒃᑕᐅᔭᕆᐊᓕᒃ ᖃᕐᑎᑦᑎᖃᑦᑕᕐᓗᑎᒃ ᓯᒃᔭᒥ ᐅᐱᖓᒃᑯᑦ ᐱᓪᓚᕆᐅᔪᖅ
- Upland surveys
- ᓄᓇᖓ ᑎᕝᕙᓱᒃᑐᖅ ᖃᐅᔨᓴᕐᑕᐅᓗᓂ
- Baseline studies for permitting
- ᐱᒋᐊᕐᕕᒃᓴᐃᑦ ᖃᐅᔨᓴᕐᑕᐅᓗᓂ ᐊᖏᕐᑕᐅᓇᓱᒃᓂᐊᕐᑐᑦ ᐱᔪᓇᐅᑎᒥᒃ

Thank you!

ᖁᔭᓐᓇᒦᒃᖁᔭ

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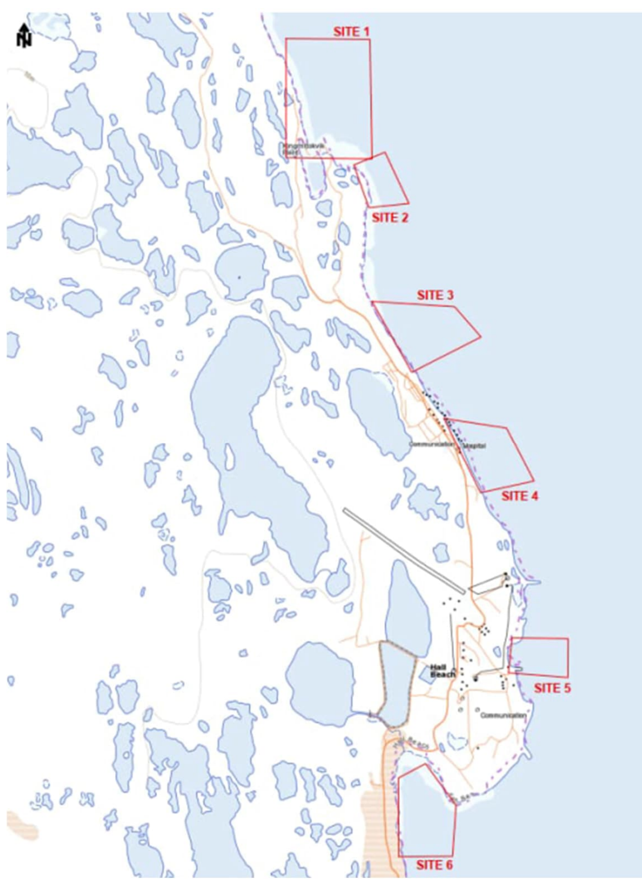
- diane.pinto@advisian.com
- Cell: 647-829-8531

Sanirajak Marine Infrastructure Feasibility Study
ᓴᓂᕋᔭᒃ ᑕᕆᐅᖕᒪᓂ ᐱᕐᑯᑎᕐᔪᐊᑦ ᐱᔭᒃᓴᐅᓂᖏᓐᓂᒃ ᖃᐅᔨᓴᕐᓂᖅ

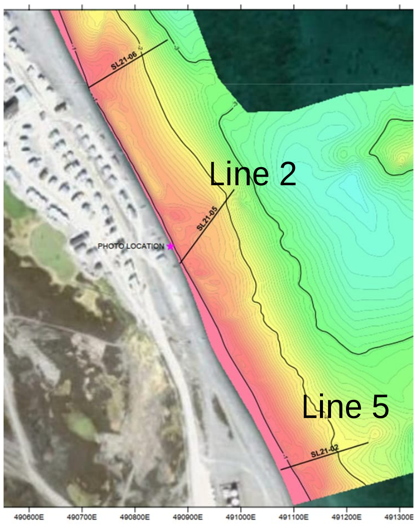
February 2023

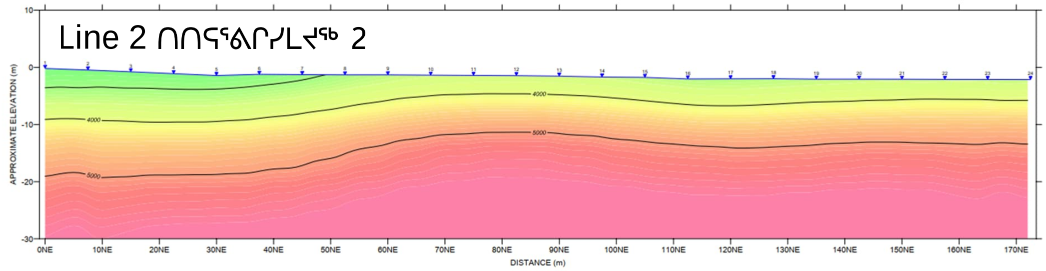
ᕼᐊᕈᑦ ᑲᓪᒪᓐ Harald Kullmann

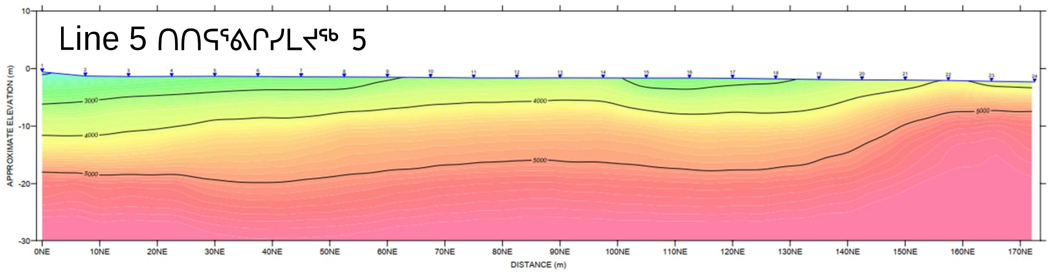
Geophysics Work
ᐅᔭᕋᓕᕆᓂᕐᒥᒃ ᓴᓇᔪᑦ

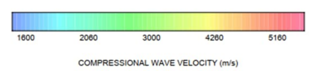


Geophysics Work ᐅᔭᕋᓕᕆᓂᕐᒥᒃ ᓴᓇᔪᑦ



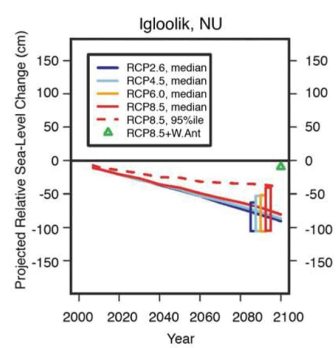


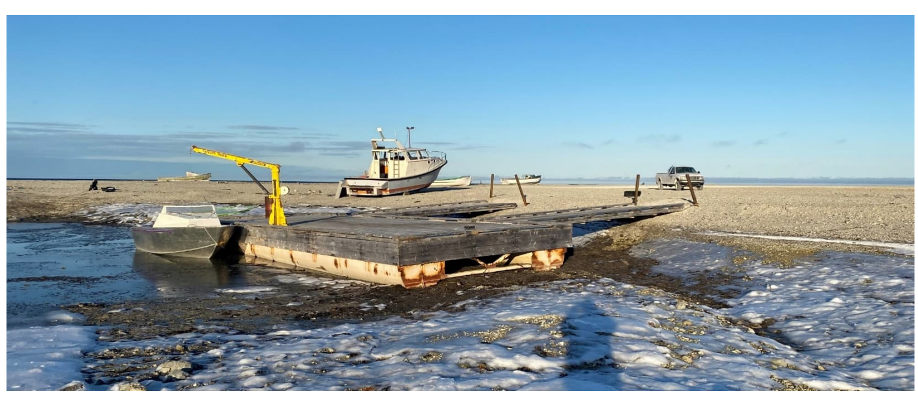




Sanirajak Challenges ᓴᓂᕋᔭᖕᒥ ᐊᔪᕐᓇᐅᑕᐅᔪᑦ

- Shallow water close to shore
- ᐃᒃᑲᓐᓂᖓ ᖃᓂᓗᐊᕐᑐᖅ ᓯᒃᔭᒧᑦ
- Bedrock is at or near the surface
- ᖃᐃᕐᓱᓂᖓ ᓴᕿᔭᕐᑐᖅ ᐅᕙᓗᓐᓂᑦ ᓴᕿᓕᒪᔪᖅ
- Low tide range
- ᑎᓂᑦᑕᕐᓂᖓ
- Land is coming up (no sea level rise)
- ᓄᓇ ᕿᕙᕐᐸᑦᑕᐊᔪᖅ (ᑕᕆᐅᖅ ᐃᒪᕐᑐᓯᕙᑦᑕᐊᖏᑦᑐᖅ)
- Very exposed shoreline
- ᓴᕿᔭᓗᐊᕐᑐᖅ ᓯᒃᔭᖓ
- No local rock to build breakwaters
- ᓄᓇᑕᖕᓂ ᐅᔭᕋᒃᑕᕐᑲᖏᑦᑐᖅ ᑐᓚᒃᑕᕝᕕᓕᐅᕈᑎᒃᓴᓂᒃ





Option Locations - ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᑦ

- Options 1 & 2: ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᑦ 1 ᐊᒻᒪ 2
  - Kingmitokvik Point
  - ᑭᖕᒥᒃᑐᖅᕕᒃ ᓄᕗᐊᕐᔪᐊᓂ
  - At floating dock
  - ᐃᐱᖅᕕᖕᒥ

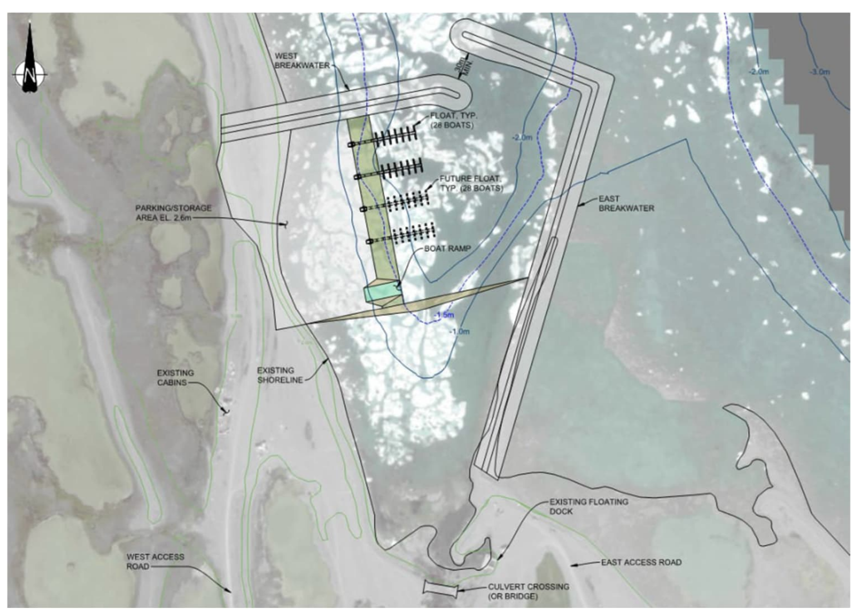
  Options 3 & 4: ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᑦ 3 ᐊᒻᒪ 4
  - At sealift beach
  - ᐅᒥᐊᕐᔪᐊᓄᑦ ᓂᐅᕋᐃᕕᖕᒥ

  Option 5: ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 5
  - South of North Warning/Airport Site
  - ᓂᒋᐊᓂ ᐅᓇᑕᖅᑐᒃᓴᖅᑲᖅᕕᐅᑉ/ᒥᑦᑕᖅᕕᐅᑦ
  - Near Hall Point
  - ᖃᓂᒋᔭᖓᓂ ᓴᓂᕋᔭᐅᑉ ᓄᕗᐊᕐᔪᐊ
- Option 6: ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 6
  - North Sand Bar
  - ᐅᐊᖕᓇᖓᓂ ᓯᐅᕋᐅᓂᖓ

Option 1 - ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 1 (ᑭᖕᒥᒃᑐᖅᕕᒃ ᓄᕗᐊᕐᔪᐊ Kingmitokvik Point)

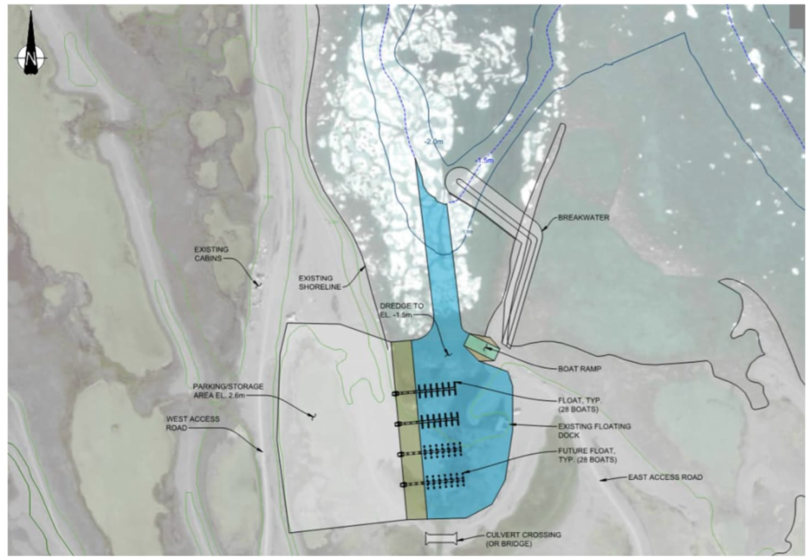
- Advantages ᐱᐅᓂᖓ:
  - Makes use of existing sandbars
  - ᓯᐅᕋᖓ ᐱᑕᖅᑲᖅᐸᒋᖅᑐᖅ ᐊᑐᖅᓗᒍ
  - Likely to affect sediment movement
  - ᐃᖅᑲᖕᒐᓂᖕᒐᖅᑐᑦ ᐊᐅᓚᑲᑕᐃᓐᓇᕆᐊᓕᑦ

- Disadvantages ᐱᐅᖏᓐᓂᖓ:
  - 4km from town, few people like location
  - 4 ᑭᓚᒥᑕ ᓄᓇᓕᖕᓂᑦ, ᐅᓄᖕᒋᑦᑐᑦ ᑕᕙᓂᖅᑯᔪᑦ
  - Likely need some import rock
  - ᐅᔭᕋᓕᒃᑲᓐᓂᑎᐊᖅᑲᕋᔭᖅᑐᖅ ᓯᓚᑕᓂᑦ
  - Location is well offshore due to depth
  - ᐃᓂᖓ ᓴᑦᑎᒃᑐᒥᑦᑐᖅ ᐃᒃᑲᓐᓂᖓᓄᑦ
  - Lots of heavy rock needed
  - ᐅᔭᕋᖕᓂᒃ ᐅᓄᖅᑐᓂᒃ ᐱᔭᕆᐊᓕᒃ
  - No deep water close by
  - ᐃᒪᖓ ᐃᑎᓂᖅᑲᖕᒋᑦᑐᖅ ᖃᓂᒋᔭᖓᓂ



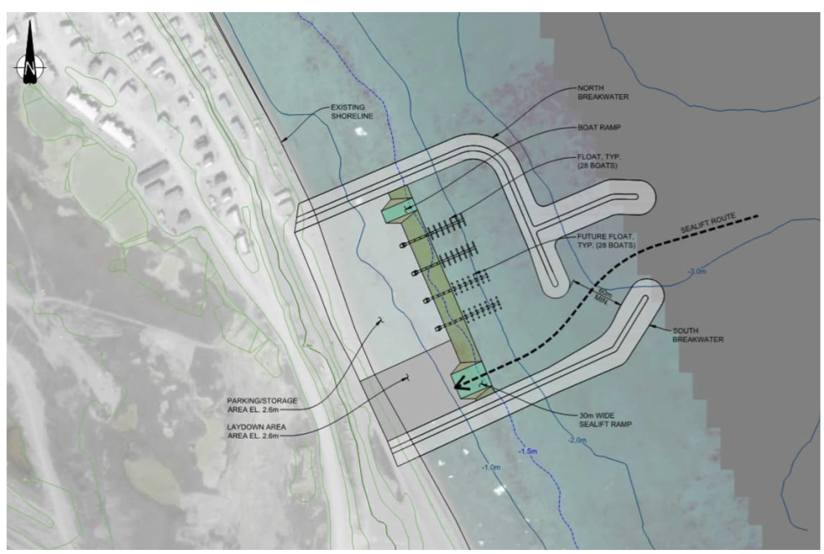
Option 2 - ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 2 (ᑭᖕᒥᒃᑐᖅᕕᒃ ᓄᕗᐊᕐᔪᐊ Kingmitokvik Point)

- Advantages ᐱᐅᓂᖓ:
  - Makes use of existing sandbars
  - ᓱᐅᕋᖓ ᐱᑕᕐᑲᕐᐸᒋᕐᑐᖅ ᐊᑐᕐᓗᒍ
  - No interruption of sediment movement
  - ᐃᕐᑲᖓ ᐃᖏᕋᕙᓪᓚᐊᖏᑦᑐᖅ
  - Minimum of big rock needed
  - ᐊᖏᓗᐊᖏᑦᑐᒥᒃ ᐅᔭᕋᖕᓂᒃ ᐱᔭᓇᐊᓚᒃ
  - Produce lots of supply rock
  - ᐅᔭᕋᒃᑕᕐᕕᐅᔪᓐᓇᕐᑐᖅ
  - Can easily make harbour basin deeper
  - ᐅᒥᐊᒃᑯᕕᒃ ᐱᔭᐃᕕᐅᔪᓐᓇᕐᑐᖅ ᐃᑎᒃᓚᒋᐊᕐᑕᐅᓗᓂ
- Disadvantages ᐱᐅᖏᓐᓂᖓ:
  - 4km from town, few people like location
  - 4 ᑭᓚᒥᑕ ᓄᓇᓛᓐᓂᑦ, ᐅᓄᖏᑦᑐᑦ ᑕᕝᓂᕐᑯᔪᑦ
  - Depth likely shallower than Option 1?
  - ᐃᒃᑲᓐᓂᕐᓴᐅᑐᐃᓐᓇᓇᐊᓚᒃ ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 1-ᒥᑦ
  - Entrance channel will be difficult
  - ᐃᓯᓇᐊᕐᕕᖓ ᓱᓪᓗᖓ ᐱᔭᕐᓂᕐᔮᐊᖏᑦᑐᖅ
  - No deep water close by
  - ᐃᒪᖓ ᐃᑎᔪᒥ ᕐᑲᓂᒋᔭᕐᑲᖏᑦᑐᖅ



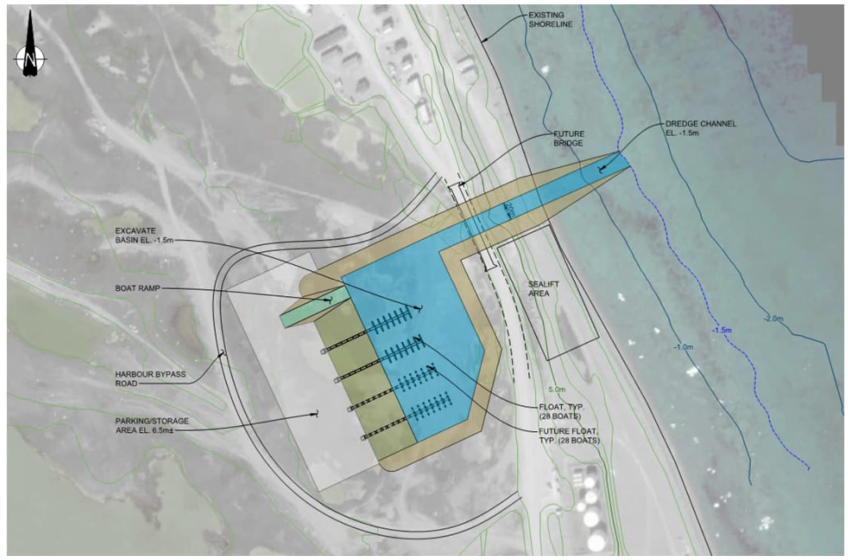
Option 3 - ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 3 (ᓂᐅᕋᐃᕕᒃ ᐅᒥᐊᕐᔪᐊᒃᑯᑦ Sealift Beach)

- Advantages ᐱᐅᓂᖓ:
  - Preferred location by many, close to hamlet
  - ᐃᓂᒋᔭᐅᔪᒪᓂᕐᓴᖅ ᐅᓄᕐᓂᖅᓴᓄᑦ, ᓄᓇᓕᖕᓄᓪᓗ ᕐᑲᓂᓪᓚᓂ
- Disadvantages ᐱᐅᖏᓐᓂᖓ:
  - Lots of import rock need
  - ᐅᔭᕋᓕᕐᓱᓇᐊᕐᑲᕐᑐᖅ ᐅᓄᕐᑐᓂᒃ
  - Conflict with sealift
  - ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᓂᐅᕋᐃᑎᓪᓗᒋᑦ ᐊᒃᕕᐊᕐᑐᖅ
  - Interrupts sediment movement
  - ᐃᕐᑲᖓᓂᒃ ᐊᐅᓚᔪᓐᓂᕐᑎᑦᑎᒐᔭᕐᑐᖅ
  - No deep water close by
  - ᐃᑎᔪᒥᒃ ᕐᑲᓂᒋᔭᕐᑲᖏᑦᑐᖅ



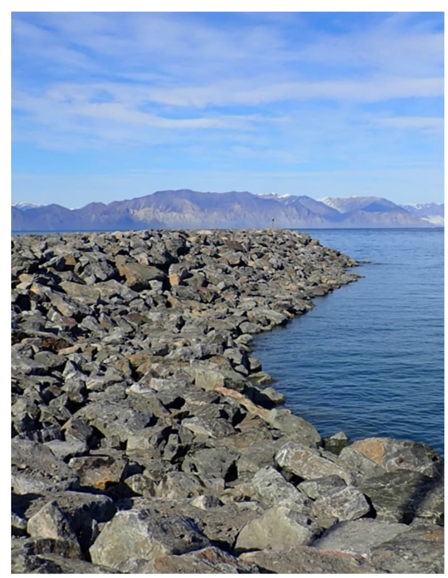
Option 4 - ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᖅ 4 (ᐅᒥᐊᕐᔪᐊᒃᑯᑦ ᓂᐅᕋᐃᕖᒃ Sealift Beach)

- Advantages ᐱᐅᓂᖓ:
  - Preferred location by many, close to hamlet
  - ᐃᓂᒋᔭᐅᔪᒪᓂᕐᓴᖅ ᐅᓄᕐᓂᖅᓴᓄᑦ, ᓄᓇᓕᖕᓄᑦ ᕿᓂᖕᓂ
  - Least import rock ᐅᓄᖏᓛᓂᒃ ᐅᔭᕋᒃᑕᕆᐊᓕᒃ
  - Produces a lot of useable rock
  - ᐅᔭᕋᒃᑕᕐᕕᐅᔪᓐᓇᕐᑐᖅ ᐊᑐᕈᓐᓇᕐᑐᓂᒃ
  - Harbour can be any size, any depth
  - ᐅᒥᐊᒃᑯᕖᒃ ᖃᓄᐃᑐᐃᓐᓇᖅ ᐊᖏᑎᒋᔪᓐᓇᕐᑐᖅ



- Disadvantages ᐱᐅᖏᓐᓂᖓ:
  - Blasting close to houses and tank farm
  - ᖃᕐᑎᕐᑎᑲᑕᒃᑐᑎᒃ ᐃᒡᓗᐃᑦ ᖃᓂᒋᔭᖓᓂ ᐊᒻᒪᓗ ᐅᕐᓱᕐᑕᕐᕕᖕᒥ
  - Annual dredging at entrance
  - ᐊᕋᒍᑕᒫᑦ ᐃᖃᖓ ᐱᔭᕐᑕᐅᖃᑦᑕᕐᕋᔭᕐᑐᖅ
  - Sealift conflict ᓂᐅᕋᐃᕖᖑᑦ ᐊᒃᕕᐊᕐᑐᖅ
  - Needs a bypass road ᐊᖅᑯᑎᑕᕆᐊᓕᒃ
  - No deep water close by ᐃᑎᔪᒥᒃ ᖃᓂᒋᔭᖃᖏᑦᑐᖅ

Costs ᐊᑭᖏᑦ



- Option 1 - Kingmitokvik Point (offshore) $94.9 million
- ᐃᓂᒃᓴᐅᔪᓐᓇᕐᑐᖅ 1 - ᑭᖕᒥᒃᑐᖅᕖᒃ ᓄᕗᐊ(ᓴᑦᑎᒃᑐᒥ)
- Option 2 - Kingmitokvik Point (inshore) $58.1 million
- ᐃᓂᒃᓴᐅᔪᓐᓇᕐᑐᖅ 2 - ᑭᖕᒥᒃᑐᖅᕖᒃ ᓄᕗᐊ (ᓱᒃᔭᕐᐸᓱᒃ)
- Option 3 – Sealift Beach (offshore) $123 million
- ᐃᓂᒃᓴᐅᔪᓐᓇᕐᑐᖅ 3 – ᐅᒥᐊᕐᔪᐊᓄᑦ ᓂᐅᕋᐃᕖᒃ (ᓴᑦᑎᒃᑐᒥ)
- Option 4 – Sealift Beach (inshore) $67.4 million
- ᐃᓂᒃᓴᐅᔪᓐᓇᕐᑐᖅ 4 – ᐅᒥᐊᕐᔪᐊᓄᑦ ᓂᐅᕋᐃᕖᒃ (ᓱᒃᔭᕐᐸᓱᖕᒥ)

Estimate Considerations ᐊᑭᖕᒋᓐᓄᑦ ᐃᓱᒪᒋᔭᐅᔪᑦ

- Does not include escalation (feds currently allowing 6-7%)
- ᐱᖃᓱᐅᑎᖕᒋᑦᑐᖅ ᐊᑭᑦᑐᕆᐊᕐᐸᓪᓕᐊᓂᖓ (ᒐᕙᒪᒃᑯᑦ ᐱᕕᖃᕐᑎᑦᑎᔪᑦ 6-7 ᐳᓴᓐᑦ)

- Current market conditions are very hot. Estimates may not be enough if this continues.
- ᒪᓐᓇ ᓂᐅᕕᕐᑕᐅᓂᒃᑯᑦ ᐱᔭᐅᔪᒪᓪᓚᕆᒃᑐᑦ. ᐊᑭᖕᒋᑦ ᐊᒥᒐᑐᐃᓐᓇᕆᐊᓕᑦ ᐊᑭᑦᑐᕆᐊᕐᐸᓪᓕᐊᖕᒋᓐᓇᕐᐸᑕ.

- All options have never been done – adds risk and cost
- ᑕᒪᕐᒥᒃ ᐃᓂᒋᔭᐅᔪᓐᓇᕐᑐᑦ ᓴᓇᔭᐅᓚᐅᕐᔨᒪᖕᒋᒻᒪᑕ – ᐅᓗᕆᐊᓇᕐᑐᖃᑐᐃᓐᓴᕆᐊᓕᒃ ᐊᒻᒪ ᐊᑭᖓ

- Other Nunavut harbours have been ~$40M
- ᓄᓇᕗᒻᒥ ᐅᒥᐊᒃᑯᕕᑦ ᐃᒪᓐᓇᖃᕐᓯᒪᔪᑦ ~$40M

Next Steps ᖃᓄᐃᓕᖓᓂᐊᕐᓂᖓ

- Confirm which option to seek funding
- ᓇᓗᓇᐃᕐᑕᐅᓗᓂ ᐃᓂᒋᔪᓐᓇᕐᑕᖓ ᓂᕈᐊᕐᑕᐅᓗᓂ ᑮᓇᐅᔭᓂᒃ ᕿᓂᕈᑕᐅᓕᕐᓗᓂ
- Decide if harbour depth is ok
- ᐊᕐᑭᒃᑕᐅᓗᓂ ᐅᒥᐊᒃᑯᕕᒃ ᐃᑎᓂᖓ ᓇᒻᒪᖕᒪᖔᑦ
- Consider further study, especially for Option 3
- ᐃᓱᒪᒋᔭᐅᓗᓂ ᖃᐅᔨᓴᕐᑕᐅᒃᑲᓐᓂᓚᐊᕐᑲᕐᓂᖓ, ᐱᓗᐊᕐᑐᒥ ᐃᓂᒋᔪᓐᓇᕐᑕᖓ 3
- Decide if blasting close to shore in spring important
- ᐊᕐᑭᒃᑕᐅᔭᓚᐊᓕᒃ ᖃᕐᑎᑦᑎᖃᑦᑕᕐᓗᑎᒃ ᓯᒃᔭᒥ ᐅᐱᖓᒃᑯᑦ ᐱᑦᑕᓚᐅᔪᖅ
- Upland surveys
- ᓄᓇᖓ ᑎᑉᐹᓯᒃᑐᖅ ᖃᐅᔨᓴᕐᑕᐅᓗᓂ
- Baseline studies for permitting
- ᐱᒋᐊᕐᕕᒃᓴᐃᑦ ᖃᐅᔨᓴᕐᑕᐅᓗᓂ ᐊᖕᒋᕐᑕᐅᓇᓱᒃᓂᐊᕐᑐᑦ ᐱᔪᓐᓇᐅᑎᒥᒃ

Thank you!

ᕿᓱᓯᓐᓇᒥᒃᑫᕿᓱᓯ

Contact information:
ᐅᖃᖅᑎᒋᔨᒋᑦ ᐅᑯᐊ:

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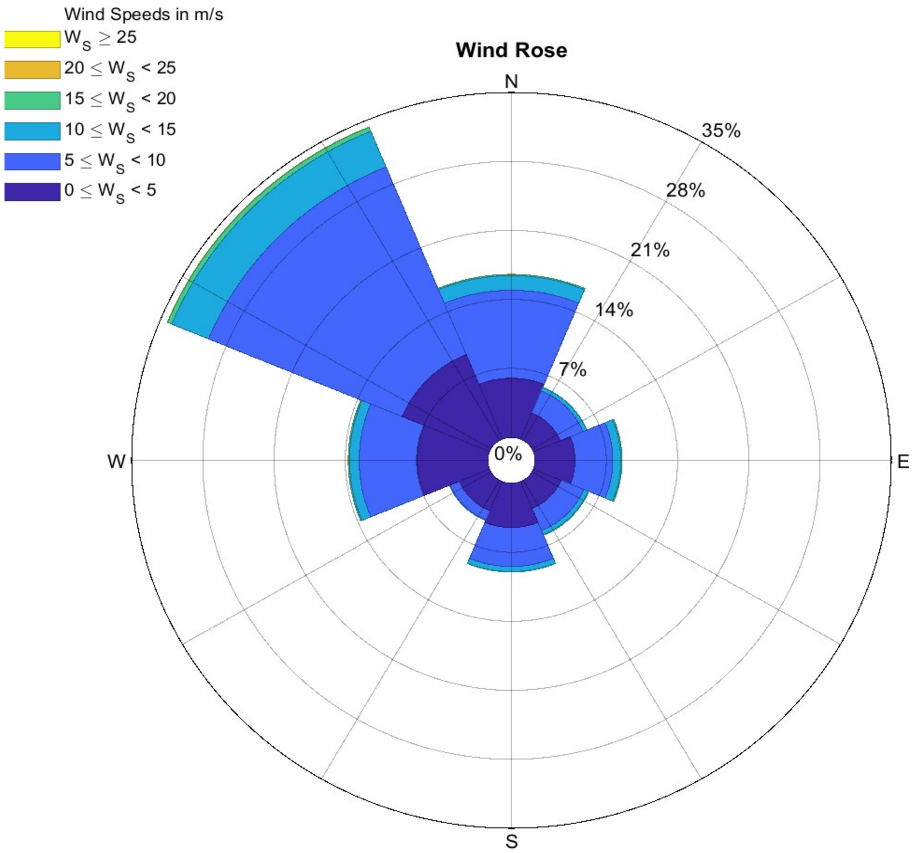
- Cell: 647-829-8531

Appendix 3
Wind Roses

Annual



Frequency Table

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0 - 3	2.137	1.304	1.928	1.384	1.893	1.809	3.108	2.433	15.996
3 - 6	6.965	2.617	3.342	2.605	4.225	2.116	5.989	13.147	41.005
6 - 9	5.321	1.425	2.226	1.397	2.263	0.496	3.326	12.559	29.012
9 - 12	1.692	0.443	0.861	0.517	0.645	0.09	1.045	4.271	9.564
12 - 15	0.563	0.139	0.331	0.196	0.192	0.018	0.367	1.662	3.467
15 - 18	0.113	0.026	0.094	0.044	0.029	*	0.099	0.38	0.787
18 - 21	0.012	*	0.02	*	*	-	0.02	0.07	0.133
21 - 24	*	*	*	*	*	-	*	0.017	0.031
24 - 27	-	-	*	-	-	-	*	*	*
27 - 30	-	-	-	-	-	-	*	*	*
>30	-	-	-	-	-	-	-	-	-
Total	16.804	5.959	8.805	6.148	9.252	4.531	13.962	34.54	100

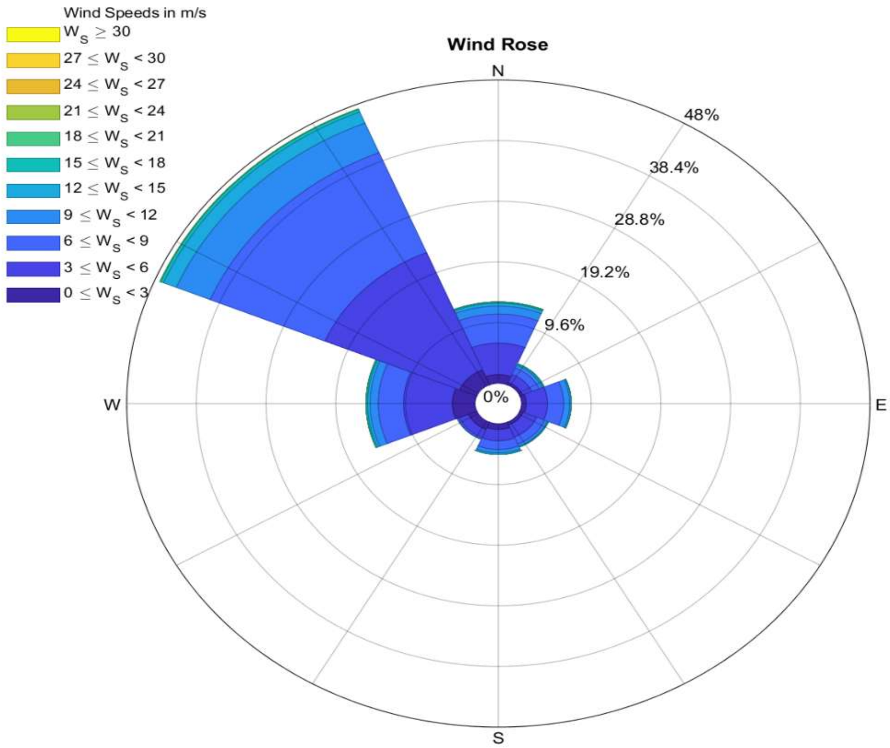
Metadata:

Location: Sanirajak (Hall Beach)
Data Period: 1956-2022
Data Source: https://climate.weather.
Blank Data: 0 %
Number of Complete Records: 555141

Key Statistics:

Maximum Speed: 29.68 m/s
Mean Wind Speed: 5.852 m/s
Std. Dev. Speed: 3.114 m/s

Sanirajak (Hall Beach)-January



Frequency Table

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	1.679	0.686	0.932	0.772	1.177	1.534	3.425	2.848	13.055
3-6	4.987	1.379	2.93	2.04	1.807	1.364	6.718	20.09	41.316
6-9	4.601	1.114	2.227	1.203	1.373	0.271	3.486	17.125	31.399
9-12	1.255	0.47	0.835	0.374	0.542	0.031	1.131	5.054	9.693
12-15	0.445	0.216	0.181	0.145	0.231	*	0.351	1.916	3.488
15-18	0.17	0.052	0.023	0.023	0.015	*	0.176	0.428	0.892
18-21	0.023	*	*	-	-	-	0.025	0.069	0.128
21-24	0.017	-	-	-	-	-	*	*	0.029
24-27	-	-	-	-	-	-	-	-	-
27-30	-	-	-	-	-	-	-	-	-
>30	-	-	-	-	-	-	-	-	-
Total	13.177	3.925	7.132	4.557	5.144	3.209	15.322	47.535	100

Metadata:

Location: Sanirajak (Hall Beach)

Data Period: 1956-2022

Data Source: https://climate.weathe

Blank Data: 0

Number of Complete Records: 47645

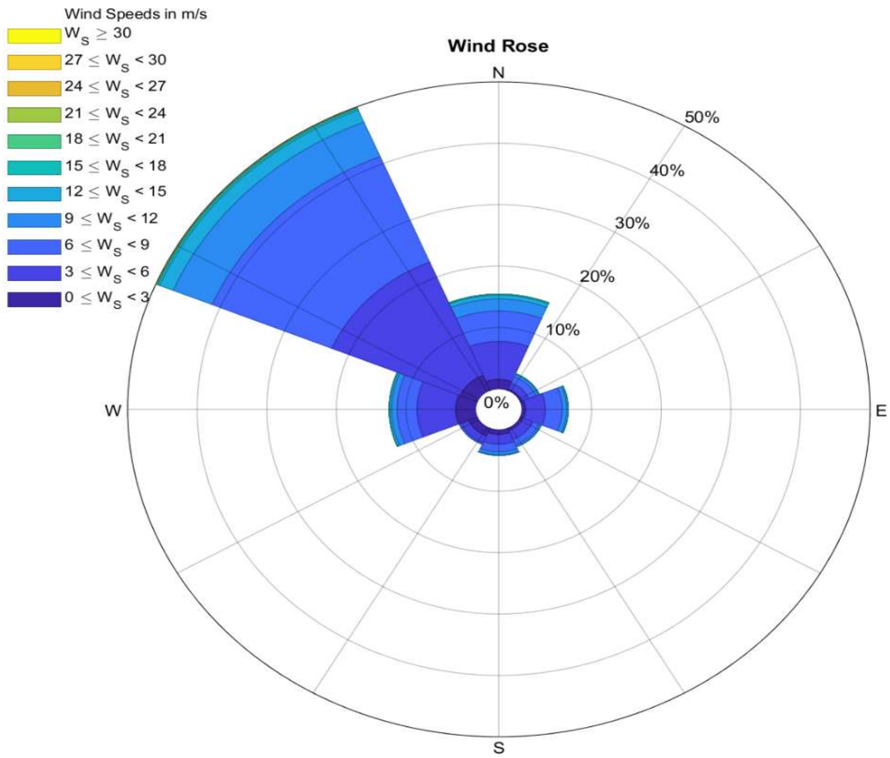
Key Statistics:

Maximum Speed: 23.8 m/s

Mean Wind Speed: 6.04 m/s

Std. Dev. Speed: 3.059 m/s

Sanirajak (Hall Beach)-February



Frequency Table

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	1.856	0.547	0.803	0.714	1.049	1.659	3.186	2.947	12.761
3-6	6.18	1.078	2.866	1.539	1.598	1.181	5.542	19.983	39.967
6-9	4.955	1.117	2.417	0.975	1.238	0.234	2.848	18.612	32.395
9-12	1.958	0.408	0.649	0.271	0.459	0.044	0.805	6.065	10.658
12-15	0.617	0.094	0.188	0.071	0.112	*	0.264	2.119	3.467
15-18	0.172	0.016	0.018	*	0.014	-	0.071	0.305	0.603
18-21	0.014	*	*	-	-	-	0.03	0.062	0.119
21-24	-	-	-	-	-	-	-	0.028	0.028
24-27	-	-	-	-	-	-	-	-	-
27-30	-	-	-	-	-	-	-	*	*
>30	-	-	-	-	-	-	-	-	-
Total	15.751	3.268	6.946	3.576	4.47	3.119	12.745	50.124	100

Metadata:

Location: Sanirajak (Hall Beach)

Data Period: 1956-2022

Data Source: https://climate.weathe

Blank Data: 0

Number of Complete Records: 43611

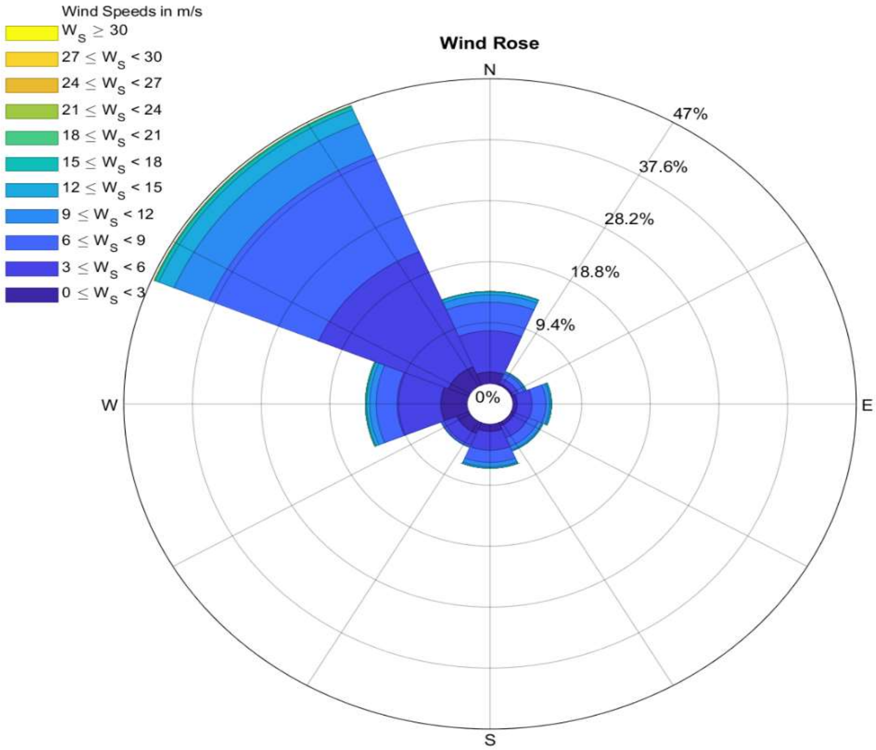
Key Statistics:

Maximum Speed: 27.16 m/s

Mean Wind Speed: 6.103 m/s

Std. Dev. Speed: 3.018 m/s

Sanirajak (Hall Beach)-March



Frequency Table

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	2.042	0.524	0.825	0.792	1.354	2.054	3.868	3.302	14.761
3-6	6.343	0.805	2.048	1.977	2.907	1.962	5.971	19.217	41.23
6-9	4.439	0.83	1.906	1.459	1.893	0.297	2.886	16.176	29.886
9-12	1.135	0.247	0.529	0.587	0.654	0.054	0.882	5.252	9.34
12-15	0.422	0.067	0.203	0.146	0.192	*	0.422	2.309	3.766
15-18	0.069	0.027	0.033	0.021	0.044	-	0.115	0.525	0.834
18-21	0.015	*	*	-	*	-	0.029	0.067	0.123
21-24	-	-	-	-	-	-	0.013	0.042	0.054
24-27	-	-	-	-	-	-	-	*	*
27-30	-	-	-	-	-	-	-	-	-
>30	-	-	-	-	-	-	-	-	-
Total	14.464	2.503	5.551	4.982	7.047	4.372	14.186	46.895	100

Metadata:

Location: Sanirajak (Hall Beach)

Data Period: 1956-2022

Data Source: https://climate.weather.

Blank Data: 0

Number of Complete Records: 47849

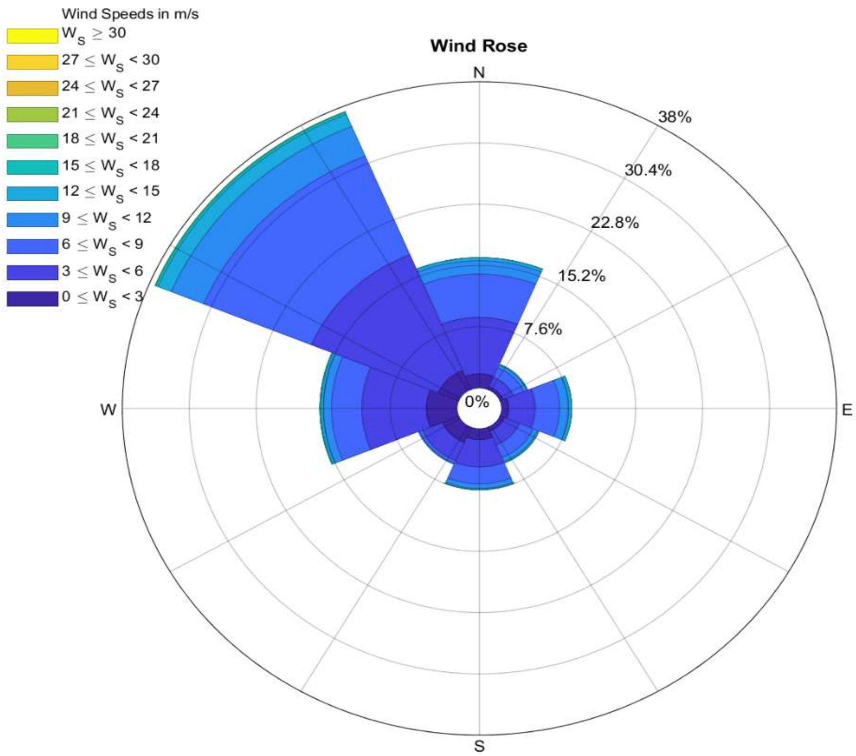
Key Statistics:

Maximum Speed: 24.92 m/s

Mean Wind Speed: 5.936 m/s

Std. Dev. Speed: 3.098 m/s

Sanirajak (Hall Beach)-April



Frequency Table

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	2.049	0.653	1.08	0.805	1.633	2.306	3.781	2.814	15.123
3-6	7.001	1.277	3.015	1.867	3.385	2.466	7.322	15.591	41.924
6-9	5.372	1.266	2.78	1.697	2.102	0.383	3.446	13.234	30.28
9-12	1.669	0.394	0.985	0.547	0.571	0.065	0.913	3.978	9.121
12-15	0.355	0.089	0.346	0.161	0.122	0.015	0.305	1.649	3.043
15-18	0.011	*	0.03	0.015	0.02	*	0.081	0.288	0.449
18-21	-	-	-	-	-	-	0.013	0.048	0.061
21-24	-	-	-	-	-	-	-	-	-
24-27	-	-	-	-	-	-	-	-	-
27-30	-	-	-	-	-	-	-	-	-
>30	-	-	-	-	-	-	-	-	-
Total	16.457	3.681	8.236	5.093	7.833	5.239	15.86	37.601	100

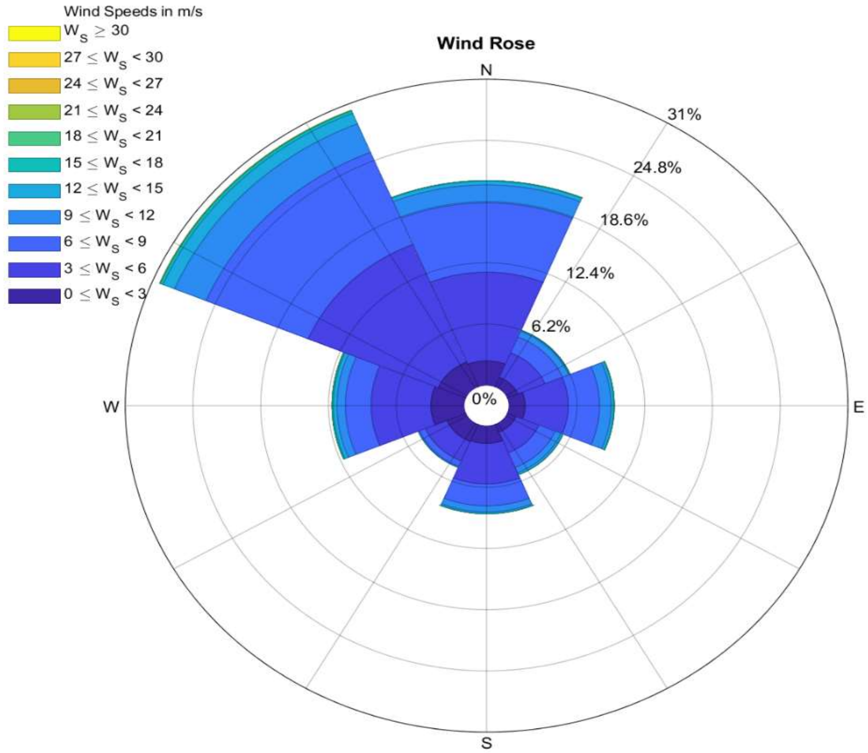
Metadata:

Location:	Sanirajak (Hall Beach)
Data Period:	1956-2022
Data Source:	https://climate.weathe
Blank Data:	0
Number of Complete Records:	45905

Key Statistics:

Maximum Speed:	20.72 m/s
Mean Wind Speed:	5.795 m/s
Std. Dev. Speed:	2.938 m/s

Sanirajak (Hall Beach)-May



Frequency Table

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	2.715	1.273	1.714	1.088	2.009	2.111	3.281	2.959	17.15
3-6	8.984	2.689	3.941	2.269	4.104	2.125	5.468	12.893	42.475
6-9	7.029	1.741	2.863	1.606	2.219	0.585	2.352	10.106	28.502
9-12	1.813	0.615	1.056	0.579	0.624	0.108	0.77	3.122	8.688
12-15	0.384	0.117	0.244	0.197	0.142	0.017	0.337	1.158	2.596
15-18	0.034	*	0.036	0.011	0.036	*	0.104	0.259	0.488
18-21	0.013	-	0.011	-	-	-	0.015	0.032	0.07
21-24	-	-	-	-	-	-	*	0.028	0.03
24-27	-	-	-	-	-	-	-	*	*
27-30	-	-	-	-	-	-	-	-	-
>30	-	-	-	-	-	-	-	-	-
Total	20.973	6.442	9.865	5.75	9.133	4.949	12.33	30.559	100

Metadata:

Location: Sanirajak (Hall Beach)

Data Period: 1956-2021

Data Source: https://climate.weather

Blank Data: 0

Number of Complete Records: 47148

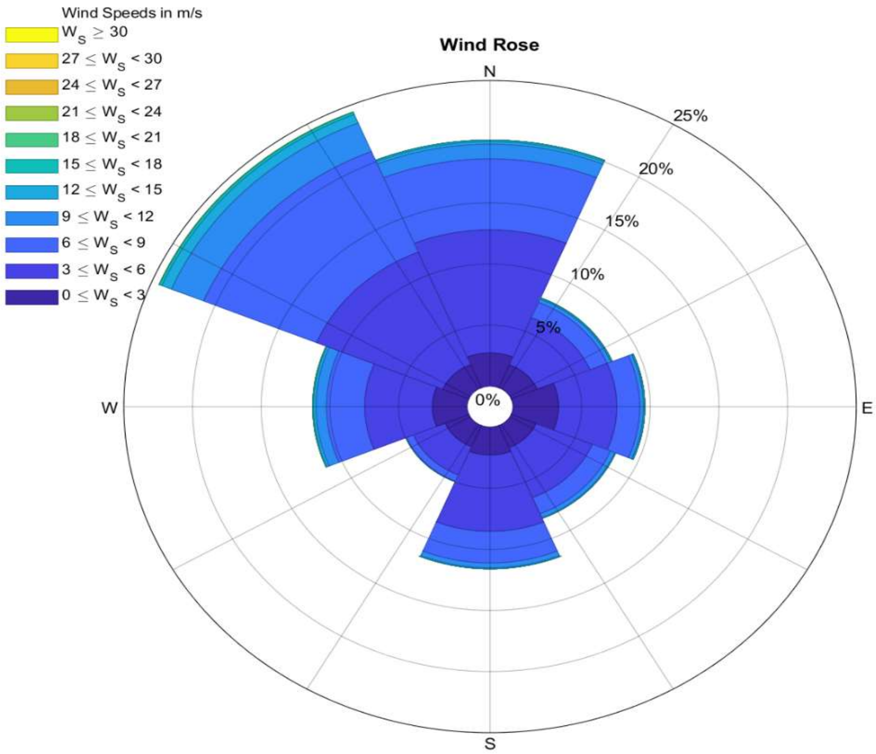
Key Statistics:

Maximum Speed: 24.92 m/s

Mean Wind Speed: 5.631 m/s

Std. Dev. Speed: 2.955 m/s

Sanirajak (Hall Beach)-June



Frequency Table

Speed m/s	N	NE	E	SE	S	SW	W	NW	Total
	Frequency (%)								
0-3	2.954	2.274	3.553	2.185	2.519	2.103	2.764	2.286	20.638
3-6	10.067	4.166	4.238	4.436	6.244	2.505	4.93	9.956	46.543
6-9	5.808	1.349	1.677	1.43	2.585	0.537	2.777	8.912	25.074
9-12	1.202	0.292	0.263	0.345	0.392	0.042	0.768	2.525	5.83
12-15	0.323	0.096	0.089	0.053	0.082	*	0.187	0.753	1.585
15-18	0.011	0.016	0.013	*	*	-	0.042	0.194	0.285
18-21	*	*	-	-	-	-	0.011	0.022	0.038
21-24	-	-	-	-	-	-	*	*	*
24-27	-	-	-	-	-	-	-	-	-
27-30	-	-	-	-	-	-	-	-	-
>30	-	-	-	-	-	-	-	-	-
Total	20.367	8.196	9.832	8.454	11.827	5.189	11.485	24.65	100

Metadata:

Location: Sanirajak (Hall Beach)

Data Period: 1956-2021

Data Source: https://climate.weather

Blank Data: 0

Number of Complete Records: 44907

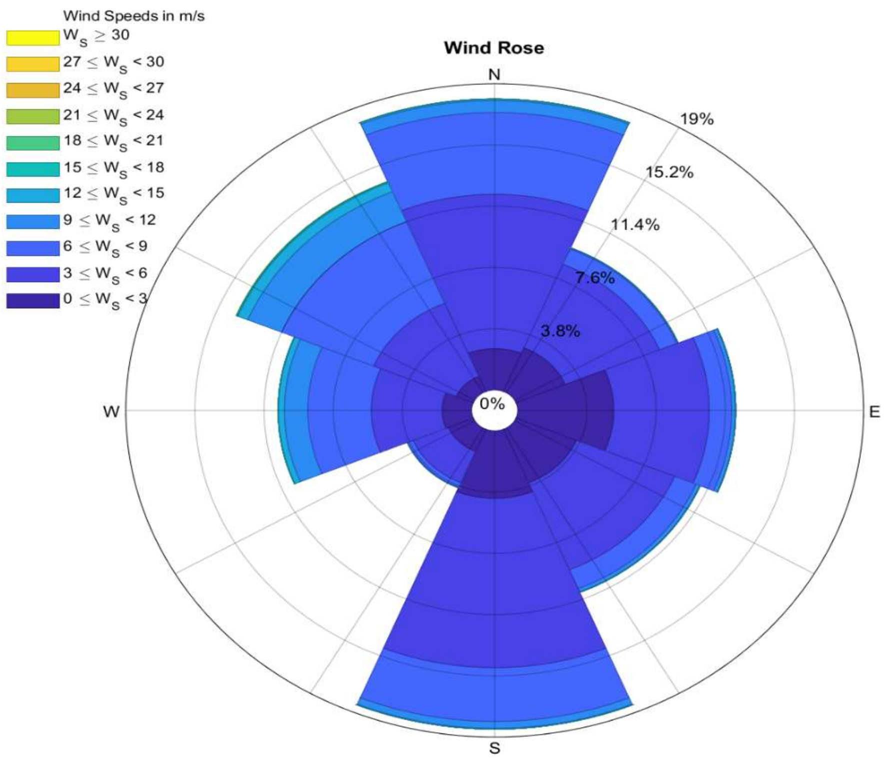
Key Statistics:

Maximum Speed: 23.8 m/s

Mean Wind Speed: 5.103 m/s

Std. Dev. Speed: 2.702 m/s

Sanirajak (Hall Beach)-July



Frequency Table

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	2.837	3.199	5.544	3.864	4.458	1.755	1.891	1.282	24.831
3-6	9.575	5.609	5.248	5.844	10.51	2.101	3.895	4.916	47.699
6-9	5.076	1.034	1.226	1.269	3.333	0.307	3.485	5.482	21.212
9-12	0.738	0.063	0.203	0.214	0.425	0.035	1.289	2.01	4.976
12-15	0.084	0.015	0.03	0.03	0.05	*	0.328	0.596	1.14
15-18	0.019	-	-	*	*	-	0.026	0.069	0.121
18-21	*	-	-	-	-	-	-	0.017	0.022
21-24	-	-	-	-	-	-	-	-	-
24-27	-	-	-	-	-	-	-	-	-
27-30	-	-	-	-	-	-	-	-	-
>30	-	-	-	-	-	-	-	-	-
Total	18.334	9.92	12.252	11.224	18.781	4.203	10.913	14.372	100

Metadata:

Location: Sanirajak (Hall Beach)

Data Period: 1956-2021

Data Source: https://climate.weathe

Blank Data: 0

Number of Complete Records: 46318

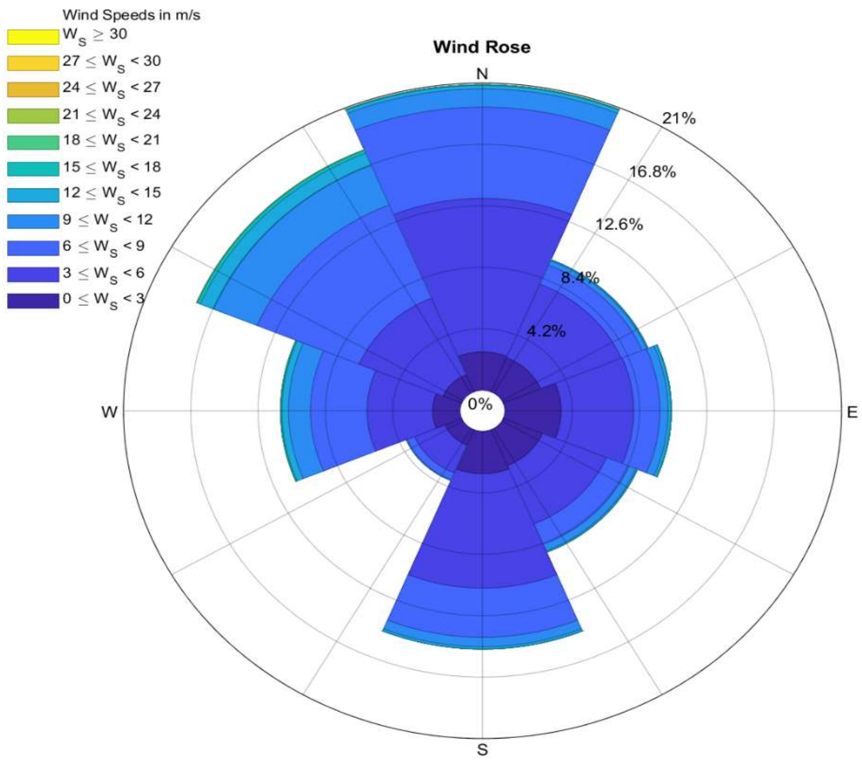
Key Statistics:

Maximum Speed: 19.6 m/s

Mean Wind Speed: 4.745 m/s

Std. Dev. Speed: 2.598 m/s

Sanirajak (Hall Beach)-August



Frequency Table

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	2.889	2.792	3.771	2.915	3.166	1.404	1.98	1.527	20.445
3-6	10.492	5.445	4.527	4.318	7.821	2.059	4.091	5.668	44.421
6-9	6.24	1.411	1.636	1.524	3.364	0.51	3.532	6.901	25.118
9-12	1.248	0.321	0.514	0.468	0.644	0.04	1.371	2.935	7.54
12-15	0.236	0.074	0.176	0.091	0.149	*	0.414	0.901	2.047
15-18	0.051	-	0.03	0.013	*	-	0.066	0.208	0.376
18-21	-	-	-	-	*	-	0.017	0.019	0.038
21-24	-	-	-	-	-	-	-	0.015	0.015
24-27	-	-	-	-	-	-	-	-	-
27-30	-	-	-	-	-	-	-	-	-
>30	-	-	-	-	-	-	-	-	-
Total	21.156	10.043	10.655	9.329	15.154	4.018	11.471	18.174	100

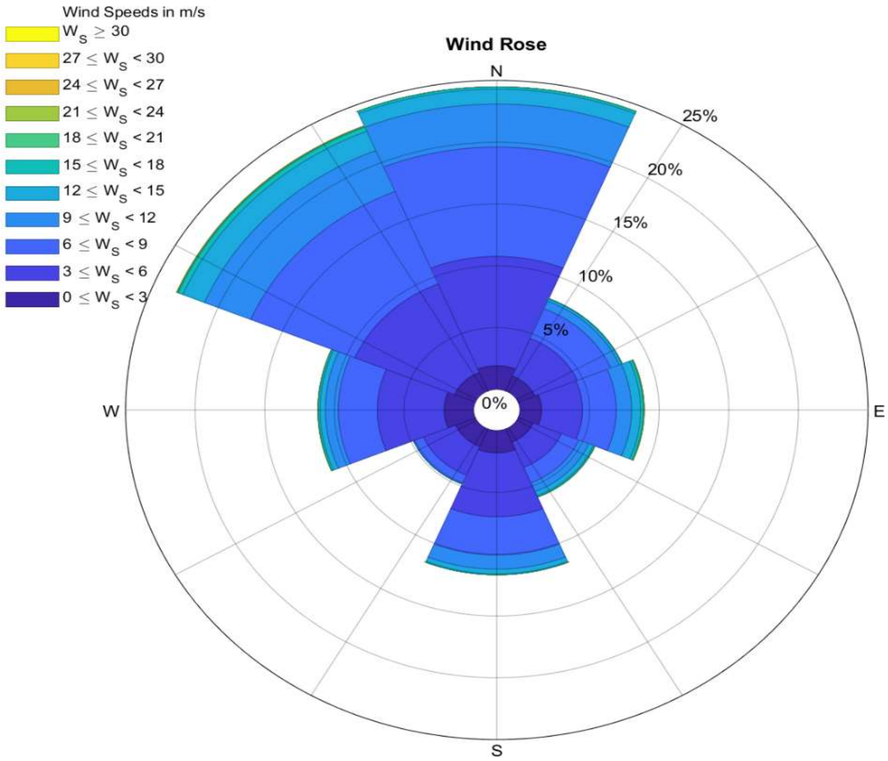
Metadata:

Location:	Sanirajak (Hall Beach)
Data Period:	1956-2021
Data Source:	https://climate.weathe
Blank Data:	0
Number of Complete Records:	47054

Key Statistics:

Maximum Speed:	23.8	m/s
Mean Wind Speed:	5.273	m/s
Std. Dev. Speed:	2.888	m/s

Sanirajak (Hall Beach)-September



Frequency Table

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	2.12	1.496	1.753	1.35	2.008	1.735	2.32	1.817	14.599
3-6	8.848	3.306	2.94	2.21	5.168	2.507	4.808	7.757	37.544
6-9	8.85	2.602	2.428	1.364	3.105	0.686	2.8	8.098	29.932
9-12	3.481	0.669	1.102	0.765	1.137	0.084	0.926	3.598	11.762
12-15	1.203	0.189	0.649	0.365	0.385	*	0.383	1.689	4.871
15-18	0.18	0.029	0.202	0.103	0.064	-	0.125	0.367	1.071
18-21	*	*	0.033	0.013	*	-	*	0.062	0.132
21-24	-	-	0.02	*	*	-	0.013	0.033	0.07
24-27	-	-	*	-	-	-	*	*	0.018
27-30	-	-	-	-	-	-	-	-	-
>30	-	-	-	-	-	-	-	-	-
Total	24.689	8.291	9.129	6.173	11.876	5.021	11.392	23.427	100

Metadata:

Location: Sanirajak (Hall Beach)

Data Period: 1956-2021

Data Source: https://climate.weathe

Blank Data: 0

Number of Complete Records: 45469

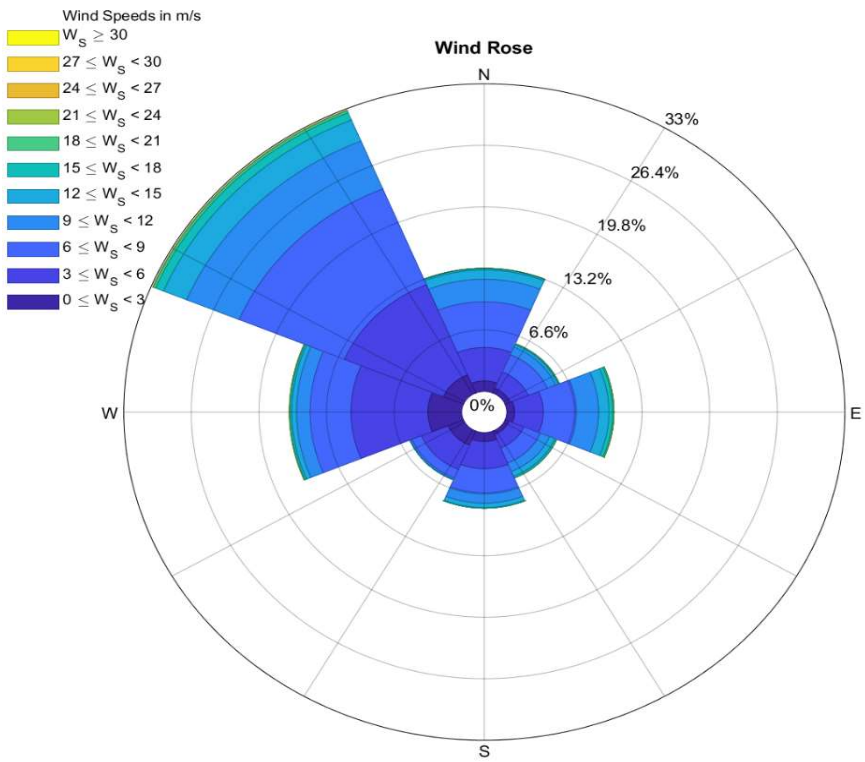
Key Statistics:

Maximum Speed: 24.92 m/s

Mean Wind Speed: 6.234 m/s

Std. Dev. Speed: 3.311 m/s

Sanirajak (Hall Beach)-October

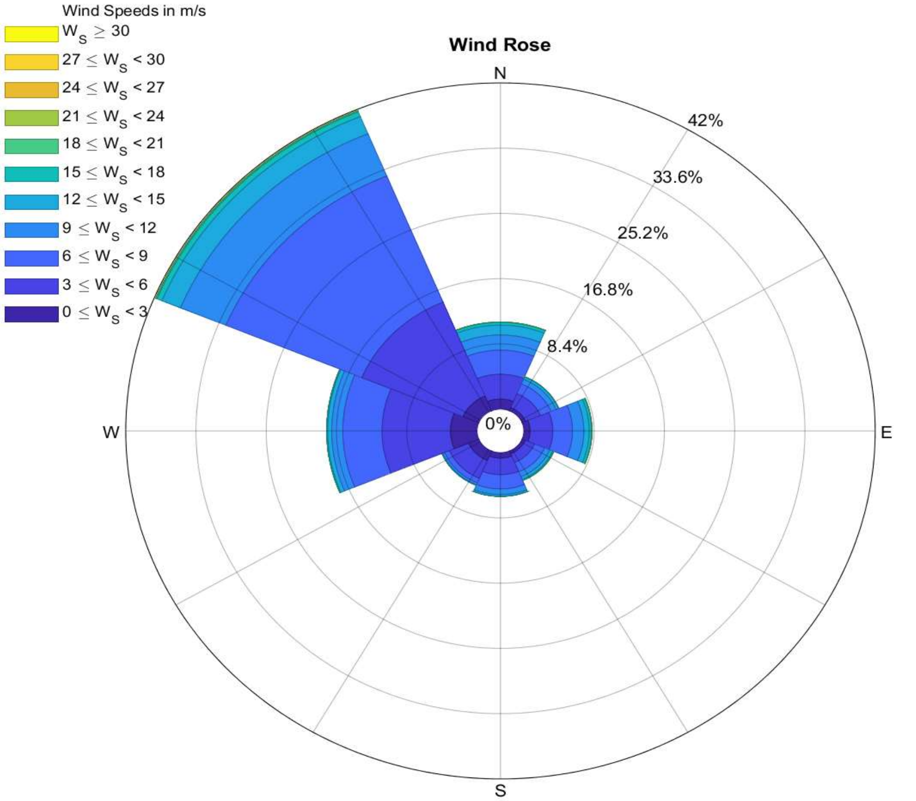


Frequency Table

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	1.345	0.755	0.96	0.612	1.163	1.834	3.506	2.325	12.5
3-6	3.586	1.897	2.792	1.568	2.92	2.822	7.519	10.467	33.57
6-9	4.909	2.01	3.228	1.743	2.6	1	3.99	11.127	30.605
9-12	2.418	0.882	2.185	0.972	1.106	0.171	1.32	5.545	14.6
12-15	0.985	0.265	1.019	0.56	0.466	0.045	0.461	2.439	6.239
15-18	0.164	0.107	0.367	0.184	0.062	*	0.171	0.852	1.912
18-21	0.021	0.017	0.107	0.019	*	-	0.038	0.239	0.444
21-24	*	0.015	*	*	-	-	0.023	0.028	0.081
24-27	-	-	*	-	-	-	*	0.013	0.021
27-30	-	-	-	-	-	-	0.019	*	0.028
>30	-	-	-	-	-	-	-	-	-
Total	13.432	5.948	10.67	5.659	8.319	5.875	17.053	33.043	100

Metadata:		**Key Statistics:**	
Location:	Sanirajak (Hall Beach)	Maximum Speed:	29.68 m/s
Data Period:	1956-2021	Mean Wind Speed:	6.768 m/s
Data Source:	https://climate.weathe	Std. Dev. Speed:	3.586 m/s
Blank Data:	0		
Number of Complete Records:	46816		

Sanirajak (Hall Beach)-November



Freque

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	1.499	0.636	0.94	0.587	0.904	1.512	3.38	2.241	11.699
3-6	3.196	1.942	2.72	1.207	2.13	2.486	8.179	13.099	34.959
6-9	3.105	1.37	2.352	1.308	1.832	0.628	4.689	17.588	32.872
9-12	1.947	0.645	1.357	0.681	0.731	0.262	1.324	5.885	12.831
12-15	1.28	0.317	0.639	0.368	0.203	0.075	0.487	2.403	5.77
15-18	0.346	0.022	0.284	0.13	0.031	*	0.099	0.643	1.564
18-21	0.042	*	0.042	0.02	-	-	0.018	0.139	0.269
21-24	-	-	*	*	-	-	*	0.024	0.037
24-27	-	-	-	-	-	-	-	-	-
27-30	-	-	-	-	-	-	-	-	-
>30	-	-	-	-	-	-	-	-	-
Total	11.414	4.941	8.337	4.305	5.831	4.972	18.179	42.021	100

Metadata:

Location: Sanirajak (Hall Beach)

Data Period: 1956-2021

Data Source: https://climate.weathe

Blank Data: 0

Number of Complete Records: 45407

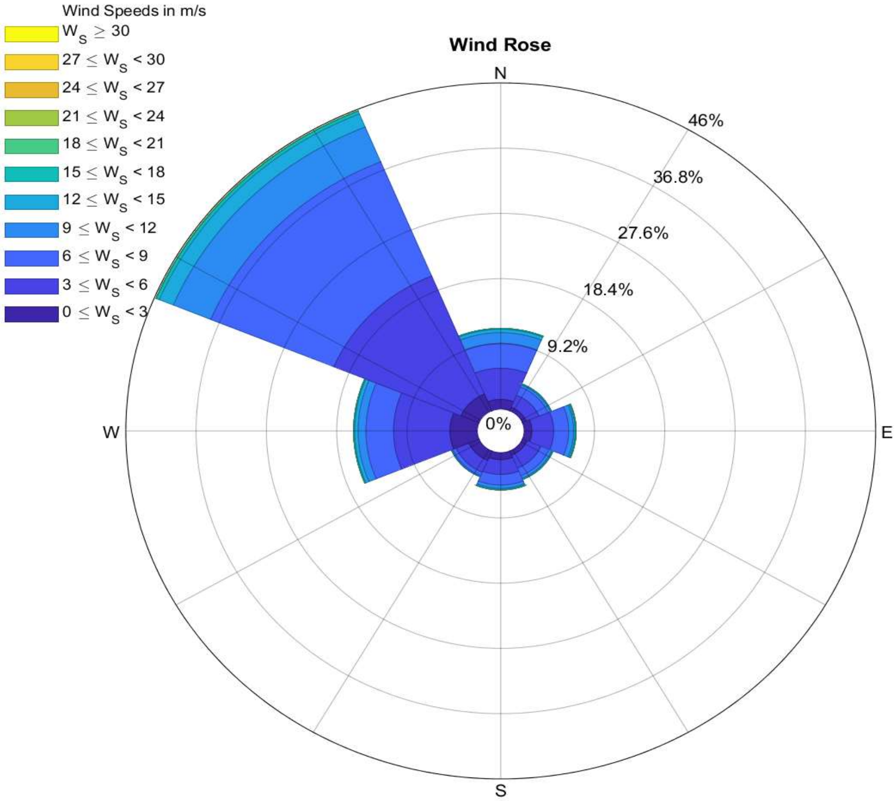
Key Statistics:

Maximum Speed: 23.8 m/s

Mean Wind Speed: 6.617 m/s

Std. Dev. Speed: 3.358 m/s

Sanirajak (Hall Beach)-December



Freque

Speed	Frequency (%)								
m/s	N	NE	E	SE	S	SW	W	NW	Total
0-3	1.659	0.817	1.277	0.917	1.264	1.7	3.863	2.821	14.318
3-6	4.386	1.823	2.855	1.972	2.087	1.81	7.377	18.025	40.334
6-9	3.516	1.274	1.974	1.159	1.497	0.508	3.608	17.438	30.975
9-12	1.51	0.313	0.638	0.389	0.449	0.14	1.025	5.305	9.77
12-15	0.455	0.134	0.208	0.155	0.166	0.032	0.449	1.999	3.599
15-18	0.132	0.028	0.091	0.017	0.047	*	0.106	0.411	0.838
18-21	*	-	0.036	*	0.019	-	0.032	0.057	0.151
21-24	-	-	-	-	0.015	-	-	-	0.015
24-27	-	-	-	-	-	-	-	-	-
27-30	-	-	-	-	-	-	-	-	-
>30	-	-	-	-	-	-	-	-	-
Total	11.661	4.389	7.079	4.614	5.544	4.197	16.46	46.057	100

Metadata:

Location: Sanirajak (Hall Beach)

Data Period: 1956-2021

Data Source: https://climate.weathe

Blank Data: 0

Number of Complete Records: 47012

Key Statistics:

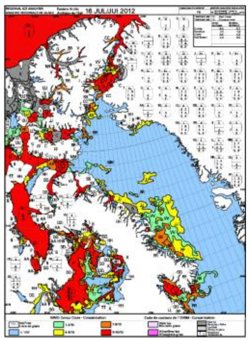
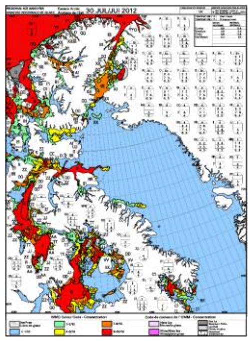
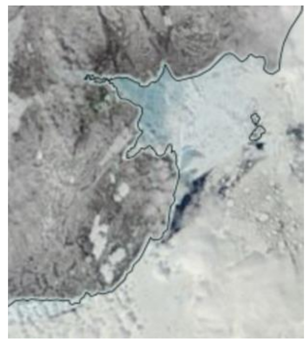
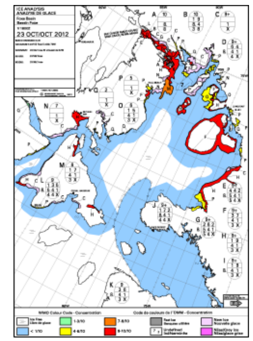
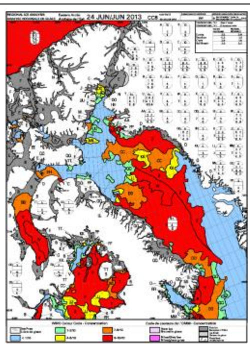
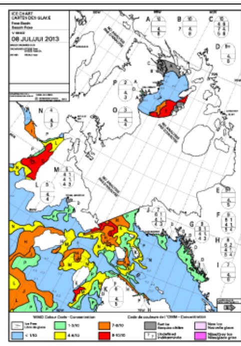
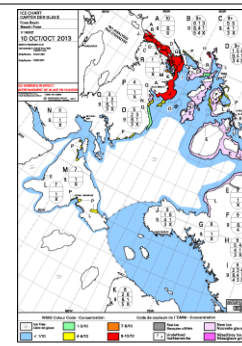
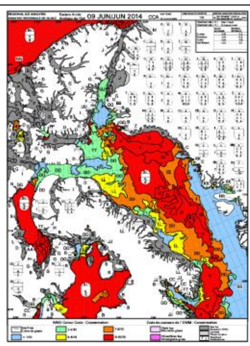
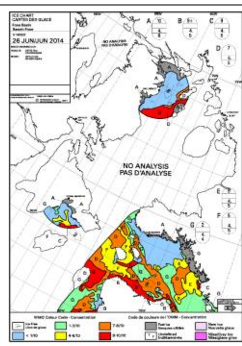
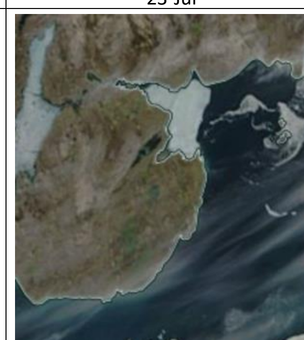
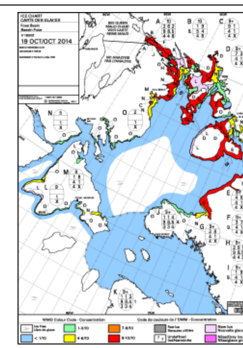
Maximum Speed: 23.8 m/s

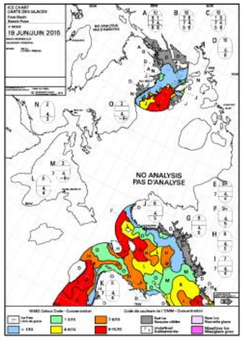
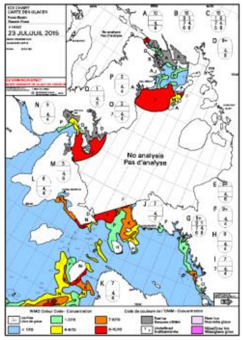
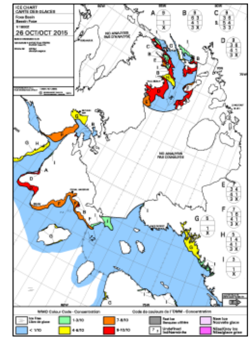
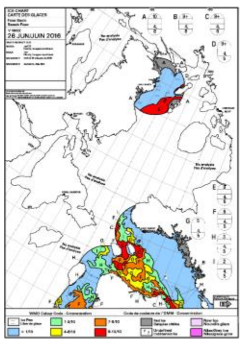
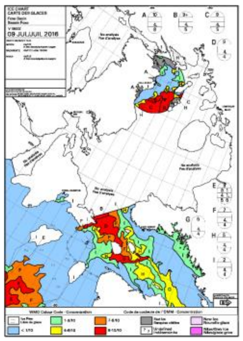
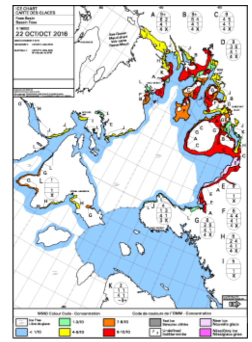
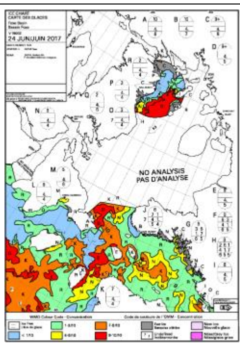
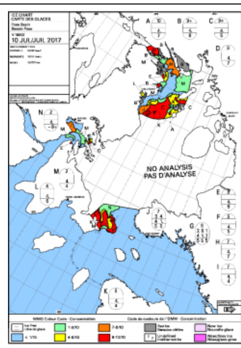
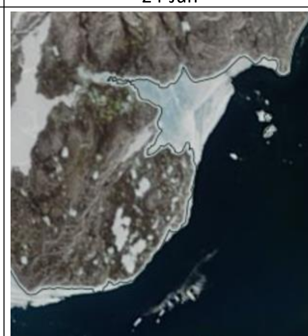
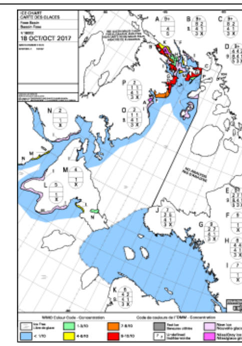
Mean Wind Speed: 5.988 m/s

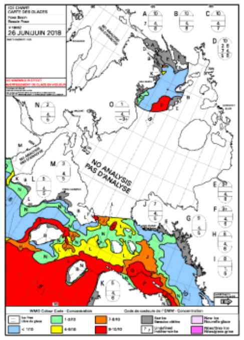
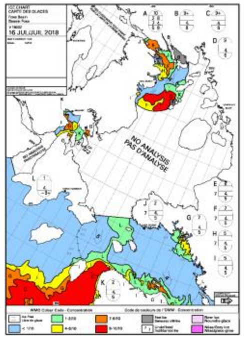
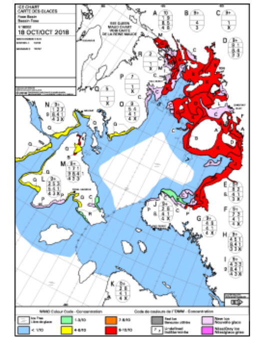
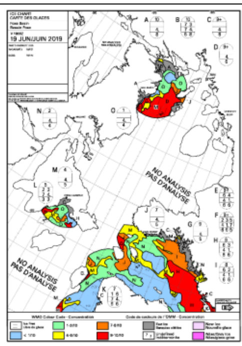
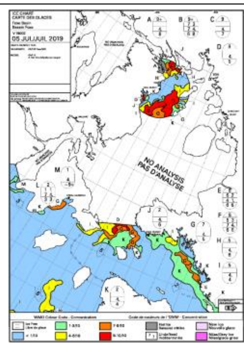
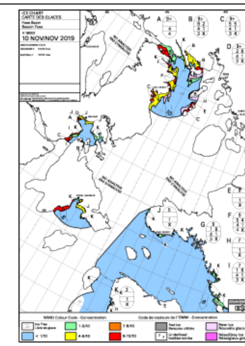
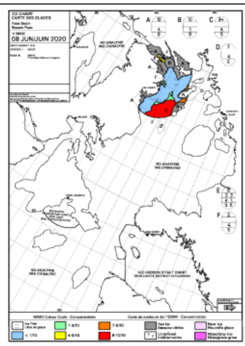
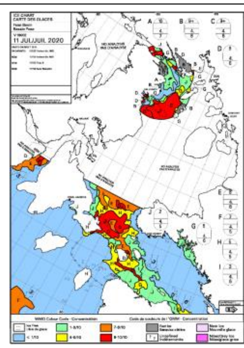
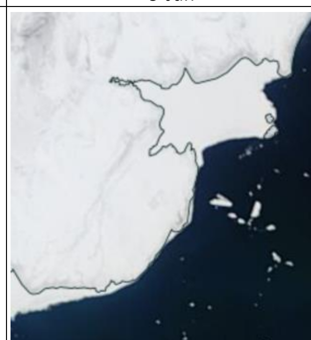
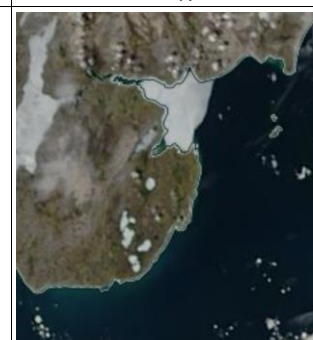
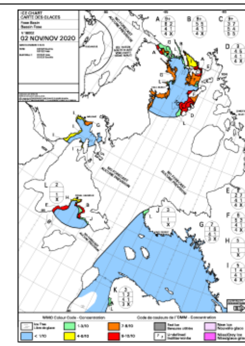
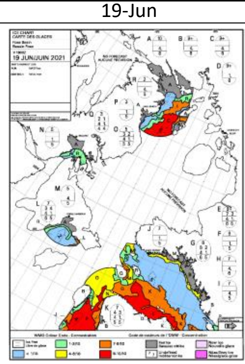
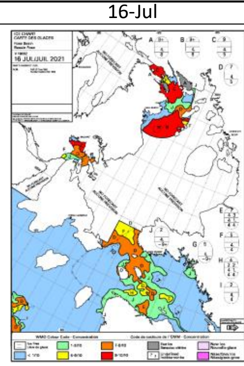
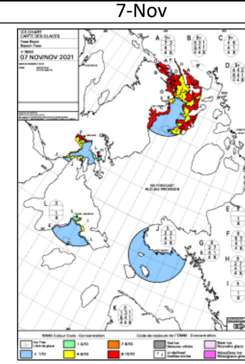
Std. Dev. Speed: 3.091 m/s

Appendix 4
Ice Data

Sanirajak Ice Charts

	Ice Charts		Satellite Imagery		Freeze-up	Comments
	Ice Break-Up	Ice-Free	Ice Break-Up	Ice-Free		
2012	16-Jul 	30-Jul 	20-Jun 	2-Aug 	23-Oct 	The ice charts and satellite imagery show breakage of ice in the week of July 16. Sanirajak is ice-free by August 2 as shown on satellite. Ice-free conditions are the latest in the season compared to other years looked at in this study. Freeze-up began by October 23.
2013	24-Jun 	8-Jul 	23-Jun 	22-Jul 	10-Oct 	Ice breakage begins the week of June 23, with the area in front of the community completely ice-free in the satellite imagery by July 22. Ice charts show ice-free conditions by July 8. Freeze-up occurs by October 10.
2014	9-Jun 	26-Jun 	25-Jun 	23-Jul 	19-Oct 	Ice break-up begins the week of June 9, as shown on ice charts, though satellite imagery shows approximately June 25. Ice charts show ice-free conditions the week of June 26, however satellite data indicate the area in front of the community is not ice-free until July 23. Freeze-up begins the week of October 19.

	Ice Charts		Satellite Imagery		Freeze-up	Comments
	Ice Break-Up	Ice-Free	Ice Break-Up	Ice-Free		
2015	19-Jun 	23-Jul 	19-Jun 	24-Jul 	26-Oct 	Ice charts and satellite imagery show break-up occuring on Jun 19, and ice-free conditions by July 23. Freeze-up begins on October 26.
2016	20-Jun 	8-Jul 	26-Jun 	9-Jul 	22-Oct 	Ice break-up begins on the week of June 20, and is shown on satellite imagery on June 26. Ice-free conditions start on July 8. Freeze-up begins the week of October 22.
2017	24-Jun 	10-Jul 	24-Jun 	10-Jul 	18-Oct 	Ice break-up begins on June 24 in both ice charts and satellite imagery, and is ice-free by July 10. Freeze-up occurs on October 18.

	Ice Charts		Satellite Imagery		Freeze-up	Comments
	Ice Break-Up	Ice-Free	Ice Break-Up	Ice-Free		
2018	26-Jun 	16-Jul 	26-Jun 	16-Jul 	18-Oct 	Ice break-up begins June 26 with ice-free conditions present by July 16, as shown on satellite. Open-water persists until freeze-up begins the week of October 18.
2019	19-Jun 	5-Jul 	19-Jun 	6-Jul 	10-Nov 	Ice break-up begins the week of June 19, with ice floes present until early July. Open-water conditions are present until early November, and this is observed as the latest freeze-up date in the analyzed dataset.
2020	8-Jun 	11-Jul 	9-Jun 	11-Jul 	2-Nov 	Ice break-up begins June 8 with ice-free conditions present by July 11. Open-water conditions remain until freeze-up beings November 2.
2021	19-Jun 	16-Jul 	19-Jun 	16-Jul 	7-Nov 	Ice break-up begins June 19 and waters are completely ice-free by July 16. Freeze-up begins in early November for the third year in a row.

Appendix 5
Geophysical Survey Report

FRONTIER GEOSCIENCES INC.

OVERWATER ACOUSTIC PROFILING AND

MARINE SEISMIC REFRACTION SURVEY REPORT

HARBOUR PROJECT

SANIRAJAK, NU

Submitted to:

Advisian

June 24, 2022

Authors:

Sean Henry, B.Sc.

Cliff Candy, P.Geo.

Project: FGI-1746

237 St. Georges Ave.
North Vancouver, B.C.
V7L 4T4

604 987 3037

Table of Contents

Illustrations

1. Introduction

During the period of August 31 to September 1 and September 3 to 4, 2021, Frontier Geosciences Inc. carried out a sub-bottom acoustic profiling and marine refraction investigation for Advisian in Sanirajak, Nunavut. A Survey Location Plan of the area is shown at a scale of 1:60,000 in Figure 1 of the Appendix. The purpose of the survey was to provide bathymetric, depth to bedrock, and material velocity classification information.

Example of computer setup

2. The Bathymetric Survey

2.1 Survey Equipment

The overwater bathymetry survey was completed using an Imagenex DeltaT multibeam sonar. This sonar sounder operates at 675 kHz, and provides a resolution of 0.2% of range. The sonar employs an ethernet connection to transmit the data at high speed to the acquisition system for real-time display and logging. The motion and orientation of the sonar system was monitored with a Honeywell HMR gyro-compass. The resolution of the Honeywell heading, roll and pitch measurement is 0.1 degrees.

The position of the sonar system was monitored with a Hemisphere S320 GNSS/GLONASS RTK Global Positioning System (GPS) receiver. The Hemisphere S320 is a 24-channel, dual frequency receiver with L1 and L2 carrier phase measurements. The system includes a GPS antenna, receiver, internal radio and a battery in a unit that is utilized as a RTK rover. The RTK position corrections can be received either by the internal radio, or by the built-in GSM module for mobile phone communication. Communication between the receiver and handheld controller is provided through Bluetooth wireless technology.

2.2 Survey Procedure

The multibeam sonar was placed in the water at a depth of 0.18 metres on the port side of the survey vessel. Data collected from the Imagenex DeltaT was logged in real-time, together with position information, and the HMR gyro-compass. All data was stored in time synced notebook computers. The horizontal datum is UTM Zone 17 North. The survey was carried out in good conditions, and the continuity and quality of the data was excellent.

2.3 Data Processing and Interpretation Procedure

The sonar position and orientation measurements, and sonar depth measurements were combined and analyzed using the MB-System multibeam data processing software, developed by the Monterey Bay Aquarium Research Institute and the Lamont-Doherty Earth Observatory. The resulting sonar files were processed to produce a map that merges each individual swath to produce a final detailed map. Gridding and contouring of the data was conducted with the Golden Software program Surfer. A value of 1470 m/s was used to convert the sonar range information into depth.

3. The Sub-Bottom Acoustic Profiling Survey

3.1 Survey Equipment

The sub-bottom acoustic profiling survey was completed with an electric pulser source (precision double coil, vertical boomer) and hydrophone receiver system. The source is an electromagnetic transducer system that generates a broad-band, acoustic signal source operating at a dominant frequency of 250 Hz. The receiver system is a pressure sensitive, multi-element hydrophone receiver array contained in an oil-filled eel. The spacing of the receiver elements is designed to maximise the signal of the wavefront arriving vertically from the sub-bottom reflection, and minimise noise due to movement through the water and the direct wave arriving horizontally from the pulser source. The reflected signals are amplified and digitised with a 24-bit data acquisition system, and recorded on a survey system computer.

3.2 Survey Procedure

The pulser source was towed at a distance of 10 metres behind the vessel, and the midpoint of the receiver system was 10 metres behind the source. In operation, pulses from the source were reflected from the bottom and sub-bottom horizons, summed in the elements of the hydrophone array, and transferred to the recording amplifiers. The computer recorded a seismogram of 200 milliseconds two-way time duration approximately twice per second.

Surveying with towed sub-bottom acoustic profiler

3.3 Data Processing and Interpretation Procedure

The sub-bottom acoustic profiling data was processed into SEG-2 format and imported into the Seismic Unix reflection processing package. The positioning information was processed to account for the lay-back of the source and receiver from the GPS receiver. After processing steps that include trace balancing, and bandpass filtering, the data was converted to SEG-Y format, correlated to the GPS position information, and imported into the Seismic Micro Technologies (SMT) 2D/3D seismic interpretation package. This software is a comprehensive 2D/3D seismic interpretation program that provides interpretive and horizon picking tools integrated into a map and section database, data management and display system. In addition, the bathymetry data were imported as a horizon into the SMT package for interpretation and to allow full handling of the time to depth conversion.

The first stage in the analysis was the use of the horizon picking tools to identify the basal layer reflector and any reflectors present within the sediment column. The software shows time markers at the intersection of lines and tie-lines, facilitating the picking of a consistent event throughout the map area. The data was then converted to depth, and the surfaces were plotted in the colour contour format.

4. Marine Seismic Refraction Survey

4.1 Survey Equipment

The marine seismic refraction investigation was carried out using a Geometric Geodes, 24 channel, signal enhancement seismograph and Oyo Geospace 10 Hz hydrophones. Hydrophone intervals along the cable were maintained at 7.5 metres along a waterproof marine seismic cable. Seismic energy was provided from a percussive firing rod firing 8 gauge, blank, black powder shells lowered over the side of the boat. Shot initiation or zero time was established by metal to metal contact of a striking hammer contacting the firing pin of the firing rod.

4.2 Survey Procedure

Field procedure entailed securing the seismograph and head of the seismic cable to on shore, then deploying the hydro cable in a straight line with a shallow draft survey vessel, and submerging the hydrophones attached to the cable. Up to seven separate 'shots' were then initiated: one at either end of the hydrophone array, three to five at intermediate locations along the seismic cable, and one off each end of the line. The shots were triggered individually, with the percussion firing rod located over the side of the boat and arrival times for each hydrophone were recorded digitally in the seismograph. For quality assurance, field inspection of raw data after each shot was carried out, with additional shots recorded if first arrivals were unclear.

4.3 Interpretive Method

The final interpretation of the seismic data was arrived at using the OYO Plotrefra tomography program, constrained by the sub-bottom isopachs. Tomographic inversion of compressional, P-wave travel times was achieved by visually picking the onset arrivals of refracted signals at each receiver. The tomographic analysis then automatically calculates velocities at points across the grid using the simultaneous iterative reconstruction technique. This modification of the initial velocity values consists of repeated cycles of three steps: forward computation of model travel times, calculation of residuals, and application of velocity corrections. An iterative approach using the Neighbourhood Algorithm generates the most accurate subsurface model that is the closest match to the picked compressional wave arrival times for each seismic spread. The best resulting model reduces or eliminates any residual differences between the picked arrival times and the calculated arrival times generated by the inversion analysis. The interpretation of seismic refraction data by tomography analysis was checked by comparison of the results with the results of the method of differences seismic refraction interpretation.

5. Geophysical Results

5.1 General

The bathymetric and sub-bottom acoustic profiling surveys were carried out at six locations, ordered from north to south. Marine seismic refraction survey lines were located at the northern Site 1, and at eight additional points along the beach front, as shown on Figure 2.

The interpreted bathymetric elevation contour plan for each of the sites is shown at a scale of 1:5,000 on Figures 3 to 8. The interpreted sea floor sediment thickness, contoured as an isopach map, is shown at the same scale on Figures 9 to14. The nine seismic refraction lines are displayed at a scale of 1:500 on Figures 15 to 23. An example sub-bottom acoustic profile is plotted in Figure 24, and also represented as a magenta line in Figure 3. All elevations are Geodetic Datum.

5.2 Discussion

The most northerly Site 1 includes a shallow bay and point of land. The bathymetric data shows generally shallow waters with depths of up to 8 m north of the bay and depths of as much as 17 m at the most easterly extent of coverage. Seismic Line 1 is approximately 250 metres from the head of the bay. The line shows velocities as low as 1600 m/s at the western end of the line which could represent unconsolidated sand and gravels. The larger part of the line shows higher velocities interpreted to represent weathered bedrock. At a depth of 5 to 10 m velocities are in the 3,500 to 4000 range, which is indicative of relatively competent bedrock.

Evidence of a zone of seafloor sediments is seen in the sub-bottom acoustic profiling data along the seaward side of the point of land. This is contoured on Figure 9 as an isopach of up to 2 metres thickness. A sub-bottom acoustic profiling example profile P23 is shown on Figure 24. This plot shows the ringing response of the hard bottom reflector associated with shallow weathered rock, and an absence of sediment cover.

Site 2, displayed on Figures 10 and 16, is located at head the beach and shows very shallow water depths, ranging up to 3 metres at a distance of 300 metres from shore. The sub-bottom acoustic profiling is interpreted to show a very thin layer of sea floors sediment in the most eastern coverage.

Site 3 is similar to site to Site 2 with very shallow waters ranging to 4 metres depth at a distance of 800 metres from shore. This site, shown on Figures 11 and 17, has seismic lines SL21-08 and SL21-09 within the coverage area. The deepest parts of the coverage show evidence of a shallow surficial sediment layer in the sub-bottom acoustic profiling.

Seismic lines SL21-08 and SL21-09 show the presence of shallow weathered rock for the full extent of the lines. Line SL21-09 exhibits a slightly deeper weathering profile in the western part of the line. in general, competent bedrock velocities are achieved a few metres beneath this lower velocity zone. SL21-07 is located between Sites 3 and 4, and shows a similar response.

Site 4 includes seismic lines to SL21-02, SL21-05 and SL21-06 and is shown on Figures 12 and 18. The seismic lines display the familiar shallow relatively high velocity weathered bedrock profile, with a transition to higher velocity, competent bedrock at 5 to 10 metres depth. Seismic lines SL21-03 and SL21-04 are located between Sites 4 and 5. The SL21-03 data shows a lower velocity weathered zone at western end, with a slightly deeper weathering profile. SL21-04 exhibits a response alike to those of the northern lines.

Some fractured bedrock was observed on shore around SL21-05, as seen in the image below. This rock was seen to be cracked and broken up, and extended in the off shore direction. The approximate location of this example of on shore bedrock is represented as a magenta star on Figure 2, as well as 6 and 12.

Example of fractured bedrock on shore near SL21-05

The bathymetry and sub-bottom acoustic profiling show an extensive foreshore of shallow water, with a thin sea floor sediment horizon interpreted at the eastern extent of coverage.

Site 5 shows a slightly steeper bathymetry gradient with depths of 8 metres achieved at a distance of 550 metres from shore. As shown on Figure 19, a zone of shallow sediments is interpreted in the deeper waters.

The most southerly Site 6 is located in a shallow bay, shown on Figures 14 and 23. The deepest point seen in the data is approximately 3 metres, in the most southerly coverage. In this southern area, a thin sediment horizon is interpreted to be present on the seafloor.

6. Limitations

The depths to ocean bottom derived from overwater bathymetric profiling surveys are generally accepted as accurate to within 0.2 percent of the depth range. Errors may arise from variations in salinity and water temperature within the water column. An underestimate of the velocity function would produce depths that are too shallow, and the reverse occurring with an overestimate of velocity. Additional, small errors may also occur in data gridding.

The depths to subsurface boundaries derived from overwater seismic sub-bottom profiling surveys are generally accepted as accurate to within fifteen percent of the true depths to the boundaries. In practice, the seismic velocity of sub-bottom materials is not determined in the course of an overwater acoustic profiling investigation. Errors may arise from application of an assumed velocity for saturated materials to determine the depths to sub-surface horizons when only the travel time to the horizon is known. An underestimate of the velocity function would produce depths that are too shallow, and the reverse occurring with an overestimate of velocity. True depths may be established by carrying out overwater seismic refraction surveying or by determining velocities with known borehole intersections. Small errors may also occur in data gridding. Additionally, near surface shallow reflectors may be masked by strong bathymetric returns in the data.

The depths to subsurface boundaries derived from seismic reflection and refraction surveys are generally accepted as accurate to within fifteen percent of the true depths to the boundaries. In some cases, unusual geological conditions may produce false or misleading readings with the result that computed depths to subsurface boundaries may be less accurate. As well, some uncertainty is present in correlating horizons between profiles where there is a lack of cross points.

The information in this report is based upon geophysical measurements and field procedures and our interpretation of the data. The results are interpretive in nature and are considered to be a reasonably accurate representation of existing subsurface conditions within the limitations of bathymetric, sub-bottom acoustic profiling, and seismic reflection and refraction survey methods.

For: Frontier Geosciences Inc.

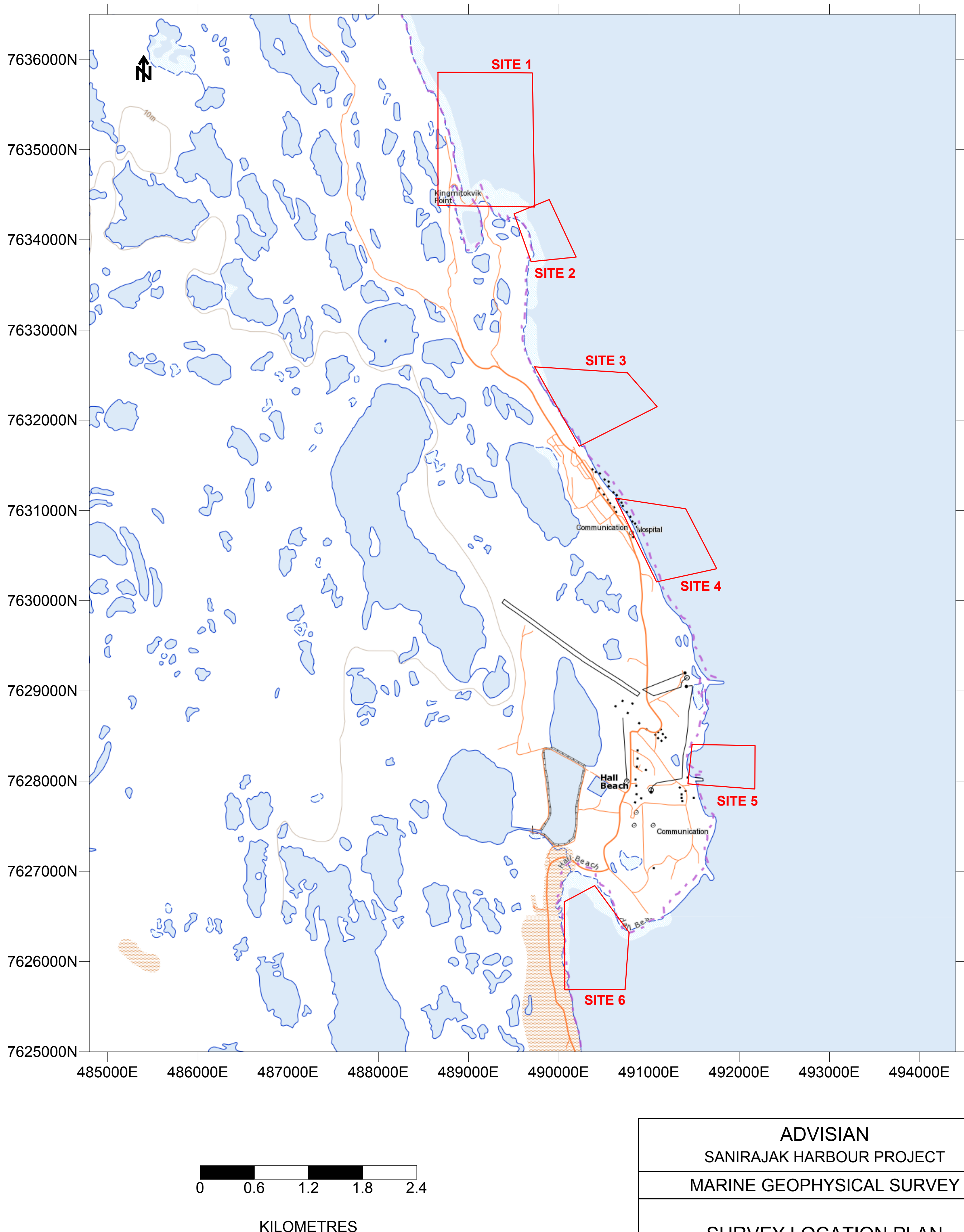
Sean Henry, B.Sc.

PROFESSIONAL
PROVINCE OF
C. E. CANDY
BRITISH COLUMBIA
GEOSCIENTIST

June 24, 2022

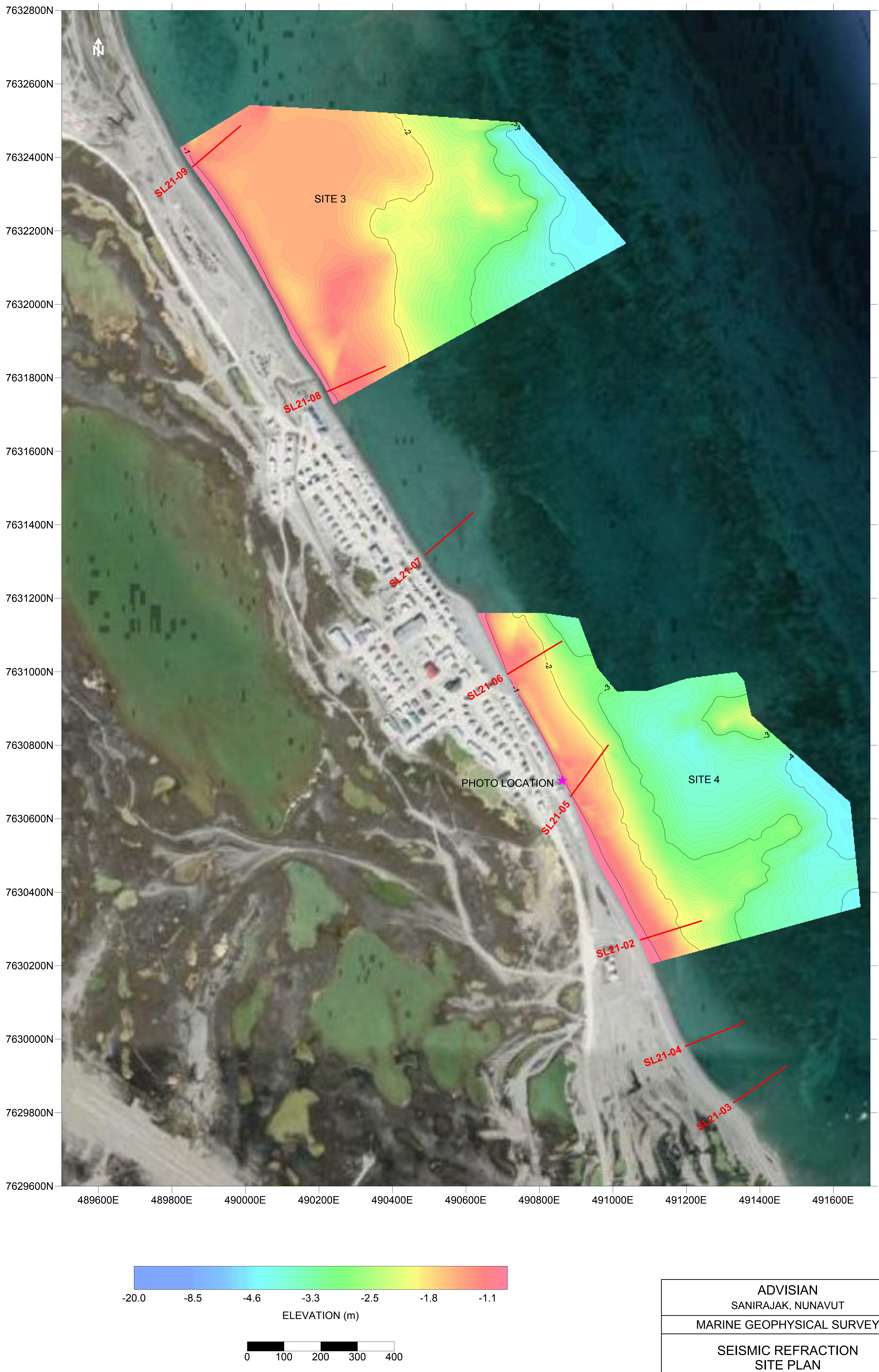
Cliff Candy, P.Geo.

APPENDIX



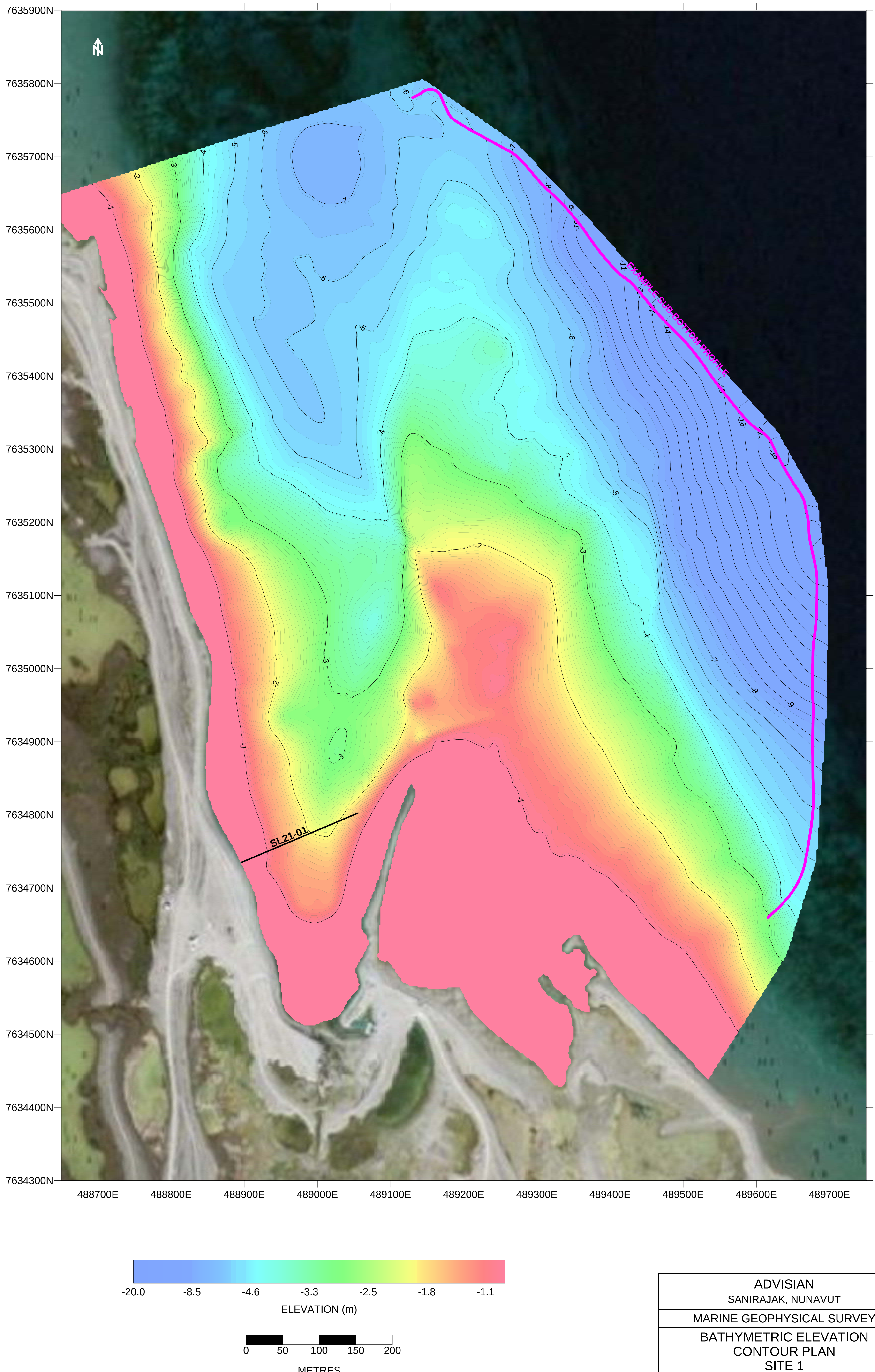
NATURAL RESOURCES CANADA
TOPORAMA MAPSHEETS 47A10 & 47A15
UTM NAD83 ZONE 17

ADVISIAN SANIRAJAK HARBOUR PROJECT		
MARINE GEOPHYSICAL SURVEY		
SURVEY LOCATION PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:60,000	FIG. 1



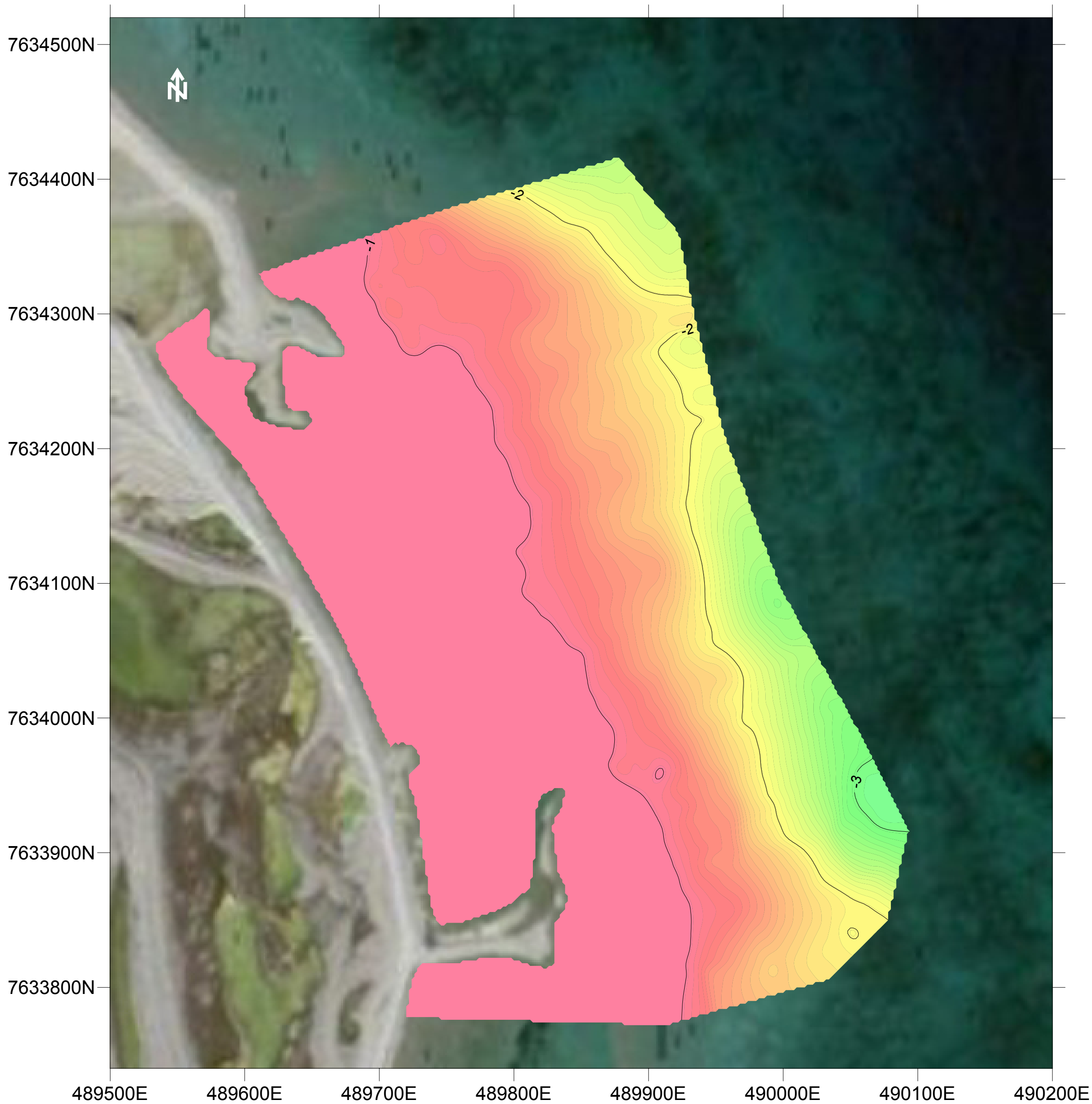
HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

ADVISIAN SANIRAJAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
SEISMIC REFRACTION SITE PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:10,000	FIG. 2



HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

ADVISIAN SANIRAJAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
BATHYMETRIC ELEVATION CONTOUR PLAN SITE 1		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:5,000	FIG. 3



-20.0 -8.5 -4.6 -3.3 -2.5 -1.8 -1.1

ELEVATION (m)

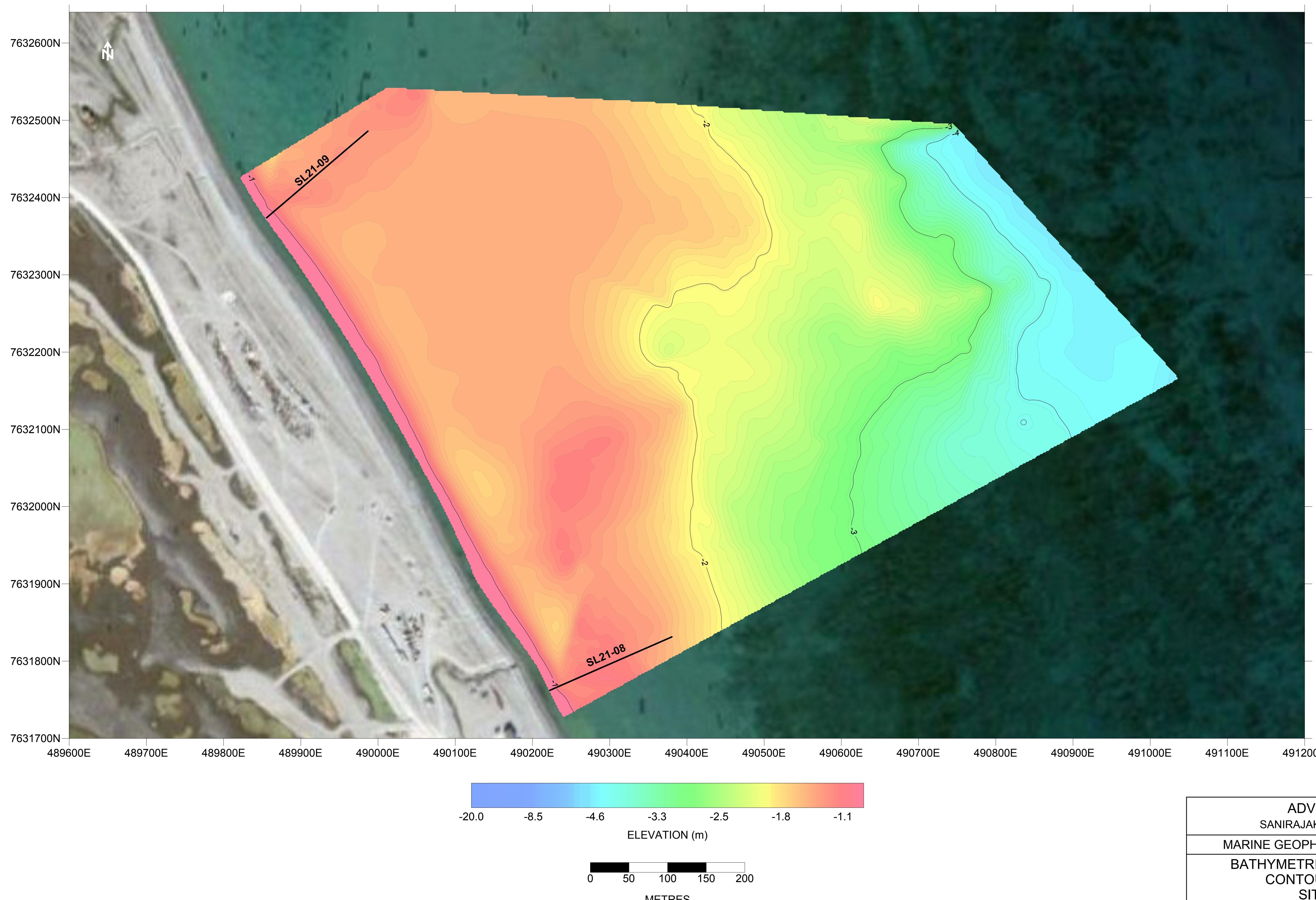
0 50 100 150 200

METRES

HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

ADVISIAN SANIRAJAK, NUNAVUT
MARINE GEOPHYSICAL SURVEY
BATHYMETRIC ELEVATION CONTOUR PLAN SITE 2
FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	SCALE 1:5,000	FIG. 4



HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

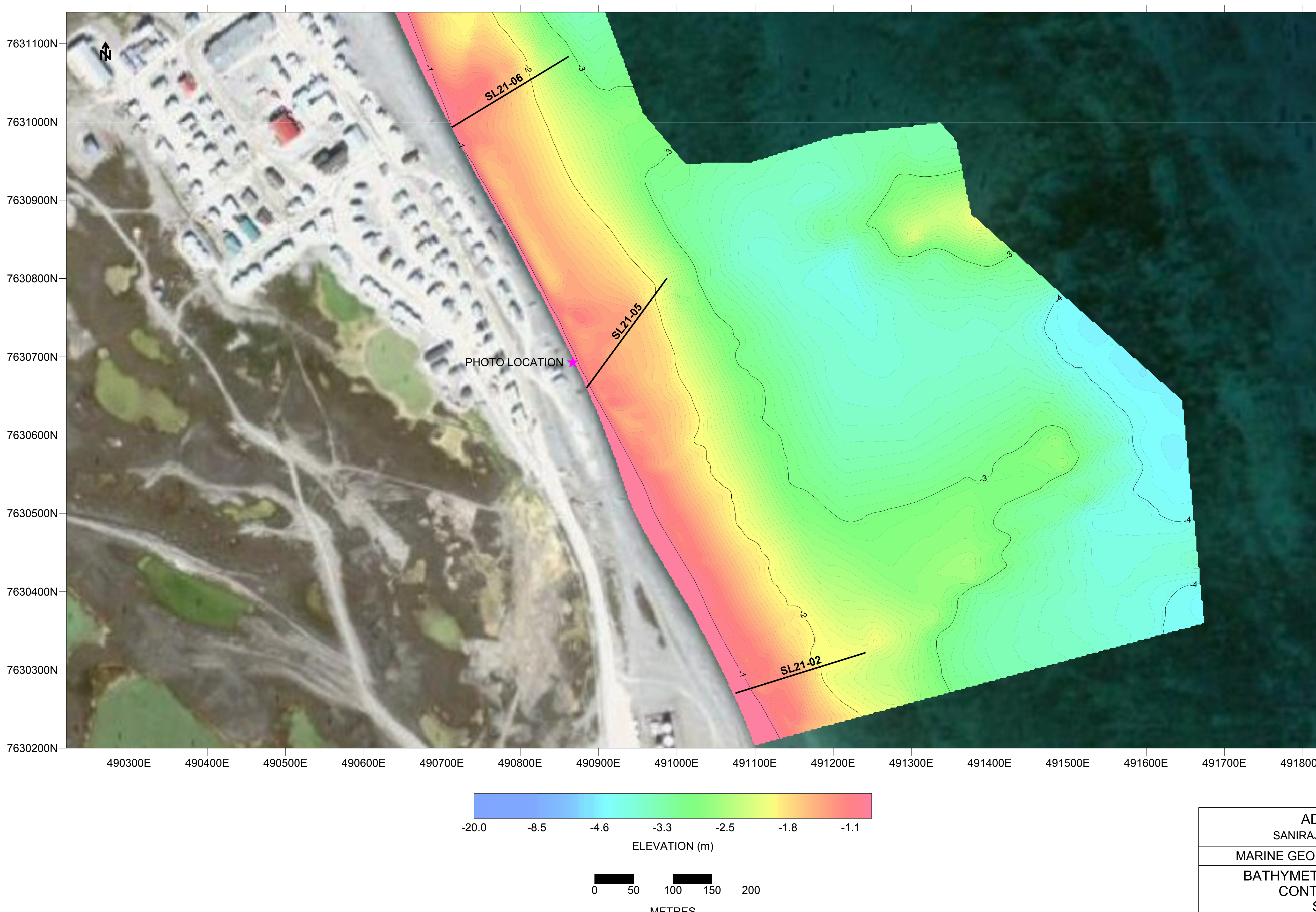
ADVISIAN
SANIRAJAK, NUNAVUT

MARINE GEOPHYSICAL SURVEY

BATHYMETRIC ELEVATION
CONTOUR PLAN
SITE 3

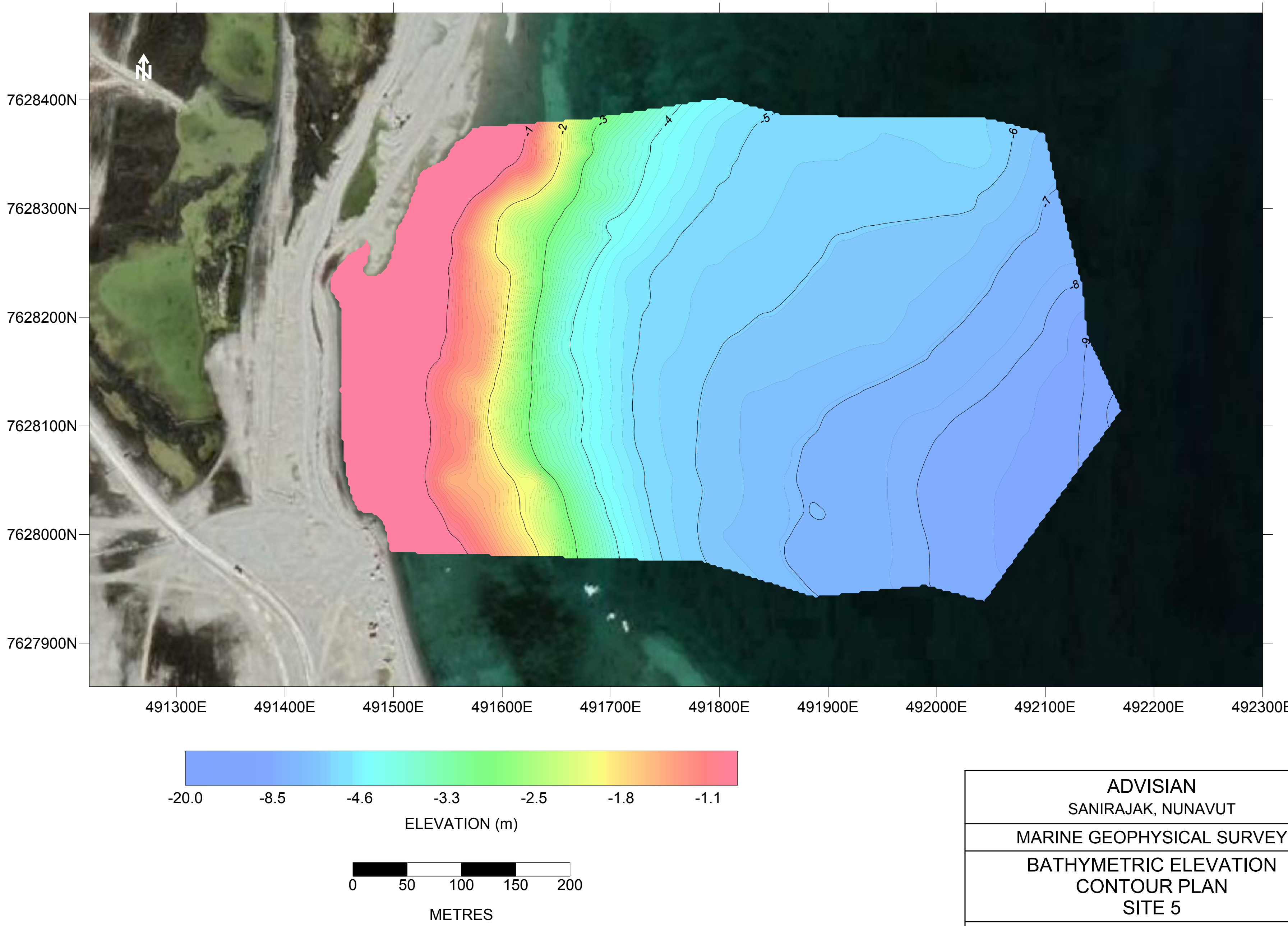
FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	SCALE 1:5,000	FIG. 5



HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

ADVISIAN SANIRAJAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
BATHYMETRIC ELEVATION CONTOUR PLAN SITE 4		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:5,000	FIG. 6



HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

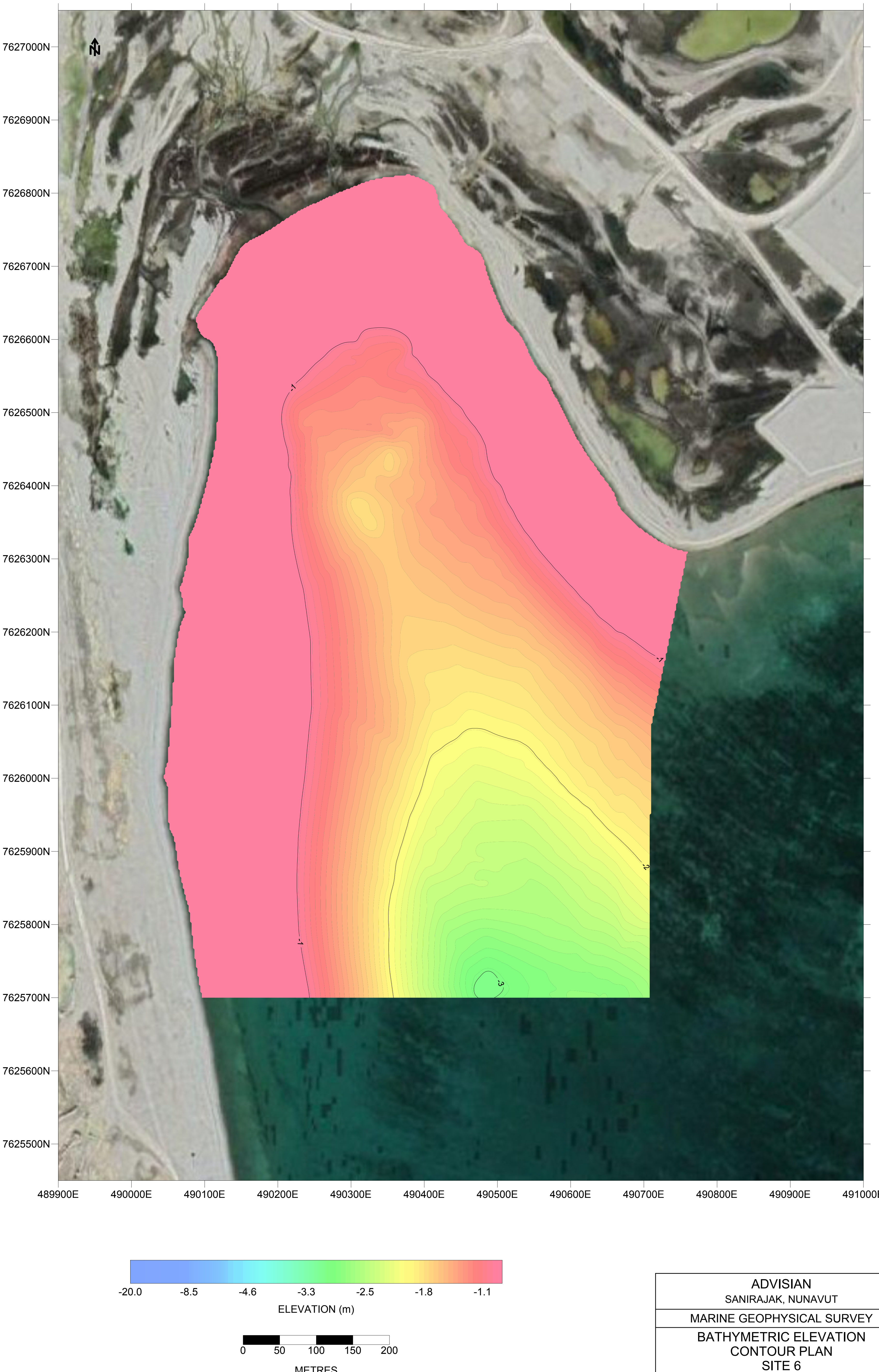
ADVISIAN
SANIRAJAK, NUNAVUT

MARINE GEOPHYSICAL SURVEY

BATHYMETRIC ELEVATION
CONTOUR PLAN
SITE 5

FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	SCALE 1:5,000	FIG. 7



HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

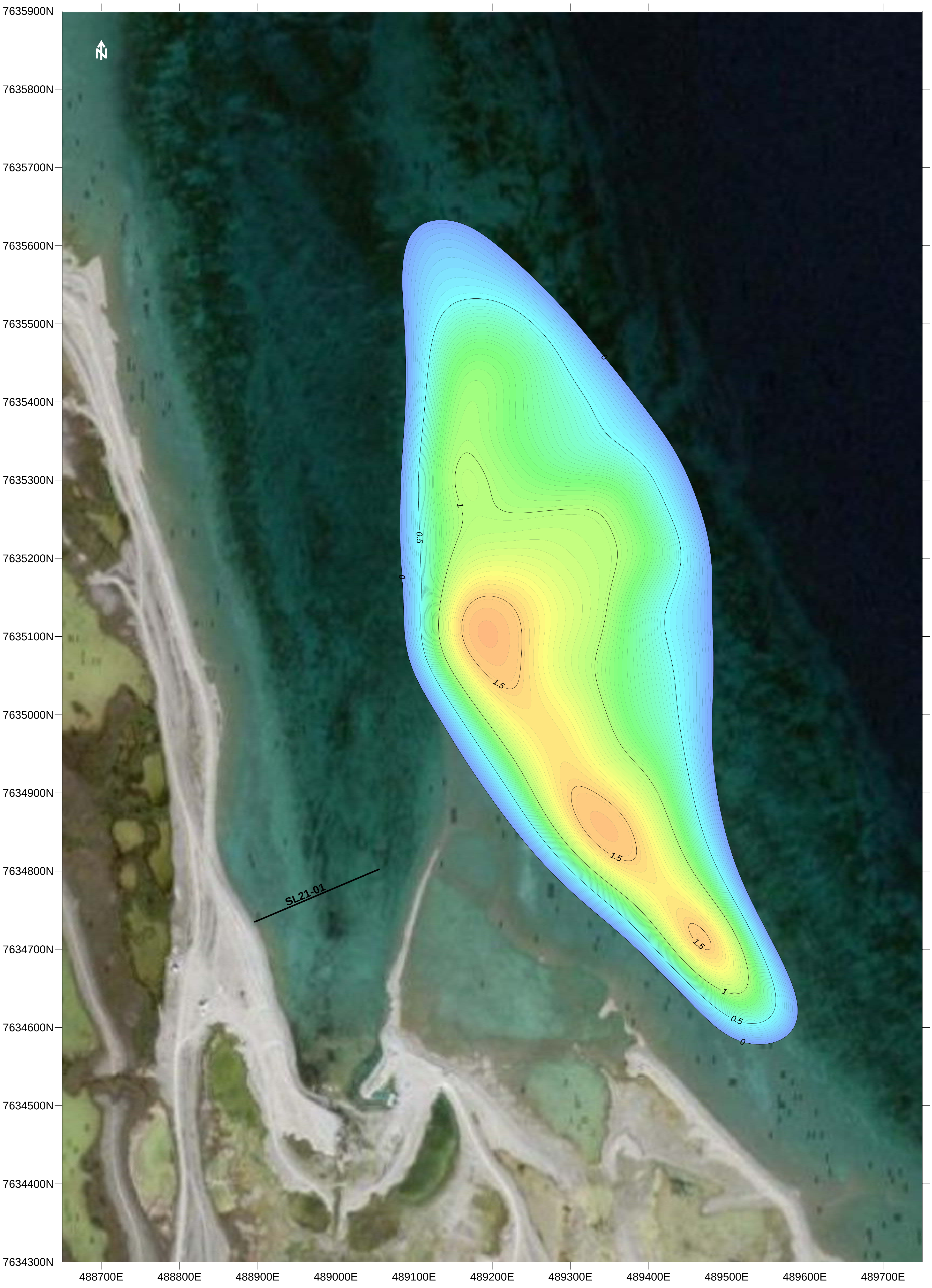
ADVISIAN
SANIRAJAK, NUNAVUT

MARINE GEOPHYSICAL SURVEY

BATHYMETRIC ELEVATION CONTOUR PLAN
SITE 6

FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	SCALE 1:5,000	FIG. 8



0 | 0.5 | 0.8 | 1.1 | 1.6 | 2.7

THICKNESS (m)

0 50 100 150 200

METRES

HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

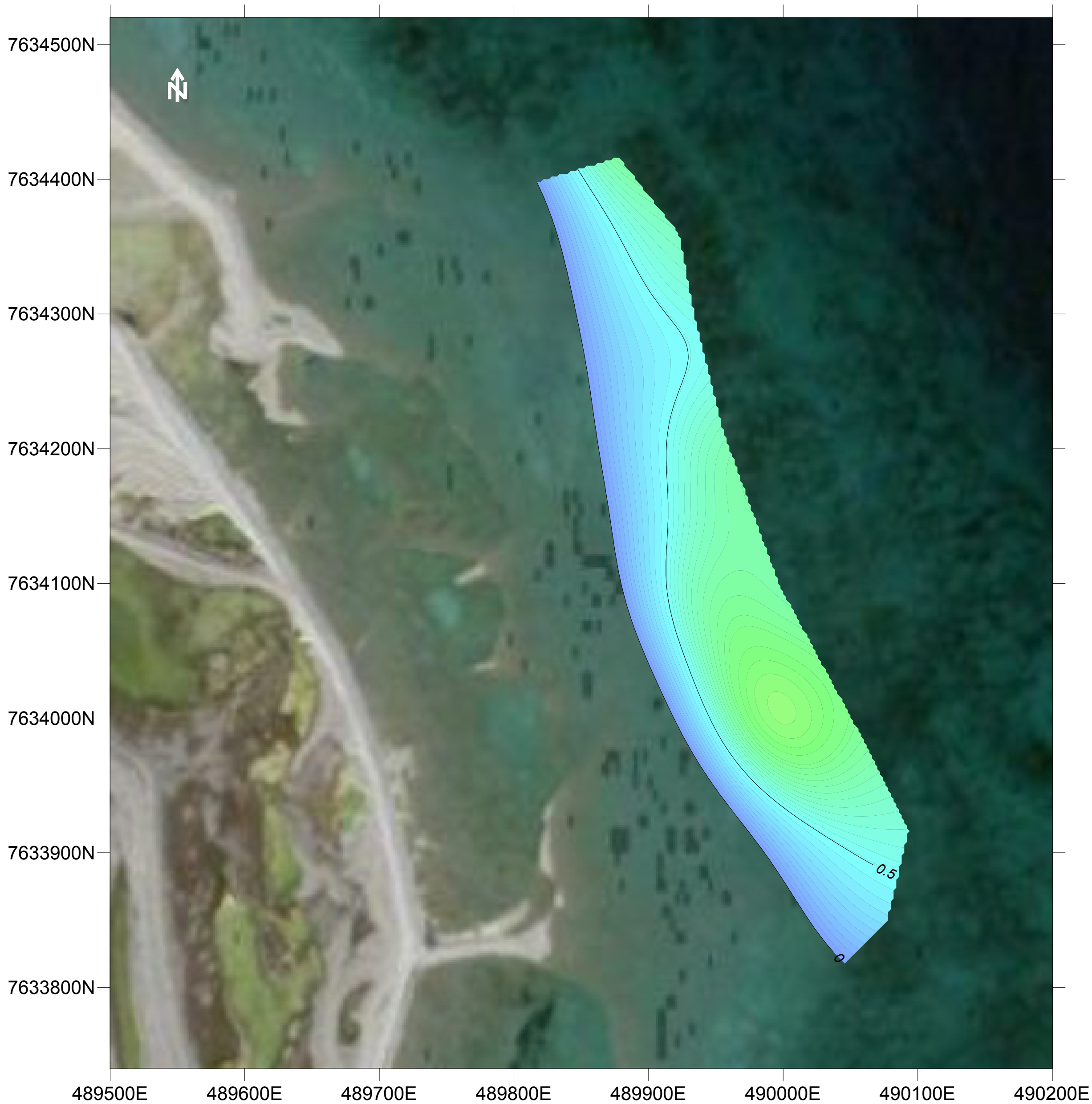
ADVISIAN
SANIRAJAK, NUNAVUT

MARINE GEOPHYSICAL SURVEY

SEDIMENT THICKNESS
CONTOUR PLAN
SITE 1

FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021 | SCALE 1:5,000 | FIG. 9



0 0.5 0.8 1.1 1.6 2.7

THICKNESS (m)

0 50 100 150 200

METRES

HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

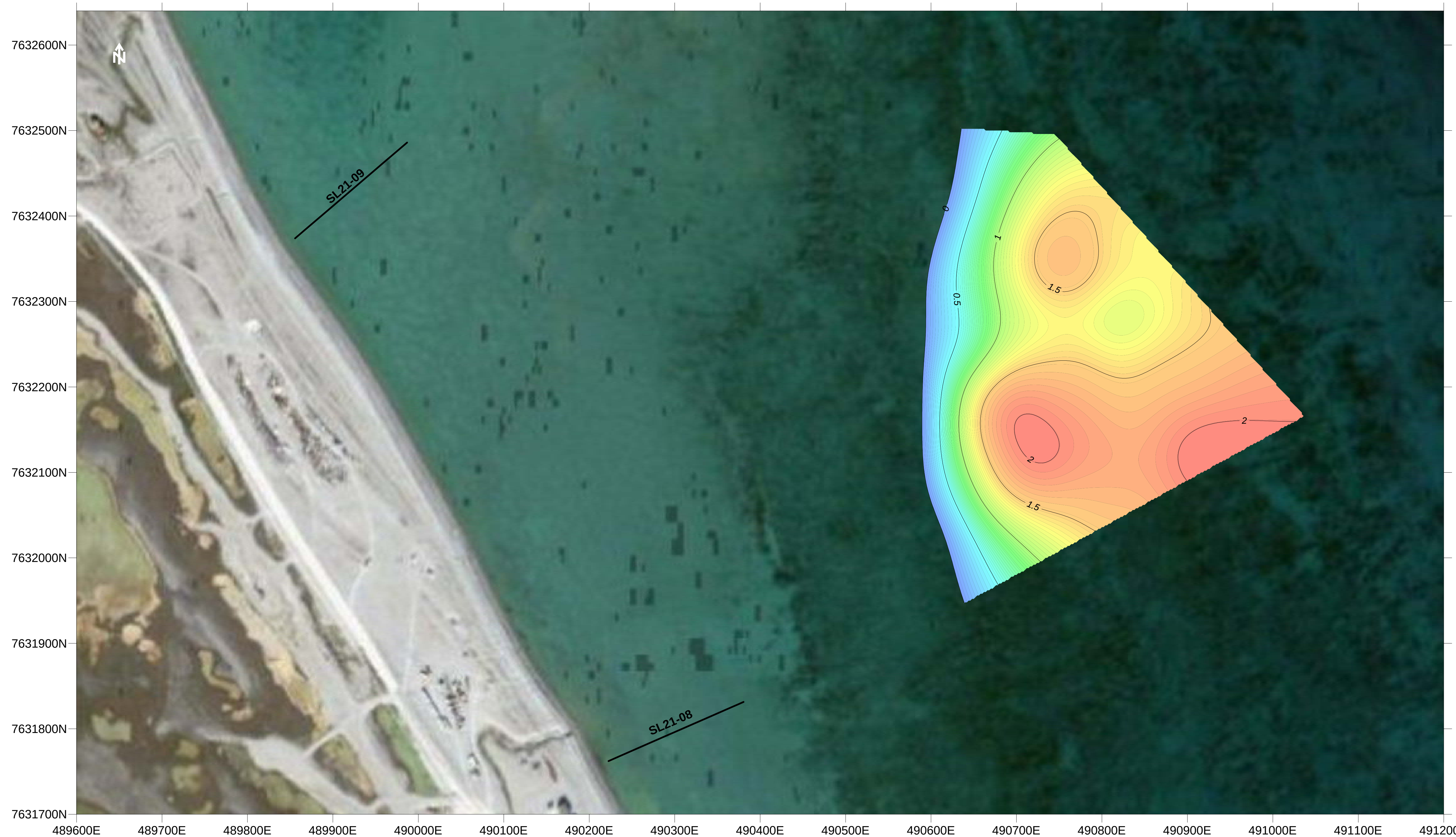
ADVISIAN
SANIRAJAK, NUNAVUT

MARINE GEOPHYSICAL SURVEY

SEDIMENT THICKNESS
CONTOUR PLAN
SITE 2

FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	SCALE 1:5,000	FIG. 10



0 0.5 0.8 1.1 1.6 2.7

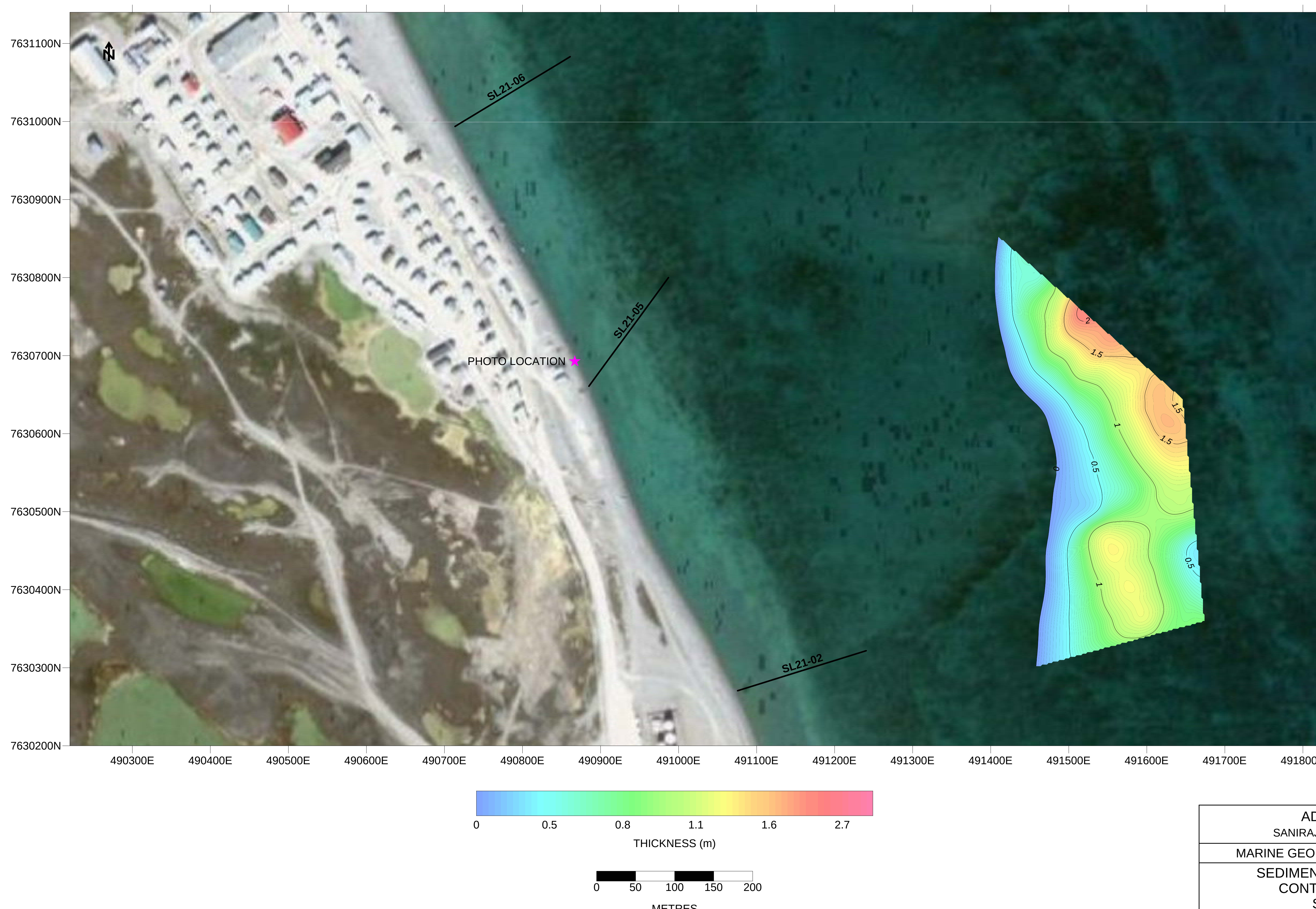
THICKNESS (m)

0 50 100 150 200

METRES

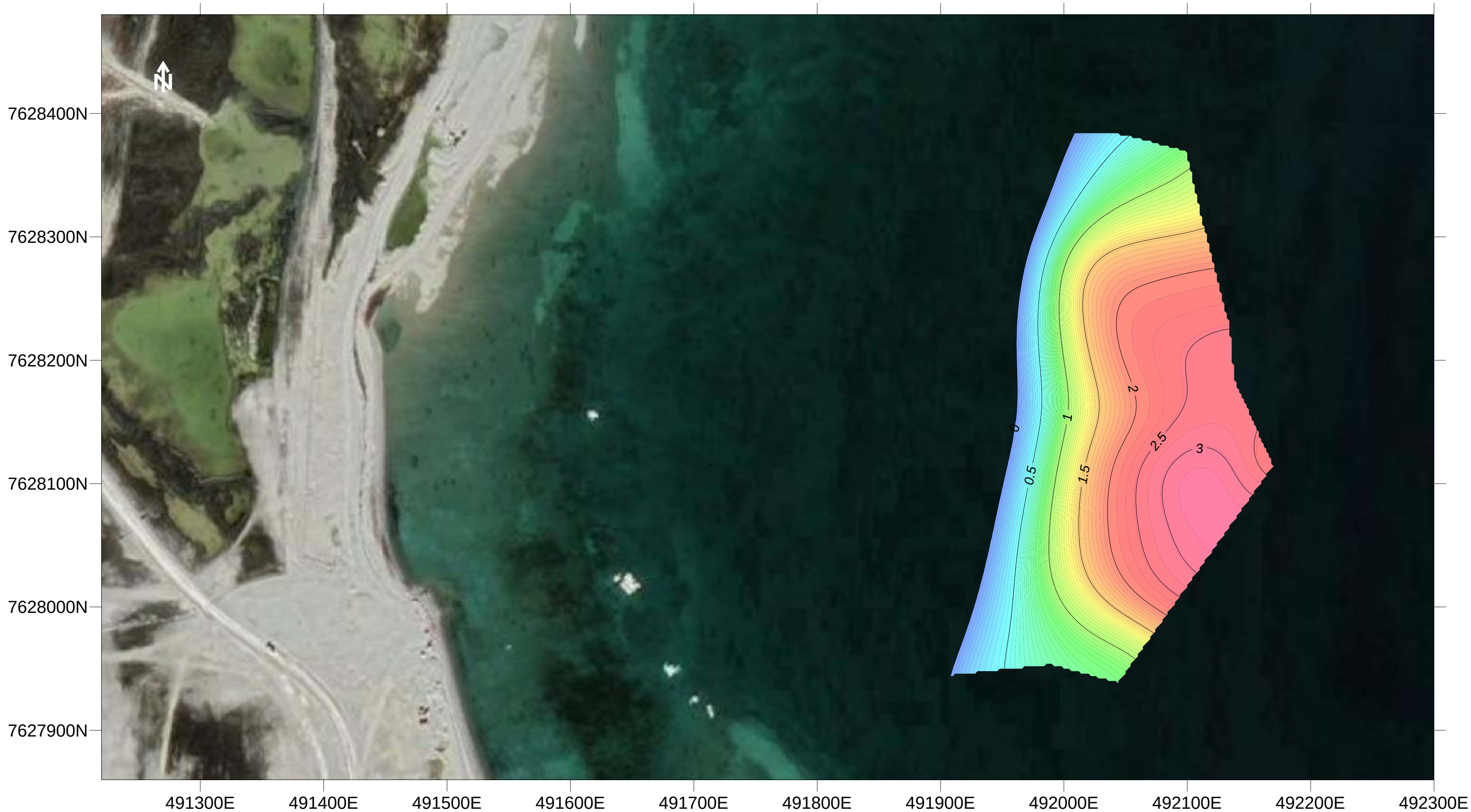
HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

ADVISIAN SANIRAJAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
SEDIMENT THICKNESS CONTOUR PLAN SITE 3		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:5,000	FIG. 11



HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

ADVISIAN SANIRAJAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
SEDIMENT THICKNESS CONTOUR PLAN SITE 4		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:5,000	FIG. 12



0 0.5 0.8 1.1 1.6 2.7

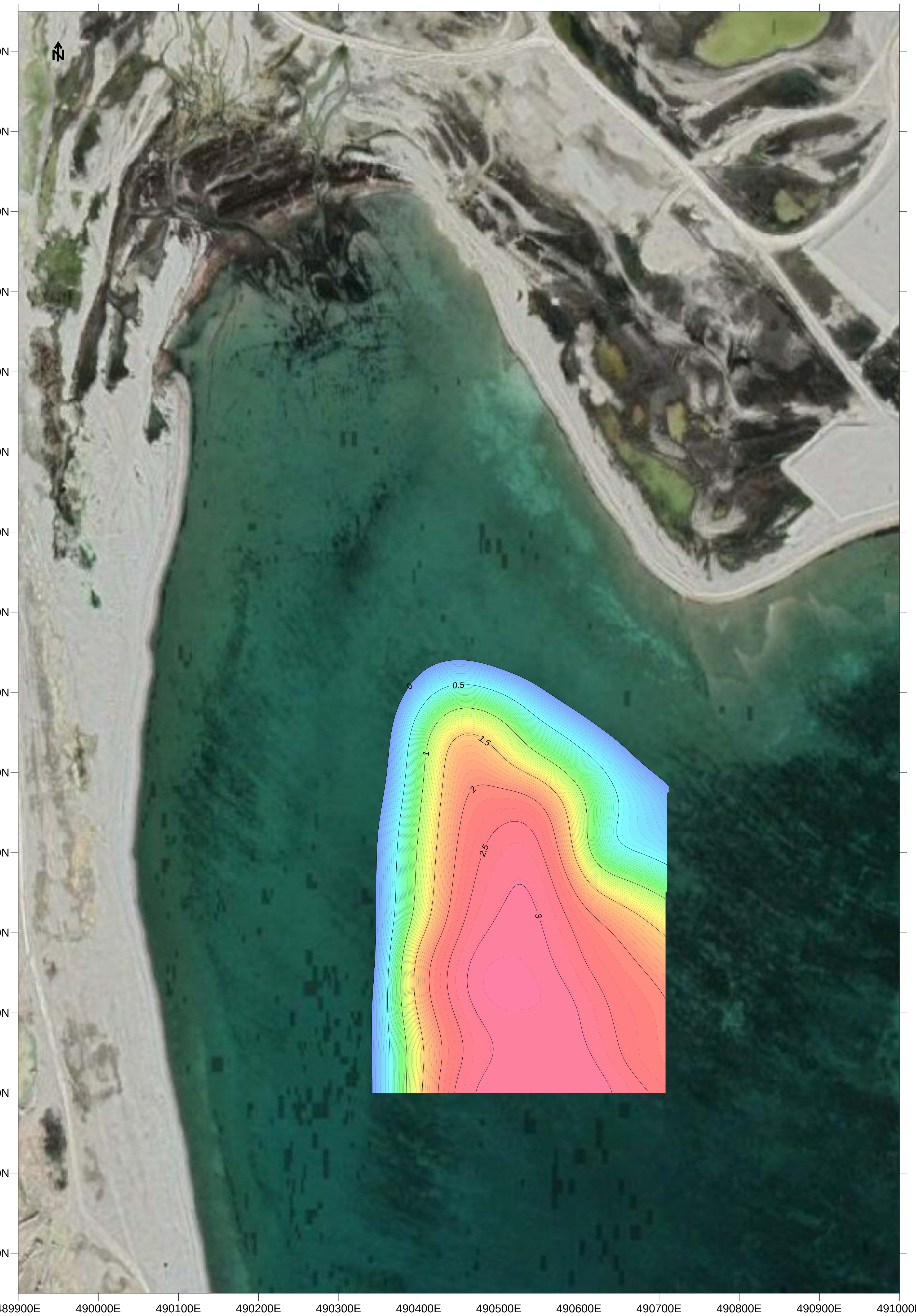
THICKNESS (m)

0 50 100 150 200

METRES

HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

ADVISIAN SANIRAJAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
SEDIMENT THICKNESS CONTOUR PLAN SITE 5		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:5,000	FIG. 13



0 | 0.5 | 0.8 | 1.1 | 1.6 | 2.7

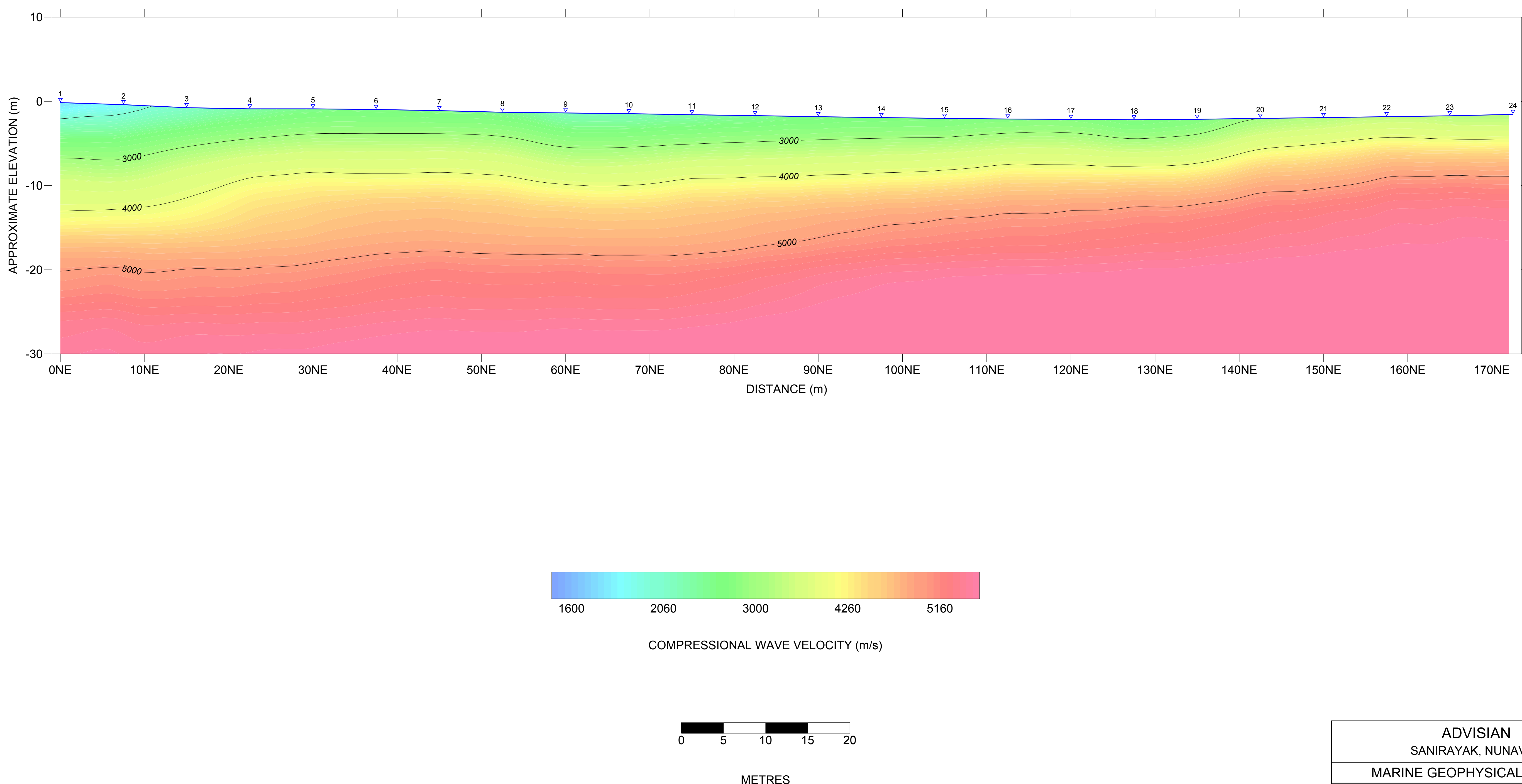
THICKNESS (m)

0 50 100 150 200

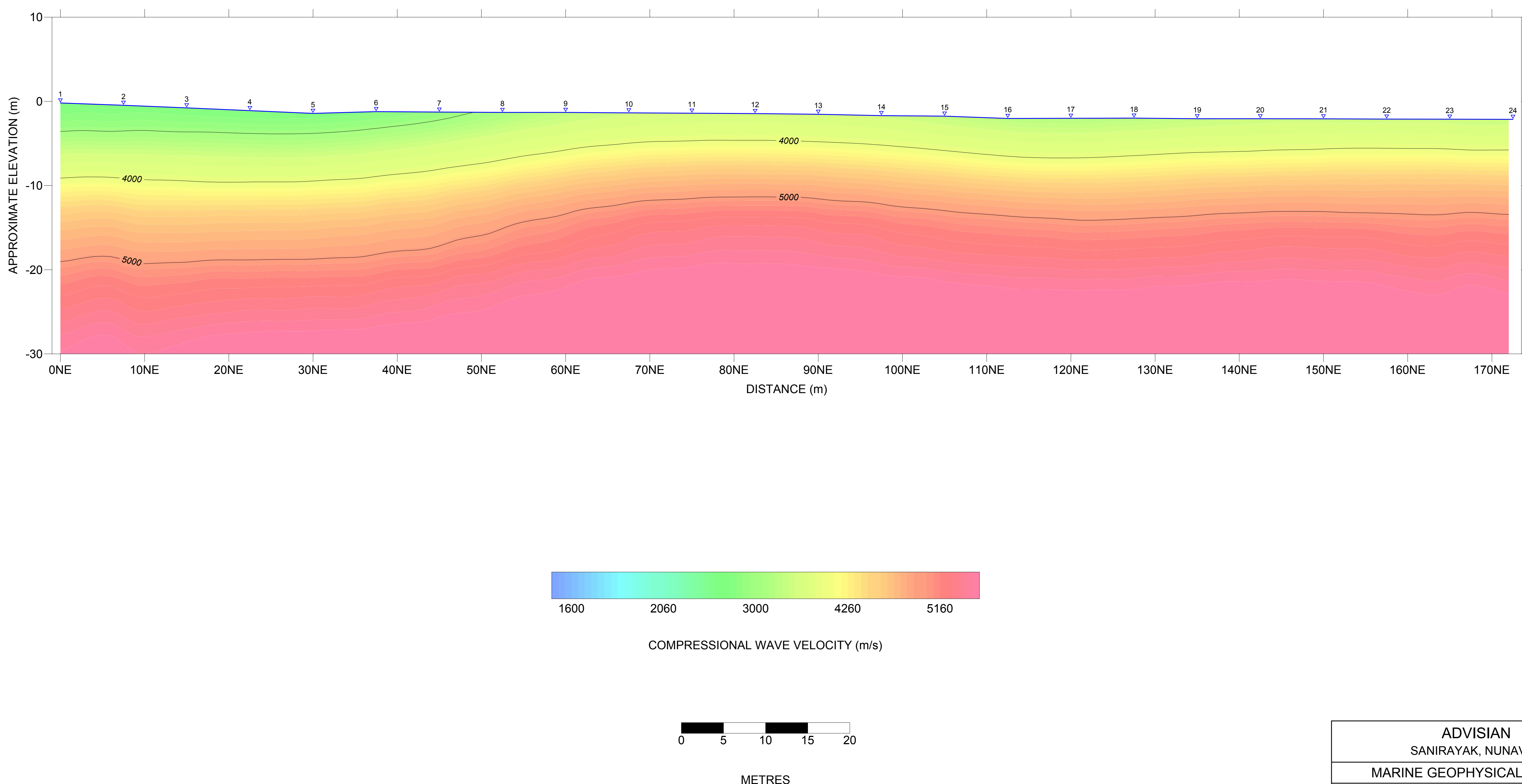
METRES

HORIZONTAL DATUM: UTM NAD83 ZONE 17
VERTICAL DATUM: GEODETIC
GOOGLE EARTH IMAGERY

ADVISIAN SANIRAJAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
SEDIMENT THICKNESS CONTOUR PLAN SITE 6		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:5,000	FIG. 14



ADVISIAN SANIRAYAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
INTERPRETED DEPTH SECTION SL21-01		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:500	FIG. 15



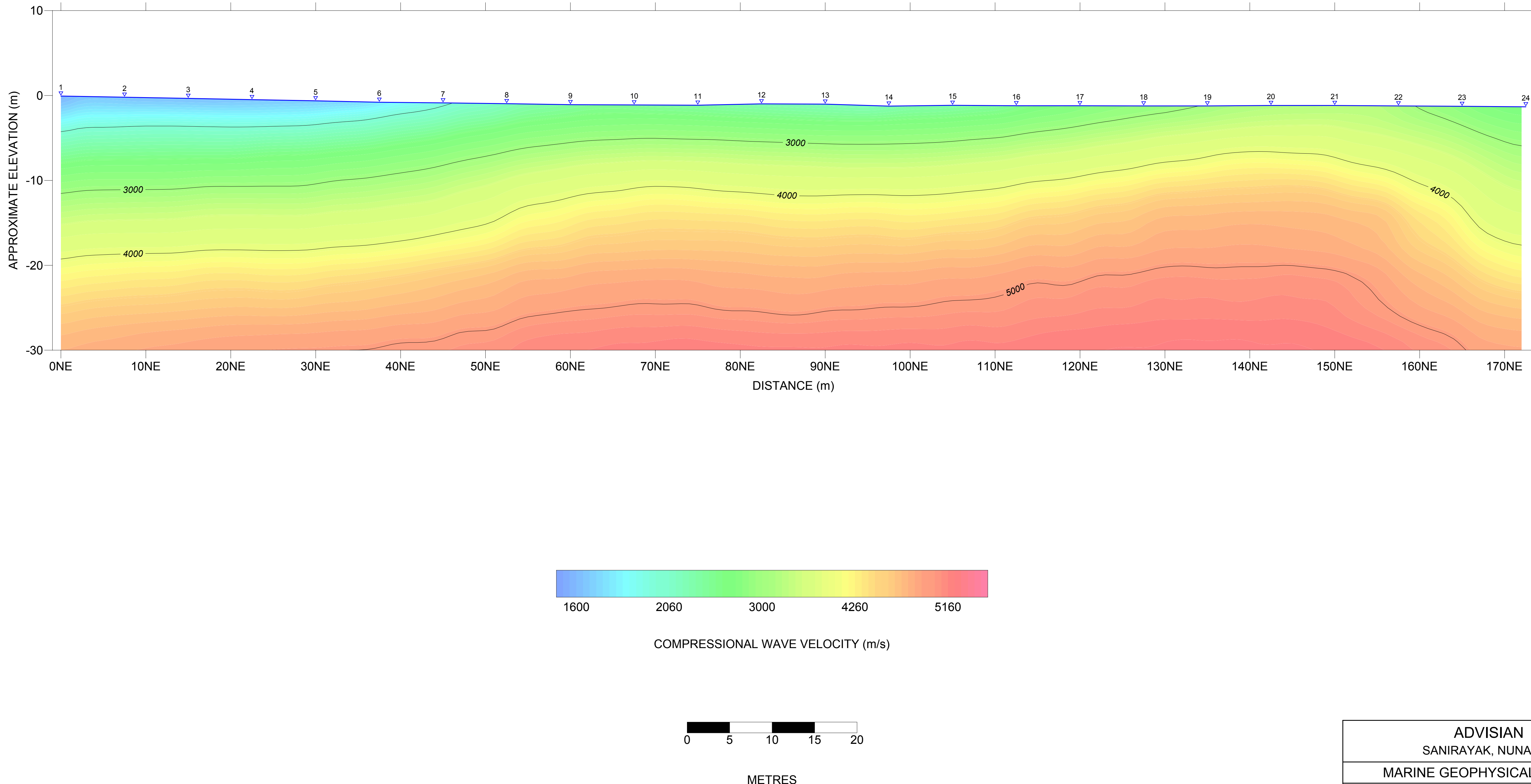
ADVISIAN
SANIRAYAK, NUNAVUT

MARINE GEOPHYSICAL SURVEY

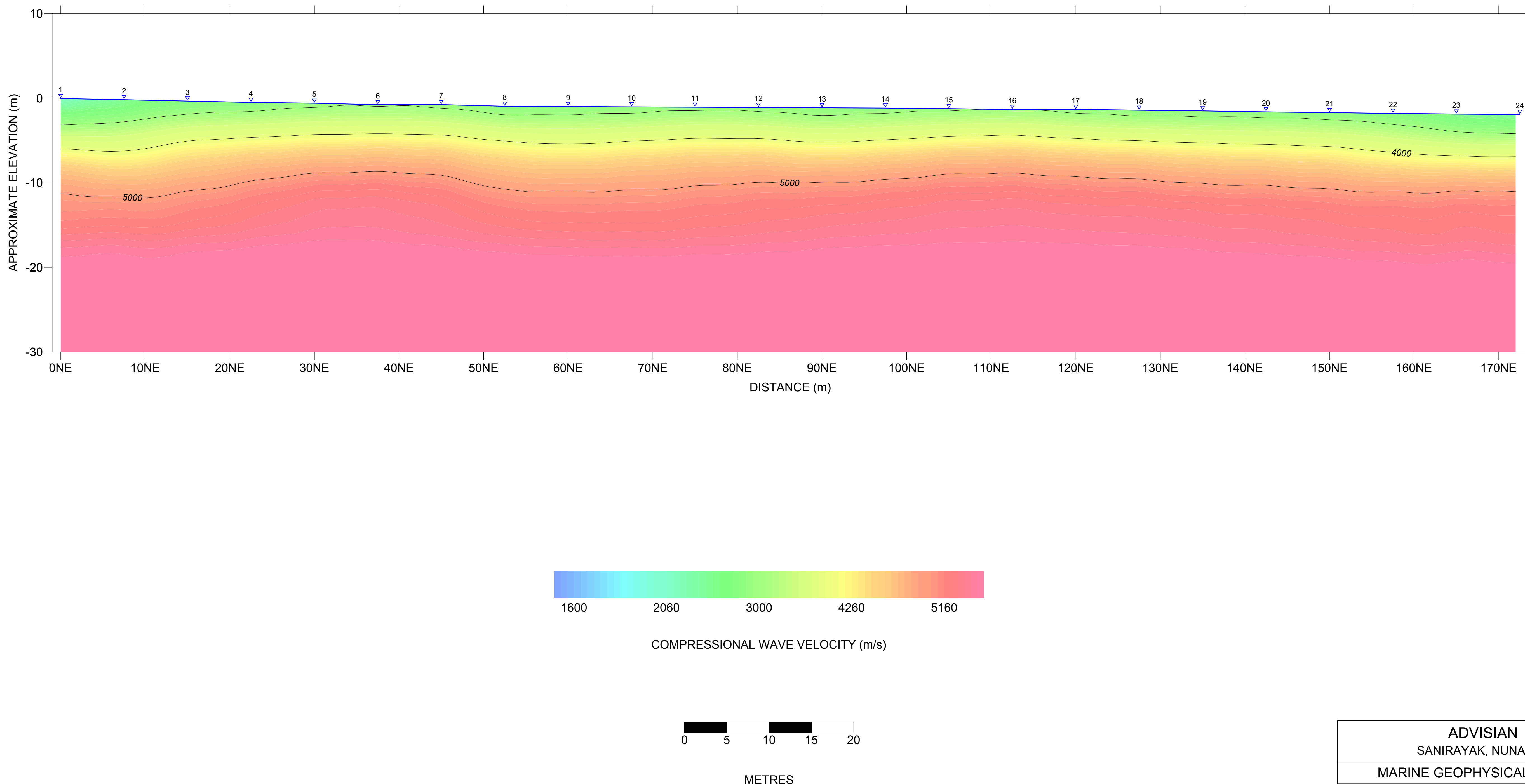
INTERPRETED DEPTH SECTION
SL21-02

FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	SCALE 1:500	FIG. 16



ADVISIAN SANIRAYAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
INTERPRETED DEPTH SECTION SL21-03		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:500	FIG. 17



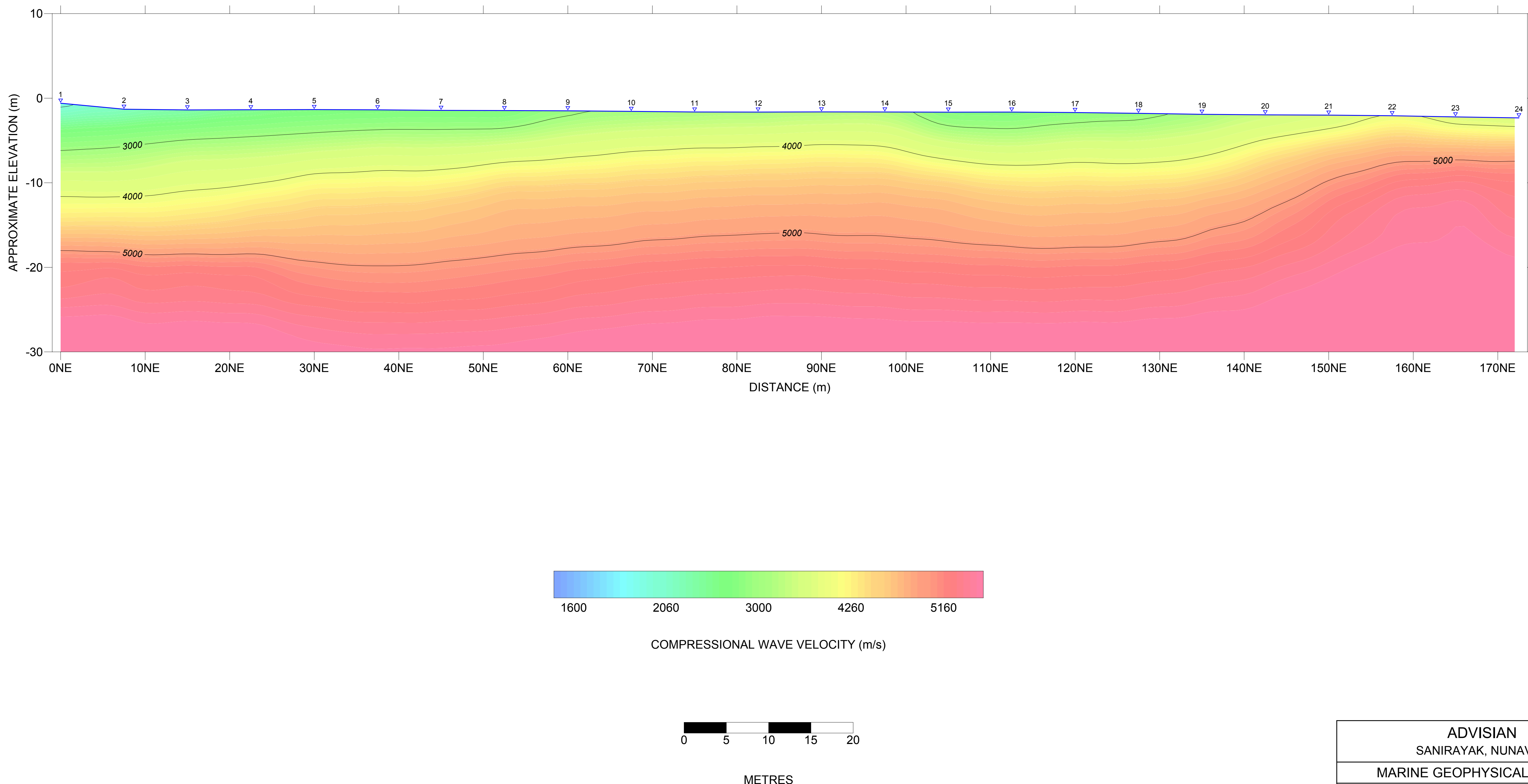
ADVISIAN
SANIRAYAK, NUNAVUT

MARINE GEOPHYSICAL SURVEY

INTERPRETED DEPTH SECTION
SL21-04

FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	SCALE 1:500	FIG. 18



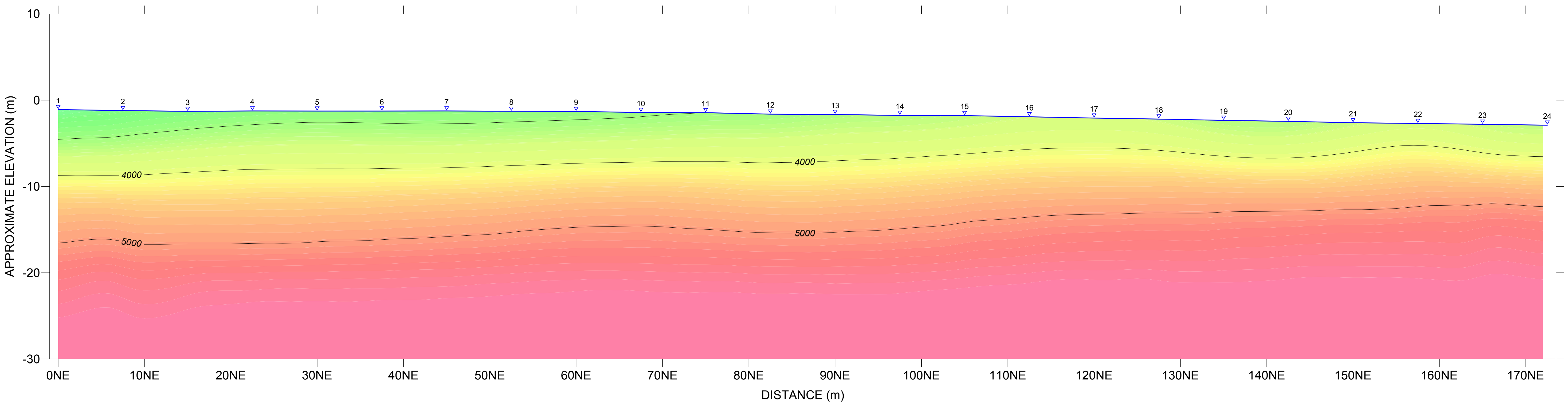
ADVISIAN
SANIRAYAK, NUNAVUT

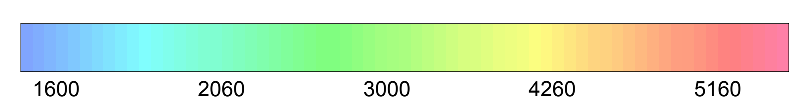
MARINE GEOPHYSICAL SURVEY

INTERPRETED DEPTH SECTION
SL21-05

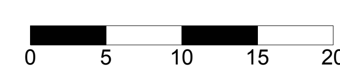
FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	SCALE 1:500	FIG. 19



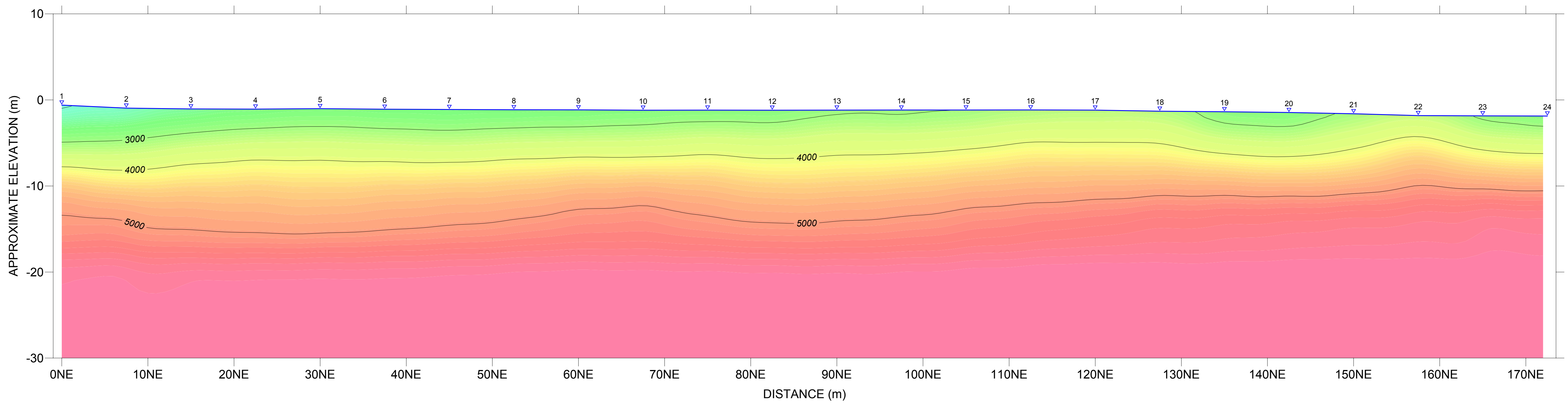


COMPRESSIONAL WAVE VELOCITY (m/s)



METRES

ADVISIAN SANIRAYAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
INTERPRETED DEPTH SECTION SL21-06		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:500	FIG. 20



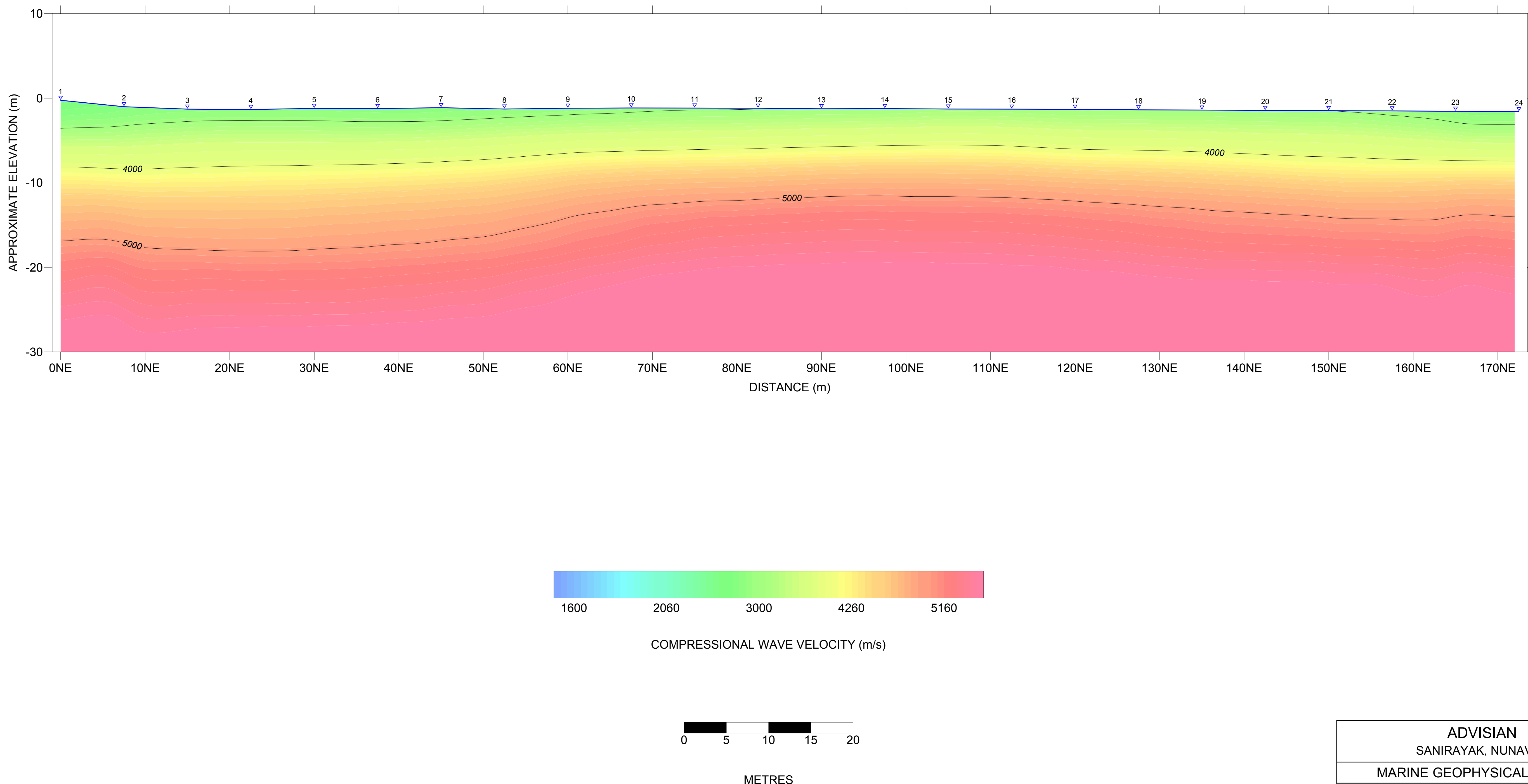
1600 2060 3000 4260 5160

COMPRESSIONAL WAVE VELOCITY (m/s)

0 5 10 15 20

METRES

ADVISIAN SANIRAYAK, NUNAVUT		
MARINE GEOPHYSICAL SURVEY		
INTERPRETED DEPTH SECTION SL21-07		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2021	SCALE 1:500	FIG. 21



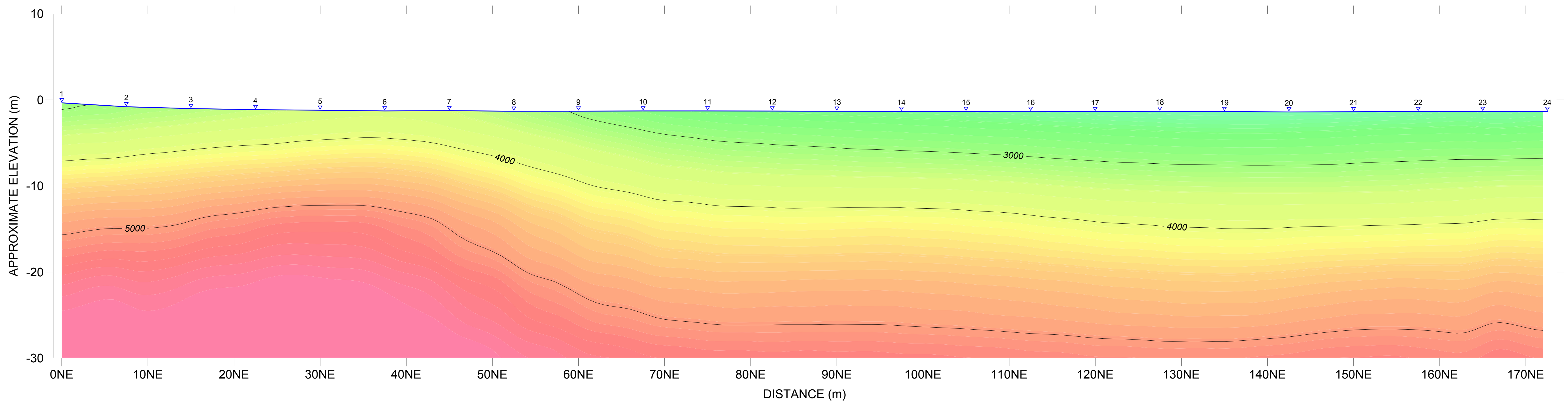
ADVISIAN
SANIRAYAK, NUNAVUT

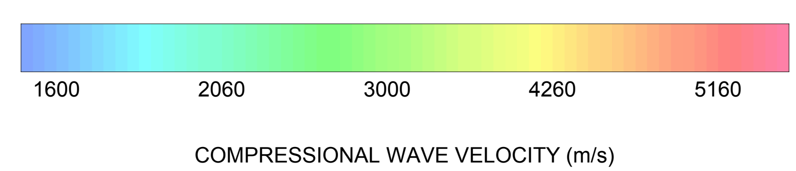
MARINE GEOPHYSICAL SURVEY

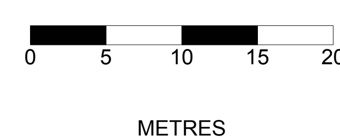
INTERPRETED DEPTH SECTION
SL21-08

FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	SCALE 1:500	FIG. 22







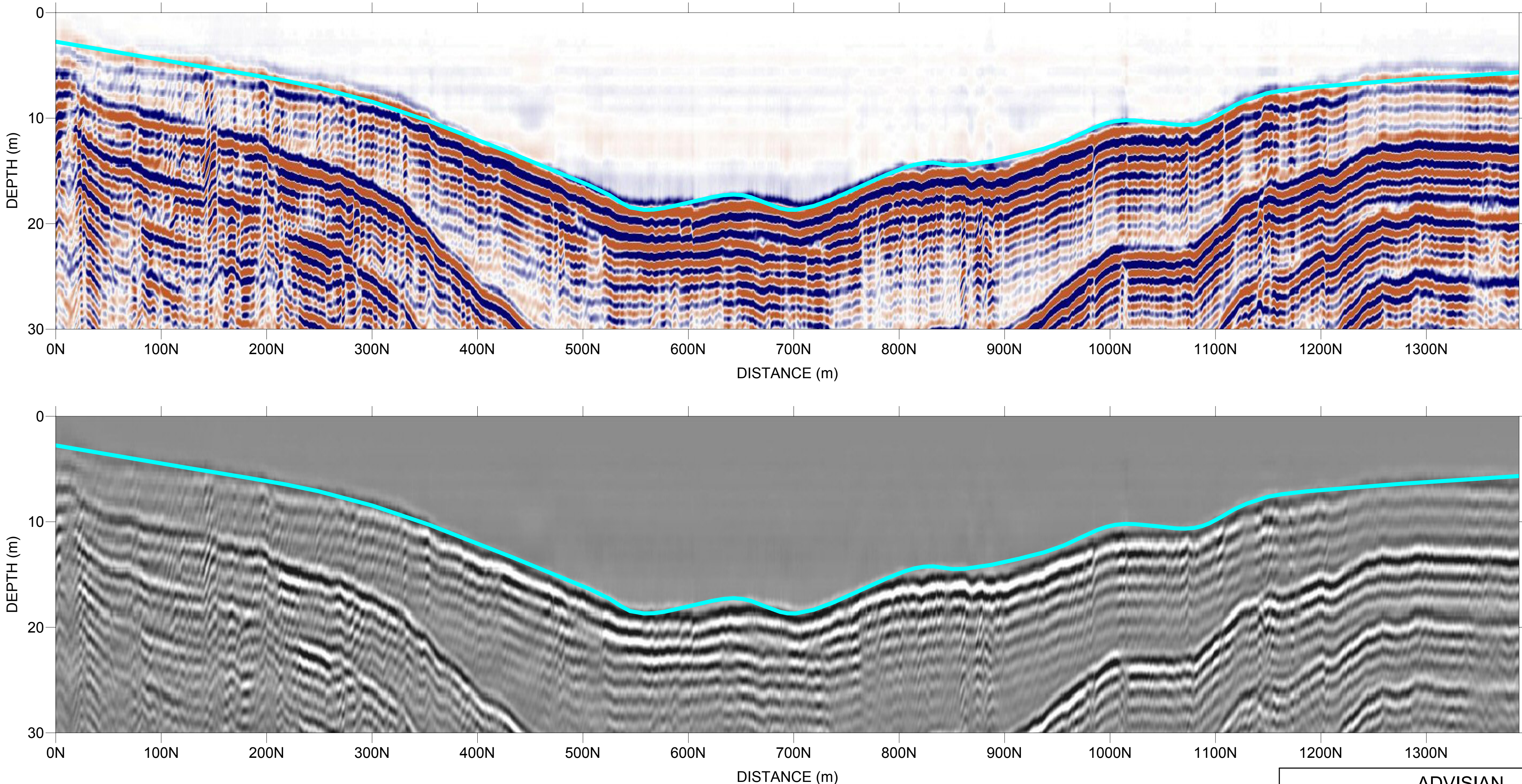
ADVISIAN
SANIRAYAK, NUNAVUT

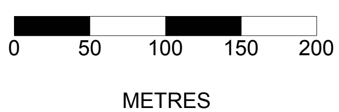
MARINE GEOPHYSICAL SURVEY

INTERPRETED DEPTH SECTION
SL21-09

FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	SCALE 1:500	FIG. 23





ADVISIAN
SANIRAJAK, NUNAVUT

MARINE GEOPHYSICAL SURVEY

OVERWATER SUB-BOTTOM
EXAMPLE PROFILE

FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2021	V. SCALE 1:500	FIG. 24

Appendix 6
Socio-Economic Conditions

Appendix 6 - Socio-Economic Conditions

A6.1 Socio-Economic Environment

A6.1.1 Objectives

This socio-economic baseline aims to provide an overview of the existing socio-economic environment of the hamlet of Sanirajak including: demographics; education; health services; community infrastructure; workforce and economic activity; transportation; and land and resource use. Its main objective is to describe the socio-economic conditions in Sanirajak to assess the benefits of a small craft harbour and to inform future permitting and planning requirements for construction of a small craft harbour in Sanirajak.

A6.1.2 Study Sources

Information for the baseline study was obtained from:

- Statistics Canada[1];
- Nunavut Bureau of Statistics;
- Sanirajak's 2022/2023 Infrastructure Plan (ICSP Toolkit);
- The Sanirajak Integrated Community Infrastructure Sustainability Plan Vol.1 and Vol. 2 (Government of Nunavut, Department of Community and Government Services, 2011);
- Nunavut Tourism (Government of Nunavut, 2022);
- Nunavut Housing Corporation's annual report 2020-2021 (NHC, 2021); and
- Consultations with Hamlet council and the Sanirajak Hunters and Trappers' Association (HTA) and interviews with the Chief Administrative Officer (CAO) and community service providers were conducted by community researcher, Solomon Allurut. Solomon Allurut also worked as an interpreter to facilitate meetings and interviews as required.

[1] Please note that to ensure the confidentiality of an individual's census response, Statistics Canada rounds values up or down, including totals, to a multiple of '5' or '10'. As stated by Statistics Canada, "as a result, when these data are summed or grouped, the total value may not match the individual values since totals and sub-totals are independently rounded" (Statistics Canada, 2022b). Any discrepancy noted in the totals for various data categories is due to random rounding and does not affect the accuracy of the data set in a significant way. Similarly, percentages may not necessarily add up to 100% because they are calculated on rounded data.

A6.1.3 Results: Socio-Economic Profile

A6.1.3.1 Demographics

Population

According to 2021 census data from Statistics Canada, the total population of Sanirajak is 891 representing an increase of 5.1% since 2016. The population is young, with children aged 0-14 years representing over a third of the total population (40.4% or 360 individuals) and a median age of 20.6 for the total population. A breakdown of key population statistics provided by Statistics Canada for Sanirajak is presented in Table A6.1-1.

Indigenous Identity

The total self-declared Inuit population is 840 or 94.3% of the total population according to 2021 census data (Table A6.1-1).

Educational Attainment and Language

In 2021, of the total population 15 years old and over in Sanirajak: 13.1% (70 individuals) held a secondary school diploma (or equivalent) as their highest educational attainment, and 21.5% held a postsecondary certificate, diploma or degree and over. Of the 115 individuals with postsecondary accreditations: just over a quarter (26.1%) held apprenticeship or trades certificates, over a half (52.2%) graduated with a College, CEGEP or other non-university certificate or diploma, and less than a quarter (21.7%) graduated with a university certification, diploma or degree at bachelor level or above. Of the total population aged 25-64 years old, over half (59.2%) the individuals held no certificate, diploma or degree.

Inuktitut is the prevalent language in Sanirajak reported as the mother tongue for 91.6% of respondents in 2021 (Statistics Canada, 2023). A majority of the total population in Sanirajak also speak English (740 or 83.1%). In 2021, over a third (39.5%) of employed residents aged 15 years and over in Sanirajak worked in settings where Inuktitut was the language most often used at work compared to 58.1% in English (Statistics Canada, 2023).

A6.1.3.2 Housing and Accommodation

The 2021 census reported Sanirajak having a total of 200 occupied private dwellings. Of the 200 occupied dwellings, the vast majority were rented (185 or 92.5%) and half needed major repairs. Additionally, according to the Nunavut Housing Needs Survey, approximately 50% of occupied dwellings in Sanirajak were classified as crowded (Government of Nunavut 2011). In about 40% of the crowded dwellings, respondents indicated that they regularly used the living room for sleeping because there was no other place to sleep (Government of Nunavut 2011). The Nunavut Housing Corporation’s Annual report for 2020/2021 listed Sanirajak’s housing stock at 19% indicating a “less severe” need for public housing compared to other communities in the territory.

Accommodation in Sanirajak is limited and provided by the Inns North -Hall Beach Hotel. The hotel has nine rooms and a restaurant owned and operated by the co-op.

A6.1.3.3 Labour Force and Economic Activity

Table A6.1-1 presents the participation, employment and unemployment rates of the total population in Sanirajak according to the 2021 Census. Sanirajak experiences lower participation rates and higher unemployment rates compared to Nunavut and Canada as a whole. Of the population 15 years old and over (535) in Sanirajak, 220 people or 41.1% participate in the labour force compared to 58.6% for Nunavut and 63.7% for Canada. The unemployment rate in Sanirajak was reported as 18.2%, just over the 17.4% for Nunavut, but nearly twice the rate for Canada (10.3%).

At the territorial level, according to Nunavut's Bureau of Statistics' latest available Labour Force Update, in December 2022, Inuit made up 69.3% of the labour force in Nunavut but had a participation rate of only 55.2% compared to non-Inuit, that accounted for less than a third (30.7%) of the labour force but had a participation rate of 93.4% (Nunavut Bureau of Statistics, 2022). This disparity is also represented in the employment rate. In the last three months of 2022, the employment rate for Inuit was 46.2% compared to 89.9% for non-Inuit.

Median total income reported for the total population (15 years and over with income) was $28,000 in 2020.

The economy in Sanirajak can be characterized as a combination of traditional activities such as subsistence harvesting (hunting, fishing, trapping and gathering) and wage based economic activities such as public administration, education services and retail. Key employers in the community include the Hamlet of Sanirajak, the territorial government (schools and health centre), and the Co-op and Northern Store.

Harvesting continues to play a vital role in Sanirajak and is an important component of life and wellbeing by reinforcing Inuit cultural practices and providing in-kind income, country food, and opportunities for commercial arts and crafts activities.

Low levels of literacy and numeracy present a challenge to labour force development in Sanirajak and across Nunavut. According to Nunavut's Inuit Labour Force Analysis Report (2018) a lack of wage-based opportunities and food insecurity are among the many challenges to labour force development across the territory.

A breakdown of how the labour force in Sanirajak was allocated across various industries during the 2021 census is provided in Table A6.1-2. Residents participated in a variety of occupations including: retail trade; construction; mining; educational services; and accommodation and food services. Educational services (22.5%), public administration (17.5%), and retail (17.5%) accounted for the largest industries, together occupying over half (57.5%) of the total labour force activity in Sanirajak (Statistics Canada, 2023).

Table A6.1-1 Sanirajak Demographics

Characteristics: 2021 Census Data	Total
Population	
Population in 2021	891
Population in 2016	848
Median age of the population	20.6
% of the population < 15 years of age	40.4
% if the population 15-64 years of age	56.2
Percent population change (from 2016)	5.1
Indigenous Population	
Inuit - single response	840
Non-Indigenous identity	45
Highest Educational Attainment	
Total population 15 years and over	535
No certificate, diploma, or degree	350
Secondary (high) school diploma or equivalency certificate	70
Postsecondary certificate, diploma, or degree	115
• Apprenticeship or trades certificate or diploma	30
• College; CEGEP or other non-university certificate or diploma	60
• Bachelor's degree or higher	25
Labour force activity	
In the labour force	220
• Employed	180
• Unemployed	40
Not in the labour force	315
Participation rate %	41.1
Employment rate %	33.6
Unemployment rate %	18.2

Source: Statistics Canada, 2021 Census of Population.

Table A6.1-2 Total Labour Force population aged 15 years and over in Sanirajak by Industry according to the North American Industry Classification System (NAICS)

NAICS Category	Total
21 Mining, quarrying, and oil and gas extraction	15
23 Construction	10
31-33 Manufacturing	10
44-45 Retail trade	35
48-49 Transportation and warehousing	10
53 Real Estate and rental and leasing	10
56 Administrative and support, waste management and remediation services	10
61 Educational services	45
62 Health care and social assistance	10
72 Accommodation and Food services	10
91 Public administration	35

Source: Statistics Canada, 2021 Census of Population.

A6.1.3.4 Community Infrastructure and Services

Utilities and Communications

The Hamlet of Sanirajak is responsible for water, sewage, and solid waste collection.

Water

Potable water for the community is drawn from a natural lake, called Water Supply Lake, located approximately 3km from the community and 1km from the airport. Water is drawn from the lake in September and stored in a reservoir located close to the water source. Water is treated with chlorine at the reservoir's truck fill station before being loaded into municipal trucks for distribution to holding tanks in all residential and commercial buildings. Currently, there are two water trucks that deliver water daily to residences and commercial operations. According to the Hamlet's CAO, water levels are regularly monitored, and Water Supply Lake has sufficient capacity to service the community's current water demand. According to the Hamlet's 2022/2023 Infrastructure Plan, a water treatment plant is the community's top priority and is required to ensure that the quality of the community's water supply meets acceptable standards. Additionally, fencing around the reservoir is required to protect the community's water source from contamination, particularly from fox and bird droppings. The fence project is being funded by the Government of Nunavut (GN) and is scheduled for completion in 2023. The next closest water source is located approximately 26 kms from the community at Fisherman's Lake. There is currently no suitable access to Fisherman's Lake for water trucks making the construction of a road to the alternate water supply a critical need and the second priority listed for the community.

Sewage

Sewage and municipal wastewater are collected by two sewage trucks daily (CAO. pers. comm. July 2022). The sewage disposal facility is located approximately 1km from the community center and consists of a truck offload discharge area where sewage flows in to a two-cell lagoon through a series of wetlands before discharging into the ocean. Cell 1 of the lagoon developed structural integrity issues resulting in leakage and seepage through the berms. The cell was expanded and rehabilitated with a liner to convert it into a containment storage structure. Cell 2 still functions as exfiltration through nature. All raw sewage generated by the community is collected using vacuum trucks and transported to the sewage disposal facility.

Solid Waste

The municipal solid waste disposal facility is located adjacent to the sewage treatment facility and includes the existing solid waste site and a hazardous materials storage area. The bulky waste site is unsorted and may contain a mixture of different types of hazardous materials. A feasibility study for a new solid waste management facility is on-going. The new fenced site will accommodate and segregate all types of wastes and is expected to be built in next 3 to 4 years. The new site will be fenced with a control gate 2km west of town and includes metal and solid waste disposal. According to Sanirajak's 2022/2023 Infrastructure Plan, the municipality would like to obtain a metal crusher to facilitate containing the size of the landfill site and make it possible to send the crushed metal down south to be recycled.

Electricity

Electricity in Sanirajak is provided via diesel generators that are owned and operated by the Qulliq Energy Corporation (QEC), a territorial corporation, 100% owned by the GN. QEC is the only generator, transmitter and distributor of electrical energy in Nunavut. All electricity needs in Nunavut are met by imported fossil fuel supplies. According to the Hamlet's 2022/2023 Infrastructure Plan, the power plant is aging and there have been a significant number of power outages and brown outs occurring over the last couple of winters. In October 2020 and October 2022, local states of emergency had to be declared when the power was out for more than a couple of days and the line crew could not get in to fix the problem in a timely manner due to inclement weather and charter availability. It is important to the community that a new power plant also be constructed outside the built up area of the community to reduce noise pollution generated by the facility. The feasibility of constructing wind turbines to be used as an alternative to using diesel for power generation in Sanirajak is also currently being explored by the Nunavut Nukkiksautiit Corporation, in partnership with Growler Energy.

Fuel

The GN's Petroleum Products Division (GN-PPD) is responsible for the import, storage, and distribution of Nunavut's fuel products. Fuel is stored at a tank farm located approximately 1km southeast of town and delivered to residents and businesses by fuel truck. There have been no recent shortages in fuel needed for the community according to the Hamlet. In 2017, there were upgrades to the fuel storage facility in Sanirajak due to code deficiencies resulting from Environment Canada's new codes under the Canadian Environmental Protection Act (CEPA). Since then, the facility has been upgraded and is now code compliant. There were shortages of aviation fuel during work on the fuel storage facility with a combination of two airlines flying in and out same time, but it was resolved and there have not been any fuel shortages since (CAO. pers. comm. July 2022). There is periodically shortage on naphtha which is shipped in by gallon containers.

Communications

Landline and mobile phone services are provided by NorthwesTel/Bell Mobility while internet service has historically been provided by Qiniq. However, as of 2019, a new open-access network by Northwestel and Bell called Tamarmik Nunaliit now delivers 15 megabits per second (Mbps) Internet and LTE wireless service to all Nunavut communities. Operating on Telesat ka-Band satellite technology, the network provides up to 20 times more internet capacity than previously available, making high-speed internet and wireless service possible in the community. However, the increased capacity provided by satellite deployment is not enough and there is a continued need for increased bandwidth in the community.

The local community radio broadcasts daily in Inuktitut and English. There is a post office located in the Northern Store.

Transportation

Sanirajak is serviced daily by scheduled commercial flights provided by Canadian North via Ottawa and routed through Iqaluit (Canadian North 2023).

The roads in Sanirajak are gravel surface with no walkways. Pedestrians, all-terrain vehicles, snow machines, cars and trucks all share the road. The Hamlet manages the condition of the roads including snow clearing and dust suppression (using water periodically, as required) (CAO pers. comm. July 2022).

Sealift is a vital link for all communities in Nunavut that supply residents with their annual cargo of goods and materials. Sealift ships travel from several southern Canadian ports with a variety of goods ranging from housewares, non-perishable items, construction materials, vehicles, and heavy equipment. Nunavut Sealink and Supply Inc. (NSSI) and Nunavut Eastern Arctic Shipping Inc. (NEAS) are the current providers of sealift carriage and associated services to Sanirajak. Dry cargo is lightered to shore in the conventional manner using small tugs and barges that are carried on board the arriving ship. Generally, the sealift carriers are contractually required to deliver the cargo to the high-water mark, where it is usually taken by a local cartage company (in this case the Hamlet) or the owner from the temporary stored location into the community. The sealift beach is cleared at the start of each season of any accumulated sediments, gravel, and boulders by loader.

The community is supplied via sealift several times throughout the shipping season. Ships tend to arrive in Sanirajak around late August to early September with the last boat of the year leaving in late September to early October.

Emergency & Protection Services

Fire protection is the responsibility of the Hamlet and currently relies on one full-time Fire Chief and 11 active volunteer firefighters. The department attends to one fire per year on average, normally caused by arson or cooking (Fire Chief. pers. comm. July 2022). The Fire Chief stated that the department is properly equipped and staffed to handle the current needs of the community and another fire truck is expected on the sealift this year (Fire Chief. pers. comm. July 2022).

The RCMP detachment office has two on duty officers. Additional officers are called in for duty relief or when the need arises in managing any high or increasing volume of calls for service in the community.

Public Health

The community's health centre is staffed by three nurse practitioners and provides basic medical care such as regular check-ups, treatment of minor illnesses, and emergency first response (Head Nurse. pers. comm. July 2022). The health centre receives regular visits from physicians, dentists and specialists such as optometrists and physiotherapists. Those requiring specialized treatment, urgent scanning, or experiencing "life or death" medical emergencies are flown to Iqaluit or south, depending on the seriousness of the case (Head Nurse. pers. comm. July 2022). Although there have been nursing shortages in the past (especially during the summer), the health centre is currently equipped and staffed to meet the demand of the community (Head Nurse. pers. comm. July 2022).

Education

Arnaqjuaq is the only school in Sanirajak providing Kindergarten to Grade 12 instruction with approximately 300 students and a staff of typically 22-26, including teachers, administrators and support staff. The school is over capacity and has been plagued with problems for far too long including a broken fire sprinkler system, overcrowding, broken water fountains, plumbing issues and a kitchen that's being used as a makeshift classroom (Nunatsiaq News 2023).

Nunavut Arctic College (NAC) runs a community learning centre in Sanirajak with one adult educator. The college is currently offering Nunavut Teacher Training- Year 1, Adult Basic Education - Essential Skills and Office Administration (Nunavut Arctic College 2022). According to the Hamlet's 2022/2023 Infrastructure Plan, the NAC building is very old and needs repair. Renovation of the building is currently 15th on the priority list for infrastructure needs in Sanirajak.

A6.1.3.5 Land and Resource use

Harvesting and Food Security

Food security, as defined by the United Nation's Food and Agriculture Organization (FAO), exists "*when all people, at all times, have physical, social and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life*" (FAO, 2002). Inuit face the highest documented prevalence of food insecurity of any Indigenous people living in a developed country (ITK, 2021). Over half (57%) of Nunavut households reported being food insecure in 2017-18 with almost half of these households being severely food insecure (Tarasuk & Mitchell, 2020).

The availability of traditionally harvested foods in Sanirajak is crucial because it lowers the demand for imported food which is expensive and most often less nutritious. Additionally, the harvesting, preparation, and sharing of meat and skins offers important opportunities for community members to maintain Inuit cultural practices. Residents in Sanirajak also buy food at the Co-Op and Northern Store and order food via the sealift. However, "Low incomes and high food prices mean most Inuit households can afford less than half the cost of a healthy food basket, while very low-income households can afford only 6–13% of the cost of a healthy food basket" (ITK, 2021).

The Qikiqtani Inuit Association (QIA), through its development arm, Qikiqtaaluk Corporation, has created the Qikiqtani Fishery Alliance, a partnership with the HTAs of the Qikiqtani communities on Foxe Basin, including Sanirajak to conduct inshore test fisheries to assess the potential in developing a viable fishing industry in these communities (Qikiqtaaluk Corporation 2021).
Research on a potential inshore fishery for Sanirajak began in September 2022 with the newly built RV Ludy Pudluk research vessel to conduct sea bottom mapping and inshore fisheries surveys with collaboration with the Sanirajak HTA (ArcticNet 2021). Further, the Hamlet has included the construction of a fish plant in their 2022/2023 Infrastructure Plan's priority list to support a commercial fishery as there is also an abundance of fish near the community and the fish plant would generate much needed employment.

Harvesting remains an essential part of life in Sanirajak including dietary staples such as walrus, Arctic char, Lake trout, ringed and bearded seals, and belugas.

"*The community requires a dock to be constructed to facilitate the loading and unloading of community boats and for a safe place for boat owners to tie their boats to during storms. As the majority of the community relies on country food as their main food source, infrastructure that supports harvesting activities is required.*" – Hamlet's 2022/2023 Infrastructure Plan

Travel Routes and Access

Preliminary land use information was shared during the HTA design workshop and meetings with Hamlet council.

Most marine activities, including dry cargo sealift and boating, occur on the waterfront adjacent to the main part of the Hamlet between the tank farm and residential houses. At the start of each season, a loader from the first sealift ship clears the beach of accumulated gravel, down to the bedrock.

In 2008, the GN-EDT designed a floating dock system to be built for various Nunavut communities. Sanirajak was selected as one of these communities, and the dock was later constructed in 2009. The dock is located 3.5 km north of the community, in a semi-protected cove that dries at low tide. The structure is comprised of a floating platform (14.4 m by 3.6 m) with two access ramps, each 2.4 m wide. The dock is only used by a few residents due to the distance from the rest of the community and is only useable at high tide as the area dries at mean to low tide.

During consultations, hunters noted the following concerning changes to the shoreline and increased challenges to safe and efficient boating and harvesting:

> *"The majority of hunters don't have access to the floating dock, it's too far and too small."*
>
> *"Most people need to pull their boats up along the shoreline in the community. Canoes need to be pulled up high – they otherwise get washed away with waves and the current."*
>
> *"We need a protected harbour – secure from waves and winds near the sealift."*
>
> *"In the 80s we would have whales within meters from shore, but the last 5 years or so whales haven't come close at all because it's getting shallower."*
>
> *"Whales in the fall are now much further out because the coastline is getting shallower. It has been getting shallower for years – even the lakes are getting shallower."*
>
> *"Hunters need to be very careful now and slow down when coming in to land to avoid shallow areas."*
>
> *"We can't anchor close to shore at all because of all the bedrock near the coastline."*

Hunters also noted that ice is easily accessible in several areas along the shoreline fronting the community.

Tourism

Sanirajak does not currently receive any cruise/passenger ship calls but does occasionally get adventurers (usually sailboats) because of the nearby Fury and Hecla Strait, which provides a shortened route to and from the Northwest Passage. There are several hunters from Igloolik that also pass through Sanirajak on their way caribou hunting (HTA board member. pers. comm. March 2021). Additionally, walrus and bowhead tours with Eagle Eye Tours have recently begun operating out of Sanirajak using local guides and their aluminum boats to bring visitors out to explore nearby islands and local wildlife, especially marine mammals (Eagle Eye Tours 2023).

Appendix 7
Detailed Cost Estimates

Sanirajak Cost Estimate

	Overview			
	Option 1	**Option 2**	**Option 3**	**Option 4**
General	$ 30,297,000.00	$ 24,106,000.00	$ 41,538,000.00	$ 25,253,000.00
Quarrying	$ 33,508,000.00	$ 9,266,000.00	$ 43,348,000.00	
Dredging/Excavation	$ 206,000.00	$ 4,396,000.00	$ -	$ 20,390,000.00
Main Breakwater	$ 2,518,000.00	$ 651,000.00	$ 3,447,000.00	$ -
Secondary Breakwater	$ 896,000.00	$ -	$ 1,937,000.00	$ -
Sealift Laydown and Ramp	$ 1,478,000.00	$ 1,472,000.00	$ 1,359,000.00	$ 2,444,000.00
Small Craft Float	$ 1,067,000.00	$ 1,067,000.00	$ 1,067,000.00	$ 1,067,000.00
Electrical	$ 660,000.00	$ 605,000.00	$ 220,000.00	$ 330,000.00
Subtotal	**$ 70,630,000.00**	**$ 41,563,000.00**	**$ 92,916,000.00**	**$ 49,484,000.00**
Contingency (%25)	$ 17,658,000.00	$ 10,391,000.00	$ 23,229,000.00	$ 12,371,000.00
Engineering/Planning/Regulatory	$ 6,625,000.00	$ 6,125,000.00	$ 6,625,000.00	$ 5,500,000.00
Total	**$ 94,913,000.00**	**$ 58,079,000.00**	**$ 122,770,000.00**	**$ 67,355,000.00**

ESTIMATE - Sanirajak Option 1

CLIENT:	Municipality of Sanirajak	DATE:	12-Aug-22
PROJECT TITLE:	Sanirajak - Marine Infrastructure Planning Study	DISCIPLINE:	Estimating
PROJECT No.:	317086-32238	ORIGINATOR:	P.Jiang
REVISION:	A	CHECKER:	H.Kullman
ACCURACY:	Class D	APPROVER:	H.Kullman

DIRECT COSTS

WBS 2	WBS 3	Description	Remarks	Qty	Unit	S/C Costs/Unit ($)	S/C Total ($)	Other/Unit ($)	Other Total ($)	Allowance %	Allowance ($)	Sub Total ($)	Contingency %	Contingency ($)	Total ($)
3100	3110	Mobilisation	Sanirajak												
3100	3110	All construction equipment & supplies		1	LS	-	-	18,342,000	18,342,000		-	18,342,000	25%	4,585,500	22,927,500
3100	3110	Overwintering Allowance		1	LS	-	-	6,114,000	6,114,000		-	6,114,000	25%	1,528,500	7,642,500
3100	3120	Demobilisation	Sanirajak			-		-							
3100	3120	Demobilisation		1	LS	-	-	4,076,000	4,076,000		-	4,076,000	25%	1,019,000	5,095,000
3200	3210	Dredge				-		-							
3200	3210	Dredge Materials		3,375	m3	61	206,348	-	-		-	206,348	25%	51,587	257,934
3300	3310	Quarry Development	Sanirajak			-		-							
3300	3310	Drill/Blast/Excavate ROQ	Aggregate Production in Sanirajak	59,000	m3	51	3,006,050	-	-		-	3,006,050	25%	751,513	3,757,563
3300	3310	Manufacture Type 1 Fill	Run of Quarry	68,000	m3	-	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 2 Fill	200mm minus, Crushing and Screening	8,000	m3	20	163,040	-	-		-	163,040	25%	40,760	203,800
3300	3310	Manufacture Type 3 Fill	150mm clear, Crushing and Screening	-	m3	25	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 4 Fill	38mm minus, Crushing and Screening	6,000	m3	40	242,359	-	-		-	242,359	25%	60,590	302,949
3300	3310	Manufacture Type 5 Fill	Bedding Sand (reclaimed)	-	m3	25	-	-	-		-	-	25%	-	-
3300	3311	Quarry Development	Rankin Inlet			-		-							
3300	3311	Mobilisation/Demobilisation	Rankin Inlet Mobilisation/Demobilisation	1	LS		-	7,642,500	7,642,500		-	7,642,500	25%	1,910,625	9,553,125
3100	3110	Overwintering Allowance		1	LS	-	-	509,500	509,500		-	509,500	25%	127,375	636,875
3300	3311	Drill/Blast/Excavate ROQ	Armour Stone Production in Rankin Inlet	31,000	m3	51	1,579,450	-	-		-	1,579,450	25%	394,863	1,974,313
3300	3311	Manufacture Type 1 Armour	D50=1500mm, Sorting Run of Quarry	33,000	m3	20	672,540	-	-		-	672,540	25%	168,135	840,675
3300	3311	Manufacture Type 1 Armour Surplus Stockpile	D50=1500mm, Sorting Run of Quarry	3,000	m3	20	61,140	-	-		-	61,140	25%	15,285	76,425
3300	3311	Manufacture Type 4 Armour	Select Run of Quarry	11,000	m3	20	224,180	-	-		-	224,180	25%	56,045	280,225
3300	3315	Armour Delivery				-		-							
3300	3315	Mobilisation/Demobilisation	Tug and Barge Mob/Demob	1	LS	1	1	4,076,000	4,076,000		-	4,076,001	25%	1,019,000	5,095,001
3300	3315	Equipment Costs	1 Tug and 1 Barge Equipment Costs (total to use 2 tugs 2 barges for 2 seasons)	322	day	17,500	5,635,000	-	-		-	5,635,000	25%	1,408,750	7,043,750
3300	3315	Fuel Costs		4,899,400	ea	1	4,899,400	-	-		-	4,899,400	25%	1,224,850	6,124,250
3300	3315	Additional Handling	On land transportation or armour (quarry to barge, barge to site)	44,000	m3	51	2,241,800	-	-		-	2,241,800	25%	560,450	2,802,250
3300	3315	Contractor Margin		2,555,240	LS	1	2,555,240	-	-		-	2,555,240	25%	638,810	3,194,050
3300	3320	East Breakwater				-		-							
3300	3320	Breakwater Core	Type 1 Aggregate	22,789	m3	41	928,880	-	-		-	928,880	25%	232,220	1,161,100
3300	3320	Type 1 Slope Protection	Type 1 Armour Stone	21,944	m3	51	1,118,037	-	-		-	1,118,037	25%	279,509	1,397,546
3300	3320	Type 4 Slope Protection	Type 4 Armour Stone	8,134	m3	51	414,432	-	-		-	414,432	25%	103,608	518,040
3300	3330	Breakwater Driving Surface	Type 4 Aggregate	754	m3	25	18,844	-	-		-	18,844	25%	4,711	23,555
3300	3330	Breakwater Driving Subbase	Type 2 Aggregate	1,206	m3	31	37,386	-	-		-	37,386	25%	9,347	46,733
3300	3330	West Breakwater				-		-							
3300	3330	Breakwater Core	Type 1 Aggregate	7,788	m3	41	317,439	-	-		-	317,439	25%	79,360	396,799
3300	3330	Type 1 Slope Protection	Type 1 Armour Stone	7,930	m3	51	404,013	-	-		-	404,013	25%	101,003	505,016
3300	3330	Type 4 Slope Protection	Type 4 Armour Stone	2,997	m3	51	152,707	-	-		-	152,707	25%	38,177	190,884
3300	3330	Breakwater Driving Surface	Type 4 Aggregate	295	m3	25	7,375	-	-		-	7,375	25%	1,844	9,219
3300	3330	Breakwater Driving Subbase	Type 2 Aggregate	472	m3	31	14,632	-	-		-	14,632	25%	3,658	18,290
3300	3340	Boat Parking Area and Ramp				-		-							

3300	3340	Parking Area Driving Surface	Type 4 Aggregate	5,300	m3	25	135,018	-	-		-	135,018	25%	33,754	168,772
3300	3340	Parking Area Driving Subbase	Type 2 Aggregate	6,625	m3	31	202,526	-	-		-	202,526	25%	50,632	253,158
3300	3340	Boat Ramp Driving Surface	Type 3 Aggregate	146	m3	25	3,726	-	-		-	3,726	25%	931	4,657
3300	3340	Dredgeate Placement	Dredgeate	3,375	m3	31	104,625	-	-		-	104,625	25%	26,156	130,781
3300	3340	Parking Core	Type 1 Aggregate	36,375	m3	28	1,000,785	-	-		-	1,000,785	25%	250,196	1,250,982
3300	3340	Boat Ramp Core	Type 1 Aggregate	1,144	m3	28	31,475	-	-		-	31,475	25%	7,869	39,344
3400	3430	Small Craft Floats				-		-							
3400	3430	Supply and Install	Performance Specification	600	m2	1,500	900,000	-	-	10%	90,000	990,000	25%	247,500	1,237,500
3400	3430	Anchor System		1	LS	70,000	70,000	-	-	10%	7,000	77,000	25%	19,250	96,250
3500	3510	Electrical				-		-							
3500	3510	QEC Power Supply to Site	Includes all necessary poles, wires, transformers, etc.	1	LS	350,000	350,000	-	-	10%	35,000	385,000	25%	96,250	481,250
3500	3510	QEC Area Lighting	Area lighting for sealift laydown	1	LS	150,000	150,000	-	-	10%	15,000	165,000	25%	41,250	206,250
3500	3510	East Breakwater Navigation Lighting	To include all trenching/backfilling, cables, poles, and lights.	1	LS	50,000	50,000	-	-	10%	5,000	55,000	25%	13,750	68,750
3500	3510	West Breakwater Navigation Lighting	To include all trenching/backfilling, cables, poles, and lights.	1	LS	50,000	50,000	-	-	10%	5,000	55,000	25%	13,750	68,750
DIRECT COST SUB TOTAL							**27,898,447**		**40,760,000**	**0%**	**152,000**	**68,810,447**	**25%**	**17,216,362**	**86,081,809**

INDIRECT COSTS

3900	3910	Site Survey Control Setup		1	LS		-	25,000	25,000		-	25,000	25%	6,250	31,250
3900	3910	Pre-Construction Bathymetric and Topographic Survey	Including quantity adjustments	1	LS		-	25,000	25,000		-	25,000	25%	6,250	31,250
3900	3910	Quarry Royalties Costs	@$1.75/m3	59,000	m3		-	1.75	103,250		-	103,250	25%	25,812.50	129,063
3900	3910	Quarry to Site Haul Road Upgrades	Temporary Haul Road	1	LS		-	1,000,000	1,000,000		-	1,000,000	25%	250,000	1,250,000
3900	3910	Quarry to Site Haul Road Maintenance	inc. in contractor unit rates	1	LS		-	-	-		-	-		-	-
3900	3910	Hotel Room Expansion Module	assumed cost - based on modular unit rental for 24 months	1	LS		-	180,000	180,000		-	180,000	25%	45,000	225,000
3900	3910	Temporary Fuel Storage Tanks	assumed not required	1	LS		-	-	-		-	-		-	-
3900	3910	Establish construction/laydown area	allowance for grading and setup	1	LS		-	50,000	50,000		-	50,000	25%	12,500	62,500
3900	3910	Temporary power/lighting	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Site fencing/security	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Temporary Buildings	site office trailers; tool cribs; porta-potties; etc. inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Temporary signage	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Janitorial and Cleaning Services	24 months duration (assumed local staff)	1	LS		-	12,000	12,000		-	12,000	25%	3,000	15,000
3900	3910	Snow Management	allowance	1	LS		-	10,000	10,000		-	10,000	25%	2,500	12,500
3900	3910	Ice Management		1	LS		-	150,000	150,000		-	150,000	25%	37,500	187,500
3900	3910	Site Bussing (Driver services)	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Warehousing and material receiving	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Health and Safety	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Commissioning and start-up	minimal allowance	1	LS		-	10,000	10,000		-	10,000	25%	2,500	12,500
3900	3910	Insurances	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Site Surveys and Mapping Services	allowance	1	LS		-	100,000	100,000		-	100,000	25%	25,000	125,000
3900	3910	Environmental monitoring and testing services	allowance	1	LS		-	100,000	100,000		-	100,000	25%	25,000	125,000
3900	3910	Contractor LOA and travel	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Logistics and freight for materials	inc. in s/c unit rates in direct costs				-		-		-	-		-	-
INDIRECT COST SUB TOTAL							**-**		**1,765,250**	**0%**	**-**	**1,765,250**	**25%**	**441,313**	**2,206,563**

OTHER COSTS

3900	3910	EPCM - EXCLUDED	excluded				-		-		-	-		-	-
3900	3910	OWNERS COSTS - EXCLUDED	excluded				-		-		-	-		-	-
3900	3910	Engineering /Planning/ Regulatory		1	LS		-	6,000,000	6,000,000		-	6,000,000	0%	-	6,000,000
3900	3910	Research Project	DFO Compensation	1	LS		-	500,000	500,000		-	500,000	25%	125,000	625,000

OTHER COST SUB TOTAL	-		6,500,000	0%	-	6,500,000	2%	125,000	6,625,000
TOTAL						77,075,697	23%	17,782,674	94,913,371

NOTES:

1 Estimate based on 2nd Quarter 2022 Canadian dollars
2 Estimate based on Feasibility Phase

ESTIMATE - Sanirajak Option 2

CLIENT:	Municipality of Sanirajak	DATE:	12-Aug-22
PROJECT TITLE:	Sanirajak - Marine Infrastructure Planning Study	DISCIPLINE:	Estimating
PROJECT No.:	317086-32238	ORIGINATOR:	P.Jiang
REVISION:	A	CHECKER:	H.Kullman
ACCURACY:	Class D	APPROVER:	H.Kullman

DIRECT COSTS

WBS 2	WBS 3	Description	Remarks	Qty	Unit	S/C Costs/Unit ($)	S/C Total ($)	Other/Unit ($)	Other Total ($)	Allowance %	Allowance ($)	Sub Total ($)	Contingency %	Contingency ($)	Total ($)
3100	3110	Mobilisation	Sanirajak												
3100	3110	All construction equipment & supplies		1	LS	-	-	15,285,000	15,285,000		-	15,285,000	25%	3,821,250	19,106,250
3100	3110	Overwintering Allowance		1	LS	-	-	5,095,000	5,095,000		-	5,095,000	25%	1,273,750	6,368,750
3100	3120	Demobilisation	Sanirajak			-		-							
3100	3120	Demobilisation		1	LS	-	-	2,038,000	2,038,000		-	2,038,000	25%	509,500	2,547,500
3200	3210	Dredge				-		-							
3200	3210	Dredge Materials		37,050	m3	61	2,265,237	-	-		-	2,265,237	25%	566,309	2,831,546
3300	3310	Basin Excavation	Sanirajak			-		-							
3300	3310	Drill/Blast/Excavate ROQ		15,000	m3	51	764,250	-	-		-	764,250	25%	191,063	955,313
3300	3310	Strip Surface Soils		1	LS		-	100,000	100,000		-	100,000	25%	25,000	125,000
3300	3310	Drainage Control		1	LS		-	300,000	300,000		-	300,000	25%	75,000	375,000
3300	3310	Blast Berms	Not required	1	LS		-	-	-		-	-	25%	-	-
3300	3310	Entrance Blast	allowance for complexity of final blast and flooding	1	LS	-	-	500,000	500,000		-	500,000	25%	125,000	625,000
3300	3310	Manufacture Type 1 Fill	Run of Quarry	6,000	m3	-	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 2 Fill	200mm minus, Crushing and Screening	9,000	m3	20	183,420	-	-		-	183,420	25%	45,855	229,275
3300	3310	Manufacture Type 3 Fill	150mm clear, Crushing and Screening	-	m3	25	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 4 Fill	38mm minus, Crushing and Screening	7,000	m3	40	282,752	-	-		-	282,752	25%	70,688	353,440
3300	3310	Manufacture Type 5 Fill	Bedding Sand (reclaimed)	-	m3	25	-	-	-		-	-	25%	-	-
3300	3310	Quarry Development	Rankin Inlet			-		-							
3300	3310	Mobilisation/Demobilisation	Rankin Inlet Mobilisation/Demobilisation	1	LS		-	2,038,000	2,038,000		-	2,038,000	25%	509,500	2,547,500
3300	3310	Drill/Blast/Excavate ROQ		8,000	m3	51	407,600	-	-		-	407,600	25%	101,900	509,500
3300	3310	Manufacture Type 1 Armour	D50=1500mm, Sorting Run of Quarry	9,000	m3	20	183,420	-	-		-	183,420	25%	45,855	229,275
3300	3310	Manufacture Type 1 Armour Surplus Stockpile	D50=1500mm, Sorting Run of Quarry	3,000	m3	20	61,140	-	-		-	61,140	25%	15,285	76,425
3300	3310	Manufacture Type 4 Armour	Select Run of Quarry	2,000	m3	20	40,760	-	-		-	40,760	25%	10,190	50,950
3300	3315	Armour Delivery				-		-							
3300	3315	Mobilisation/Demobilisation	Tug and Barge Mob/Demob	1	LS	1	1	2,038,000	2,038,000		-	2,038,001	25%	509,500	2,547,501
3300	3315	Equipment Costs	1 Tug and 1 Barge Equipment Costs (total to use 2 tugs 2 barges for 1 season)	102	day	17,500	1,785,000	-	-		-	1,785,000	25%	446,250	2,231,250
3300	3315	Fuel Costs		1,402,500	ea	1	1,402,500	-	-		-	1,402,500	25%	350,625	1,753,125
3300	3315	Additional Handling	On land transportation or armour (quarry to barge, barge to site)	11,000	m3	51	560,450	-	-		-	560,450	25%	140,113	700,563
3300	3315	Contractor Margin		749,590	LS	1	749,590	-	-		-	749,590	25%	187,398	936,988
3300	3320	East Breakwater				-		-							
3300	3320	Breakwater Core	Type 1 Aggregate	4,792	m3	41	195,322	-	-		-	195,322	25%	48,830	244,152
3300	3320	Type 1 Slope Protection	Type 1 Armour Stone	6,170	m3	51	314,367	-	-		-	314,367	25%	78,592	392,958
3300	3320	Type 4 Slope Protection	Type 4 Armour Stone	2,327	m3	51	118,584	-	-		-	118,584	25%	29,646	148,229
3300	3330	Breakwater Driving Surface	Type 4 Aggregate	303	m3	25	7,563	-	-		-	7,563	25%	1,891	9,453
3300	3330	Breakwater Driving Subbase	Type 2 Aggregate	484	m3	31	15,004	-	-		-	15,004	25%	3,751	18,755
3300	3340	Boat Parking Area and Ramp				-		-							
3300	3340	Parking Area Driving Surface	Type 4 Aggregate	6,620	m3	25	168,645	-	-		-	168,645	25%	42,161	210,806

3300	3340	Parking Area Driving Subbase	Type 2 Aggregate	8,275	m3	31	252,967	-	-		-	252,967	25%	63,242	316,208
3300	3340	Boat Ramp Driving Surface	Type 3 Aggregate	146	m3	25	3,726	-	-		-	3,726	25%	931	4,657
3300	3340	Dredgeate Placement	Dredgeate	33,100	m3	31	1,026,100	-	-		-	1,026,100	25%	256,525	1,282,625
3300	3340	Parking Core	Type 1 Aggregate	-	m3	28	-	-	-		-	-	25%	-	-
3300	3340	Boat Ramp Core	Type 1 Aggregate	758	m3	28	20,864	-	-		-	20,864	25%	5,216	26,080
3400	3430	Small Craft Floats				-		-							
3400	3430	Supply and Install	Performance Specification	600	m2	1,500	900,000	-	-	10%	90,000	990,000	25%	247,500	1,237,500
3400	3430	Anchor System		1	LS	70,000	70,000	-	-	10%	7,000	77,000	25%	19,250	96,250
3500	3510	Electrical				-		-							
3500	3510	QEC Power Supply to Site	Includes all necessary poles, wires, transformers, etc.	1	LS	350,000	350,000	-	-	10%	35,000	385,000	25%	96,250	481,250
3500	3510	QEC Area Lighting	Area lighting for sealift laydown	1	LS	150,000	150,000	-	-	10%	15,000	165,000	25%	41,250	206,250
3500	3510	East Breakwater Navigation Lighting	To include all trenching/backfilling, cables, poles, and lights.	1	LS	50,000	50,000	-	-	10%	5,000	55,000	25%	13,750	68,750
DIRECT COST SUB TOTAL							**12,329,260**		**27,394,000**	**0%**	**152,000**	**39,875,260**	**25%**	**9,968,815**	**49,844,075**

INDIRECT COSTS

3900	3910	Site Survey Control Setup		1	LS		-	25,000	25,000		-	25,000	25%	6,250	31,250
3900	3910	Pre-Construction Bathymetric and Topographic Survey	Including quantity adjustments	1	LS		-	25,000	25,000		-	25,000	25%	6,250	31,250
3900	3910	Quarry Royalties Costs	@$1.75/m3	15,000	m3		-	1.75	26,250		-	26,250	25%	6,562.50	32,813
3900	3910	Quarry to Site Haul Road Upgrades	Temporary Haul Road	1	LS		-	1,000,000	1,000,000		-	1,000,000	25%	250,000	1,250,000
3900	3910	Quarry to Site Haul Road Maintenance	inc. in contractor unit rates	1	LS		-	-	-		-	-		-	-
3900	3910	Hotel Room Expansion Module	assumed cost - based on modular unit rental for 24 months	1	LS		-	180,000	180,000		-	180,000	25%	45,000	225,000
3900	3910	Temporary Fuel Storage Tanks	assumed not required	1	LS		-	-	-		-	-		-	-
3900	3910	Establish construction/laydown area	allowance for grading and setup	1	LS		-	50,000	50,000		-	50,000	25%	12,500	62,500
3900	3910	Temporary power/lighting	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Site fencing/security	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Temporary Buildings	site office trailers; tool cribs; porta-potties; etc. inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Temporary signage	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Janitorial and Cleaning Services	24 months duration (assumed local staff)	1	LS		-	12,000	12,000		-	12,000	25%	3,000	15,000
3900	3910	Snow Management	allowance	1	LS		-	10,000	10,000		-	10,000	25%	2,500	12,500
3900	3910	Ice Management		1	LS		-	150,000	150,000		-	150,000	25%	37,500	187,500
3900	3910	Site Bussing (Driver services)	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Warehousing and material receiving	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Health and Safety	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Commissioning and start-up	minimal allowance	1	LS		-	10,000	10,000		-	10,000	25%	2,500	12,500
3900	3910	Insurances	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Site Surveys and Mapping Services	allowance	1	LS		-	100,000	100,000		-	100,000	25%	25,000	125,000
3900	3910	Environmental monitoring and testing services	allowance	1	LS		-	100,000	100,000		-	100,000	25%	25,000	125,000
3900	3910	Contractor LOA and travel	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Logistics and freight for materials	inc. in s/c unit rates in direct costs				-		-		-	-		-	-
INDIRECT COST SUB TOTAL							**-**		**1,688,250**	**0%**	**-**	**1,688,250**	**25%**	**422,063**	**2,110,313**

OTHER COSTS

3900	3910	EPCM - EXCLUDED	excluded				-		-		-	-		-	-
3900	3910	OWNERS COSTS - EXCLUDED	excluded				-		-		-	-		-	-
3900	3910	Engineering /Planning/ Regulatory		1	LS		-	5,500,000	5,500,000		-	5,500,000	0%	-	5,500,000
3900	3910	Research Project	DFO Compensation	1	LS		-	500,000	500,000		-	500,000	25%	125,000	625,000
OTHER COST SUB TOTAL							**-**		**6,000,000**	**0%**	**-**	**6,000,000**	**2%**	**125,000**	**6,125,000**

TOTAL						**47,563,510**	**22%**	**10,515,877**	**58,079,387**

NOTES:

1 Estimate based on 2nd Quarter 2022 Canadian dollars
2 Estimate based on Feasibility Phase

ESTIMATE - Sanirajak Option 3

CLIENT:	Municipality of Sanirajak	DATE:	12-Aug-22
PROJECT TITLE:	Sanirajak - Marine Infrastructure Planning Study	DISCIPLINE:	Estimating
PROJECT No.:	317086-32238	ORIGINATOR:	P.Jiang
REVISION:	A	CHECKER:	H.Kullman
ACCURACY:	Class D	APPROVER:	H.Kullman

DIRECT COSTS

WBS 2	WBS 3	Description	Remarks	Qty	Unit	S/C Costs/Unit ($)	S/C Total ($)	Other/Unit ($)	Other Total ($)	Allowance %	Allowance ($)	Sub Total ($)	Contingency %	Contingency ($)	Total ($)
3100	3110	Mobilisation	Sanirajak												
3100	3110	All construction equipment & supplies		1	LS	-	-	28,532,000	28,532,000		-	28,532,000	25%	7,133,000	35,665,000
3100	3110	Overwintering Allowance		1	LS	-	-	6,623,500	6,623,500		-	6,623,500	25%	1,655,875	8,279,375
3100	3120	Demobilisation	Sanirajak			-		-							
3100	3120	Demobilisation		1	LS	-	-	4,585,500	4,585,500		-	4,585,500	25%	1,146,375	5,731,875
3200	3210	Dredge				-		-							
3200	3210	Dredge Materials		-	m3	61	-	-	-		-	-	25%	-	-
3300	3310	Quarry Development	Sanirajak			-		-							
3300	3310	Drill/Blast/Excavate ROQ		77,000	m3	51	3,923,150	-	-		-	3,923,150	25%	980,788	4,903,938
3300	3310	Manufacture Type 1 Fill	Run of Quarry	91,000	m3	-	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 2 Fill	200mm minus, Crushing and Screening	10,000	m3	20	203,800	-	-		-	203,800	25%	50,950	254,750
3300	3310	Manufacture Type 3 Fill	150mm clear, Crushing and Screening	-	m3	25	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 4 Fill	38mm minus, Crushing and Screening	7,000	m3	40	282,752	-	-		-	282,752	25%	70,688	353,440
3300	3310	Manufacture Type 5 Fill	Bedding Sand (reclaimed)	-	m3	25	-	-	-		-	-	25%	-	-
3300	3310	Quarry Development	Rankin Inlet			-		-							
3300	3310	Mobilisation/Demobilisation	Rankin Inlet Mobilisation/Demobilisation	1	LS		-	7,642,500	7,642,500		-	7,642,500	25%	1,910,625	9,553,125
3100	3110	Overwintering Allowance		1	LS	-	-	509,500	509,500		-	509,500	25%	127,375	636,875
3300	3310	Drill/Blast/Excavate ROQ		44,000	m3	51	2,241,800	-	-		-	2,241,800	25%	560,450	2,802,250
3300	3310	Manufacture Type 1 Armour	D50=1500mm, Sorting Run of Quarry	47,000	m3	20	957,860	-	-		-	957,860	25%	239,465	1,197,325
3300	3310	Manufacture Type 1 Armour Surplus Stockpile	D50=1500mm, Sorting Run of Quarry	3,000	m3	20	61,140	-	-		-	61,140	25%	15,285	76,425
3300	3310	Manufacture Type 4 Armour	Select Run of Quarry	15,000	m3	20	305,700	-	-		-	305,700	25%	76,425	382,125
3300	3315	Armour Delivery				-		-							
3300	3315	Mobilisation/Demobilisation	Tug and Barge Mob/Demob	1	LS	1	1	6,114,000	6,114,000		-	6,114,001	25%	1,528,500	7,642,501
3300	3315	Equipment Costs	1 Tug and 1 Barge Equipment Costs (total to use 3 tugs 3 barges for 2 season)	442	day	17,500	7,735,000	-	-		-	7,735,000	25%	1,933,750	9,668,750
3300	3315	Fuel Costs		6,694,600	ea	1	6,694,600	-	-		-	6,694,600	25%	1,673,650	8,368,250
3300	3315	Additional Handling	On land transportation or armour (quarry to barge, barge to site)	62,000	m3	51	3,158,900	-	-		-	3,158,900	25%	789,725	3,948,625
3300	3315	Contractor Margin		3,517,700	LS	1	3,517,700	-	-		-	3,517,700	25%	879,425	4,397,125
3300	3320	North Breakwater				-		-							
3300	3320	Breakwater Core	Type 1 Aggregate	36,775	m3	41	1,498,949	-	-		-	1,498,949	25%	374,737	1,873,686
3300	3320	Type 1 Slope Protection	Type 1 Armour Stone	27,863	m3	51	1,419,594	-	-		-	1,419,594	25%	354,899	1,774,493
3300	3320	Type 4 Slope Protection	Type 4 Armour Stone	9,381	m3	51	477,962	-	-		-	477,962	25%	119,490	597,452
3300	3330	Breakwater Driving Surface	Type 4 Aggregate	671	m3	25	16,781	-	-		-	16,781	25%	4,195	20,977
3300	3330	Breakwater Driving Subbase	Type 2 Aggregate	1,074	m3	31	33,294	-	-		-	33,294	25%	8,324	41,618
3300	3330	South Breakwater				-		-							
3300	3330	Breakwater Core	Type 1 Aggregate	19,750	m3	41	809,750	-	-		-	809,750	25%	202,438	1,012,188
3300	3330	Type 1 Slope Protection	Type 1 Armour Stone	15,735	m3	51	801,698	-	-		-	801,698	25%	200,425	1,002,123
3300	3330	Type 4 Slope Protection	Type 4 Armour Stone	5,740	m3	51	292,740	-	-		-	292,740	25%	73,185	365,925
3300	3330	Breakwater Driving Surface	Type 4 Aggregate	438	m3	25	10,938	-	-		-	10,938	25%	2,734	13,672
3300	3330	Breakwater Driving Subbase	Type 2 Aggregate	700	m3	31	21,700	-	-		-	21,700	25%	5,425	27,125

3300	3340	Sealift and Boat Parking Area and Ramp				-		-							
3300	3340	Parking Area Driving Surface	Type 4 Aggregate	6,280	m3	25	159,983	-	-		-	159,983	25%	39,996	199,979
3300	3340	Parking Area Driving Subbase	Type 2 Aggregate	7,850	m3	31	239,975	-	-		-	239,975	25%	59,994	299,968
3300	3340	Sealift and Boat Ramp Driving Surface	Type 3 Aggregate	439	m3	25	11,177	-	-		-	11,177	25%	2,794	13,971
3300	3340	Parking Core	Type 1 Aggregate	31,400	m3	28	863,908	-	-		-	863,908	25%	215,977	1,079,885
3300	3340	Sealift and Boat Ramp Core	Type 1 Aggregate	3,068	m3	28	84,410	-	-		-	84,410	25%	21,102	105,512
3400	3430	Small Craft Floats				-		-							
3400	3430	Supply and Install	Performance Specification	600	m2	1,500	900,000	-	-	10%	90,000	990,000	25%	247,500	1,237,500
3400	3430	Anchor System		1	LS	70,000	70,000	-	-	10%	7,000	77,000	25%	19,250	96,250
3500	3510	Electrical				-		-							
3500	3510	QEC Power Supply to Site	Includes all necessary poles, wires, transformers, etc.	1	LS	50,000	50,000	-	-	10%	5,000	55,000	25%	13,750	68,750
3500	3510	QEC Area Lighting	Area lighting for sealift laydown	1	LS	50,000	50,000	-	-	10%	5,000	55,000	25%	13,750	68,750
3500	3510	QEC North Breakwater Navigation Lighting	To include all trenching/backfilling, cables, poles, and lights.	1	LS	50,000	50,000	-	-	10%	5,000	55,000	25%	13,750	68,750
3500	3510	QEC South Breakwater Navigation Lighting	To include all trenching/backfilling, cables, poles, and lights.	1	LS	50,000	50,000	-	-	10%	5,000	55,000	25%	13,750	68,750
DIRECT COST SUB TOTAL							**36,995,262**		**54,007,000**	**0%**	**117,000**	**91,119,262**	**25%**	**22,779,816**	**113,899,078**

INDIRECT COSTS

3900	3910	Site Survey Control Setup		1	LS		-	25,000	25,000		-	25,000	25%	6,250	31,250
3900	3910	Pre-Construction Bathymetric and Topographic Survey	Including quantity adjustments	1	LS		-	25,000	25,000		-	25,000	25%	6,250	31,250
3900	3910	Quarry Royalties Costs	@$1.75/m3	77,000	m3		-	1.75	134,750		-	134,750	25%	33,687.50	168,438
3900	3910	Quarry to Site Haul Road Upgrades	Temporary Haul Road	1	LS		-	1,000,000	1,000,000		-	1,000,000	25%	250,000	1,250,000
3900	3910	Quarry to Site Haul Road Maintenance	inc. in contractor unit rates	1	LS		-	-	-		-	-		-	-
3900	3910	Hotel Room Expansion Module	assumed cost - based on modular unit rental for 24 months	1	LS		-	180,000	180,000		-	180,000	25%	45,000	225,000
3900	3910	Temporary Fuel Storage Tanks	assumed not required	1	LS		-	-	-		-	-		-	-
3900	3910	Establish construction/laydown area	allowance for grading and setup	1	LS		-	50,000	50,000		-	50,000	25%	12,500	62,500
3900	3910	Temporary power/lighting	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Site fencing/security	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Temporary Buildings	site office trailers; tool cribs; porta-potties; etc. inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Temporary signage	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Janitorial and Cleaning Services	24 months duration (assumed local staff)	1	LS		-	12,000	12,000		-	12,000	25%	3,000	15,000
3900	3910	Snow Management	allowance	1	LS		-	10,000	10,000		-	10,000	25%	2,500	12,500
3900	3910	Ice Management		1	LS		-	150,000	150,000		-	150,000	25%	37,500	187,500
3900	3910	Site Bussing (Driver services)	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Warehousing and material receiving	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Health and Safety	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Commissioning and start-up	minimal allowance	1	LS		-	10,000	10,000		-	10,000	25%	2,500	12,500
3900	3910	Insurances	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Site Surveys and Mapping Services	allowance	1	LS		-	100,000	100,000		-	100,000	25%	25,000	125,000
3900	3910	Environmental monitoring and testing services	allowance	1	LS		-	100,000	100,000		-	100,000	25%	25,000	125,000
3900	3910	Contractor LOA and travel	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Logistics and freight for materials	inc. in s/c unit rates in direct costs				-		-		-	-		-	-
INDIRECT COST SUB TOTAL							**-**		**1,796,750**	**0%**	**-**	**1,796,750**	**25%**	**449,188**	**2,245,938**

OTHER COSTS

3900	3910	EPCM - EXCLUDED	excluded				-		-		-	-		-	-
3900	3910	OWNERS COSTS - EXCLUDED	excluded				-		-		-	-		-	-
3900	3910	Engineering /Planning/ Regulatory		1	LS		-	6,000,000	6,000,000		-	6,000,000	0%	-	6,000,000

3900	3910	Research Project	DFO Compensation	1	LS		-	500,000	500,000		-	500,000	25%	125,000	625,000
OTHER COST SUB TOTAL							**-**		**6,500,000**	**0%**	**-**	**6,500,000**	**2%**	**125,000**	**6,625,000**
TOTAL												**99,416,012**	**23%**	**23,354,003**	**122,770,015**

NOTES:

1 Estimate based on 2nd Quarter 2022 Canadian dollars

2 Estimate based on Feasibility Phase

ESTIMATE - Sanirajak Option 4

CLIENT:	Municipality of Sanirajak	**DATE:**	12-Aug-22
PROJECT TITLE:	Sanirajak - Marine Infrastructure Planning Study	**DISCIPLINE:**	Estimating
PROJECT No.:	317086-32238	**ORIGINATOR:**	P.Jiang
REVISION:	A	**CHECKER:**	H.Kullman
ACCURACY:	Class D	**APPROVER:**	H.Kullman

DIRECT COSTS

WBS 2	WBS 3	Description	Remarks	Qty	Unit	S/C Costs/Unit ($)	S/C Total ($)	Other/Unit ($)	Other Total ($)	Allowance %	Allowance ($)	Sub Total ($)	Contingency %	Contingency ($)	Total ($)
3100	3110	Mobilisation													
3100	3110	All construction equipment & supplies		1	LS	-	-	17,323,000	17,323,000		-	17,323,000	25%	4,330,750	21,653,750
3100	3110	Overwintering Allowance		1	LS	-	-	4,076,000	4,076,000		-	4,076,000	25%	1,019,000	5,095,000
3100	3120	Demobilisation				-		-							
3100	3120	Demobilisation		1	LS	-	-	2,038,000	2,038,000		-	2,038,000	25%	509,500	2,547,500
3200	3210	Dredge				-		-							
3200	3210	Dredge Materials		2,400	m3	61	146,736	-	-		-	146,736	25%	36,684	183,420
3300	3310	Basin Excavation				-		-							
3300	3310	Strip Surface Soils		1	LS		-	200,000	200,000		-	200,000	25%	50,000	250,000
3300	3310	Drainage Control		1	LS		-	200,000	200,000		-	200,000	25%	50,000	250,000
3300	3310	Blast Berms	Added protection for adjacent houses	1	LS		-	100,000	100,000		-	100,000	25%	25,000	125,000
3300	3310	Drill/Blast/Excavate ROQ	Stockpile nearby for future use by hamlet. Include allowance at $15/cm for working with blast mats.	292,000	m3	65	18,980,000	-	-		-	18,980,000	25%	4,745,000	23,725,000
3300	3310	Entrance Blast	allowance for complexity of final blast and flooding	1	LS	-	-	500,000	500,000		-	500,000	25%	125,000	625,000
3300	3310	Manufacture Type 1 Fill	Run of Quarry	79,000	m3	-	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 2 Fill	200mm minus, Crushing and Screening	5,000	m3	20	101,900	-	-		-	101,900	25%	25,475	127,375
3300	3310	Manufacture Type 3 Fill	150mm clear, Crushing and Screening	-	m3	25	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 4 Fill	38mm minus, Crushing and Screening	4,000	m3	40	161,573	-	-		-	161,573	25%	40,393	201,966
3300	3310	Manufacture Type 5 Fill	Bedding Sand (reclaimed)	-	m3	25	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 1 Armour	D50=1500mm, Sorting Run of Quarry	-	m3	20	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 1 Armour Surplus Stockpile	D50=1500mm, Sorting Run of Quarry		m3	20	-	-	-		-	-	25%	-	-
3300	3310	Manufacture Type 4 Armour	Select Run of Quarry	-	m3	20	-	-	-		-	-	25%	-	-
3300	3320	Side Berms				-		-							
3300	3320	Side Berm Core Fill	Type 1 Aggregate	55,750	m3	28	1,533,850	-	-		-	1,533,850	25%	383,462	1,917,312
3300	3340	Boat Parking Area and Ramp				-		-							
3300	3340	Parking Area Driving Surface	Type 4 Aggregate	4,145	m3	25	105,594	-	-		-	105,594	25%	26,398	131,992
3300	3340	Parking Area Driving Subbase	Type 2 Aggregate	5,181	m3	31	158,391	-	-		-	158,391	25%	39,598	197,989
3300	3340	Boat Ramp Driving Surface	Type 3 Aggregate	300	m3	25	7,643	-	-		-	7,643	25%	1,911	9,553
3300	3340	Parking Core	Type 1 Aggregate	20,625	m3	28	567,456	-	-		-	567,456	25%	141,864	709,320
3300	3340	Boat Ramp Core	Type 1 Aggregate	2,587	m3	28	71,167	-	-		-	71,167	25%	17,792	88,959
3400	3430	Small Craft Floats				-		-							
3400	3430	Supply and Install	Performance Specification	600	m2	1,500	900,000	-	-	10%	90,000	990,000	25%	247,500	1,237,500
3400	3430	Anchor System		1	LS	70,000	70,000	-	-	10%	7,000	77,000	25%	19,250	96,250
3500	3510	Electrical				-		-							
3500	3510	QEC Power Supply to Site	Includes all necessary poles, wires, transformers, etc.	1	LS	50,000	50,000	-	-	10%	5,000	55,000	25%	13,750	68,750
3500	3510	QEC Area Lighting	Area lighting for sealift laydown	1	LS	200,000	200,000	-	-	10%	20,000	220,000	25%	55,000	275,000
3500	3510	Navigation Lighting	To include all trenching/backfilling, cables, poles, and lights.	1	LS	50,000	50,000	-	-	10%	5,000	55,000	25%	13,750	68,750
DIRECT COST SUB TOTAL							**23,104,308**		**24,437,000**	**0%**	**127,000**	**47,668,308**	**25%**	**11,917,077**	**59,585,385**

INDIRECT COSTS

3900	3910	Site Survey Control Setup		1	LS		-	25,000	25,000		-	25,000	25%	6,250	31,250
3900	3910	Pre-Construction Bathymetric and Topographic Survey	Including quantity adjustments	1	LS		-	25,000	25,000		-	25,000	25%	6,250	31,250
3900	3910	Quarry Royalties Costs	@$1.75/m3	88,000	m3		-	1.75	154,000		-	154,000	25%	38,500.00	192,500
3900	3910	Quarry to Site Haul Road Upgrades	Temporary Haul Road	1	LS		-	1,000,000	1,000,000		-	1,000,000	25%	250,000	1,250,000
3900	3910	Quarry to Site Haul Road Maintenance	inc. in contractor unit rates	1	LS		-	-	-		-	-		-	-
3900	3910	Hotel Room Expansion Module	assumed cost - based on modular unit rental for 24 months	1	LS		-	180,000	180,000		-	180,000	25%	45,000	225,000
3900	3910	Temporary Fuel Storage Tanks	assumed not required	1	LS		-	-	-		-	-		-	-
3900	3910	Establish construction/laydown area	allowance for grading and setup	1	LS		-	50,000	50,000		-	50,000	25%	12,500	62,500
3900	3910	Temporary power/lighting	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Site fencing/security	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Temporary Buildings	site office trailers; tool cribs; porta-potties; etc. inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Temporary signage	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Janitorial and Cleaning Services	24 months duration (assumed local staff)	1	LS		-	12,000	12,000		-	12,000	25%	3,000	15,000
3900	3910	Snow Management	allowance	1	LS		-	10,000	10,000		-	10,000	25%	2,500	12,500
3900	3910	Ice Management		1	LS		-	150,000	150,000		-	150,000	25%	37,500	187,500
3900	3910	Site Bussing (Driver services)	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Warehousing and material receiving	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Health and Safety	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Commissioning and start-up	minimal allowance	1	LS		-	10,000	10,000		-	10,000	25%	2,500	12,500
3900	3910	Insurances	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Site Surveys and Mapping Services	allowance	1	LS		-	100,000	100,000		-	100,000	25%	25,000	125,000
3900	3910	Environmental monitoring and testing services	allowance	1	LS		-	100,000	100,000		-	100,000	25%	25,000	125,000
3900	3910	Contractor LOA and travel	inc. in contractor unit rates				-		-		-	-		-	-
3900	3910	Logistics and freight for materials	inc. in s/c unit rates in direct costs				-		-		-	-		-	-
INDIRECT COST SUB TOTAL							**-**		**1,816,000**	**0%**	**-**	**1,816,000**	**25%**	**454,000**	**2,270,000**

OTHER COSTS

3900	3910	EPCM - EXCLUDED	excluded				-		-		-	-		-	-
3900	3910	OWNERS COSTS - EXCLUDED	excluded				-		-		-	-		-	-
3900	3910	Engineering /Planning/ Regulatory		1	LS		-	5,500,000	5,500,000		-	5,500,000	0%	-	5,500,000
3900	3910	Research Project	DFO Compensation	1	LS		-		-		-	-	25%	-	-
OTHER COST SUB TOTAL							**-**		**5,500,000**	**0%**	**-**	**5,500,000**	**0%**	**-**	**5,500,000**
TOTAL												**54,984,308**	**22%**	**12,371,077**	**67,355,385**

NOTES:

1 Estimate based on 2nd Quarter 2022 Canadian dollars

2 Estimate based on Feasibility Phase