CSR GeoSurveys Limited

GEOPHYSICAL & GEOTECHNICAL SURVEY REPORT
PICTOU HARBOUR AND CARIBOU HARBOUR
PROPOSED PIPELINE CORRIDORS

Submitted to:

NORTHERN PULP
NOVA SCOTIA CORPORATION
A PAPER EXCELLENCE COMPANY

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STATEMENT OF QUALITY

CSR GeoSurveys Ltd. warrants that its service with respect to this study was performed with a degree of skill and care equal to or greater than that ordinarily exercised under similar conditions by reputable members of our profession practising in the same or similar locality. No other warranty, expressed or implied, is made or intended. Geophysical surveying is a remote sensing method that may not detect all surface or subsurface features of interest or concern.

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EXECUTIVE SUMMARY

A new wastewater treatment plant is being proposed to replace the Boat Harbour system. The treated effluent from the new facility is proposed to be discharged into the Northumberland Strait outside Caribou Harbour. Two sections of the proposed pipeline route are located in marine areas; Pictou Harbour and Caribou Harbour. CSR GeoSurveys conducted marine geophysical, geotechnical and harbour bottom video investigations to gain an understanding of the bathymetry, geology, surficial features, benthic habitats and archeological resources within the Pictou Harbour and Caribou Harbour survey corridors.

Marine survey operations were conducted during April and May 2019. The survey equipment included multibeam sonar, sidescan sonar, marine magnetometer, boomer shallow seismic system, chirp sub-bottom profiler, seismic refraction, and underwater video system. Grab samples were collected to aid the surficial interpretation and vibracores were collected to support the geotechnical and environmental testing of sediments.

The Pictou Harbour survey corridor parallels the Pictou Causeway from Abercrombie Point to the northern end of the Pictou Causeway. The Caribou Harbour survey corridor extended from the ferry terminal located on the southern shoreline of Caribou Harbour to the proposed outfall location in the Northumberland Strait. Kilometre Postings (KP) were generated for the Pictou Harbour proposed pipeline route from Abercrombie Point (PKP 0) to the Pictou Causeway (PKP 1.582). Kilometre Postings were also generated for the Caribou Harbour proposed pipeline route adjacent to the ferry terminal (CKP 0) to the outfall location in the Northumberland Strait (CKP 3.604). The geophysical data were referenced to NAD83 (CSRS) and Chart Datum (LLWLT).

The bathymetry over the proposed Pictou Harbour pipeline route is relatively flat and shallow immediately offshore of Abercrombie Point. The old West River channel is located between PKP 0.460 and PKP 0.965 with a maximum depth of 9.9 m. The remainder of the proposed pipeline route occurs over a flat shallow seabed to the Pictou Causeway toe at PKP 1.415.

The bathymetry along the Caribou Harbour proposed pipeline route ranges from 0.2 m to 19.1 m. The seabed is generally flat between CKP 0.100 and CKP 0.400 with water depths ranging from 1.2 m to 2.8 m. The proposed pipeline route transects a channel within Caribou Harbour between CKP 0.400 and CKP 0.675 with a maximum depth of 6.8 m. North of the channel, water depths remain very shallow as the proposed route approaches and crosses Gull Spit. At CKP 2.270, the seabed begins to deepen as the proposed route follows a gradual slope towards the Caribou Channel to the end of the proposed route at CKP 3.604 (outfall location) where the water depth is 19.04 m below Chart Datum or 20.2 m below Mean Water Level.

The sidescan data were interpreted visually to identify and map surficial geological boundaries and seabed features. To support the interpretation, grab samples, vibracores and underwater video were correlated with the geophysical data.

The surficial geology of the Pictou Harbour survey corridor is dominated by an extensive area of silt with local areas of cobble and boulders interpreted as outcropping glacial till.

The surficial geology of the Caribou Harbour survey corridor is dominated by extensive areas of sand and gravel. An area of finer grained sediments including clayey silt, silt and sandy silt occurs nearshore. From CKP 0.667 to the proposed pipeline outfall location (CKP 3.604) the seabed is comprised of sand, silty sand and sand/gravel.

Three areas of bed-forms caused by sediment transport have been identified within the Caribou Harbour survey corridor. These sediment transport features occur in non-cohesive sand produced by currents and or waves. Sediment transport features observed adjacent to the proposed outfall location include megaripples and sand waves. These features were likely formed by currents with near bed-flow velocity of 40 to 100 cm/s (Amos & King, 1984). The near bed-flow direction that formed these features was moving in either a northeast or southwest direction. No sediment transport features were observed at the proposed outfall which may indicate an increase in gravel within the surficial sediments at this location.

The sub-bottom geology in the Pictou Harbour and Caribou Harbour survey corridors was mapped from chirp profiler, boomer sub-bottom and seismic refraction data. Identification of geological sequences was based on the internal characteristics of each sequence and correlation with the vibracore sampling.

Four major reflectors, R1 through R3 and Acoustic Basement, were identified and mapped from the sub-bottom data along the proposed pipeline routes as well as areas of shallow gas. CSR identified four main sub-bottom geological sequences.

Sequence 1 consists primarily of soft silt and clay with occasional sandy lenses. Sequence 2 is common throughout the Caribou Harbour survey corridor and is composed of sand & gravel. Sequence 3 consists of proglacial sediments composed of clay, silty sand and gravel. In the Caribou Harbour survey corridor a distinct reflector was observed within Sequence 3. As a result the Sequence was subdivided into Sequence 3a and Sequence 3b. Sequence 4 has been interpreted as glacial till consisting of poorly sorted, sub-rounded, coarse gravel with finer sediment. Cobbles and boulders may also be present in this sequence and could be concentrated in the upper sequence as a relict lag deposit. Onshore the glacial till includes a surface boulder layer in some areas and a stony sandy facies.

The acoustic basement reflector was interpreted as the top of bedrock or boulder rich glacial till. The acoustic basement over the proposed pipeline was usually faint and discontinuous. Within the Pictou Harbour corridor the acoustic basement was observed over the old West River Channel. Within the offshore Caribou Harbour survey corridor the acoustic basement was discernable within the boomer sub-bottom data. The acoustic basement was difficult to map over the nearshore section of the proposed Caribou Harbour pipeline route as a result of shallow gas, shallow water multiples in the seismic data, and the presence of Sequence 4 (glacial till) near the seabed. As a result, seismic refraction data was collected in this area to aid in the interpretation of the depth to bedrock.

The seismic refraction data indicates bedrock velocities in the range of 2000 m/s to 2700 m/s which are typical of sandstone and shale. Velocities in the mid 2000 m/s range may be representative of a weathered and/or fractured bedrock zone. The calculated velocity of bedrock from refraction modelling indicates the rock quality is very poor at the bedrock surface.

There are three areas along the proposed Caribou Harbour pipeline route where glacial till encroaches within the planned trench depth of 3 m. It is also uncertain whether bedrock will be encountered during installation of the pipeline in these areas. The areas have been identified on the interpreted geological profiles as an area where dredging may be constrained due to the sub-bottom geology. The glacial till sequence in Caribou Harbour is interpreted as sub-angular to angular coarse gravel, sand, silt, cobble and possible boulders. Considering the seismic velocities modelled increase with depth, it is likely the bedrock surface is weathered and in the rippable range. The rippability of bedrock is a measure of its ability to be excavated with conventional excavation equipment.

Within the Northumberland Strait, ice scouring is the process whereby ice ridges contact the seabed forming linear gouges in the seabed sediments. The extent and thickness of Northumberland Strait ice is influenced by winter temperatures, severity and duration of storms as well as wind direction. Strong winds can cause ice to fracture and pile up into ridges by compression or shear in the ice cover and are typically found in the shear zone between the landfast ice and the drift or pack ice. Subsequent movement of these ridges can cause their keels to scour the seabed sediments. The scour depth parameter is perhaps the most important measurement in estimating the minimum trenching depths required for a pipeline installation.

During this study ice scour features were identified through an examination of multibeam and sidescan sonar data acquired during the 2019 geophysical survey in order to characterize those ice scours that could pose a risk to the pipeline. One-hundred and forty-six ice scours were identified from the geophysical data. Thirteen ice scours occur within the Pictou survey corridor while one-hundred and thirty-three ice scours were observed within the Caribou area. The ice scour survey was conducted in early spring soon after the break-up of ice in the Northumberland Strait. This was the ideal time to survey in order to identify and measure the ice scours before they degrade.

The ice scours observed within the Pictou Harbour survey corridor all occur offshore of Abercrombie Point within water depths ranging from 2 m to 3 m. The deepest ice scour observed was 0.3 m. The ice scours observed within the Caribou area occur within water depths ranging from 1 m to 9 m. The age of the ice scours is not known but they were likely formed during the winter of 2018/2019. No ice scours were observed within the area of the proposed diffuser. Of the one-hundred and thirty-three ice scours observed in the Caribou area only fifteen had a scour depth ≥ 0.2 m with a maximum recorded depth of 0.4 m. Within the nearshore Caribou Harbour area west of Munroes Island the seabed includes an area that may have been disturbed as a result of ice grounding. The area is approximately 70 m by 100 m and includes small pit features that have a maximum depth of 0.7 m. The water depth within this area ranges from 2 to 3 m and the surficial sediments are sand and gravel. The age of the features is not known.

CSR utilized both sidescan sonar data and marine magnetometer data to identify anthropogenic features in the survey corridors. CSR provided all sidescan sonar data and magnetic anomalies mapped from the marine magnetometer data to Stantec for detailed analysis by a marine archaeologist.

In total, 43 sidescan sonar contacts representing possible anthropogenic features on the seabed were mapped in the Pictou Harbour survey corridor while 7 sidescan sonar contacts were mapped in the Caribou Harbour survey corridor. Seven magnetic anomalies were mapped in the Caribou Harbour survey corridor while 31 were mapped in the Pictou Harbour survey corridor.

A harbour bottom video investigation was conducted to analyze the benthic habitat, ground truth seabed sediment types to support the surficial geology interpretation, and to examine anthropogenic seabed contacts present in the Pictou Harbour and Caribou Harbour survey corridors.

1.0 INTRODUCTION

1.1 BACKGROUND

The Northern Pulp Nova Scotia Corporation (NPNS) kraft pulp mill located on Abercrombie Point near the town of New Glasgow, Nova Scotia has been in operation since 1967. Originally built by Scott Paper, the mill has seen several ownership changes until its purchase in 2011 by Paper Excellence Canada. The mill produces bleached kraft market pulp.

At the time of construction, the Government of Nova Scotia agreed to build and operate a treatment system for the mill's process effluent. This system was built in the western portion of an area known as Boat Harbour in Pictou Landing. The aerated lagoon system was refurbished in 1996, at which time the mill took over operations of the system. The current effluent treatment system is located 3.5 km east of the mill across the East River and consists of constructed sedimentation basins, followed by aeration in a natural basin equipped with baffle curtains, which direct effluent flow to prevent channeling. A large natural final polishing/stabilization basin follows, prior to release into the Northumberland Strait.

A new wastewater treatment plant is being proposed to replace the Boat Harbour system. This proposed wastewater treatment system includes a treatment facility located on the Northern Pulp property on Abercrombie Point. The treated effluent from the new facility is proposed to be discharged into the Northumberland Strait at an engineered outfall location outside Caribou Harbour. A pipeline is proposed to carry the effluent from the new treatment facility on Abercrombie Point to the outfall location. Two sections of the proposed pipeline route are located in marine areas; Pictou Harbour and Caribou Harbour. To support the engineering design and environmental assessment of these two marine pipeline crossings, an extensive marine geophysical, geotechnical and harbour bottom video investigation was completed.

CSR GeoSurveys Ltd. (CSR) was contracted by NPNS to execute the marine geophysical, geotechnical and harbour bottom video investigations required for the engineering design and environmental assessment of the proposed marine pipeline route and outfall. The marine investigations were required in Pictou Harbour, east of the Pictou Causeway, and in Caribou Harbour extending from the ferry terminal to the proposed outfall location approximately 3.6 kilometres offshore within the Northumberland Strait. The two marine survey corridors are shown on the project location map, see Figure 1.1.1.

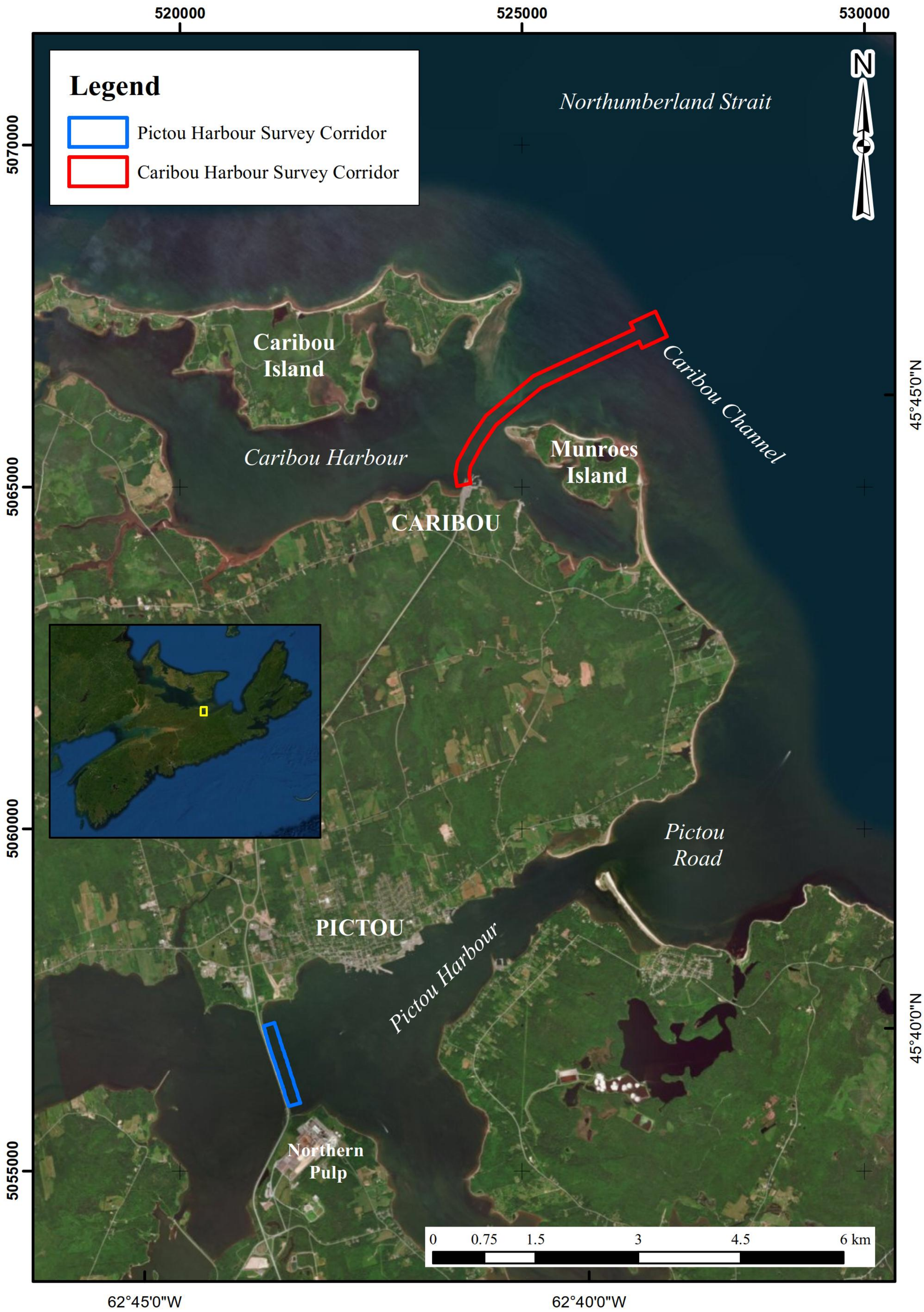

Figure 1.1.1 – Project location map.

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1.2 Project Team

CSR sub-contracted Stantec Consulting Ltd. (Stantec) to support the geotechnical survey and harbour bottom video investigation. Huntley's Sub-Aqua Construction Ltd. (Huntley) was sub-contracted by CSR to provide vessel services during field operations.

Makai Ocean Engineering Inc. (Makai) was retained by NPNS to support the design and installation of marine components of the project.

1.3 Pre-Survey Route Selection

The proposed Pictou Harbour pipeline route was undetermined prior to the survey execution. The exit point from the mill, where the pipeline enters Pictou Harbour, will be located within the boundaries of the mill property. Based on discussions between CSR and NPNS, it was anticipated that the marine route would parallel the Pictou Causeway without encroaching on the causeway footprint until the northern landfall. A suitable distance between the marine pipeline route and the causeway toe of slope was required to avoid possible hazards to the pipeline and/or causeway. The survey corridor in Pictou Harbour extended approximately 200 m east of the Pictou Causeway centerline. The final proposed route in Pictou Harbour was selected based on survey data collected by CSR.

The proposed Caribou Harbour pipeline route was developed through collaboration between NPNS, CSR and Makai. NPNS provided the concept route location. Evaluation by CSR and Makai resulted in minor adjustments to the concept route. The proposed Caribou Harbour route was centered within a 200 m wide survey corridor extending from the ferry terminal to the outfall location in the Northumberland Strait. The proposed outfall location was centered inside a 400 m x 400 m diffuser survey area which was included in the marine geophysical, geotechnical and harbor bottom video investigations.

1.4 Survey Objectives

Marine geophysical, geotechnical and harbour bottom video investigations were required to gain an understanding of the bathymetry, geology, surficial features, benthic habitats and possible archeological resources within the Pictou Harbour and Caribou Harbour survey corridors.

The objectives of the marine surveys were accomplished through the collection, interpretation and subsequent reporting of the acquired datasets. The following datasets were acquired:

- Differential GPS and/or RTK-GPS positioning provided real-time geo-referencing of all datasets acquired during the marine surveys.

- Seabed bathymetry data were collected using a multibeam echosounder. Vessel motion heading, and sound velocity profiler data were collected in conjunction with the multibeam echosounder data.

- Sidescan sonar data were acquired to categorize surficial sediment types, benthic habitat types and to identify potential hazards or constraints to the pipeline installation exposed at the surface of the seabed.

- High-resolution chirp profiler data were acquired during the geophysical survey to aid in the characterization of the sub-surface geology.

- High-resolution single channel seismic reflection data were acquired during the geophysical survey to map the sub-surface geological conditions and aid in the delineation of the top of bedrock.

- Marine refraction data were collected to assist in the delineation of bedrock and provide information on bedrock velocity/competency.

- Marine magnetometer data were collected to identify the presence and location of ferrous targets located on or under the seabed along the proposed pipeline routes.

- High-resolution, geo-referenced underwater video was collected to aid in the mapping of benthic habitats in the survey corridors and to examine possible archeological resources identified during the field program.

- Grab samples were collected to ground truth the interpretation of the sidescan data and support surficial geological mapping.

- Vibracores were collected to ground truth the surficial and sub-bottom geology interpretation and to acquire seabed material required for geotechnical and environmental testing.

1.5 Report Overview

This section presents a general overview of the report structure. Table 1.5.1 defines the abbreviations used throughout the report.

Section 2 of the report provides information on the Northumberland Strait regional setting, ice scour, and geology. Section 3 includes a discussion of the survey operations including survey equipment and survey coverage. Section 4 includes a discussion on data processing and interpretation methodologies. The results of the processing, interpretation and geological mapping are documented in Section 5. This section is followed by a project summary in Section 6 and recommendations in Section 7. References can be found in Section 8.

Four Appendices and nine Enclosures accompany this report.

Table 1.5.1 – Abbreviation Definitions

Acronym	Definition
AB	Acoustic Basement
CD	Chart Datum
CHS	Canadian Hydrographic Service
CKP	Caribou Kilometre Posting
cm	Centimetre
CSR	CSR GeoSurveys Ltd.
CSRS	Canadian Spatial Reference System
DGPS	Differential Global Positioning System
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
Hz	Hertz
IMU	Inertial Measurement Unit
ka	Thousands of Years Before Present
kg	Kilogram
kHz	Kilohertz
km	Kilometre
kN	Kilonewton
KP	Kilometre Posting
kw	Kilowatt
LLWLT	Lower Low Water Large Tide
ma	Million Years Before Present
m	Metres
mm	Millimetre
m/s	Metres/second
msec	Millisecond
NAD	North American Datum of 1983
NPNS	Northern Pulp Nova Scotia Corporation
NS	Nova Scotia

Acronym	Definition
nT	NanoTesla
OSM	Over the Side Mount
PC	Personal Computer
P. Geo.	Professional GeoScientist
PKP	Pictou Kilometre Posting
ppm	Part Per Million
RMS	Root Mean Squared
RTK	Real-time kinematic
SBP	Sub-bottom Profiler
SGY	Society of Exploration Geophysicists Data Format
SSS	Sidescan Sonar
SVP	Sound Velocity Profile
TPU	Transceiver and Processing Unit
TVG	Time Varied Gain
UTM	Universal Transverse Mercator
vpm	Vibrations per Minute
WAAS	Wide Area Augmentation System
ya	Years Before Present

2.0 REGIONAL SETTING

2.1 PHYSIOGRAPHY

Pictou Harbour

Pictou Harbour is located on the north shore of Nova Scotia on the Northumberland Strait. The harbour is oriented in a NE-SW direction, see Figure 1.1.1. The distance from the mouth of Pictou Harbour to the Pictou Causeway is approximately five kilometres and the average width of the Harbour is approximately one kilometre. Three rivers flow into Pictou Harbour, the East River, Middle River and West River. Pictou Harbour separates the Town of Pictou (on the northwest shore of the harbour) and Pictou Landing (on the southeast shore of the harbour). Water depths reach a maximum depth of approximately 15 metres in the center of the harbour with shoal areas extending offshore from each shoreline. The NPNS Kraft mill is located on Abercrombie Point, which is bounded by Pictou Harbour to the north, and flanked to the east and west by the East River and Middle River.

Caribou Harbour

Caribou Harbour is located on the north shore of Pictou County, approximately eight kilometres north of Pictou Harbour, see Figure 1.1.1. Caribou Harbour is bounded by Caribou Island to the north and west and Munroes Island to the east. The harbour is part of the estuarial system created by the tributaries of the Caribou River flowing into the Northumberland Strait. The distance from the ferry terminal to the mouth of Caribou Harbour is approximately two kilometres. A dredged navigation channel extends from the ferry terminal into the Northumberland Strait. Water depths within the harbour reach a maximum depth of approximately nine metres although the majority of the harbour is shallower than four metres. A large natural shoal (Gull Spit) with water depths less than one metre occurs northwest of the navigation channel to Caribou Island.

2.2 ICE AND ICE SCOURING

The Northumberland Strait is completely ice covered during most winters. Significant ice formation begins in late December to early January with ice thickness increasing throughout the winter to a maximum thickness of approximately one metre. Thicker ice formed in the Gulf of St. Lawrence may be transported into the Strait during periods of prevailing northerly winds. Break-up usually occurs after the third week of March and may last up to 2 months. During break-up, ice movement is subject to the influences of both winds and tides. Ice ridges, formed by the collision of ice flows with the land-fast ice edge during periods of ice movement, have corresponding keels that can extend and scour into the seabed.

Ice scours are formed by the interaction of ice keels and the seabed sediments. Linear gouges and lateral berms are formed as the advancing ice keel ploughs through the seabed sediments and pushes material to either side of its path. The resultant textural modification and morphological changes associated with ice scours are ideally suited to detection with sonar technology. Distinctive scour signatures observed on the sonograms include; ridge and groove morphology (scour multiplets), linear back-wall and near-berm reflections, rough berm texture and scour termination berm structures.

This scouring process has long been recognised as a potential hazard to submarine pipeline and cable installations as well as offshore structures. The scour depth parameter is perhaps the most important measurement in estimating the minimum trenching depths required for a sub-sea installation. Scour depth is a variant parameter, depending on a number of factors including size of the scouring ice keel, scour age, sediment infill, bathymetry, physiographic location and the geotechnical soil conditions (Gilbert, 1989). Figure 2.2.1 shows the formation of an ice scour due to pressure ridging at the boundary between land-fast ice and the drifting pack ice.

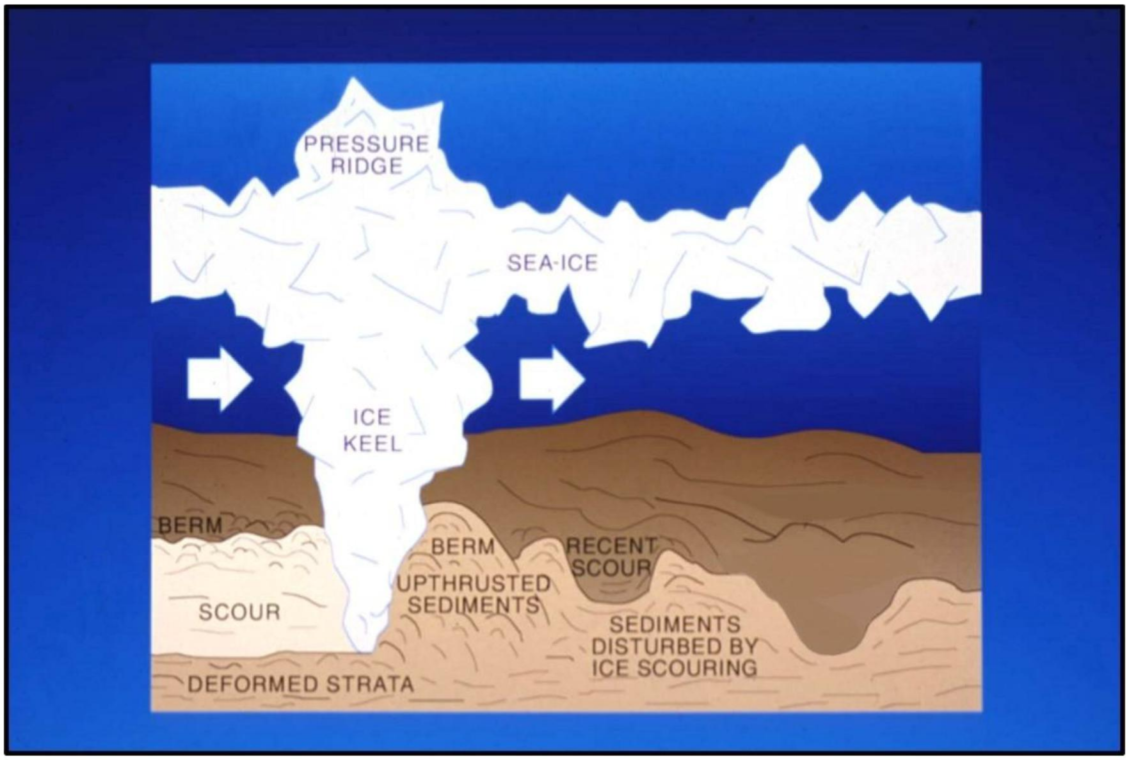

Figure 2.2.1 – The process of Pressure Ridge Ice Scouring (modified from Blasco, 2006).

2.3 Glacial & Post Glacial (Quaternary) Geology

The Quaternary deposits in the Northumberland Strait region consist of glacial sediments, residual sand and gravel and post-glacial sediments (Kranck, 1971). Glacial till typically overlies bedrock, either as continuous cover over large areas, or in small irregular patches (Kranck, 1972). Pro-glacial sediments are generally associated with and overlie the glacial till sequence. In some areas the pro-glacial sediments have a compact structureless appearance and in other areas they are well stratified. These features indicate the pro-glacial units were likely deposited as delta valley trains when the sea encroached the melting ice front. Glacial sequences mapped by Kranck in the area of Pictou Harbour and Caribou Harbour include Pomquet Drift and Henry Island Sediments. The youngest sediments in the Northumberland Strait are post-glacial marine sediments. These sediments range from fine silt to medium sand (Kranck, 1971). Surficial sediment units mapped by Kranck in the area of Pictou Harbour and Caribou Harbour include Pugwash Mud and Buctouche Sand and Gravel.

Onshore surficial geology has been mapped by Stea & Myers (1990), see Figure 2.3.1 and Figure 2.3.2. The areas surrounding Pictou Harbour and Caribou Harbour are dominated by Eatonville-Lawrencetown glacial till. This till is moderately compact to compact reddish brown silty sand till. The clast lithology within the till is 50-95% Carboniferous red and grey sandstones and 5 to 50% erratics. A surface boulder layer occurs in some regions. The till forms fluted, drumlinized and rolling ground moraine up to 15 m thick (Stea & Myers, 1990). A stony sandy facies of the Eatonville-Lawrencetown glacial till occurs on both Abercrombie Point in Pictou Harbour and on Caribou Island adjacent to Gull Spit. This facies is loose to moderately compact with gravelly sand and sand inclusions. The till forms hummocky and ribbed moraine generally in topographic depressions 3 to 20 m thick (Stea & Myers, 1990).

2.4 Bedrock Geology

The northern shore of Pictou County sits at the southern end of the Maritimes Basin, a large composite of several late Paleozoic depocenters which formed during the tectonic activity associated with the Appalachian Orogeny. Along this southern flank of the Maritimes Basin lies the Merigomish Sub-basin, a broad northeast trending trough extending from the Antigonish Highlands in the southeast, to the Cobequid Highlands in the northwest (Stevens et al., 1999). The rocks of the Merigomish Sub-basin are Middle Devonian to Late Carboniferous in age.

Pictou Harbour and Caribou Harbour specifically, are both underlain by undifferentiated Pictou Group sedimentary rocks of Late Carboniferous age. Pictou Group (encompassing the Cape John, Tatamagouche and Balfron Formations) consists of floodplain mudstones, both fluvial and arkosic sandstones, shale, conglomerates and minor to rare occurrences of lacustrine limestone.

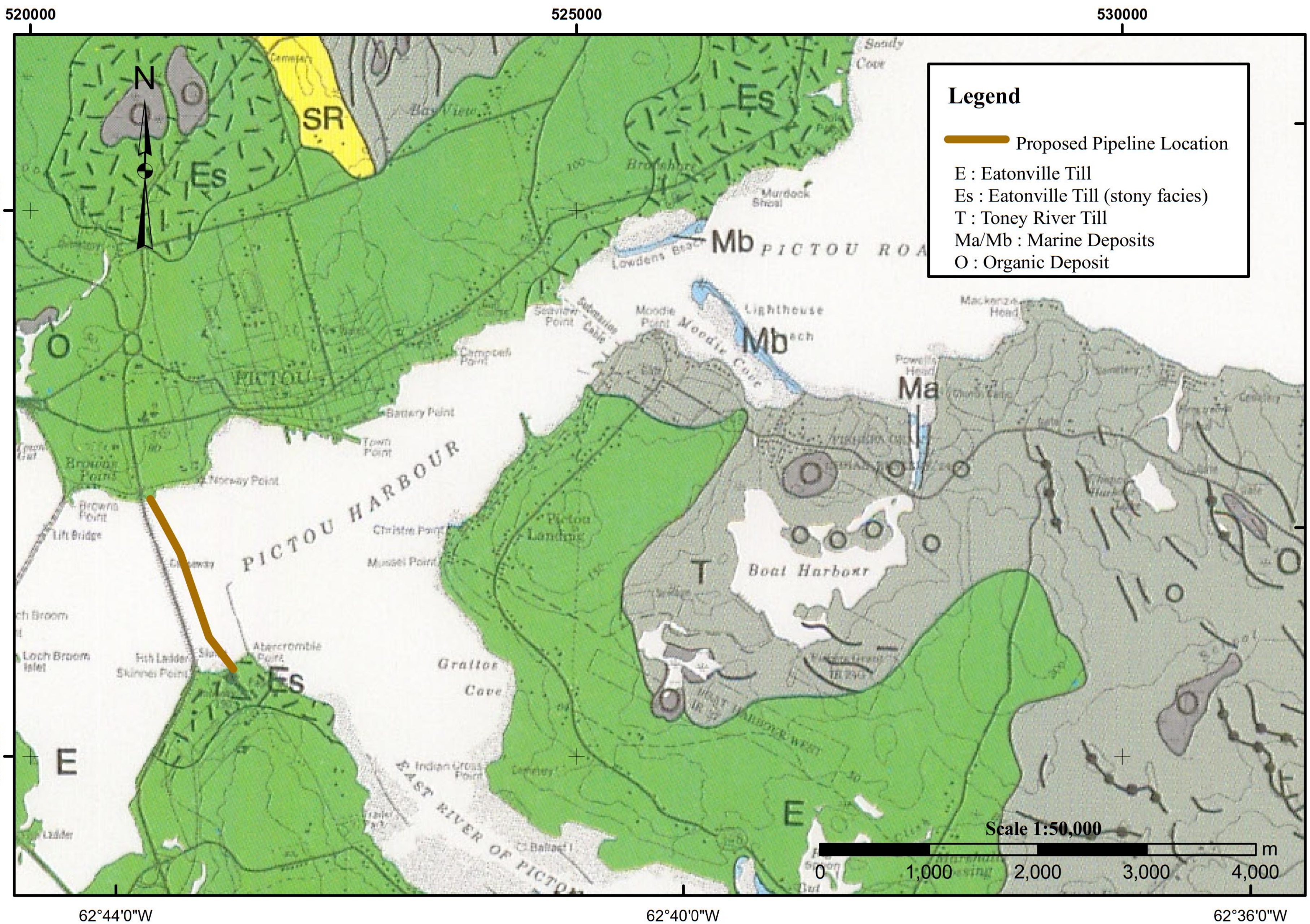

Figure 2.3.1 – Pictou Onshore Surficial Geology (Stea & Myers, 1990).

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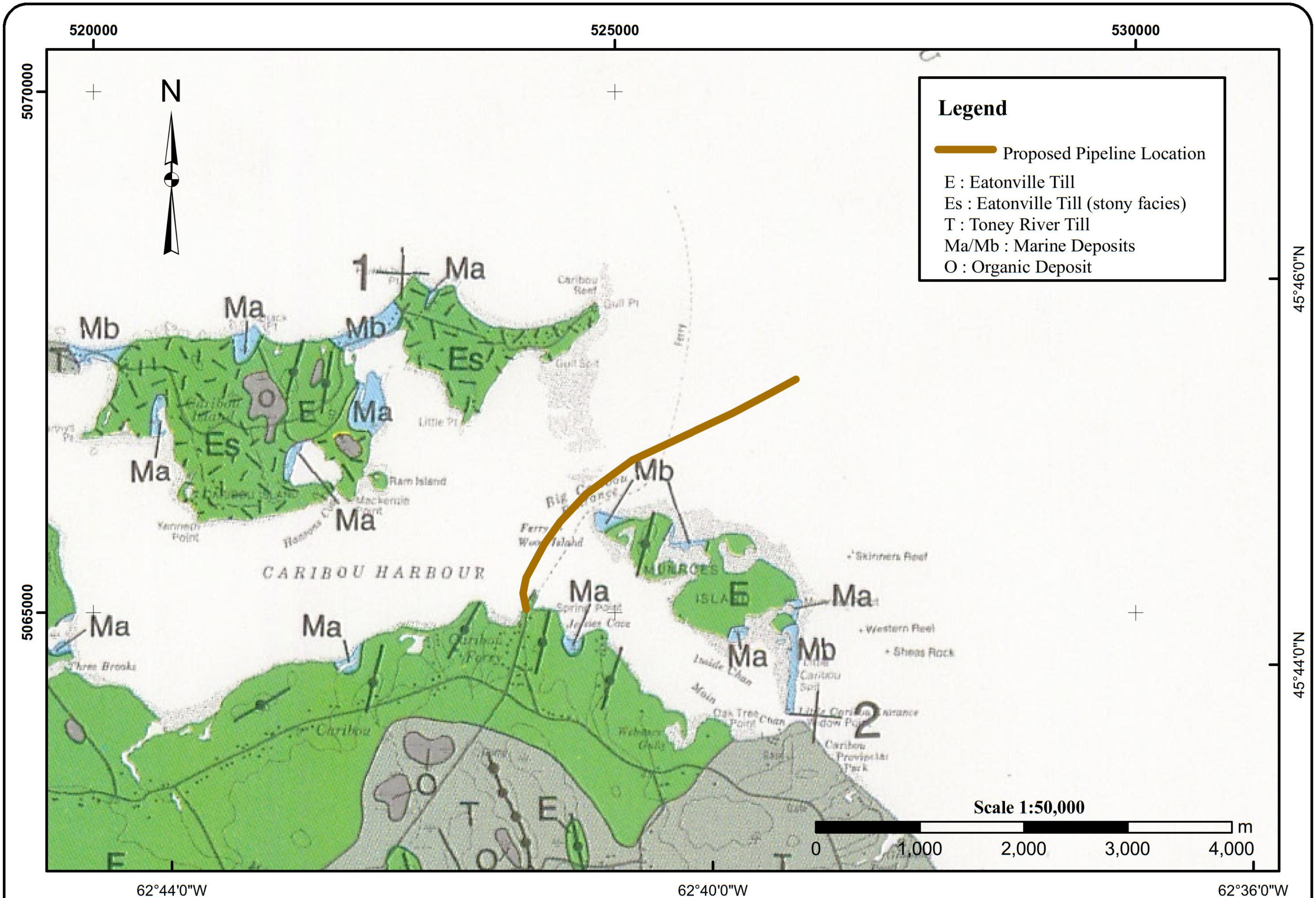

Figure 2.3.2 – Caribou Onshore Surficial Geology (Stea & Myers, 1990).

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3.0 SURVEY OPERATIONS

Marine geophysical, geotechnical and harbour bottom video investigations were required in order to provide information for the engineering design and environmental assessment of the proposed effluent pipeline. This section documents the surveys conducted during April and May 2019.

3.1 Survey Team

The survey team for this project included personnel from CSR, Stantec and Huntley's Sub-Aqua Construction. Table 3.1.1 lists the survey team members including their role on the project.

Table 3.1.1 – Survey Team Personnel

Name	Function	Affiliation
Colin Toole	Party Chief	CSR
Matt Savelle	Hydrographic Surveyor	CSR
Luke Melanson	Marine Geologist	CSR
Cole Gilbert	Vessel Operator/Electronics Technologist	CSR
Mitch Grace	Marine Geophysicist	CSR
Glen Gilbert	Marine Geophysicist	CSR
Dillon Rowe	Field Assistant	CSR
Emile Colpron	Environmental Scientist	Stantec
Paul Sampson	Geotechnical	Stantec
Alex McKenney	Geotechnical	Stantec
Mike Huntley	Vessel Captain	Huntley
Tim Carty	Vessel Alternate Captain	Huntley
Garret Hickey	Vessel Crew	Huntley
Ryan Amero	Vessel Crew	Huntley

3.2 Marine Geophysical Survey

The marine geophysical survey was conducted from April 14th to May 17th, 2019. Geophysical survey operations were conducted from CSR's survey vessel *SeaQuest* (Figure 3.2.1) and Huntley's Sub-Aqua Construction vessel *Nova Endeavor*. Both vessels were mobilized and demobilized at Pier C in Pictou Harbour. Vessel offsets for geophysical equipment used on the survey is presented in Appendix I. Daily survey operations were conducted from Pier C between 7:00 am - 5:00 pm daily unless poor weather conditions resulted in standby. Each morning both vessels transited to an assigned survey area to accomplish specific survey objectives.

Figure 3.2.1 – CSR survey vessel *SeaQuest*.

3.3 Marine Geotechnical Survey

The marine geotechnical survey was conducted from April 25th to May 8th, 2019 using Huntley's Sub-Aqua Construction vessel *Nova Endeavor* (Figure 3.3.1). The vessel was mobilized and demobilized at Pier C in Pictou Harbour. A vibracore sampler was used to collect seabed sediments within both the Pictou Harbour and Caribou Harbour survey corridors. The marine geotechnical survey was supported by a geotechnical technician from Stantec.

Figure 3.3.1 – Huntley's Sub-Aqua Construction vessel *Nova Endeavor.*

3.4 Harbour Bottom Video Investigation

The harbour bottom video investigation was conducted from May 2nd to May 7th, 2019 using CSR's survey vessel *SeaQuest.* The video investigation field operations were supported by an environmental scientist from Stantec.

3.5 Survey Equipment

This section describes the equipment utilized during the marine geophysical, geotechnical and harbour bottom video investigations.

Survey Navigation
Hemisphere VS-330 GNSS Receiver & Heading System
Hemisphere R110 DGPS Receiver
Trimble 5700/5800 RTK-GPS
HYPACK Survey Navigation Software
CAN-NET RTK-GPS Positioning Service

Multibeam Echosounder
Teledyne-Reson SeaBat T-20P Multibeam Echosounder (200-400 kHz)
SBG Ekinox D IMU
Teledyne-Reson SVP
HYSWEEP Multibeam Acquisition System
Odom Digi-Bar Pro Velocimeter

Sidescan Sonar
Klein 3000 (100/500 kHz) Sidescan Sonar System
SonarPro Sidescan Sonar Acquisition Software

Chirp Sub-bottom Profiler
Klein 3000 Chirp Profiler (2-8 kHz)
SonarPro Sidescan Sonar Acquisition Software

Boomer Sub-bottom Profiler
EG&G 240 Low Frequency (400-14,000 Hz) Shallow Seismic System
Applied Acoustics CSP-300 Power Supply
Mini streamer with GeoSpectrum M5 Hydrophones
SonarWiz SBP Acquisition & Processing Software

Marine Magnetometer
Marine Magnetics SeaSpy Marine Magnetometer

Seismic Refraction
Pro-Seismic Services 24 channel marine hydrophone with Geospace MP25SW-250 hydrophones
Geometrics Geode Seismic Recorder

Video
High Definition Delta Vision Underwater Video Camera
SeaTrack GPS Overlay System

Sampling
Van Veen Grab Sampler
Petite Ponar Grab Sampler

Vibracore
Rossfelder P-3C Vibracore System

3.5.1 Survey Positioning

Hypack/Hysweep Survey Acquisition Software
All geo-referenced survey data collected during the project was logged using Hypack 2019. Hypack is a complete hydrographic survey navigation software package that includes survey preparation, data collection, data editing, cross-section display, geodesy and exporting capabilities. In operational survey mode, the system supports a helmsman display with survey line indicator to assure survey lines are followed as accurately as possible. In addition to planned survey grid lines, the survey screen also displays bathymetric contours, coastline, navigational hazards and target/sample locations.

Trimble 5700/5800 RTK-GPS
Horizontal and vertical positioning for the multibeam bathymetric survey was supplied by a Trimble 5700/5800 RTK-GPS system receiving corrections via Can-Net Virtual Reference Station Network. The horizontal accuracy of the Trimble 5700/5800 RTK-GPS system is ±10 mm + 1 ppm RMS and the vertical accuracy is ±20 mm + 1 ppm RMS.

SBG Ekinox D Inertial Navigation System with Dual Antenna GNSS Aiding
An SBG Ekinox D was used during the multibeam bathymetry survey to provide high accuracy attitude motion within 0.03° and high accuracy heading within 0.08°.

Hemisphere R110 DGPS
A Hemisphere R110 DGPS system was used to provide horizontal positioning during the marine geophysical survey and harbour bottom video investigation. The Hemisphere R110 is a single antenna GPS system with a horizontal accuracy of 0.6 metres under ideal conditions.

Hemisphere VS-330 GNSS Receiver & Heading System
A Hemisphere VS-330 GNSS system is a dual antenna DGPS system with a horizontal accuracy of 0.3 metres under ideal conditions. The secondary antenna (forward) is used to calculate heading to an accuracy of 0.09° RMS. The system was configured to receive differential corrections and was used on the Nova Endeavor during the marine geotechnical survey. The accurate heading information provided by the Hemisphere VS-330 GNSS system allowed for precise real-time positioning of the vibracore locations.

3.5.2 Multibeam Bathymetry System

Bathymetry data were collected using a Teledyne-Reson SeaBat T20-P Multibeam Echosounder. The T20-P system transmits on a frequency of 200 - 400 kHz and has a maximum swath width of 140°. The system has a maximum range of 575 m and a maximum ping rate of 50 Hz.

The multibeam system requires input from other sensors including vessel motion, position, heading and sound velocity. A Reson SVP provided continuous real-time sound velocity data at the location of the multibeam transducer. The transducer depth was measured, and the draft offset was applied during post-processing. Horizontal offsets from the RTK-GPS antenna to the sounder transducer were also applied during post processing in order to calculate exact positions of the bathymetric data.

An SBG Ekinox D system (heave, pitch, and roll) was mounted in the vessel. Vessel motion was recorded continuously during the bathymetric survey at a rate of 50 Hz. This data, including sensor offset values, were applied to the bathymetry data during post processing.

Sound velocity profiles through the water column were collected at a minimum of twice daily during the bathymetric survey using an Odom Digibar Pro SVP. The SVP data were applied during processing to correct for speed of sound variations within the water column.

3.5.3 Sidescan Sonar

Acoustic imaging in the marine environment is used to provide wide area, high resolution images of the seabed. The sidescan sonar data acquired allowed for mapping and detection of objects on the seabed at a resolution of approximately 0.1 metres. CSR provided a Klein 3000 (100/500 kHz) Sidescan Sonar System (Figure 3.5.1) to complete the seabed imaging component of the pipeline route assessment. The Klein 3000 consisted of a sonar instrumented towfish, a transceiver and processing unit (TPU) and an acquisition computer running Klein's SonarPro software. Capable of simultaneous dual frequency operation (100/500 kHz) and constructed with advanced electronics and transducers, the Klein 3000 produced high-resolution imagery of the seafloor. High frequency (500 kHz) ranges of between 50 and 100 metres on both the port and starboard channels allowed for wide area swath coverage and target detection along the route.

Frequency:	100 kHz and 500 kHz
Range Setting:	50 m, 75 m and 100 m
Target Resolution:	10-20 cm in ideal conditions
Rationale:	100% seafloor coverage; target detection & surficial geology mapping

The system was towed at an appropriate depth above the seabed to optimize acoustic returns. Layback was calculated using the offset between the GPS and the sidescan sonar towpoint, the length of cable deployed and the depth of the system below the surface. Where possible, feature matching between the sidescan sonar, sub-bottom profiler and multibeam data were used to confirm accurate positioning.

SonarPro was used to operate the Klein 3000 towfish. The software provides navigational recording, target management and real-time display of the sidescan sonar and sub-bottom data. SonarPro also provided options to adjust the towfish sensors while data were being acquired, including range and transmit power, which was recorded with the raw data. The target management feature enabled the selection of seabed targets in both real-time and during playback following collection. The sidescan sonar and sub-bottom data were recorded in XTF format.

Figure 3.5.1 – Klein 3000 mobilized on Nova Endeavor.

3.5.4 Sub-bottom Profilers

<u>Chirp Sub-bottom Profiler</u>
CSR supplied a Klein 3000 chirp sub-bottom profiler (SBP) for high resolution imaging of the sub-surface. The Klein 3000 chirp SBP integrates with the Klein 3000 sidescan sonar system. It mounts directly to the Klein 3000 towfish and uses the existing physical connections and electrical communications. This option takes advantage of the existing Klein 3000 hardware by using the same tow cable, transceiver processor unit (TPU), workstation and towing systems. The chirp sub-bottom profiler consisted of a subsea assembly used to contain the transmit projectors, receive hydrophone and SBP electronics. These components were enclosed in a fiberglass shroud with an integrated support structure to allow for combined transducer/electronics mounting and towing. The amplifier modulates both amplitude and phase of the transmit waveform for pulse lengths up to 40 msec.

Specifications
Chirp Frequency: 2-8 kHz
Beam Angle: 20° along track; 40° cross track @ 5 kHz
Resolution: 12.5 cm or better
Power: 1 kw
Source Level: 204 db @ 1 m

CSR mobilized the chirp sub-bottom profiler on a custom float package to allow for surveying in the shallow water sections within both the Pictou Harbour and Caribou Harbour survey corridors; see Figure 3.5.2.

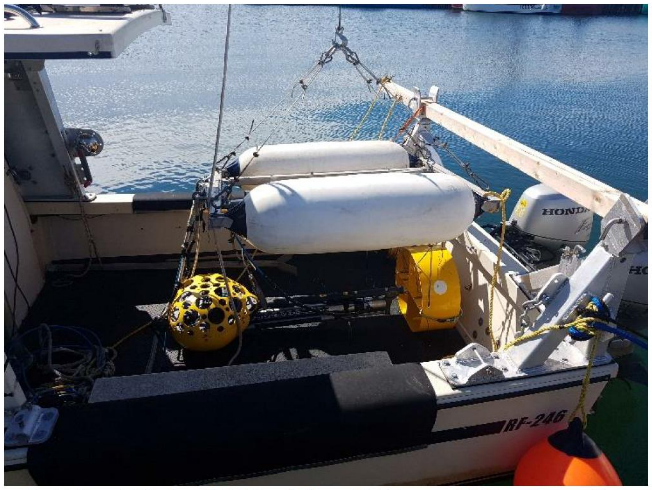

Figure 3.5.2 – Klein 3000 chirp SBP mobilized on *SeaQuest*.

Boomer Sub-bottom Profiler

Seismic reflection data were collected using a single channel seismic (Boomer) system; see Figure 3.5.3. This system provided low frequency energy in the range of 400-10,000 Hz and included four main components (boomer plate, power supply, hydrophone, and acquisition computer). The energy source for the system was the Applied Acoustics CSP-300 which has output settings ranging from 50-350 joules. The CSP supplied power to the boomer plate which was towed in conjunction with a low frequency hydrophone streamer. The boomer plate was responsible for transmitting the sound energy through the water column and seabed sediments. The hydrophone streamer received the reflected sound energy and transmitted the signal to the topside recording computer.

The raw and processed acoustic signal was recorded on a topside computer running SonarWiz acquisition software. DGPS positioning information was integrated with the data in real-time and recorded by SonarWiz in SGY format. Acoustic frequency filters applied to the data in real time using SonarWiz were not recorded to the raw data. The frequency filters essentially “cleaned” the data allowing for better visualization and interpretation of the sub-surface sediments. Low-Cut (400 Hz) and High-Cut (4000 Hz) frequency filters were applied to the data in real time using the SPA-3 processing unit. This data were recorded to a second channel within the SGY file. In addition to filter processing, the SPA-3 unit (IKB Technologies Ltd) also controlled the firing rate of the boomer system.

During this survey the energy source was operated at an output level of 200-300 joules with a firing rate of 1/4 to 3/8 seconds. The record length was synced to the firing rate within SonarWiz. The maximum penetration achieved was 20-30 m within post glacial and glacial sediments. The boomer signal was impeded in areas where shallow gas was present.

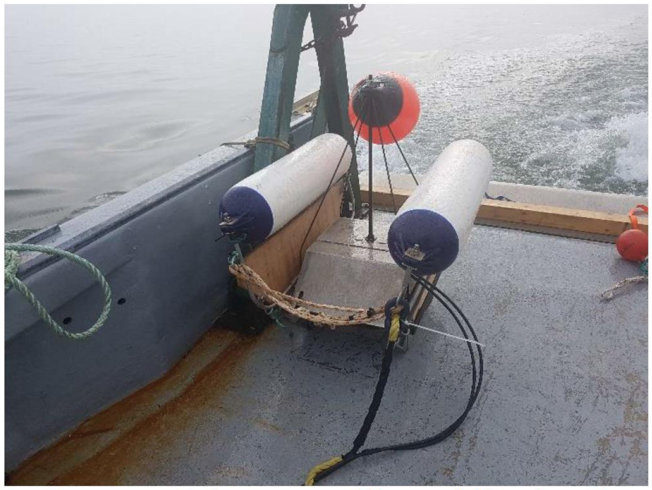

Figure 3.5.3 – Boomer sub-bottom profiler mobilized on *Nova Endeavor*.

3.5.5 Marine Magnetometer

CSR provided a Marine Magnetics SeaSpy Magnetometer for the survey. The SeaSpy is a total field magnetometer and measures the magnitude of the total magnetic field in nanoTeslas (nT). Total field magnetometers measure the magnitude of the magnetic field vector, independent of its direction with respect to the sensor. Total-field magnetometers are inherently superior to vector magnetometers in the detection of ferromagnetic anomalies within the Earth's magnetosphere, especially for long-term monitoring applications, and are widely used in the fields of oceanography, geophysical exploration, and object detection.

Magnetometers consist of two basic parts; a sensor and a measurement device. The sensor produces an analog electrical signal that is proportional to the external influence being sensed, in this case a magnetic field. The measurement device converts the analog signal produced by the sensor into digital magnetic field units. All total-field magnetometer sensors produce a signal whose frequency is proportional to the magnetic field (Hrvoic, 2007).

The SeaSpy is a proton magnetometer utilizing the Overhauser effect. This effect allows the sensor to be polarized with a low power, high frequency, magnetic field, instead of a high power DC magnetic field. The advantages are that it does not produce a heading error, have a dead zone or display a temperature drift like many Cesium models. The SeaSpy operates at a resolution of 0.001 nT, with a sensitivity of 0.015 nT and an absolute accuracy of 0.2 nT. The typical operating range of the SeaSpy is 18,000 to 120,000 nT in all directions resulting in no dead zones although magnetic readings outside of the minimum and maximum range will be recorded by the acquisition system

3.5.6 Seismic Refraction

CSR provided a marine refraction system as part of the marine geophysical survey in Caribou Harbour. Marine refraction techniques are capable of delineating geological boundaries such as glacial till and bedrock horizons. Seismic velocities of sub-surface geologic units can also be measured using marine refraction. These velocities provide insight into the composition and competency of the sub-surface sequences.

The marine refraction system comprised of a 24-channel marine hydrophone cable, a Geometrics Geode seismic recorder and Geometrics Seismodule controller software. Data files were recorded in SEG2 format.

CSR’s 24-channel marine hydrophone cable included 24 Geospace Technologies MP25SW-250 hydrophones spaced 6 m apart along a 138 m active section. The lead in section included minimal length of cable between the Geode seismograph and the first hydrophone due to the shallow exploration depths in the Caribou survey corridor. A tail buoy was attached to the refraction cable to provide drag on the cable to maintain a straight spread. Small buoys and floats were incrementally attached to the hydrophone cable to provide flotation and visibility to vessel traffic.

3.5.7 Underwater Video

The underwater video system provided by CSR for the benthic habitat mapping combined a Delta Vision Underwater Video Camera configured with an Evolve HDMI Video Junction Box. The junction box recorded the video on a hard drive and also passed the video signal from the camera into a topside monitor for real-time viewing. Prior to the video signal entering the junction box, a VideoLogix GPS Overlay System embedded real time latitude and longitude coordinates on the video. This overlay process enabled the video to be geo-referenced for post processing identification of targets or areas of interest. Lighting for the video system was provided by two LED rechargeable lights designed for underwater video recording. CSR used a Klein K-Wing for deployment of the underwater video system, see Figure 3.5.4.

Figure 3.5.4 – Delta Vision underwater drop video camera mobilized on *SeaQuest*.

3.5.8 Sediment Samplers

Van Veen Sampler

CSR provided a Van Veen sediment sampler to collect surficial grab samples from Nova Endeavor. The Van Veen sampler was deployed using the A-frame off the stern of the vessel; see Figure 3.5.5.

Petite Ponar Sampler

CSR provided a Petite Ponar sediment sampler to collect surficial grab samples from SeaQuest. The Petite Ponar sediment sampler was hand deployed.

Figure 3.5.5 – Van Veen sediment sampler mobilized on the *Nova Endeavor*.

Rossfelder Vibracorer

CSR provided a Rossfelder P-3C modular vibracorer (Figure 3.5.6 through Figure 3.5.8) to collect sediment cores within the Pictou Harbour and Caribou Harbour survey corridors. The Rossfelder P-3C is the newest version of the P-3 vibracorer. It is designed for coring unconsolidated sediments at sea, in lakes, rivers, harbours, ponds and wetlands. The P-3C pressure housing is rated for operation in water depths to 600 m. The vibracorer head attaches to a 3-4 m long, 101.6 mm (4”) diameter steel core tube. A core liner is inserted into the core tube, which is designed to collect the sediment sample. The vibracorer is supported by a buoyant frame which helps to suspend the vibracorer in the water column and ensure it enters the seabed in a vertical position.

Specifications

Depth Capability: 600 m

Vibrations per minute: 3,450 vpm @ 60 Hz or 2,850 vpm @ 50 Hz

Approximate weight: 68 kg in air, 32 kg submerged

Centrifugal Force:

	At 60Hz	At 50 Hz
Low Setting	16 kN	10.9 kN
Med Setting	20 kN	13.7 kN
High Setting	24 kN	16.4 kN

Figure 3.5.6 – Rossfelder P-3 vibracorer mobilized on *Nova Endeavor.*

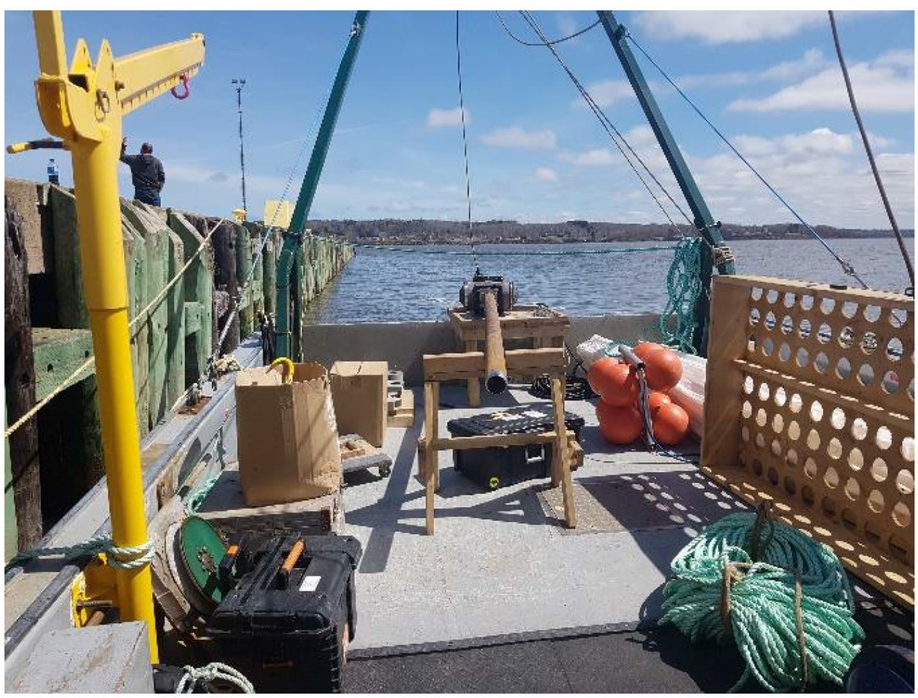

Figure 3.5.7 – Rossfelder P-3 vibracorer mobilized on the deck of Nova *Endeavor*.

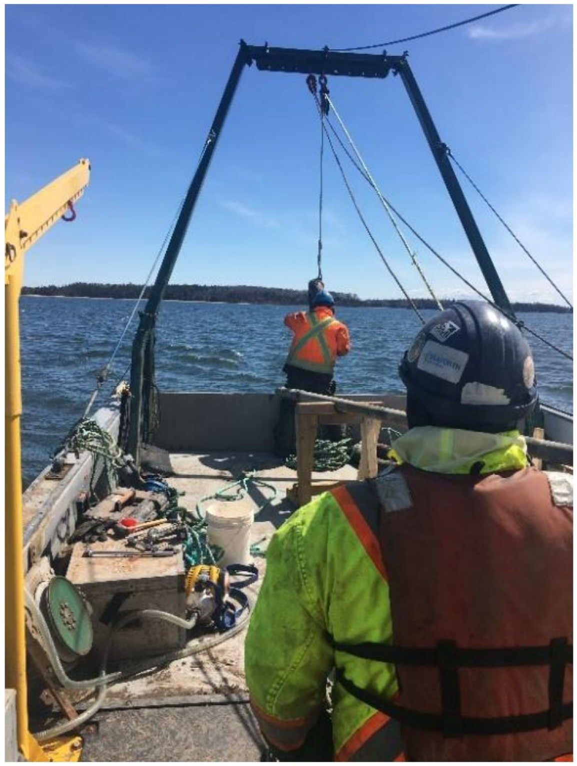

Figure 3.5.8 – Rossfelder P-3 vibracore deployment.

3.6 Survey Reference

Horizontal Datum:	NAD83 (CSRS)
Vertical Datum:	Chart Datum (LLWLT)
Projection:	Universal Transverse Mercator, Zone 20N
Central Meridian	63°W
False Easting:	500000.00
False Northing:	0.000000
Scale Factor:	0.999600
Latitude of Origin:	0.0
Linear Unit:	Metre

3.7 Calibrations and Equipment Check

During mobilization all hydrographic, geophysical and ancillary equipment were dry and wet tested at dockside prior to commencing the marine surveys.

3.7.1 Multibeam Sonar

The RTK-GPS antenna was installed on the multibeam over the side mount (OSM) to provide high accuracy horizontal and vertical positioning for the multibeam survey. Offsets from the RTK-GPS antenna to the sonar head were measured precisely to correct the positioning of the bathymetry data.

The SBG DGPS antennas were installed on the survey vessel, aligned with the main axis of the vessel. The antennas were installed above the multibeam transducer with a 2 m baseline separation. The SBG provided high accuracy heading calculations for the multibeam survey.

The SBG motion unit mount angle offsets were calculated according to the manufacturer's system calibration procedure. Calibration lines were surveyed during calm conditions within the survey area.

Prior to collecting bathymetry data each day, the multibeam system was calibrated using a procedure known as a patch test. The patch test was designed to precisely determine the static configuration of the sonar head (pitch, roll, and yaw) and the latency between the reception of the RTK-GPS fix and its integration by the acquisition system. The procedure for performing a patch test requires the survey vessel to collect data over a series of predetermined lines. The location and orientation of the test lines were selected based on seabed characteristics ideal for patch test value computations. For the variables of pitch, yaw and latency, a seabed slope or feature was required. The roll variable is best computed along lines collected over a flat seabed.

Sound velocity measurements were continuously recorded at the sonar head to aid in beam forming. Sound velocity casts of the water column were collected multiple times each day and applied to the bathymetry data during post-processing.

3.7.2 Tides

Tide values were calculated for the multibeam survey in real-time using RTK tides. Ellipsoid heights were measured at the RTK-GPS antenna. The ellipsoid to chart datum conversion for the water level heights were calculated using separation values provided to CSR by CHS. Water level heights were checked daily using RTK-GPS.

3.7.3 Sidescan Sonar

Prior to deploying the towfish, a `rub´ test was performed on deck to ensure the transducers and receivers were operating properly. The towfish pressure sensor, heading and navigation data were also recorded and confirmed prior to deployment.

3.7.4 Chirp Sub-bottom Profiler

Prior to collecting sub-bottom data, the chirp profiler was configured and tested dock side at Pier C. The transmit and receive (hydrophone) components of the system were placed in the water at the dock. Once in the water, the system was powered on to test the operation of the power source in conjunction with the receive components. The resulting data were recorded and reviewed on the topside computers prior to deployment.

3.7.5 Boomer Sub-bottom Profiler

Prior to collecting sub-bottom data, the boomer was configured and tested dock side at Pier C. Test data were reviewed and system noise was then mitigated through additional grounding of the system components and adjustment to the placement and orientation of the mini streamer.

After confirmation that the sub-bottom system was operating correctly at the dock, test lines were run in the survey area. During testing, frequency filters were manipulated to highlight the interpretable data and filter noise. Time varied gain (TVG) was also adjusted for optimal data collection prior to commencement of the survey.

3.7.6 Marine Magnetometer

The marine magnetometer was mobilized on *SeaQuest* and tested on the deck prior to deployment. Raw nT values were recorded and reviewed. The pressure sensor in the marine magnetometer was calibrated at a depth of 5 m, 10 m and 15 m prior to commencement of the survey.

3.8 SURVEY COVERAGE

3.8.1 Pictou Harbour Survey Corridor

<u>Geophysical Data</u>
The Pictou Harbour survey corridor parallels the Pictou Causeway starting in shallow water offshore of the mill property on Abercrombie Point to the northern end of the Pictou Causeway, see Figure 1.1.1. The Pictou Harbour survey corridor was approximately 1.5 km in length and approximately 200 m wide. Areas of extreme shallow water were not surveyed due to inaccessibility and safety concerns for the vessel and crew. Borehole data in this area was completed for the construction of the mill and is available in Appendix III.

The following geophysical datasets were collected over the Pictou Harbour survey corridor:

1. Multibeam bathymetry: 5 m - 25 m line spacing, 100% seafloor coverage; see Figure 3.8.1.
2. Sidescan sonar: 20 m line spacing, 50 m range, 100% seafloor coverage; see Figure 3.8.2.
3. Chirp sub-bottom profiler: 20 m line spacing; see Figure 3.8.2.
4. Boomer sub-bottom profiler: 20 m line spacing; see Figure 3.8.3.
5. Magnetometer: 20 m line spacing, 4 Hz cycling rate; see Figure 3.8.4.

<u>Underwater Video</u>
The harbour bottom video investigation in Pictou Harbour consisted of six transects approximately 200 m in length oriented perpendicular to the survey corridor. These transect locations were selected by Stantec’s environmental scientist and based on review of the preliminary surficial geology interpretation provided by CSR. An additional transect was collected along the length of the survey corridor approximately 25 m east of the Pictou Causeway toe of slope.

Underwater video was also collected over three potential cultural resource targets identified during preliminary investigation of the sidescan sonar data.

The locations of all underwater video transects in Pictou Harbour are presented on Figure 3.8.5.

Vibracore

Vibracore samples were collected within the Pictou Harbour survey corridor to ground truth the sub-bottom interpretation and to gather seabed material for geotechnical and environmental testing. In total, five vibracore samples were collected at a spacing of approximately 250 m, see Figure 3.8.6.

3.8.2 Caribou Harbour Survey Corridor

Geophysical Data

The Caribou Harbour survey corridor extends from the ferry terminal located on the southern shoreline of Caribou Harbour to the proposed outfall location in the Northumberland Strait, see Figure 1.1.1. The length of the Caribou Harbour survey corridor is approximately 3.6 km and the corridor width is 200 m. The Caribou Harbour survey also included a 400 m x 400 m area over the proposed outfall location. Gull Spit included areas of extreme shallow water that were not surveyed due to inaccessibility and safety concerns for the vessel and crew.

The following geophysical datasets were collected in the Caribou Harbour survey corridor:

1. Multibeam bathymetry: 10 m - 25 m line spacing, 100% seafloor coverage; see Figure 3.8.7.
2. Sidescan sonar: 20 m - 25 m line spacing, 50 m, 75 m, 100 m range; 100% seafloor coverage: see Figure 3.8.8.
3. Chirp sub-bottom profiler: 20 m line spacing; see Figure 3.8.8.
4. Boomer sub-bottom profiler: 25 m line spacing; see Figure 3.8.9.
5. Magnetometer: 25 m line spacing, 4 Hz cycling rate; see Figure 3.8.10.

Marine Refraction

Marine refraction data were collected along the preliminary proposed pipeline route within Caribou Harbour between CKP 0.250 and CKP 2.500. Refraction shots were taken at 25 m intervals along the surveyed line. Figure 3.8.11 shows the locations of the refraction shot points.

Underwater Video

The harbour bottom video investigation in Caribou Harbour consisted of 15 transects oriented perpendicular to the survey corridor ranging in length from 400 m to 800 m. The transect locations were selected by Stantec's environmental scientist and were based on review of the preliminary surficial geology interpretation provided by CSR. An additional routing transect was collected along the survey corridor starting at the landfall location and extending approximately 1.3 km offshore into Caribou Harbour.

The locations of all underwater video transects in Caribou Harbour are presented on Figure 3.8.12.

Grab Samples

Surficial sediment grab samples were collected at 19 locations within the Caribou Harbour survey corridor to ground truth the sidescan sonar data; see Figure 3.8.13.

Vibracore

Vibracore samples were collected within the Caribou Harbour survey corridor to ground truth the sub-bottom interpretation and to gather seabed material for geotechnical and environmental testing. In total, 22 vibracore samples were collected within the survey corridor; see Figure 3.8.14.

3.8.3 Regional Ice Scour Surveys

Geophysical data were acquired along regional survey lines outside of Caribou Harbour within the Northumberland Strait as part of an ice scour assessment. Figure 3.8.15 includes all sidescan sonar and multibeam sonar survey lines reviewed for ice scours during this study. These lines were designed to collect information on the impact of ice on the seabed in the vicinity of the proposed pipeline route and outfall location. The surveys included the acquisition of sidescan and multibeam sonar data.

Preliminary regional reconnaissance surveys included the collection of sidescan sonar deployed from *Nova Endeavor*. The sidescan sonar data were reviewed in the field to identify areas of the seabed where ice scours were observed. The multibeam sonar, mobilized on *SeaQuest*, was then used to survey the ice scour features in detail to ascertain additional information including water depth, scour depth, sour width and scour orientation.

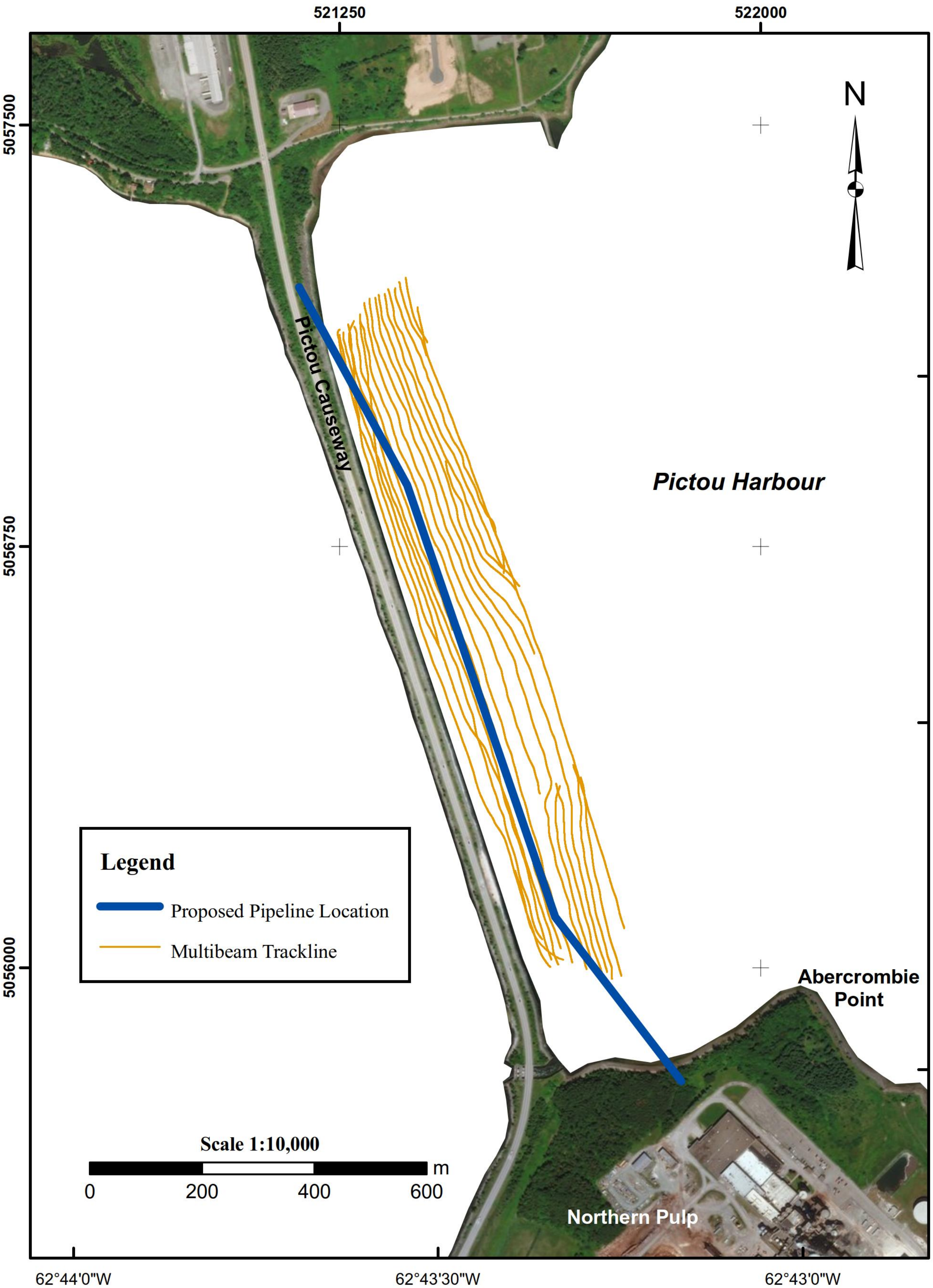

Figure 3.8.1 – Pictou Harbour multibeam bathymetry trackline locations.

CSR GeoSurveys Ltd.

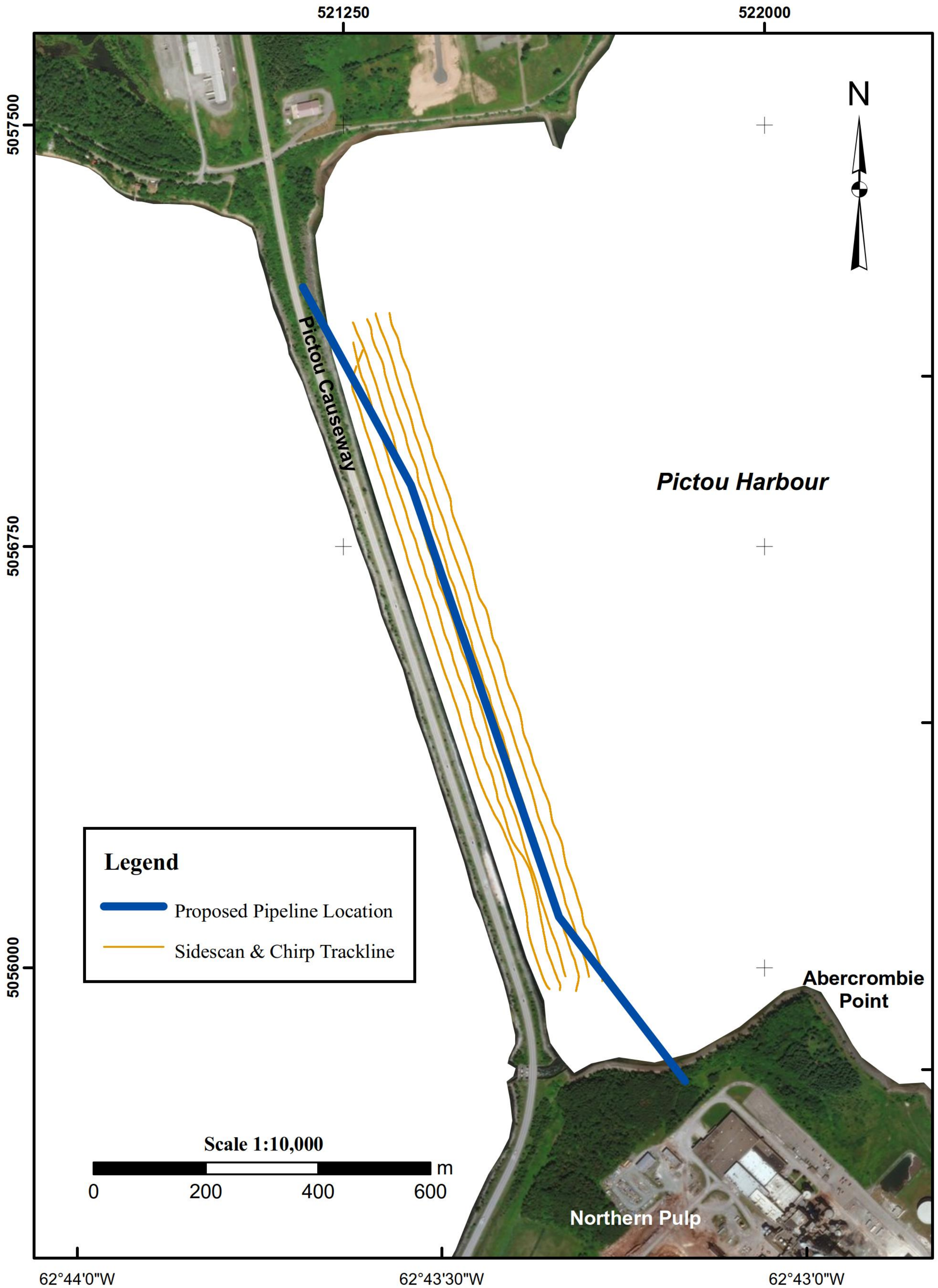

Figure 3.8.2 – Pictou Harbour sidescan sonar and chirp sub-bottom profiler trackline locations.

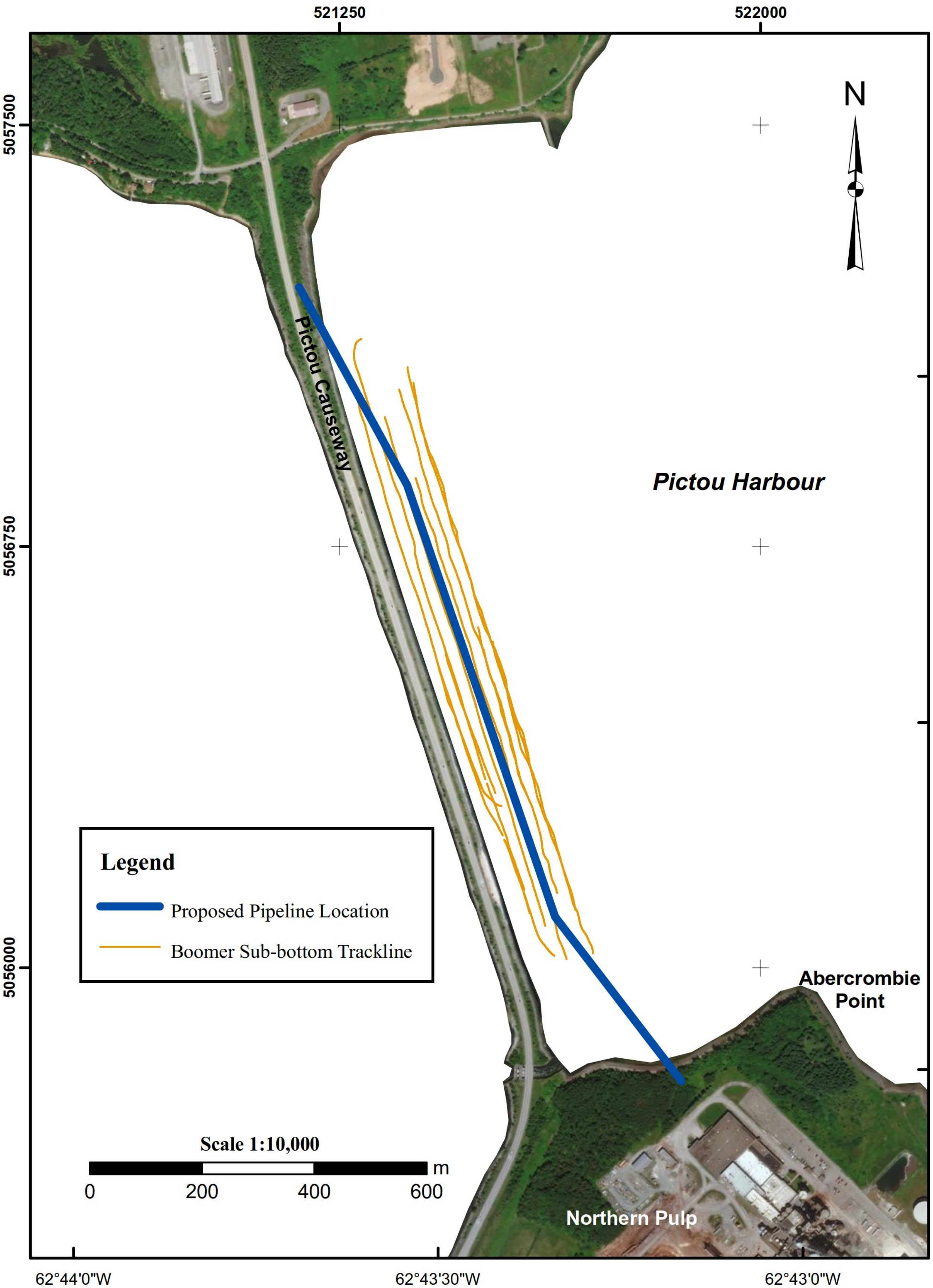

Figure 3.8.3 – Pictou Harbour boomer sub-bottom profiler trackline locations.

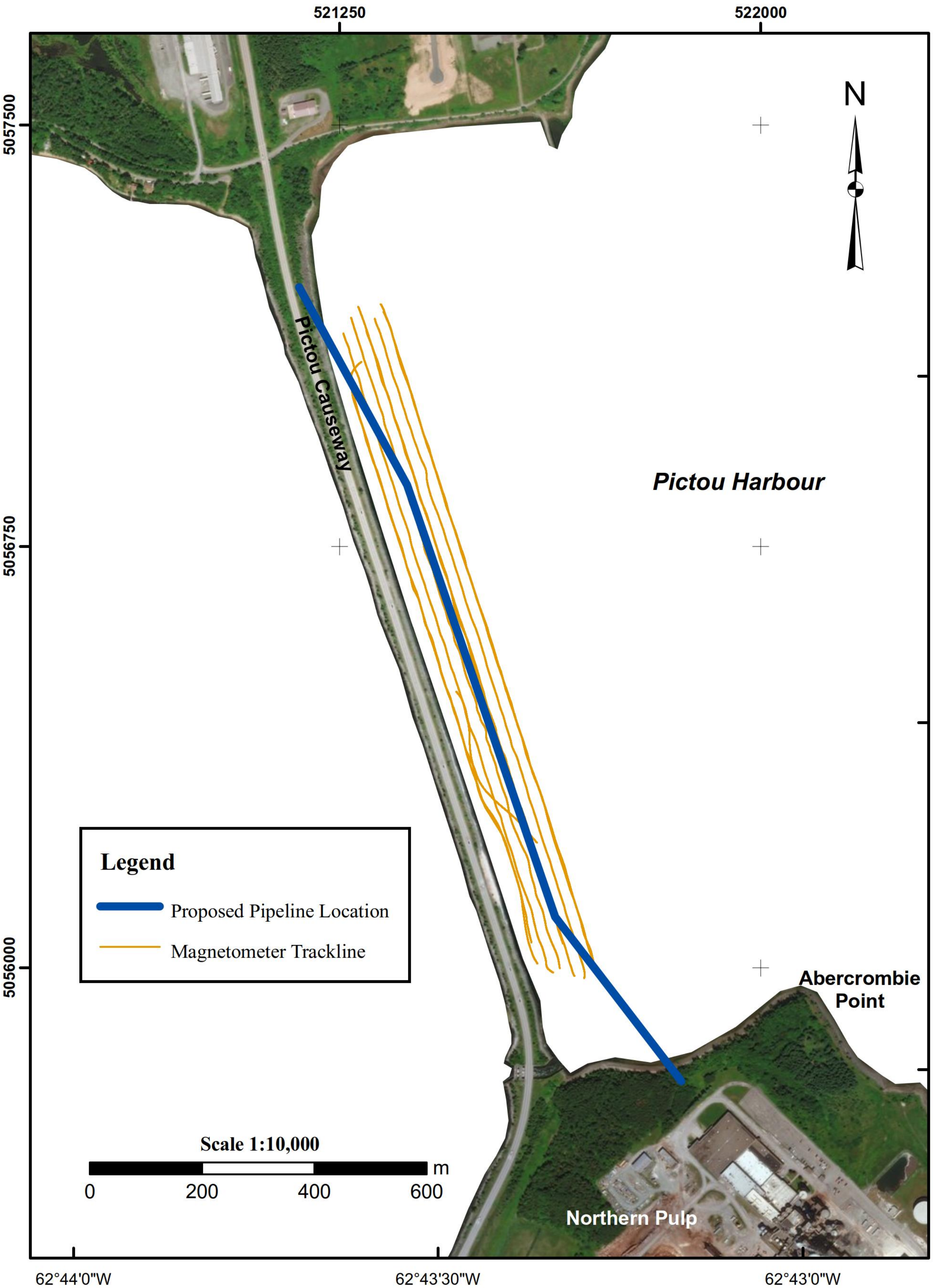

Figure 3.8.4 – Pictou Harbour magnetometer trackline locations.

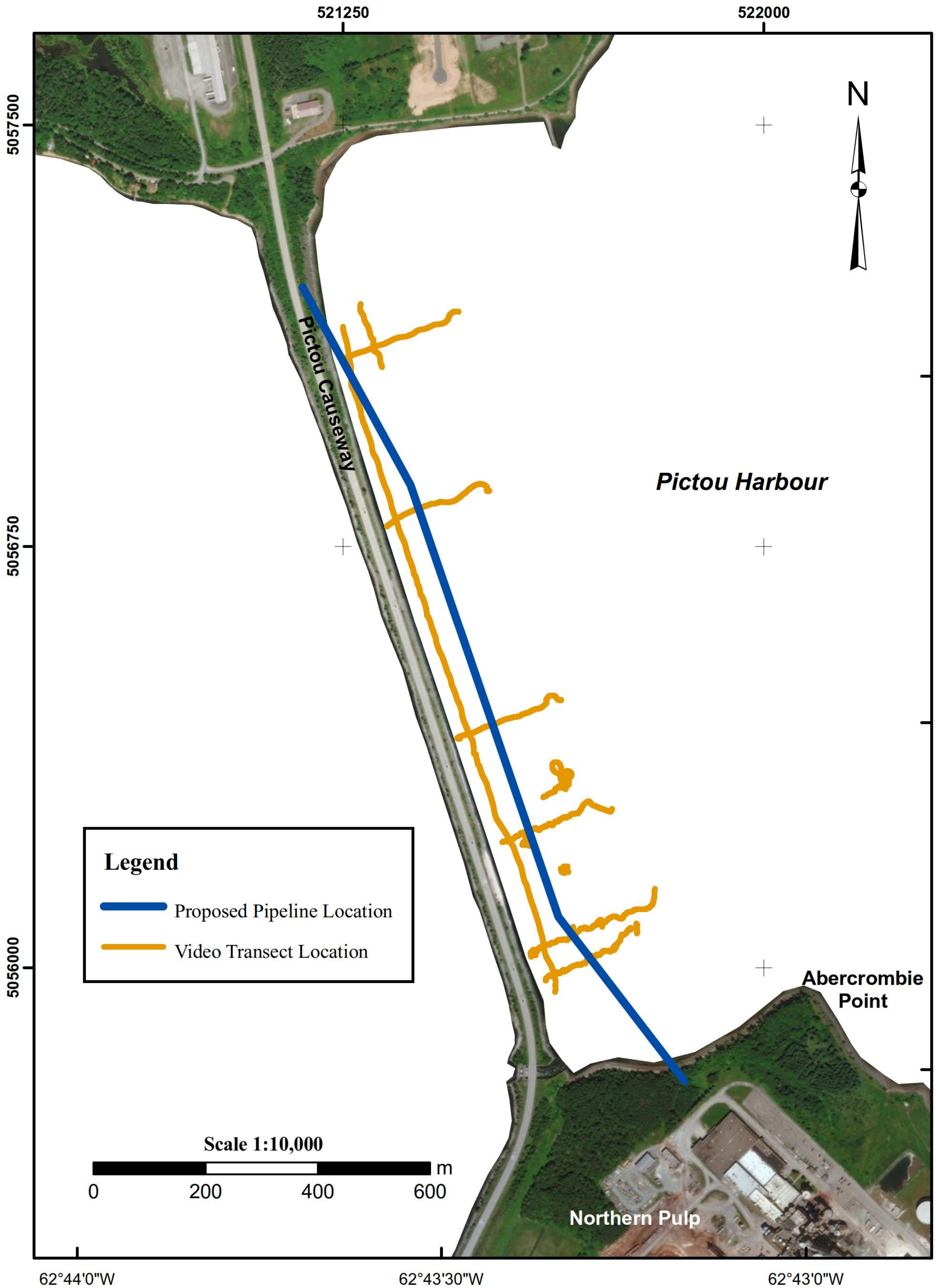

Figure 3.8.5 – Pictou Harbour underwater video transect locations.

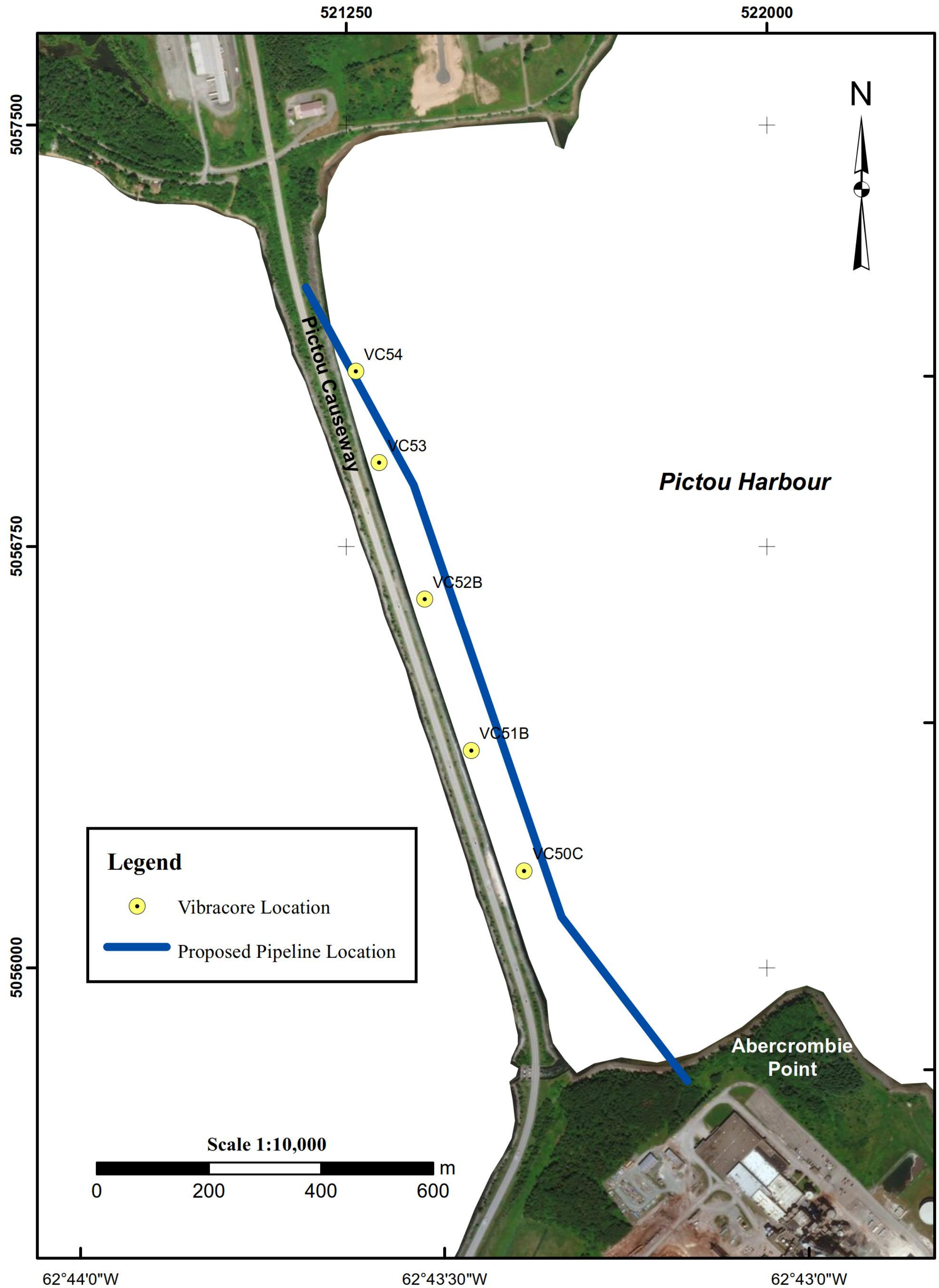

Figure 3.8.6 – Pictou Harbour vibracore locations.

CSR GeoSurveys Ltd.

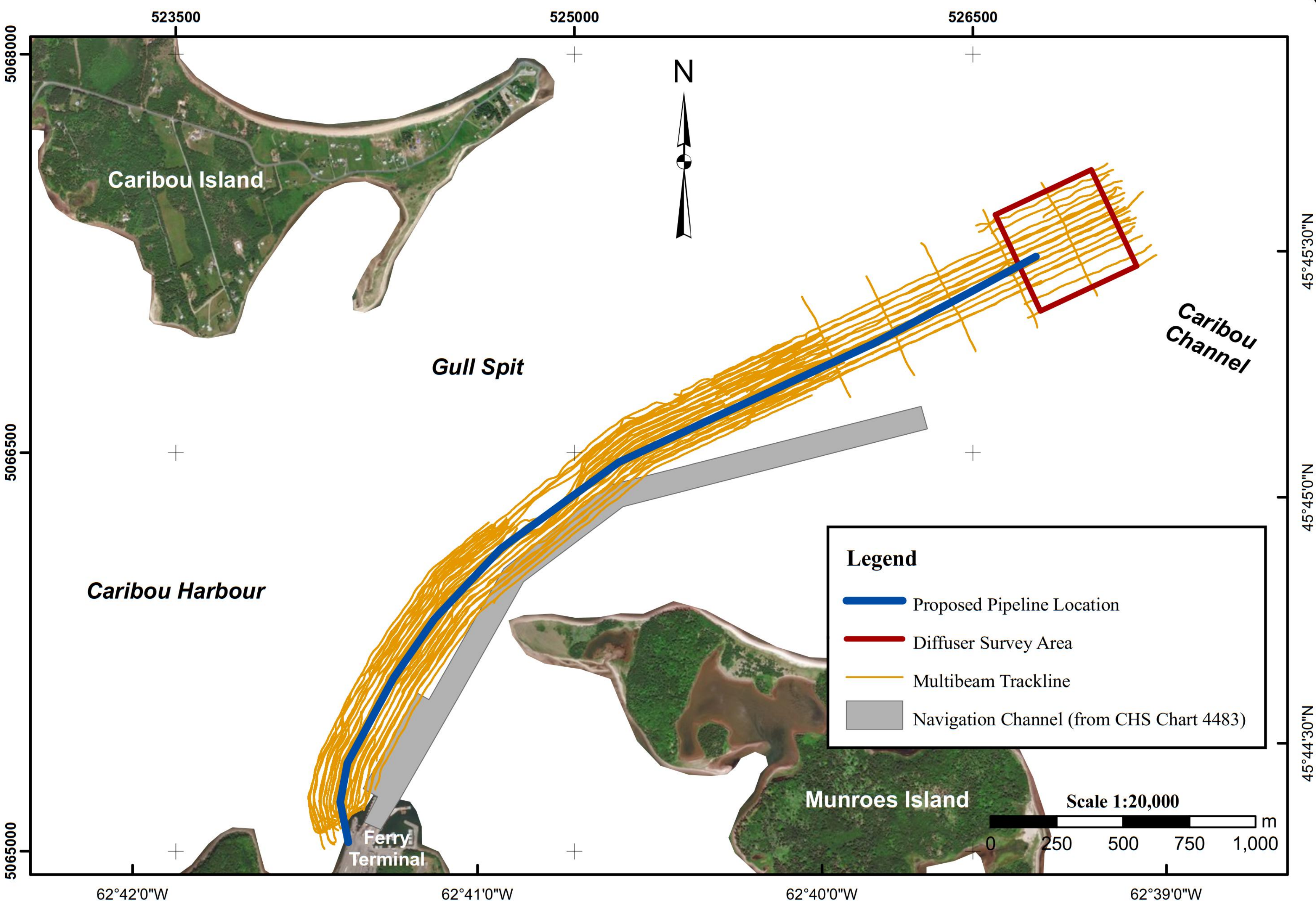

Figure 3.8.7 – Caribou Harbour multibeam bathymetry trackline locations.

CSR GeoSurveys Ltd.

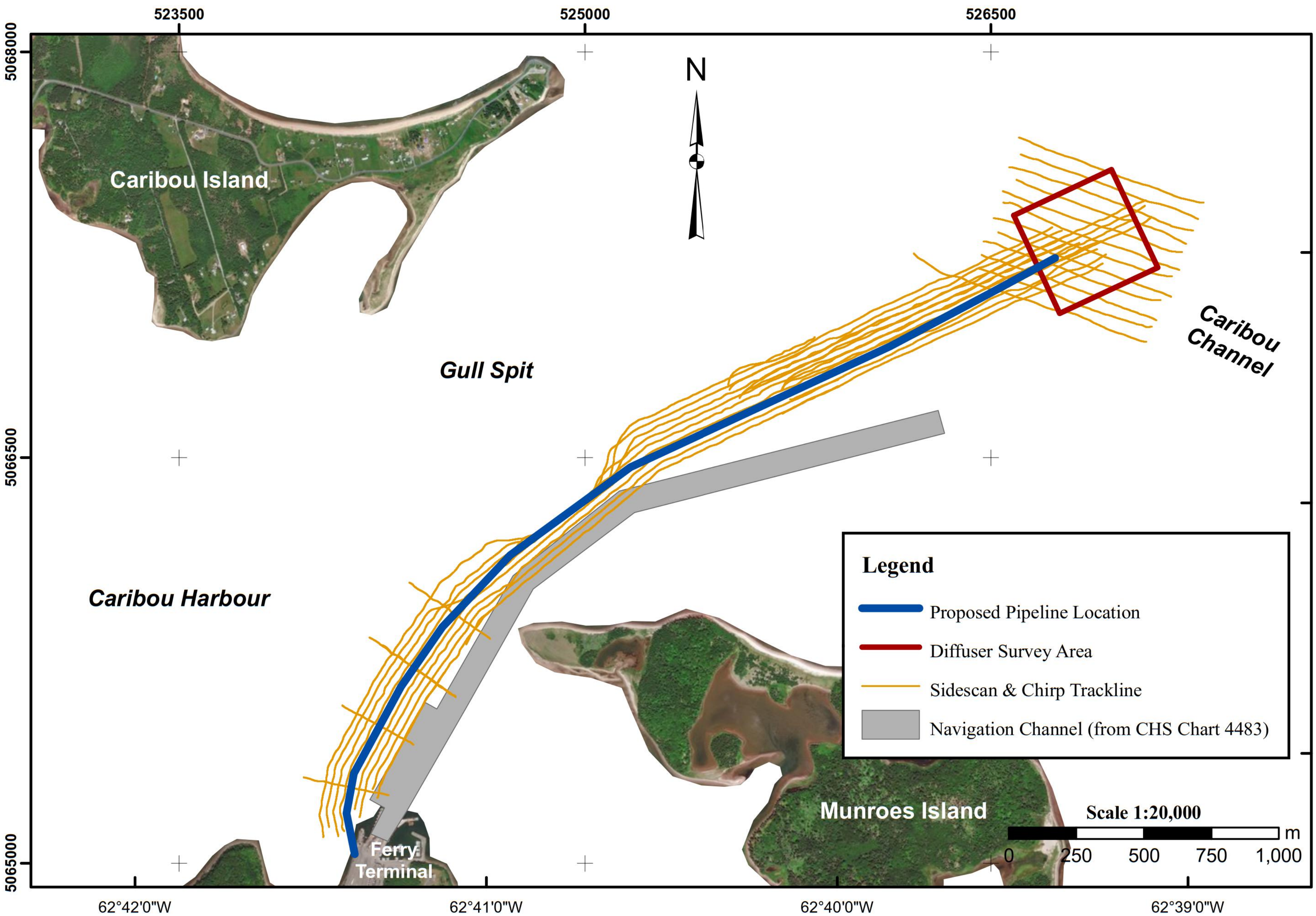

Figure 3.8.8– Caribou Harbour sidescan sonar and chirp sub-bottom profiler trackline locations.

CSR GeoSurveys Ltd.

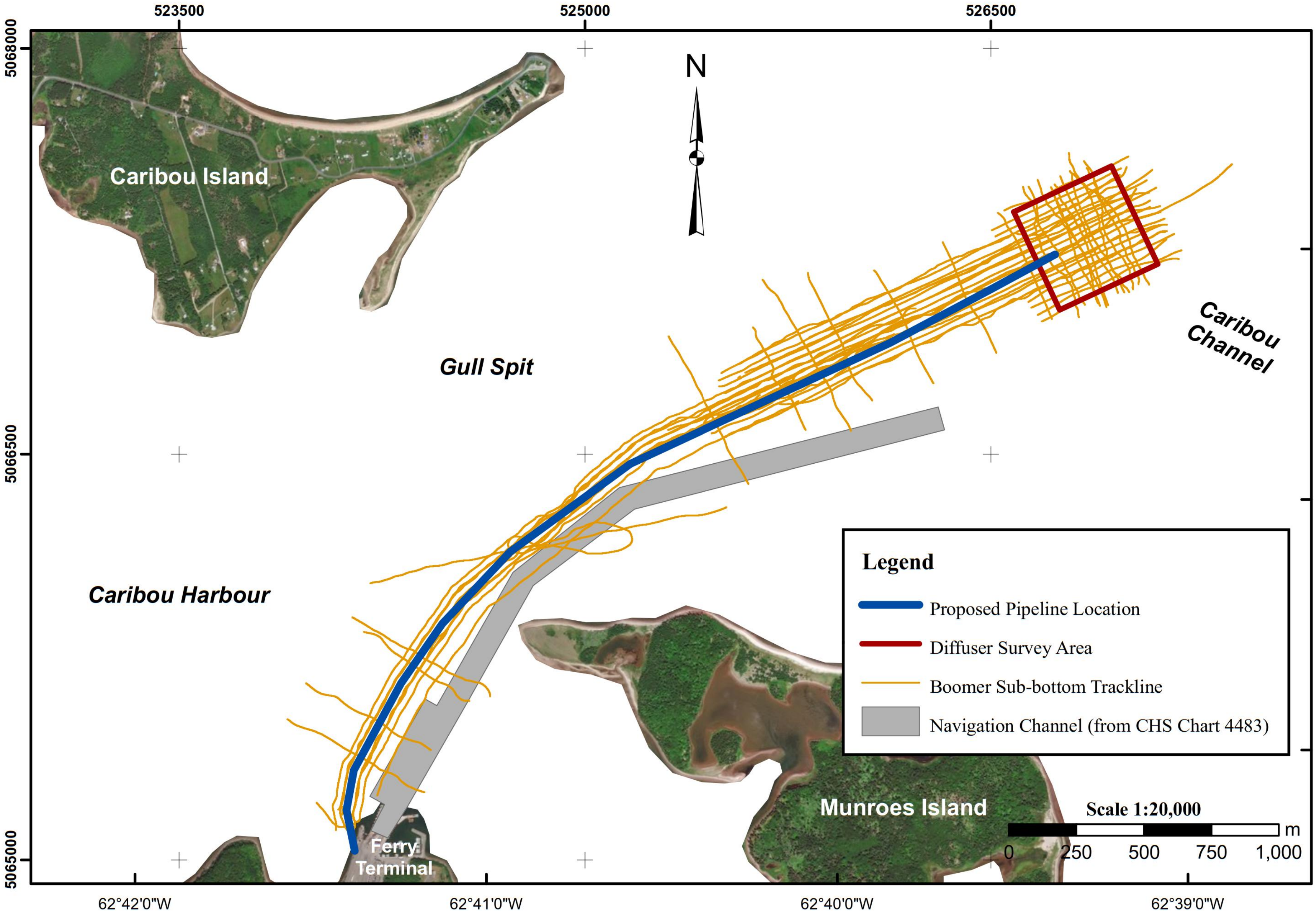

Figure 3.8.9 – Caribou Harbour boomer sub-bottom trackline locations.

CSR GeoSurveys Ltd.

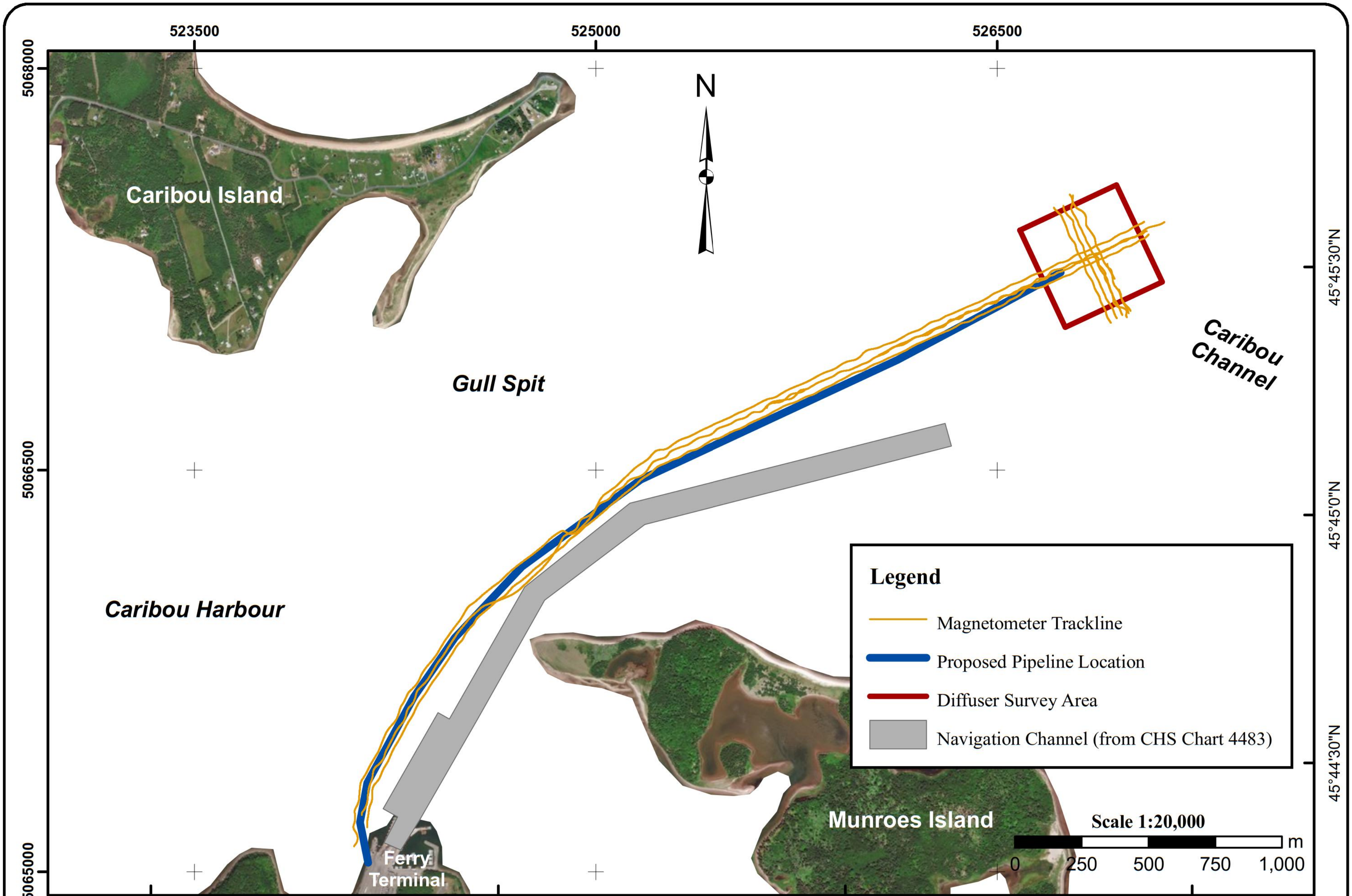

Figure 3.8.10 – Caribou Harbour magnetometer trackline locations.

CSR GeoSurveys Ltd.

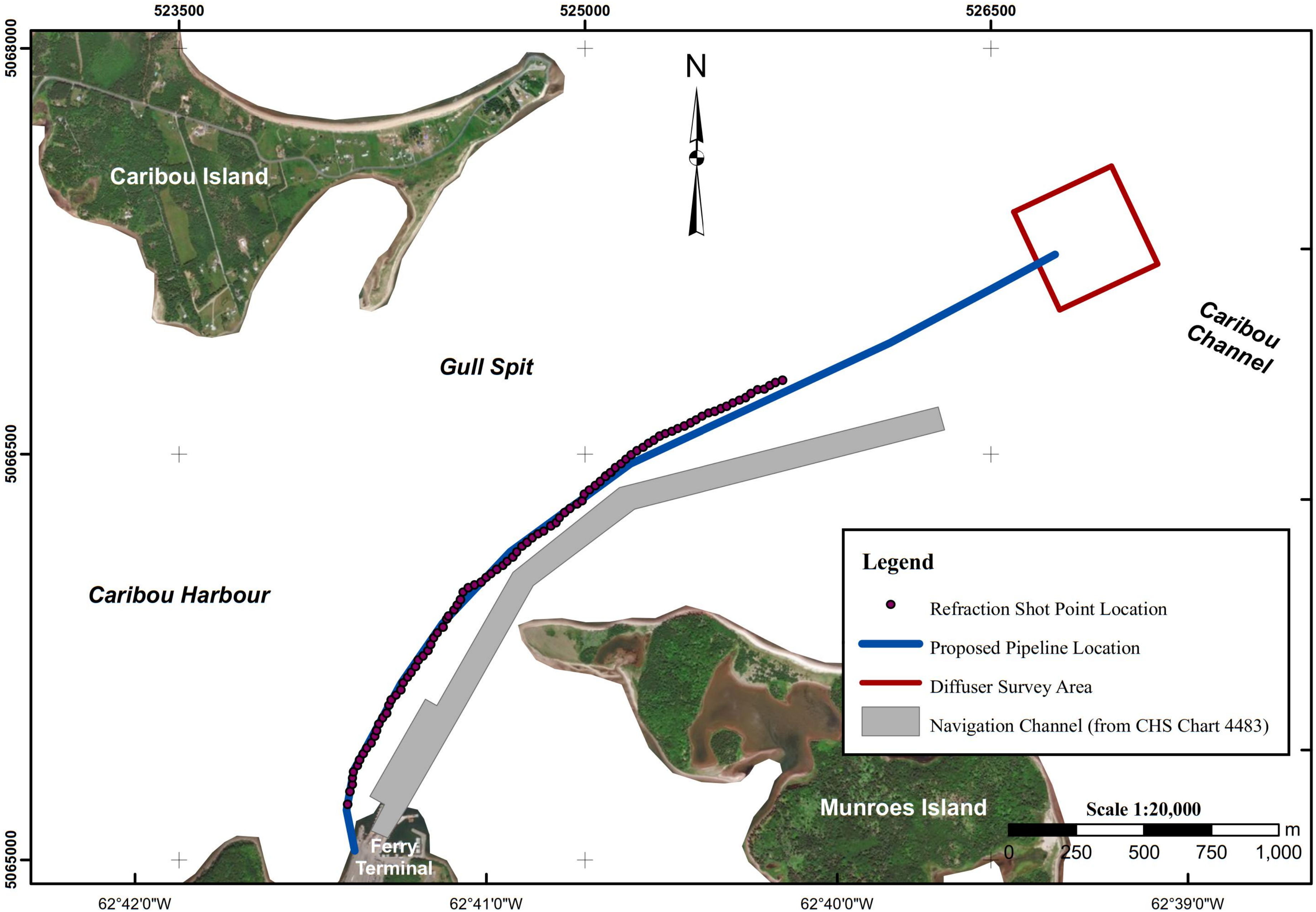

Figure 3.8.11 – Caribou Harbour seismic refraction shot point locations.

CSR GeoSurveys Ltd.

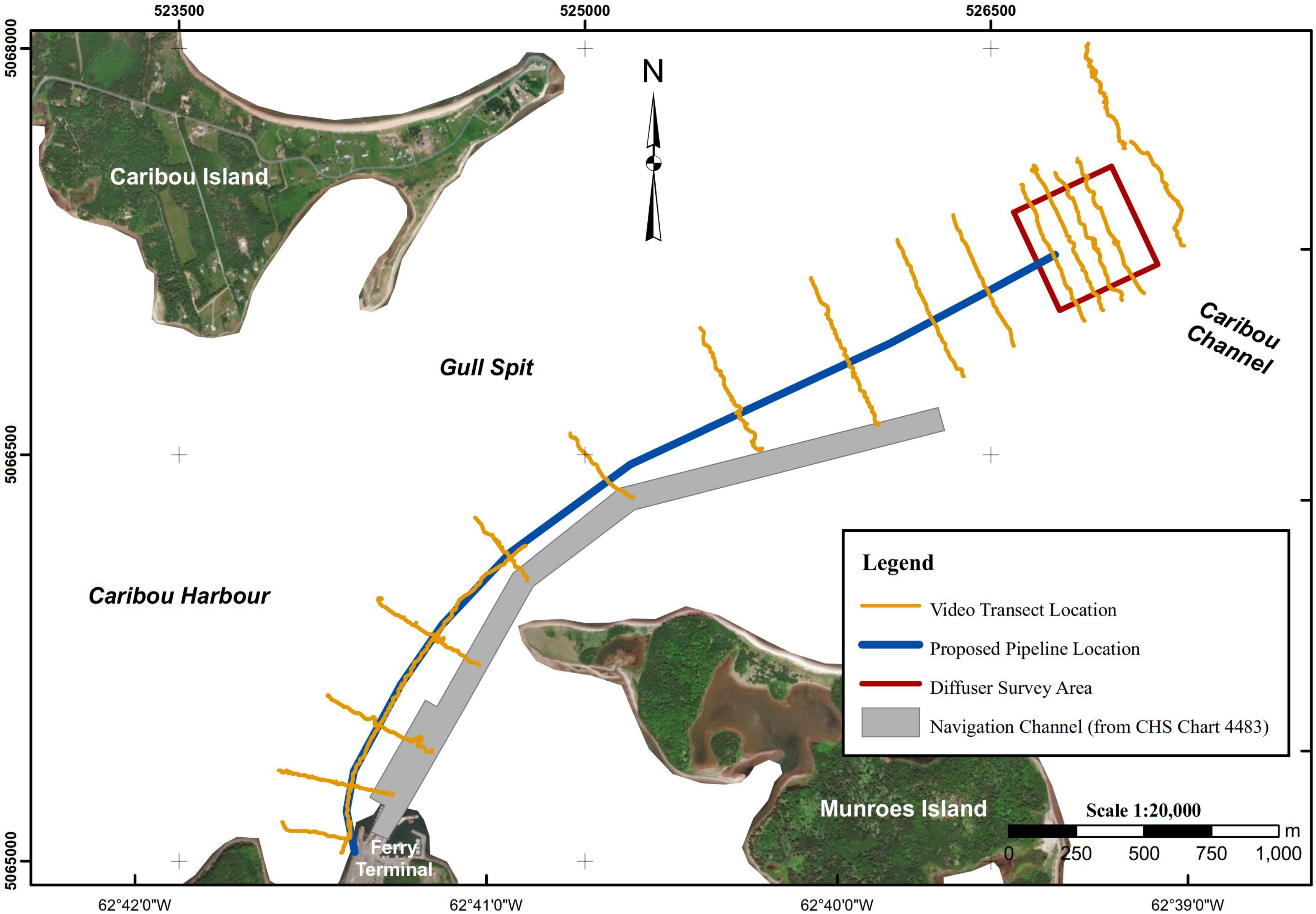

Figure 3.8.12 – Caribou Harbour underwater video transect locations.

CSR GeoSurveys Ltd.

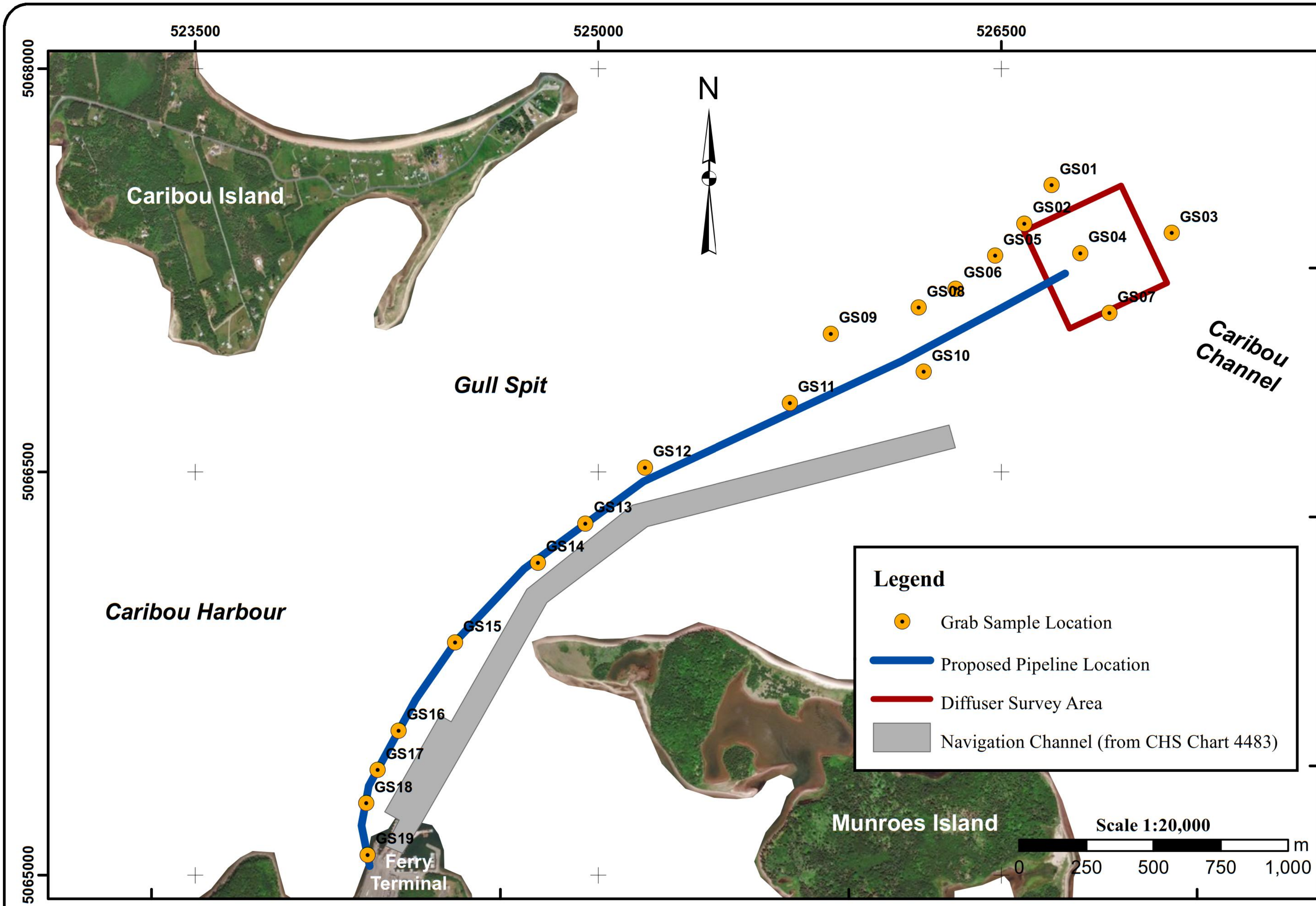

Figure 3.8.13 – Caribou Harbour grab sample locations.

CSR GeoSurveys Ltd.

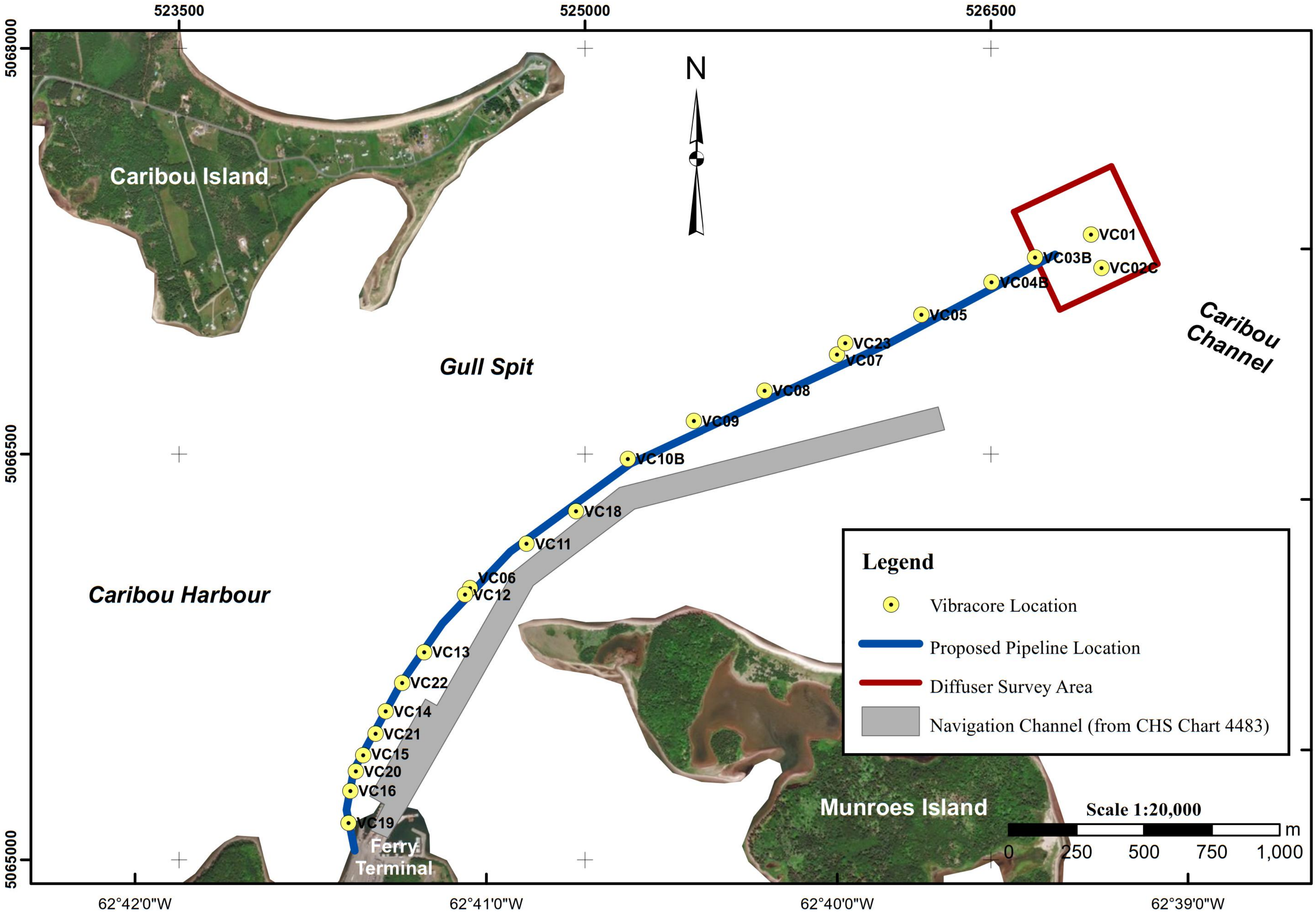

Figure 3.8.14 – Caribou Harbour vibracore locations.

CSR GeoSurveys Ltd.

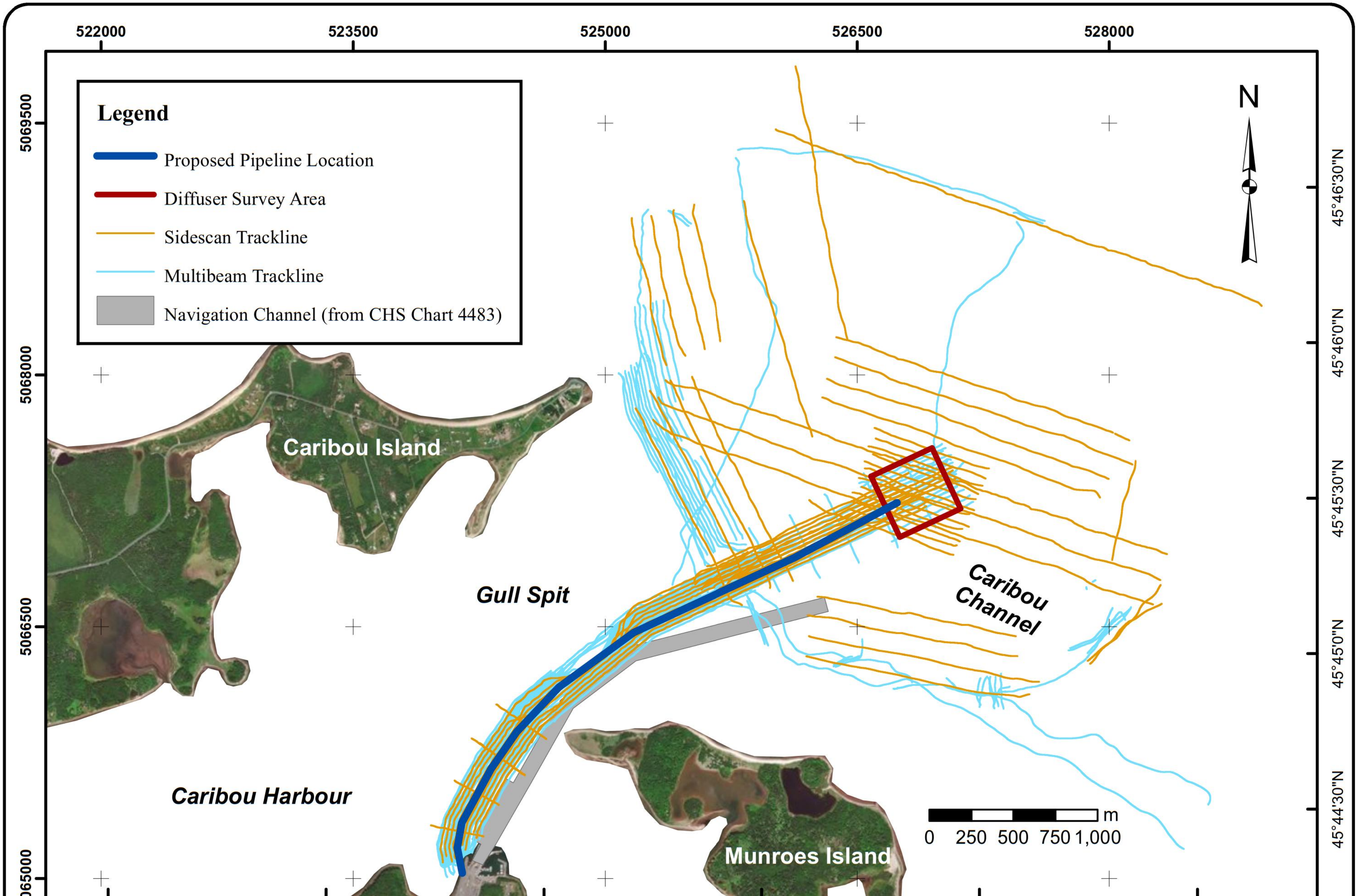

Figure 3.8.15 – Caribou Harbour survey locations reviewed for ice scours.

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4.0 GEODESY, MAPPING & DATA PROCESSING

4.1 Geodesy

All Figures and Enclosures (map sheets) compiled by CSR for this report are referenced to NAD83 (CSRS) UTM Zone 20N projection. Elevations and bathymetry contours are referenced to Chart Datum (LLWLT). Horizontal and vertical units used in this report are metres.

4.2 Multibeam Bathymetry Processing

The raw multibeam sonar data collected during the survey were post processed with hydrographic information processing software Caris. Caris allows for the integration of bathymetric data including raw sonar information, sound velocity, tide corrections and vessel offset information. The following steps were conducted to post process the raw multibeam sounding data.

- The raw hysweep data (.hsx) were imported into CARIS HIPS 10.1, where horizontal and vertical offsets were applied.
- All patch test data acquired during the survey were reviewed independently by two multibeam processors. The mean pitch / roll / yaw values from these redundancy checks were used during final processing of the data.
- Sound velocity profile files were created from each sound velocity cast performed during the survey and applied during post-processing.
- RTK tides were applied during post-processing.
- The multibeam data were extensively examined for erroneous soundings and artifacts using Caris.
- The processed data were exported as a 0.5 m resolution average BASE surface in ASCII XYZ format.

4.2.1 Multibeam Contours and Profile

The processed multibeam dataset (referenced to Chart Datum) was reviewed in Hypack. This dataset was imported into Surfer, where 1 m resolution grid files were created using a kriging interpolation algorithm. Contours were generated from the 1 m resolution grid files and are displayed on the Figures and Enclosures.

Profiles referenced to Chart Datum were generated along the proposed pipeline routes from the 1 m resolution grid file within Surfer. Each elevation profile has been included on the Bathymetric and Geological Profile panel of the Alignment Sheets (Enclosures 3, 8 and 9).

4.3 Sidescan Sonar Processing

During the survey, raw uncorrected sidescan data were recorded with SonarPro in XTF format. DGPS positions were embedded into each raw XTF file. Towfish layback was applied and sidescan sonar positions were checked for accuracy based on the corresponding multibeam data recorded during the survey. During post processing, the data were imported into SonarWiz where adjustments to the gain, color, contrast were made to each acoustic file. The highest quality acoustic files were mosaiced together creating a geo-referenced image of the seafloor at 0.2 m resolution.

The sidescan data were interpreted visually, using variations in the intensity and character of backscatter returns to identify and map surficial geological boundaries and seabed features. Typically, low-intensity returns (backscatter) are associated with smoother seafloor conditions and fine-grained surficial sediments. Higher levels of backscatter indicate increased bottom roughness, typically related to coarser sediments, cobbles, boulders, bedrock outcrops and anthropogenic debris. The size, shape, homogeneity, apparent relief and acoustic character of the returns were used to map surficial units and identify seabed features. The sidescan sonar data were ground truthed with grab samples, vibracore samples and underwater video.

Anthropogenic features were mapped and assigned a unique sonar contact ID within Sonarwiz. Each contact was measured and sonograms generated for the archeological assessment.

4.4 Sub-bottom Processing

Chirp sub-bottom profiler data were recorded simultaneously with the sidescan data in XTF format using SonarPro. Processing of the chirp sub-bottom profiler data were completed using SonarWiz 7, an advanced software package designed for sonar interpretation and processing. DGPS positions were embedded within each raw XTF file and layback was applied during processing to correct the sub-bottom positions. During processing, frequency filters were applied, and gains were optimized prior to interpretation of seismic reflectors.

The seismic reflection (Boomer) data were recorded in raw uncorrected SEGY data files. The dataset was post-processed with CODA Survey Engine. During this process layback and cross-track offsets were applied and the gains were optimized.

Sub-bottom data were interpreted using established seismo-stratigraphic techniques. Seismo-stratigraphic analysis involves the identification of seismic sequences, based on variations in acoustic character and correlation of bounding reflectors throughout the survey areas. Identification of probable sediment types is based on the geometry and internal characteristics of each sequence. The sub-bottom data were then ground truthed based on the vibracore results. The data were utilized in the interpretation and mapping of the sub-bottom geological sequences and shallow gas accumulations. All sub-surface measurements were calculated based on a sound velocity of 1600 m/s.

Profiled sequences that were exposed at the seabed were correlated with sidescan sonar data to assist the interpretation. The presence of sub-bottom reflectors below the seabed provided information on the surficial geology. Areas where sub-bottom reflectors were obscured due to the attenuation of the profiler signal suggest coarse sediments such as cobbles and boulders at the seabed surface.

When an acoustic signal from a seismic source encounters an interface between two sequences with different acoustic impedances, some of the energy will reflect back to the hydrophone. A reflection within the seismic record that has incurred more than once is called a multiple. Multiples from the seabed (water/sediment) and geological units (sediment/rock) are common in marine reflection data. These multiples can be difficult to suppress or remove in single channel seismic data. The following methods were used within Coda to remove or suppress acoustic noise / interference.

- Acoustic interference within the water column was removed with a zap filter.
- Low-cut and high-cut filters were used to suppress/remove noise within the seismic section.
- Multiple tracking tools provided a visual tool for the interpreter during mapping.

Upon completion of the sub-bottom interpretation, the easting, northing and depth below seabed of all interpreted reflectors were exported from SonarWiz 7 and Coda. The elevation of each interpreted sub-bottom reflector was referenced to Chart Datum based on the processed multibeam soundings over each reflector location. The reflectors mapped from the chirp and boomer sub-bottom profiler data are presented on the Alignment Sheet Interpreted Geological Profile, see Enclosures 3, 8 and 9.

4.5 Magnetometer Processing

During post-processing, the raw magnetometer data (nT) were georeferenced based on offsets from the DGPS antenna and cable out measurements on a line-by-line basis within Hypack's Magnetic Editor. Processing of the data included the following methodology.

- DGPS antenna offsets and layback measurements were applied to the data when imported into Hypack.
- Each survey line magnetic profile was reviewed and erroneous readings were removed.
- Magnetic anomalies were identified and mapped in Hypack.
- Positions of magnetic anomalies were exported from Hypack.
- Magnetic anomalies were then reviewed and correlated with sidescan sonar data.

4.6 Seismic Refraction Processing

Marine refraction data were recorded on a shot-by-shot basis in SEG2 format utilizing Geometrics geode control software Seismodule. The data were post-processed using SeisImager and 2D Pickwin software. Pickwin displays each shot record and allows for manual picking of arrival time for each individual trace. If the data is noisy, filters can be applied to attenuate or remove undesired signals.

The process of picking the arrival time of each individual trace is referred to as first break picking. The first break represents the first wave detected by each hydrophone from the sound source, whether it is the wave coming directly from the sound source, or higher velocity refracted waves that travelled through the subsurface. For each shot record, the first breaks can be manually picked and saved as a pick file. The pick file keeps record of the hydrophone distance from the source and the first break time for each hydrophone/trace.

Determining Time Delay Corrections

Time delay corrections must be determined in order to accurately position the interpreted layer boundary. The direct arrival is used to determine the time delay present in the raw data. The direct arrival is the energy from the sound source which travels along the water surface directly to each hydrophone. The direct wave travels at a constant velocity (speed of sound in water) so the arrival times of the wave recorded by each hydrophone of increased distance will exhibit a linear trend.

Theoretically, if there is no delay, when the arrival time of the direct wave at each hydrophone is plotted and the trend extrapolated back to the source position (zero) the arrival time should be zero. An arrival time at the source location larger than zero represents the delay between triggering and the release of energy from the sound source.

Velocity Modeling

The pick file generated in Pickwin was opened in Plotrefa (SeisImager refraction analysis module) for refraction modelling. Once opened, the travel time information in the file was displayed on a time vs distance graph. Before proceeding with refraction modelling, necessary adjustments were made to the travel time curves to correct for trigger delay.

First, an initial model was created from the travel time data, specifying minimum and maximum velocity ranges for the model. For marine data, typically ~1490 m/s (water velocity) is the lower bound and ~3000 m/s or the expected bedrock velocity is the upper bound.

Once the initial model was created the inversion was run, specifying the number of iterations the software processed the data before outputting the final inversion result. The number of iterations should be great enough to allow the error for each iteration result to stabilize.

Before accepting the final model, the RMS error in the model results was checked and verified. An error of approximately 1 millisecond or less is acceptable. A larger error indicates the model does not match the data. This may occur because the inversion requires additional iterations (if the error value has not stabilized) or the original time picks and data quality need to be re-assessed.

4.7 Underwater Video Processing

CSR reviewed the underwater video in order to ground truth the sidescan sonar data during interpretation of the surficial geology. Processing and analysis of the underwater video was completed by Stantec Consulting and included in the following report.

Stantec Consulting Ltd., 2019a. Underwater Benthic Habitat Survey of Caribou Harbour and Pictou Harbour Pipeline Corridors. Final Report, 2019. Prepared for CSR GeoSurveys Ltd., Porter's Lake, NS and submitted to Northern Pulp Nova Scotia Corporation, New Glasgow, NS. Stantec File: 121621877

4.8 Vibracore Logging and Testing

Processing, logging and analysis of the vibracore samples was completed by Stantec Consulting Ltd. CSR`s sub-bottom geological interpretation were ground truthed based on the vibracore logging and test results provided by Stantec. Stantec's report "*Summary of Vibrocore Observations and Laboratory Testing Proposed Northern Pulp Outfall, Pictou County, NS"* is included within Appendix II.

5.0 SURVEY RESULTS

This section presents the results of the marine geophysical, geotechnical and harbour bottom video investigations. The bathymetry, sidescan sonar, magnetometer and sub-bottom datasets have been mapped, interpreted and the results presented in the accompanying Figures and Enclosures. The results of the geotechnical investigation were used to support the interpretation of the geophysical data.

The Enclosures are listed below and include six north-up map sheets and three alignment sheets. The Pictou Harbour survey corridor is presented on Enclosures 1 through 3 while the Caribou Harbour survey corridor is presented on Enclosures 4 through 9.

- Enclosure 1: North-Up Map Sheet 1 – Pictou Harbour Bathymetry Map
- Enclosure 2: North-Up Map Sheet 2 – Pictou Harbour Surficial Geology Map
- Enclosure 3: Alignment Sheet 1 – Pictou Harbour
- Enclosure 4: North-Up Map Sheet 3 – Caribou Harbour Nearshore Bathymetry Map
- Enclosure 5: North-Up Map Sheet 4 – Caribou Harbour Offshore Bathymetry Map
- Enclosure 6: North-Up Map Sheet 5 – Caribou Harbour Nearshore Surficial Geology Map
- Enclosure 7: North-Up Map Sheet 6 – Caribou Harbour Offshore Surficial Geology Map
- Enclosure 8: Alignment Sheet 2 – Caribou Harbour Nearshore
- Enclosure 9: Alignment Sheet 3 – Caribou Harbour Offshore

Figure 5.1 through Figure 5.4 display the geographical areas presented on the Enclosures.

For reference, Kilometre Postings (KP's) were generated for the Pictou Harbour proposed pipeline route from the start location on Abercrombie Point (PKP 0) to the end location on the Pictou Causeway (PKP 1.582), see Figure 5.5. Kilometre Postings were also generated for the Caribou Harbour proposed pipeline route from the start location at the ferry terminal (CKP 0) to the end at the outfall location in the Northumberland Strait (CKP 3.604) see Figure 5.6. Table 5.1 includes the UTM and geographic coordinates for the proposed Pictou Harbour and Caribou Harbour pipeline route start and end points. KP's and distances in this report and presented on the Enclosures are planar distances and do not account for changes in the upland and seabed morphology.

Table 5.1 – Proposed Pipeline Route Coordinates

Description	KP	Latitude			Longitude			East	North
Northern Pulp, Abercrombie Point	PKP 0.000	45	39.32362	N	62	43.16684	W	521858.31	5055798.80
Pictou Causeway	PKP 1.582	45	40.08788	N	62	43.68690	W	521178.19	5057211.63
Caribou Ferry Terminal	CKP 0.000	45	44.30653	N	62	41.37559	W	524148.52	5065034.14
Diffuser	CKP 3.604	45	45.49176	N	62	39.37196	W	526737.00	5067239.45

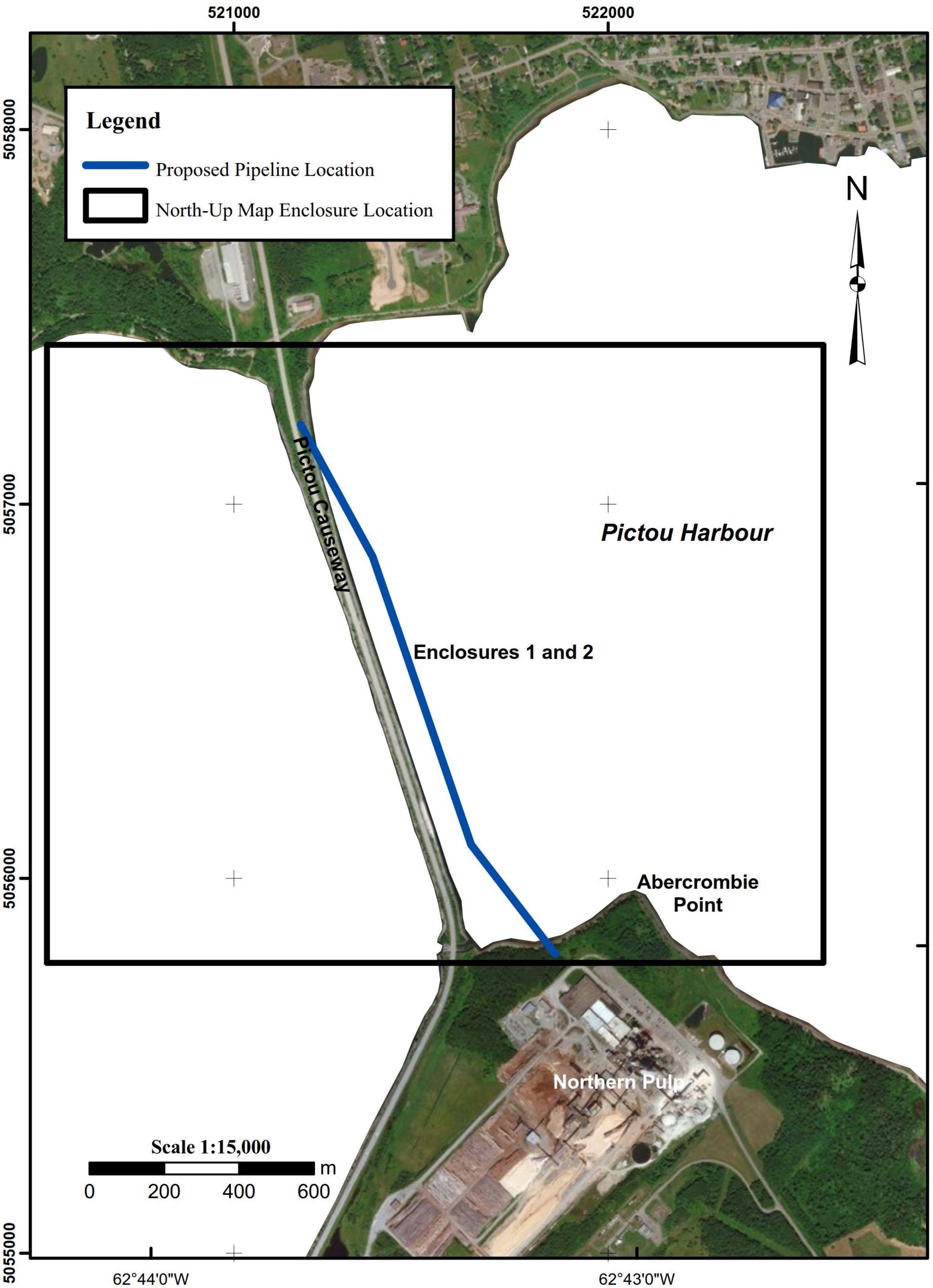

Figure 5.1 – Pictou Harbour north-up map enclosure locations.

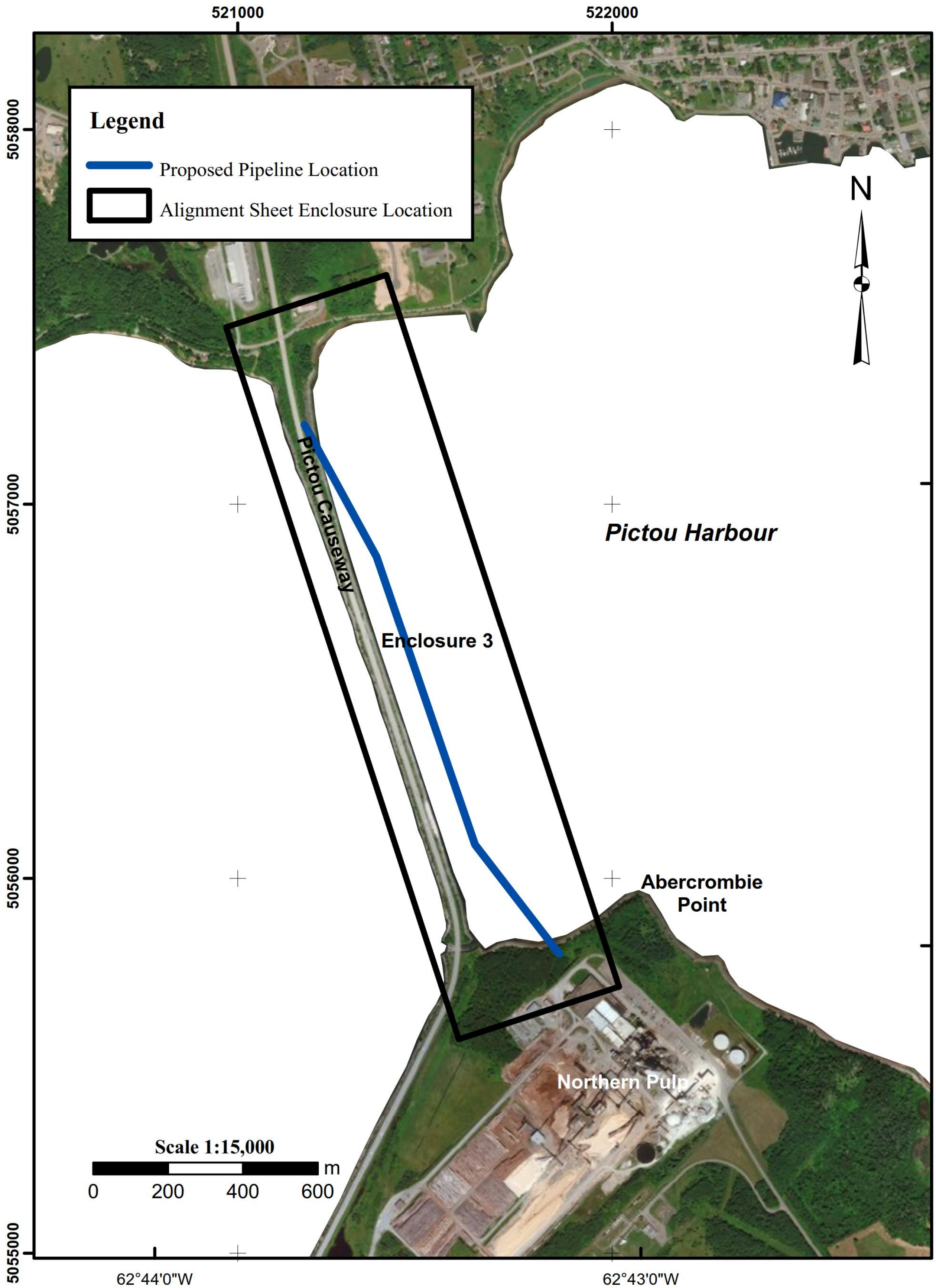

Figure 5.2 – Pictou Harbour alignment sheet enclosure location.

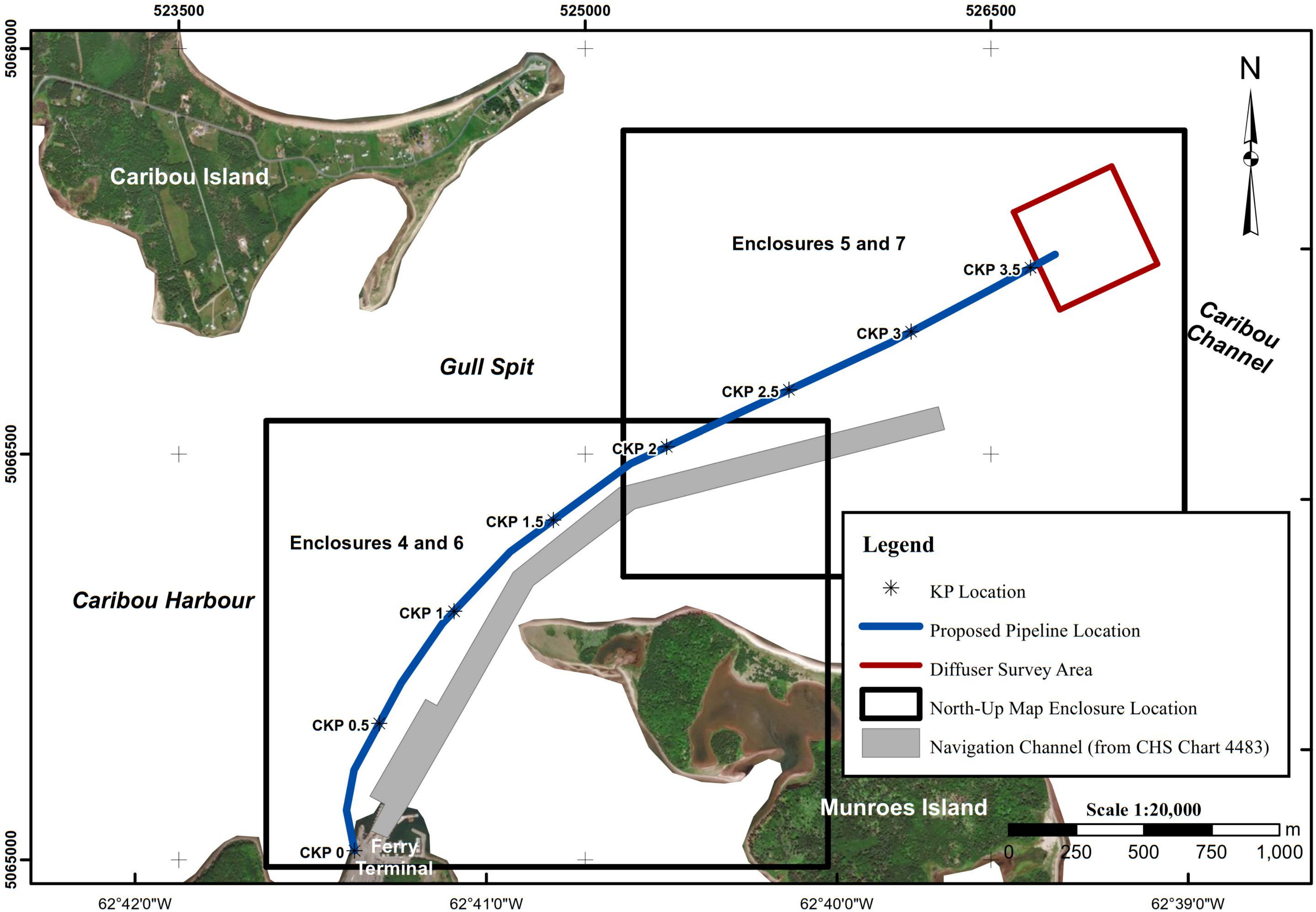

Figure 5.3 – Caribou Harbour north-up map enclosure locations.

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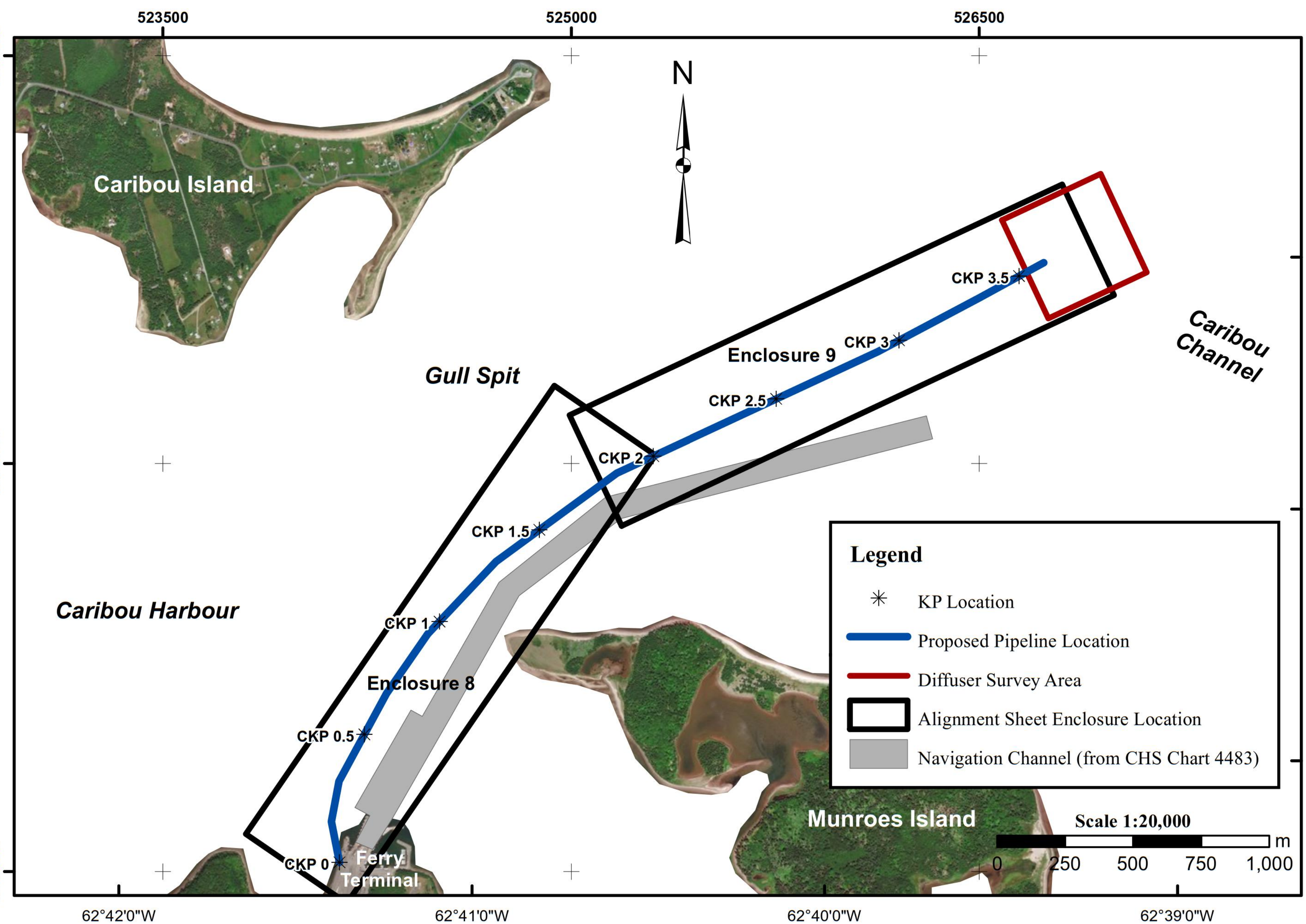

Figure 5.4 – Caribou Harbour alignment sheet enclosure locations.

CSR GeoSurveys Ltd.

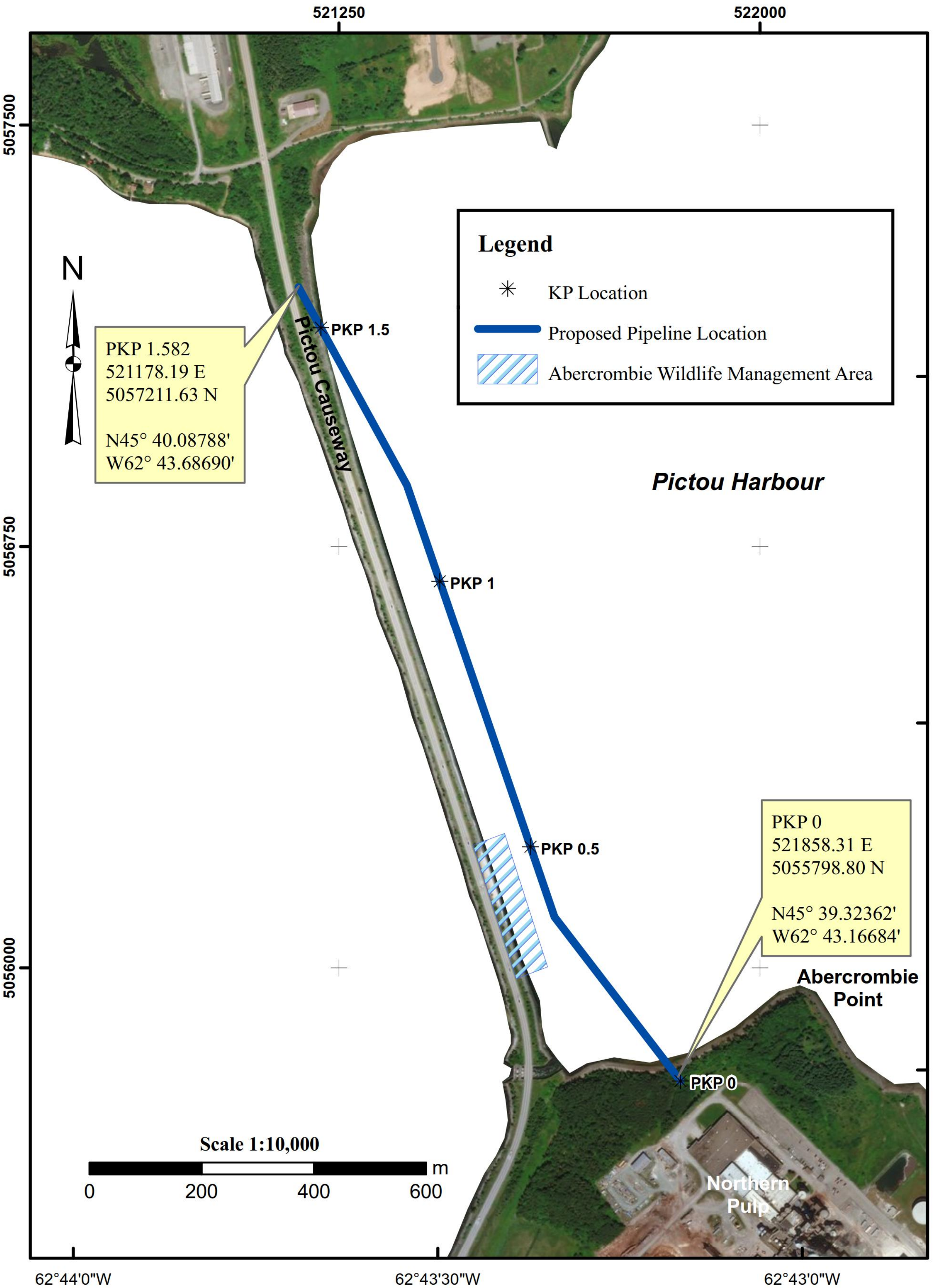

Figure 5.5 – Pictou Harbour Kilometre Postings (KP's).

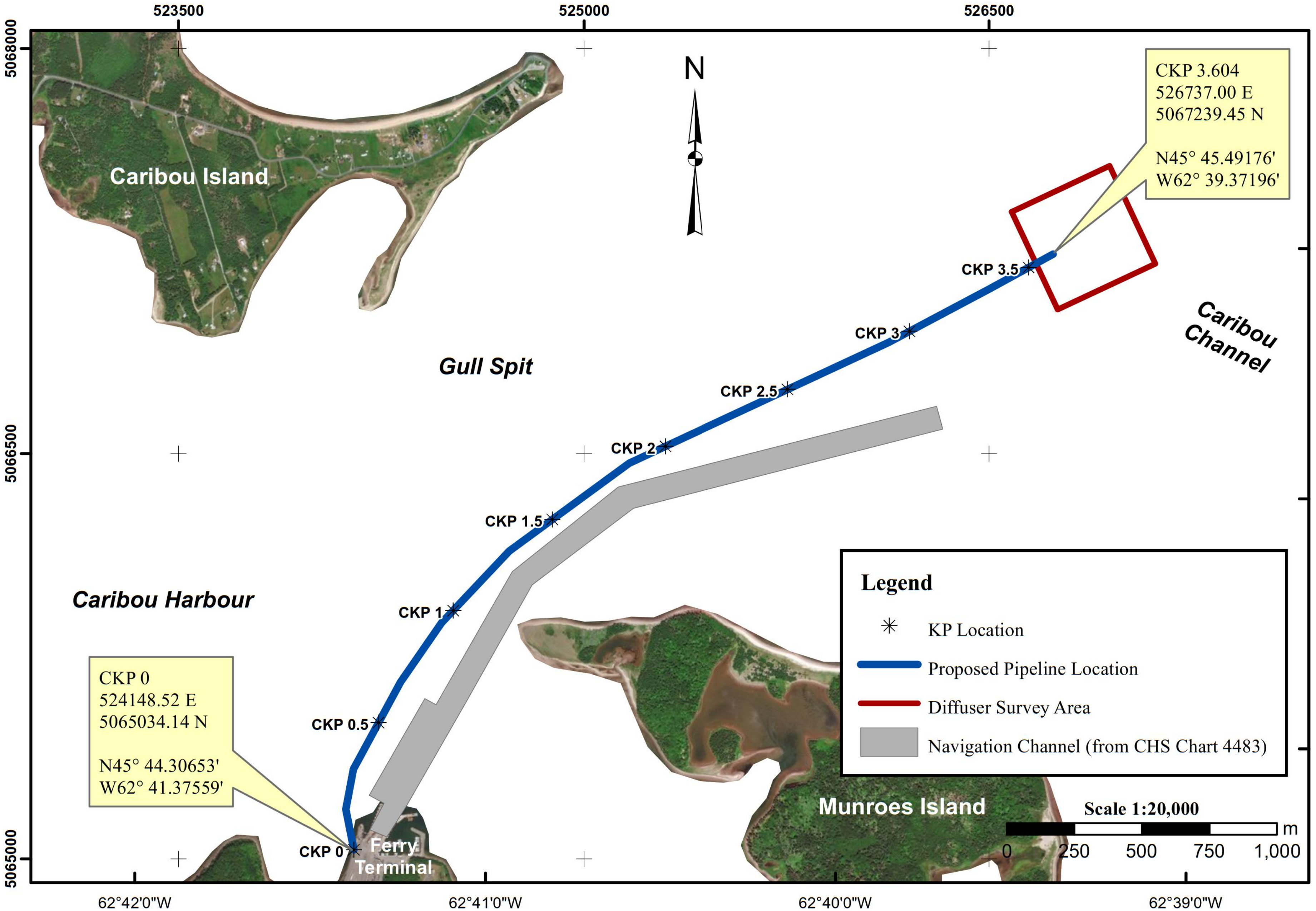

Figure 5.6 – Caribou Harbour Kilometre Postings (KP's).

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5.1 Bathymetry

The bathymetry data collected within the Pictou Harbour and Caribou Harbour survey corridors are referenced to Chart Datum. The bathymetric soundings were reduced to Chart Datum (LLWLT) using RTK tides. One metre bathymetric contours are presented on Enclosure 1 and 3 (Pictou) and Enclosures 4, 5, 8 and 9 (Caribou).

5.1.1 Pictou Harbour Pipeline Route Bathymetry

The bathymetry over the Pictou Harbour survey corridor is illustrated on Figure 5.1.1 while the seabed slope referenced in degrees from the horizontal is included on Figure 5.1.2. Figure 5.1.3 presents the elevation and slope variations along the proposed pipeline route while Table 5.1.1 provides a summary of the elevations along the proposed route according to KP.

The bathymetry of the Pictou Harbour proposed pipeline route (Figure 5.1.1) is relatively flat and shallow immediately offshore of Abercrombie Point. From PKP 0.207 to PKP 0.460 water depths range from 1.87 m to 2.26 m. At PKP 0.460 the seabed begins to slope downward to the old West River channel (KPK 0.710). The maximum depth along the proposed route is 9.93 m at PKP 0.710. The seabed slopes upward between PKP 0.710 and PKP 0.965 to a depth of 2.30 m. The remainder of the proposed pipeline route occurs over a very flat shallow seabed until reaching the Pictou Causeway toe of slope at PKP 1.415. From PKP 0.965 to PKP 1.415, water depths range from 2.51 m to 1.97 m. The bathymetric survey coverage included the slope face of the Pictou Causeway at the north end of the proposed route. The minimum water depth measured along the causeway slope was 0.20 m above Chart datum at the multibeam data extent (PKP 1.451).

Within the survey area the seabed slope is generally < 5 degrees. The slope exceeds 10 degrees offshore each landfall location at PKP 0.200 and PKP 1.430. The maximum slope along the south and north West River channel is 6 and 7 degrees respectively.

Table 5.1.1 – Pictou Harbour Proposed Route Bathymetry Summary

Start PKP	End PKP	Elevation (m)		Notes
		Start	End	
0	0	-	-	Pictou Harbour Start 521858.31E, 5055798.80N
-	0.207	-	-1.87	PKP 0.207; multibeam data extent
0.207	0.300	-1.87	-2.03	
0.300	0.400	-2.03	-2.35	
0.400	0.500	-2.35	-2.91	
0.500	0.600	-2.91	-5.81	
0.600	0.700	-5.81	-9.80	
0.700	0.800	-9.80	-6.25	Deepest recorded depth along route 9.93 m at PKP 0.710.
0.800	0.900	-6.25	-4.19	

Start PKP	End PKP	Elevation (m)		Notes
		Start	End	
0.900	1.000	-4.19	-2.35	
1.000	1.100	-2.35	-2.36	
1.100	1.200	-2.36	-2.32	
1.200	1.300	-2.32	-2.23	
1.300	1.400	-2.23	-2.06	
1.400	1.451	-2.06	+0.20	PKP 1.415; toe of causeway slope PKP 1.451; multibeam data extent
1.582	1.582	-	-	Pictou Harbour End 521178.19E, 5057211.63N

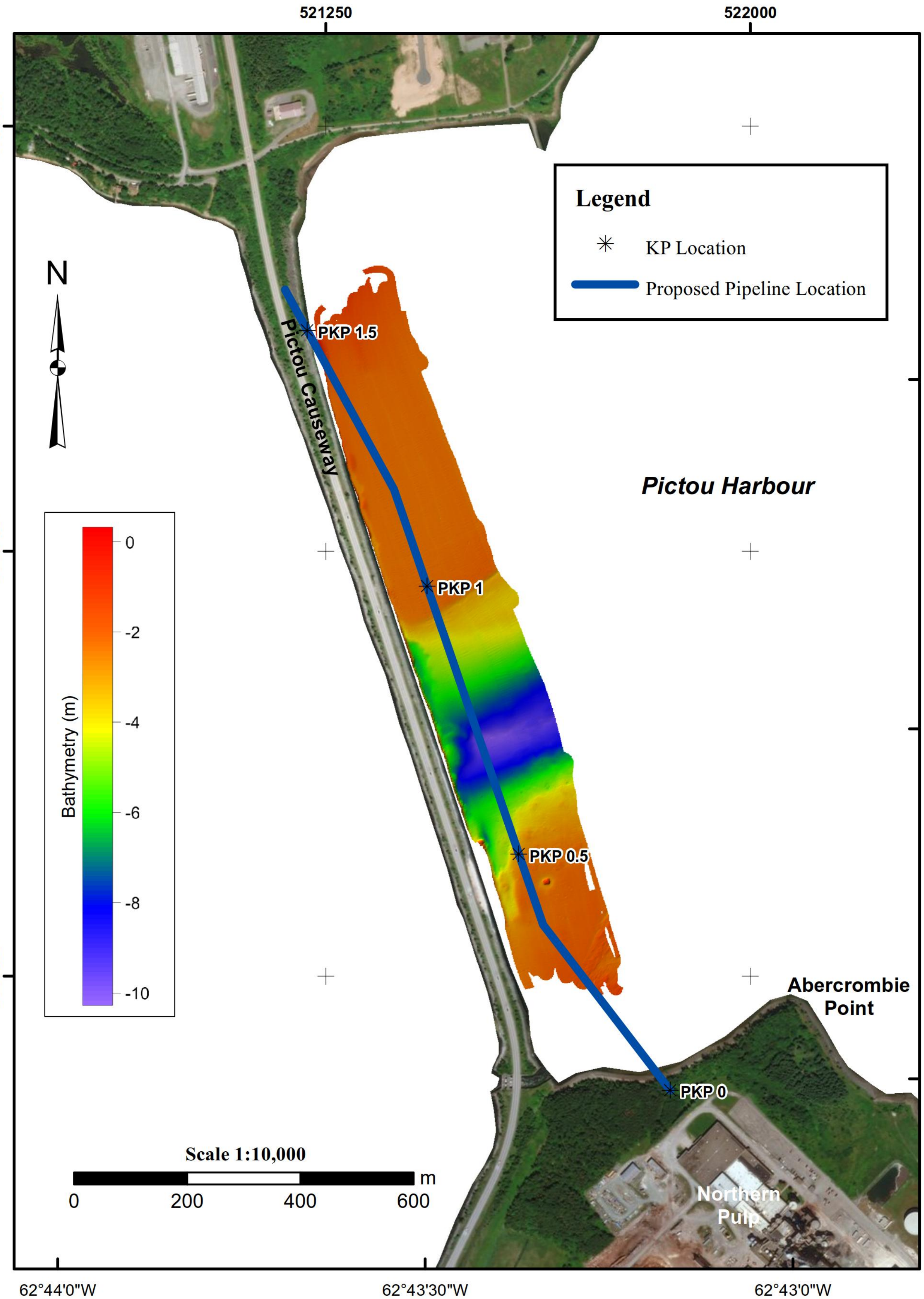

Figure 5.1.1 – Pictou Harbour multibeam bathymetric coverage with proposed pipeline route.

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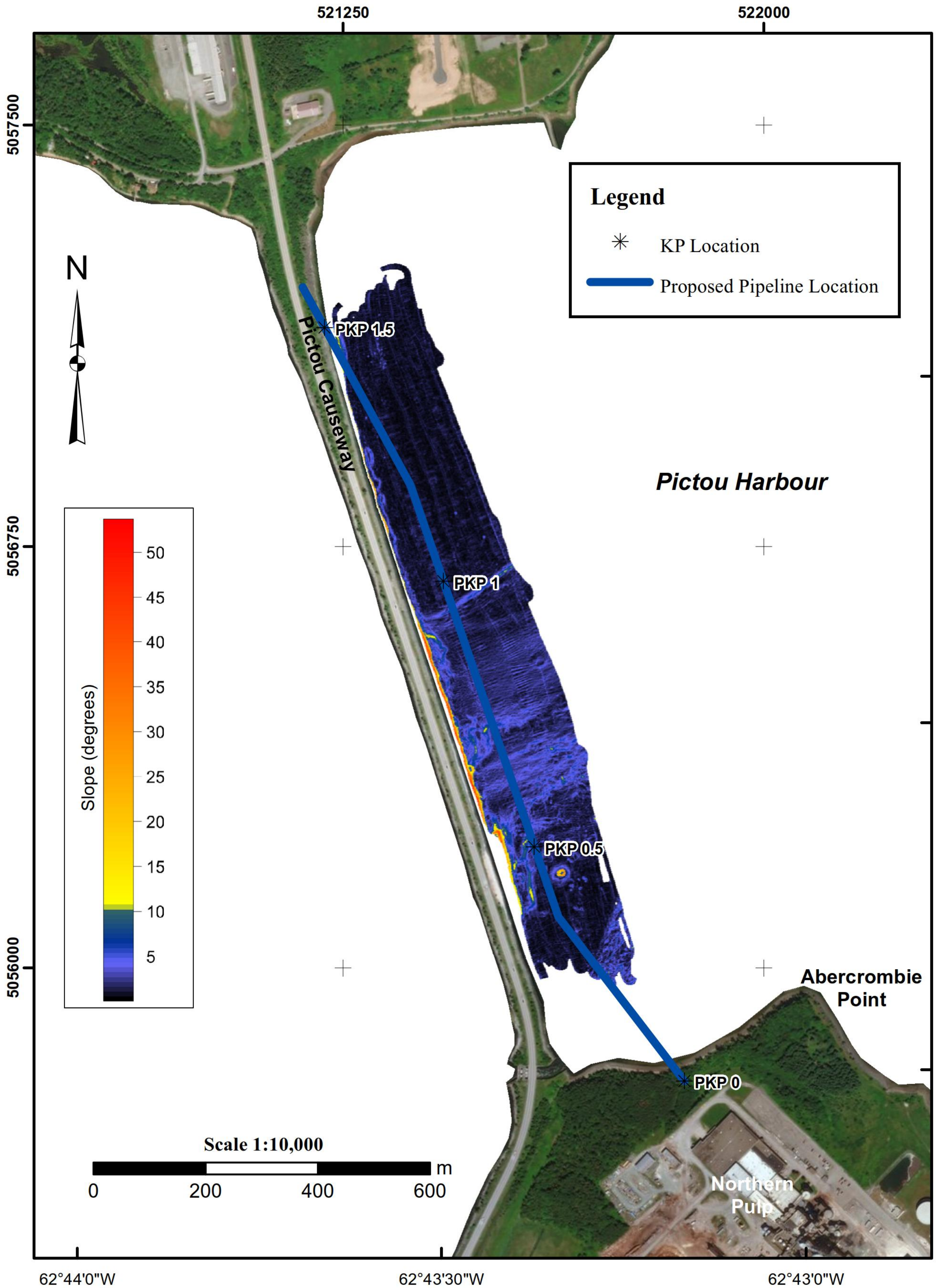

Figure 5.1.2 – Pictou Harbour seabed slope referenced in degrees from horizontal.

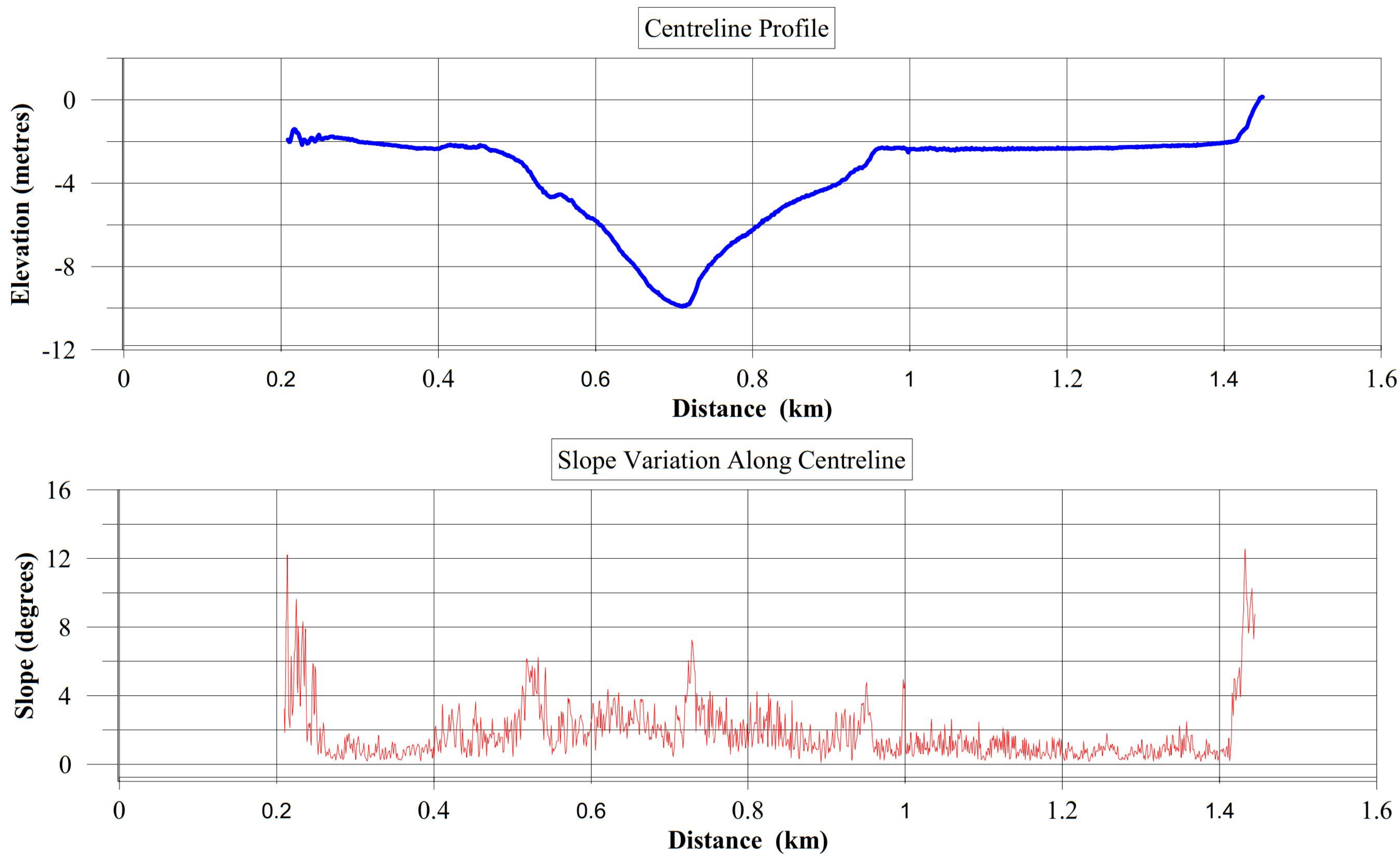

Figure 5.1.3 - Pictou Harbour proposed pipeline route centreline profile (top) and slope variation in degrees (bottom).

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5.1.2 Caribou Harbour Pipeline Route Bathymetry

The bathymetry over the Caribou Harbour survey corridor is illustrated on Figure 5.1.4 while the seabed slope referenced in degrees from the horizontal is included on Figure 5.1.5. Figure 5.1.6 presents the elevation and slope variations along the proposed pipeline route while Table 5.1.2 provides a summary of the elevations along the proposed route according to KP.

The bathymetry of the Caribou Harbour proposed pipeline route ranges from 0.22 m to 19.06 m; see Figure 5.1.4. The data extent of the bathymetric survey coverage begins at CKP 0.078 where the water depth is 1.03 m. Between CKP 0.100 and CKP 0.400 the seabed is generally flat with water depths ranging between 1.15 m and 2.75 m. The proposed pipeline route transects a channel within Caribou Harbour between CKP 0.400 and CKP 0.675. The maximum depth measured in the channel along the proposed route is 6.80 m at CKP 0.496. North of the channel, water depths remain very shallow as the proposed route approaches and crosses Gull Spit. Multibeam data was not acquired across the entire survey corridor in some locations over Gull Spit because they were not navigable. At CKP 1.472, the shallowest water depth along the proposed route was measured at 0.22 m. Water depths remain very shallow along the route offshore of Gull Spit. At CKP 2.270, the seabed begins to deepen as the proposed route follows a gradual slope towards the Caribou Channel. From CKP 2.270 to CKP 2.975 water depths along the proposed route range from 1.67 m to 7.15 m. The seabed deepens rapidly from CKP 2.975 to the end of the proposed route at CKP 3.604 (outfall location) within the Caribou Channel where the depth of the outfall location is 19.04 m below Chart Datum (LLWLT) or 20.2 m below Mean Water Level.

Within the survey area the seabed slope is generally < 5 degrees. The greatest slopes occur at CKP 0.415 (10 degrees), CKP 0.660 (8 degrees), CKP 1.020 to CKP 1.080 (10 to 16 degrees), and CKP 1.360 (10 degrees). The seabed slope is variable with a maximum slope of 8 degrees between CKP 3.000 to CKP 3.480 due to the presence of sediment transport features.

Table 5.1.2 – Caribou Harbour Proposed Route Bathymetry Summary

Start CKP	End CKP	Elevation (m)		Notes
		Start	End	
0	0	-	-	Caribou Harbour Start 524148.52, 5065034.14
0	0.078	-	-1.03	CKP 0.078; multibeam data extent
0.078	0.1	-1.03	-1.15	
0.1	0.2	-1.15	-2.62	
0.2	0.3	-2.62	-1.97	
0.3	0.4	-1.97	-1.84	
0.4	0.5	-1.84	-6.71	
0.5	0.6	-6.71	-5.34	
0.6	0.7	-5.34	-2.30	
0.7	0.8	-2.30	-1.69	
0.8	0.9	-1.69	-2.52	
0.9	1.0	-2.52	-2.35	

Start CKP	End CKP	Elevation (m)		Notes
		Start	End	
1.0	1.1	-2.35	-1.48	
1.1	1.2	-1.48	-3.43	
1.2	1.3	-3.43	-2.96	
1.3	1.4	-2.96	-1.37	
1.4	1.5	-1.37	-0.78	Shallowest recorded depth along route 0.22 m at CKP 1.472
1.5	1.6	-0.78	-0.71	
1.6	1.7	-0.71	-1.56	
1.7	1.8	-1.56	-1.14	
1.8	1.9	-1.14	-1.45	
1.9	2.0	-1.45	-1.57	
2.0	2.1	-1.57	-1.71	
2.1	2.2	-1.71	-1.63	
2.2	2.3	-1.63	-2.07	
2.3	2.4	-2.07	-3.47	
2.4	2.5	-3.47	-4.82	
2.5	2.6	-4.82	-5.81	
2.6	2.7	-5.81	-6.23	
2.7	2.8	-6.23	-6.34	
2.8	2.9	-6.34	-6.59	
2.9	3.0	-6.59	-7.65	
3.0	3.1	-7.65	-10.46	
3.1	3.2	-10.46	-12.94	
3.2	3.3	-12.94	-14.38	
3.3	3.4	-14.38	-15.75	
3.4	3.5	-15.75	-17.46	
3.5	3.6	-17.46	-19.05	
3.6	3.604	-19.05	-19.04	Deepest recorded depth along route 19.06 m at CKP 3.602
3.604	3.604	-19.04	-19.04	Caribou Harbour Outfall Location 526737.00, 5067239.45

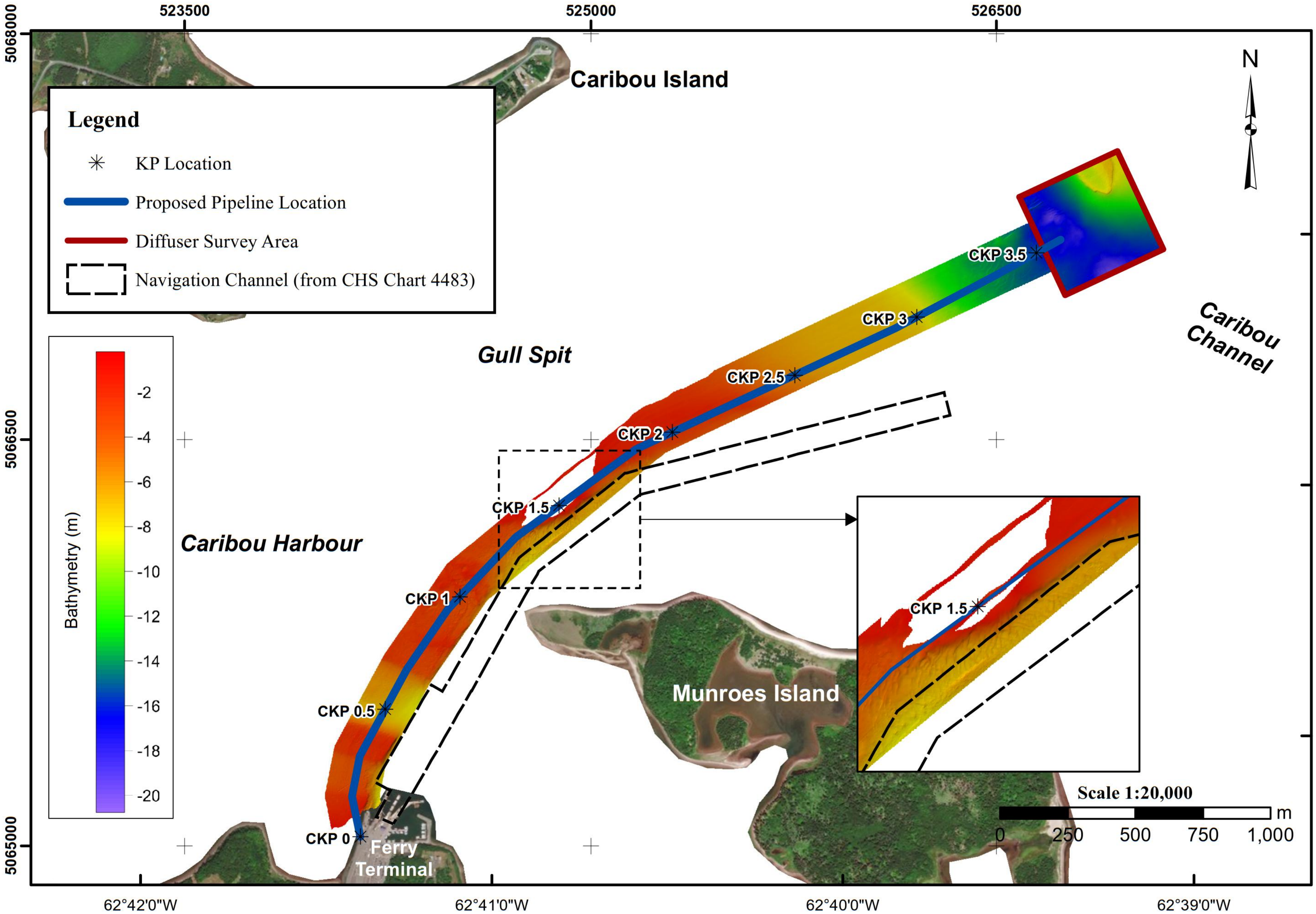

Figure 5.1.4 – Caribou Harbour multibeam bathymetric coverage with proposed pipeline route.

CSR GeoSurveys Ltd.

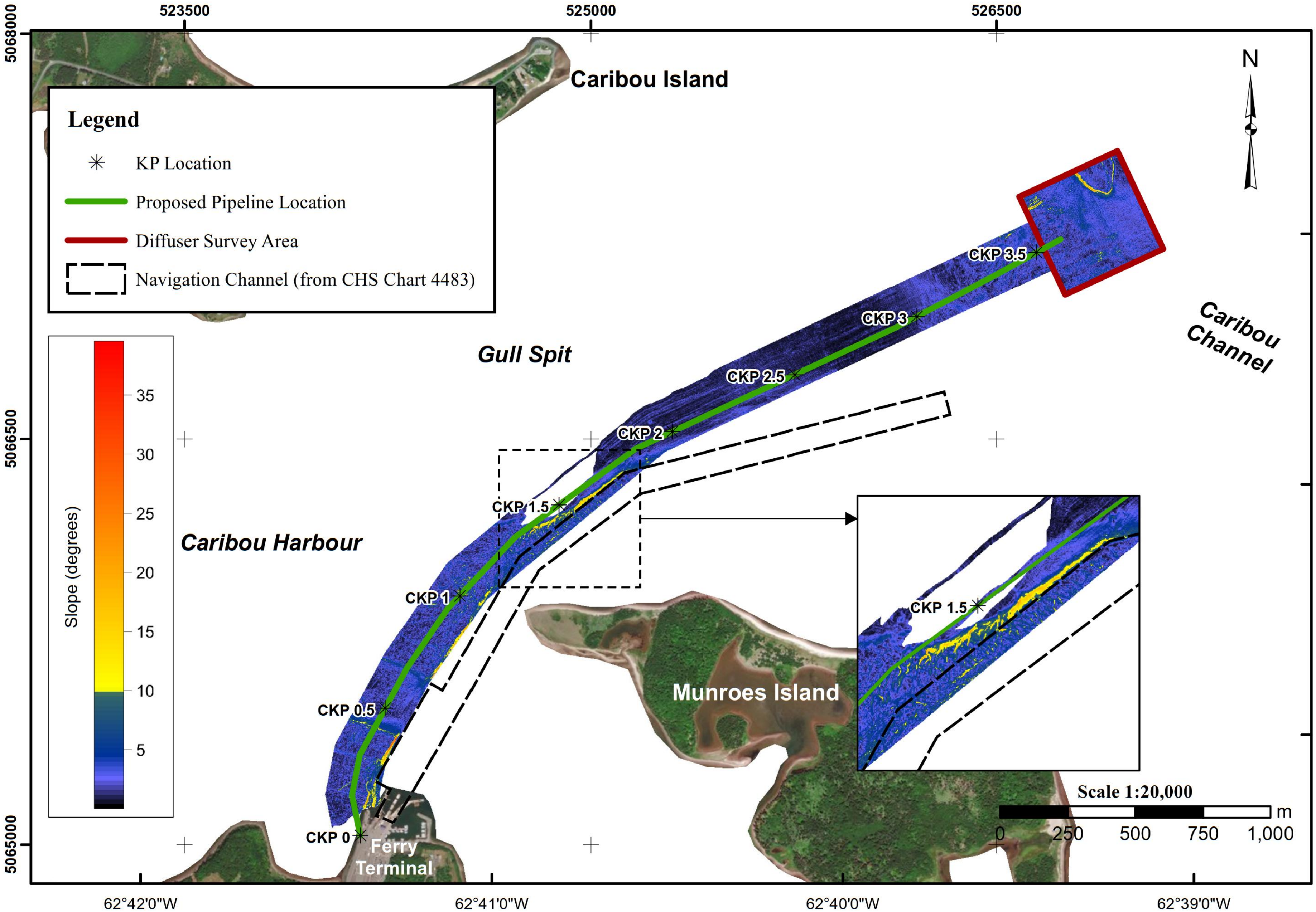

Figure 5.1.5 – Caribou Harbour seabed slope referenced in degrees from horizontal.

CSR GeoSurveys Ltd.

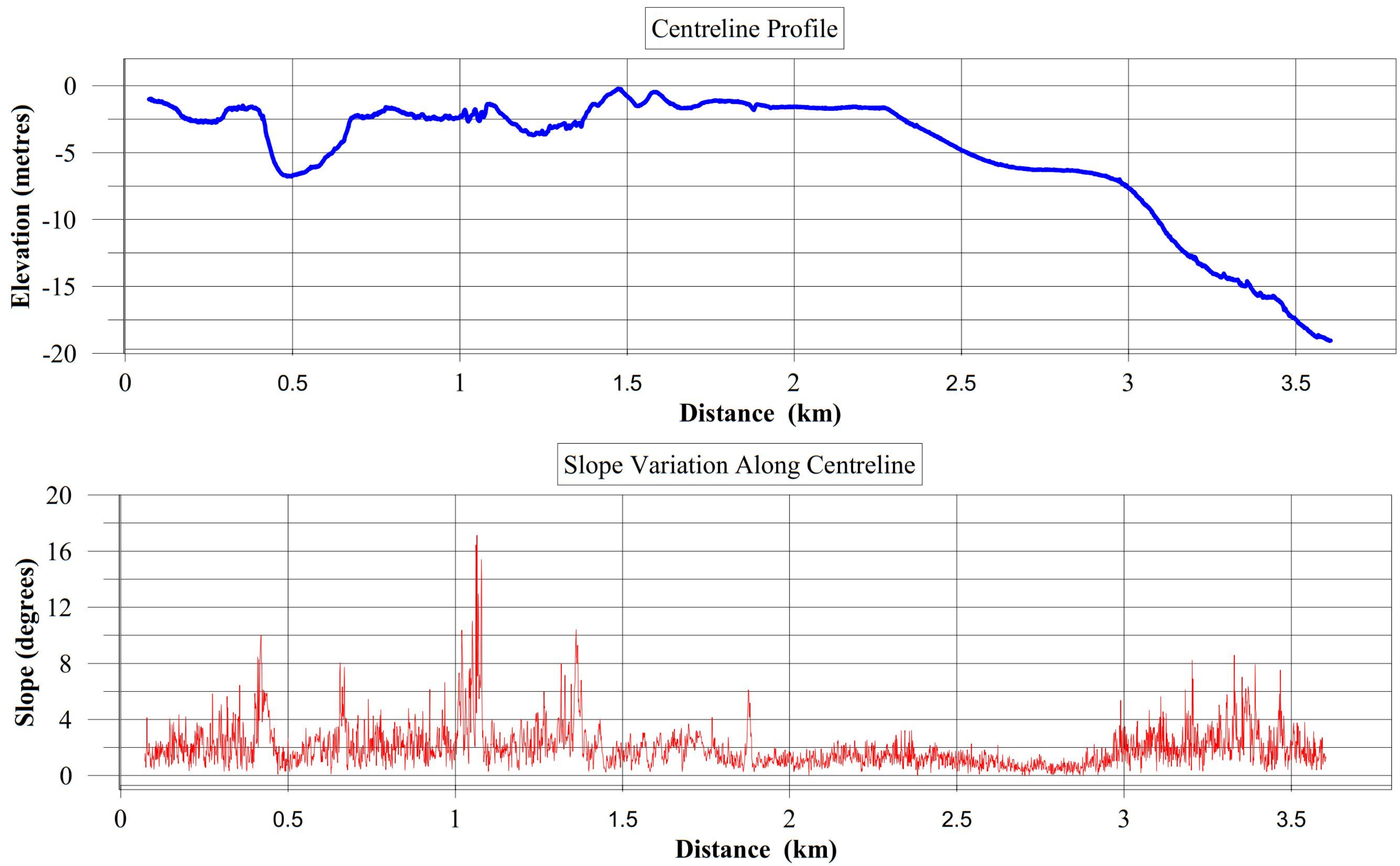

Figure 5.1.6 - Caribou Harbour proposed pipeline route centreline profile (top) and slope variation in degrees (bottom).

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5.2 Geotechnical Results

The 2019 marine geotechnical survey in Pictou Harbour and Caribou Harbour consisted of vibracore sampling and grab sampling. A total of 5 vibracores were collected in the Pictou Harbour survey corridor and 22 vibracores were collected in the Caribou Harbour survey corridor. In addition to the vibracores, 19 grab samples of surface sediment were collected in the Caribou Harbour survey corridor for the purpose of ground truthing the sidescan sonar data.

5.2.1 Vibracore Sampling

A summary of the vibracore sampling is presented in Table 5.2.1 (Pictou) and Table 5.2.2 (Caribou). The tables include vibracore sample coordinates, approximate water depth at sample location, penetration depth and surficial sediment type.

Vibracore sample locations in Pictou Harbour were spaced at approximately 250 m. Vibracore sample locations in Caribou Harbour were selected based on preliminary analysis of the sub-bottom profiler data. The nearshore section of Caribou Harbour required additional vibracore samples compared to the offshore section due to the variable sub-bottom geology encountered.

The target depth for all vibracore sampling conducted during the marine geotechnical survey was 3 m below seabed. CSR utilized both 3.0 m and 4.3 m vibracore barrels during the vibracore program. Sample recovery for each vibracore varied and was dependent on sediment type. In general, very good recovery was achieved in soft sediments including silt and fine sand. Sample recovery was less in medium to coarse sand due to the less cohesive nature of the material. At some locations, multiple attempts were made to achieve the best recovery possible.

Penetration depth of the vibracore was measured using a marked line on the core barrel. In soft sediments the penetration depth was typically equivalent to the length of the vibracore barrel, which was the maximum penetration possible. In stiffer sediments, vibracore penetration was sometimes limited by refusal before maximum penetration was achieved.

Vibracore samples collected during the marine geotechnical program were logged and tested in the field by a geotechnical technician from Stantec Consulting Ltd. The vibracore samples were then transported to Pier C in Pictou, transferred to a courier who delivered the samples to Stantec’s geotechnical lab in Dartmouth. At the lab, the vibracore material was extruded from the core liners, classified, logged and photographed; see Figure 5.2.1 through Figure 5.2.3. Samples were then selected for further analysis which included moisture content, grain size analysis, Atterberg limits and penetrometer tests. The final logs and results of the vibracore sample testing are included in Appendix II.

Table 5.2.1 – Pictou Harbour Vibracore Summary Table

Sample Id	Northing (m)	Easting (m)	Water Depth (m)	Penetration (m)	Surficial Sediment Type
VC50 (c)	5056172	521567	3.6	3.0	Silt
VC51 (b)	5056386	521473	6.1	3.0	Clay
VC52 (b)	5056656	521390	2.3	4.3	Silt
VC53	5056899	521309	2.2	3.0	Silt
VC54	5057062	521267	2.1	2.5	Silt

Table 5.2.2 – Caribou Harbour Vibracore Summary Table

Sample Id	Northing (m)	Easting (m)	Water Depth (m)	Penetration (m)	Surficial Sediment Type
VC1	5067312	526869	15.6	3.0	Sand
VC2 (c)	5067189	526907	19.1	2.9	Sand
VC3 (b)	5067227	526663	18.0	2.9	Sand
VC4 (b)	5067135	526502	14.9	2.9	Sand
VC5	5067015	526242	9.3	2.6	Sand
VC6	5066004	524574	1.4	0.9	Sand
VC7	5066868	525931	6.2	2.3	Sand
VC8	5066735	525663	4.1	1.1	Sand
VC9	5066622	525401	1.4	1.3	Sand
VC10 (b)	5066483	525157	1.4	1.2	Sand
VC11	5066168	524783	2.5	2.2	Sand
VC12	5065980	524556	1.7	2.1	Sand
VC13	5065768	524405	1.8	0.4	Gravel
VC14	5065548	524262	6.2	3.0	Silt
VC15	5065386	524179	1.7	3.0	Silt
VC16	5065255	524132	2.7	3.0	Silt
VC18	5066289	524965	0.7	2.0	Sand
VC19	5065137	524125	1.3	4.3	Silt
VC20	5065327	524152	1.8	4.3	Silt
VC21	5065466	524225	6.3	4.3	Silt
VC22	5065655	524323	2.6	4.3	Silt
VC23	5066910	525961	6.3	3.2	Sand

Figure 5.2.1 – Vibracore sample from VC1 composed of coarse sand and gravel.

Figure 5.2.2 – Vibracore sample from VC20 composed of silt.

Figure 5.2.3 – Vibracore sample from VC53 composed of silt.

5.2.2 Grab Sampling

A total of 19 grab samples were collect in the Caribou Harbour survey corridor to ground truth the sidescan sonar data and aid in the interpretation of the surficial geology. Field logs and classification of each grab sample were recorded in Hypack. No testing was conducted on the grab samples. Table 5.2.3 lists details of the grab samples collected.

Table 5.2.3 – Caribou Harbour Grab Sample Summary Table

Sample Id	Northing (m)	Easting (m)	Water Depth (m)	Sediment Type
GS01	5067568	526686	14.0	Gravel
GS02	5067424	526585	19.8	Sand
GS03	5067389	527133	11.2	Gravel
GS04	5067314	526792	18.6	Sand
GS05	5067305	526476	15.5	Sand
GS06	5067182	526329	13.6	Sand
GS07	5067092	526900	20.4	Silt
GS08	5067111	526191	10.3	Silt
GS09	5067015	525864	6.6	Sand/Silt
GS10	5066873	526210	6.8	Gravel
GS11	5066757	525712	4.7	Sand
GS12	5066517	525172	1.3	Sand/Silt
GS13	5066308	524951	0.5	Sand/Silt
GS14	5066163	524773	3.6	Sand/Gravel
GS15	5065865	524466	2.4	Sand/Gravel
GS16	5065538	524256	6.4	Silt
GS17	5065391	524177	1.6	Silt
GS18	5065267	524135	2.6	Silt
GS19	5065076	524141	0.9	Silt

5.3 Surficial Geology

The surficial geology identified in the Pictou Harbour and Caribou Harbour survey corridors were interpreted from the geophysical data based on their acoustic signature. To support the interpretation, grab samples, vibracores and underwater video were correlated with the geophysical data. The results of the interpretation are presented on Enclosure 2 and 3 (Pictou) and Enclosures 6, 7, 8 and 9 (Caribou).

The following surficial geology units have been identified within the Pictou Harbour and Caribou Harbour survey corridors:

1. Clayey silt
2. Silt

6. Sand
7. Sand and Gravel

3. Silty sand
4. Sandy clay
5. Sandy silt
8. Cobble / Gravel
9. Boulders

The surficial unit descriptions were based on geological observations of the surface grab samples and vibracored seabed sediments. Grain size analysis tests (ASTM) were conducted on vibracore sub-samples at depth (Appendix II) and did not include grain size analysis of the surficial sediments. Figure 5.3.1 includes a correlation chart showing the relationships between phi sizes, millimeter diameters, size classifications (Wentworth, 1922), and ASTM sieve sizes from Poppe et al (eds., 2014).

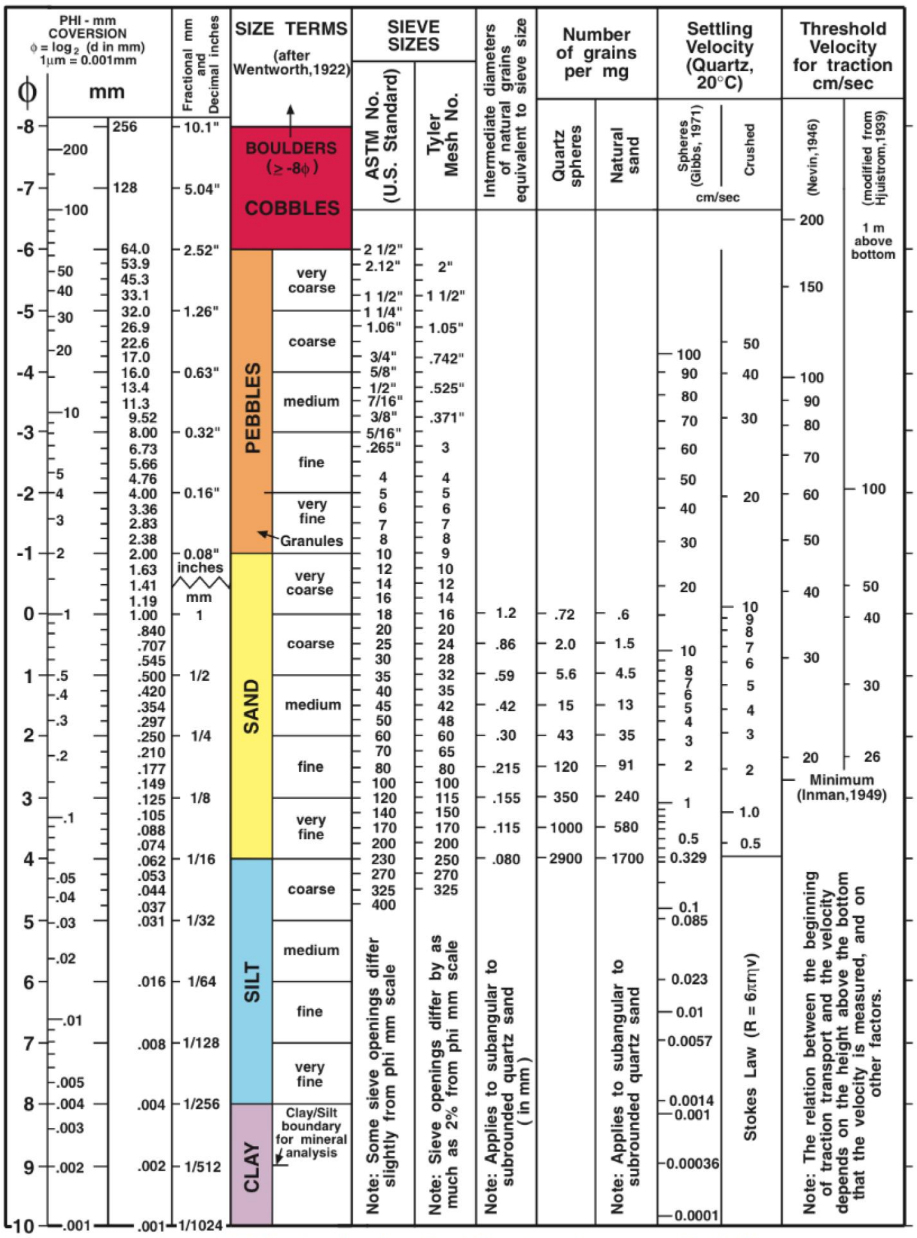

Figure 5.3.1 – Grain size classification (Poppe et al, 2014).

The surficial units identified in this report can be correlated with the regional surficial units described by Kranck (1971), see Table 5.3.1.

Table 5.3.1 – Surficial Geology Unit Summary Table

Survey Corridor Surficial Unit	Regional Northumberland Strait Surficial Unit
Clayey silt Silt Sandy clay Sandy silt	**Pugwash Mud** A thin, widespread veneer of soft clay to silty mud which, where present overlays all relict deposits.
Silty sand Sand Sand and gravel	**Buctouche Sand & Gravel** Formed as the post-glacial transgressing sea winnowed silt and clay sized particles from the glacial till
Cobble / Gravel Boulders	**Pomquet Drift** Poorly sorted glacial till consisting of subangular to angular coarse gravel, sand, silt and cobble. Boulders are also present within this unit. Can be correlated with Eatonville-Lawrencetown Till mapped onshore by Stea & Myers (1990).

Figure 5.3.2 and Figure 5.3.4 include the sidescan mosaics utilized for the surficial interpretation of the Pictou Harbour and Caribou Harbour survey corridors. These sidescan mosaics represent the acoustic intensity of the seabed. Typically, low-intensity returns (backscatter) are associated with smoother seafloor conditions and fine-grained surficial sediments. Higher levels of backscatter indicate increased bottom roughness, typically related to coarser sediments, cobbles, boulders, bedrock outcrops and anthropogenic debris.

5.3.1 Pictou Harbour Surficial Geology

The sidescan mosaic and interpreted surficial geology of the Pictou Harbour survey corridor are presented on Figure 5.3.2 and Figure 5.3.3 respectively. The survey corridor is dominated by an extensive area of silt covering the majority of the seabed. Three areas of boulders occur within the survey corridor. Two areas of boulders within the southern section of the survey corridor are interpreted to be anthropogenic in origin. The third area of boulders occurs within the northern section of the survey corridor and has been interpreted as outcropping glacial till, sub-bottom sequence 4 (Pomquet Drift). The areas of boulders do not occur along the proposed pipeline route. The Pictou Causeway submerged embankment has also been mapped and included in the surficial geology interpretation. Table 5.3.2 details the surficial geology along the proposed pipeline route in Pictou Harbour.

Point source reflectors interpreted as boulders greater than 1 m have been mapped from the sidescan sonar data. The locations of the point source reflectors are included on Enclosures 2 and 3. Boulders may also be present in the shallow sub-surface sediments where sub-bottom Sequence 4 is near the seabed; see Section 5.4.3.

Table 5.3.2 – Pictou Harbour Proposed Route Surficial Geology Summary

Start PKP	End PKP	Surficial Geology	Start Water Depth (m)	End Water Depth (m)	Notes
0	0.236	-	-	2.01	Outside of marine survey coverage
0.236	0.267	Cobble / Gravel	2.01	1.79	
0.267	0.658	Silt	1.79	8.41	
0.658	0.812	Sandy Clay	8.41	5.85	
0.812	1.418	Silt	5.85	1.83	
1.418	1.483	Causeway Embankment	1.83	0	
1.483	1.582	-	-	-	Outside of marine survey coverage

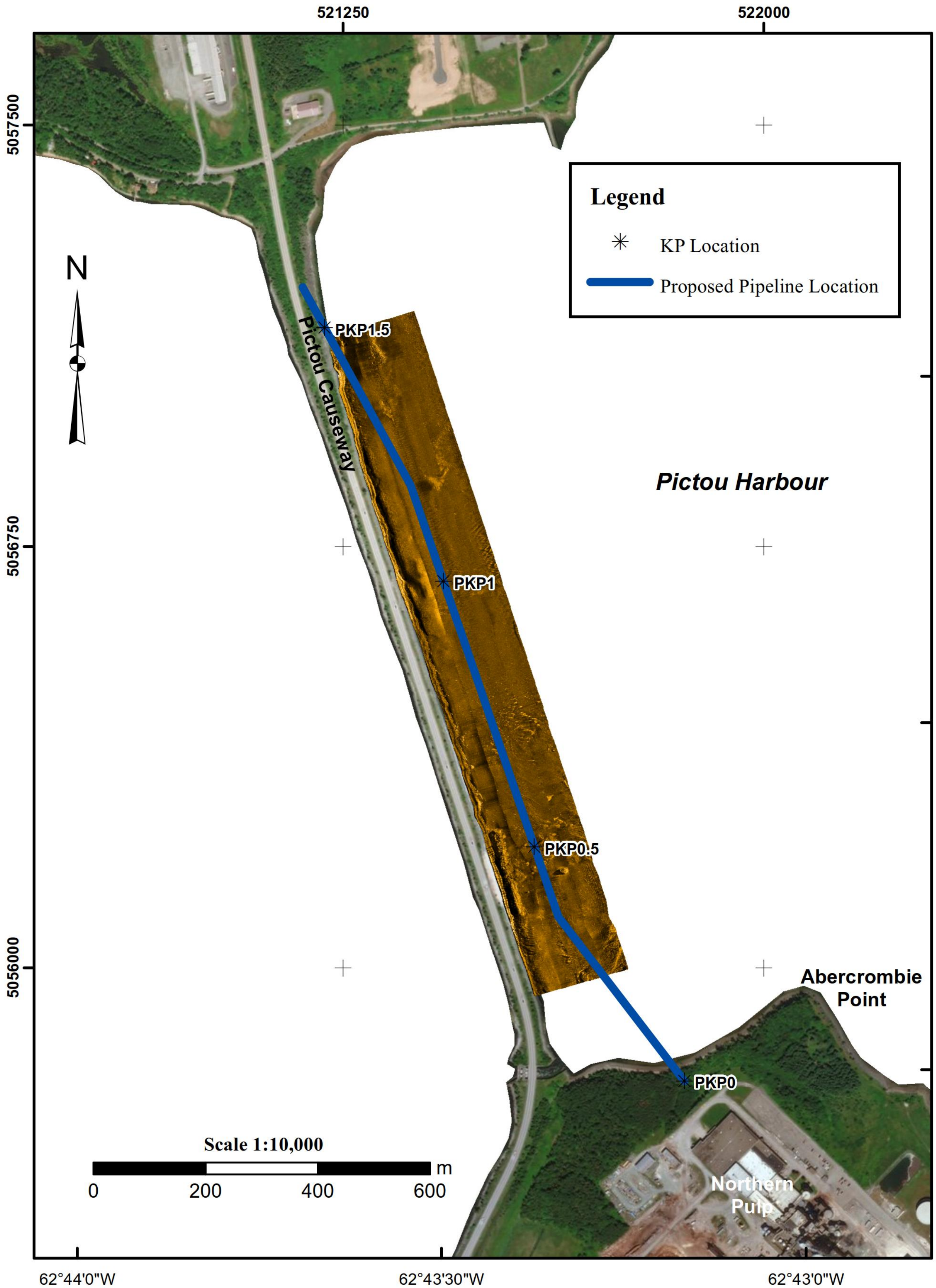

Figure 5.3.2 – Pictou Harbour sidescan sonar mosaic.

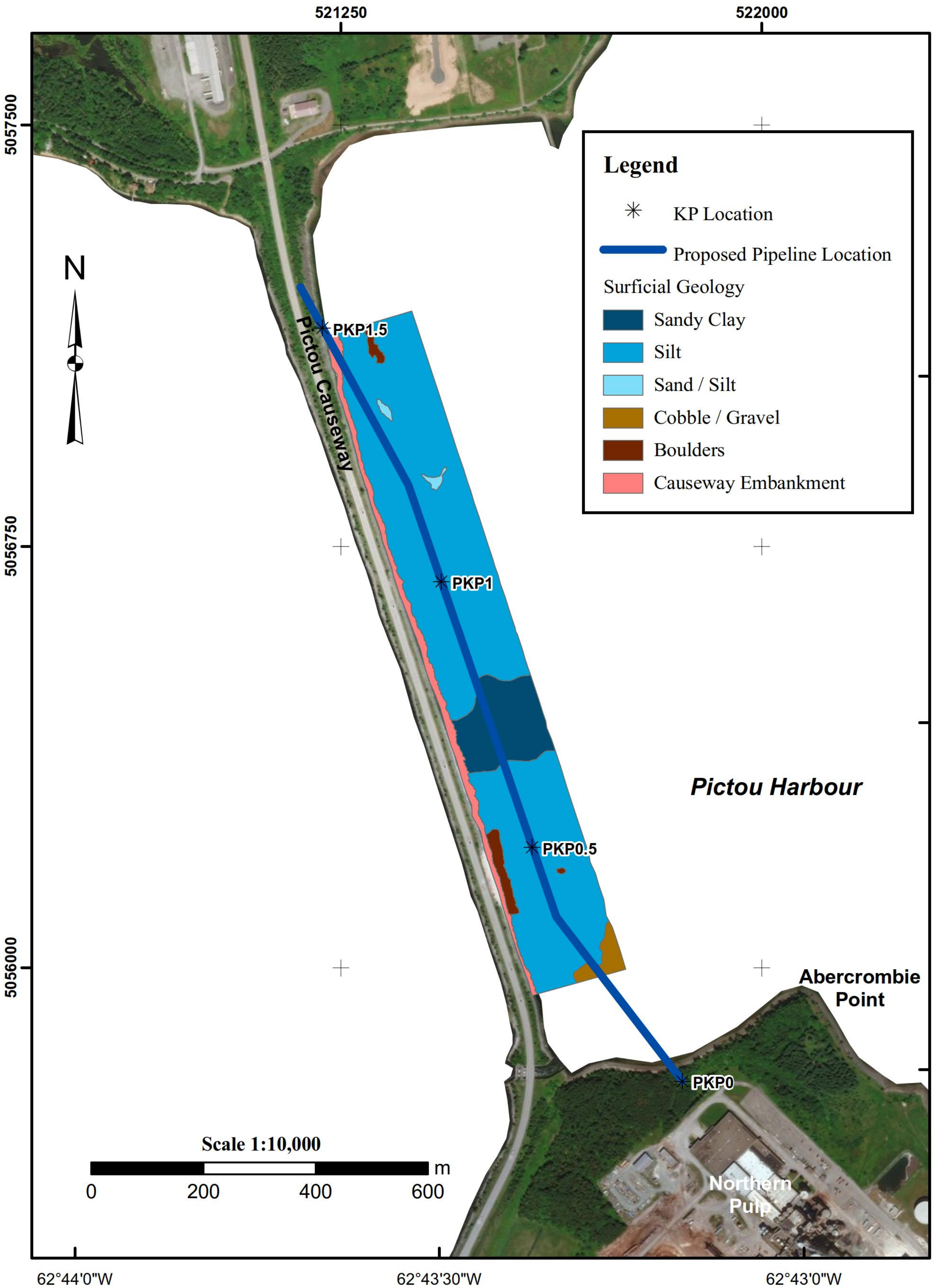

Figure 5.3.3 – Pictou Harbour surficial geology interpretation.

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5.3.2 Caribou Harbour Surficial Geology

The sidescan mosaic and interpreted surficial geology of the Caribou Harbour survey corridor are presented on Figure 5.3.4 and Figure 5.3.5 respectively. The surficial geology of the Caribou Harbour survey corridor is dominated by extensive areas of silty sand, sand, and sand/gravel, see Figure 5.3.5. An area of finer grained sediments including clayey silt, silt and sandy silt occurs nearshore extending from CKP 0.085 to CKP 0.667. From CKP 0.667 to CKP 2.175 the seabed within the survey corridor is composed of sand and sand/gravel. An area of silty sand was observed between CKP 2.175 and CKP 3.178.

The surficial geology from CKP 3.178 to the proposed pipeline outfall location (CKP 3.604) is composed primarily of sand. Further offshore of the proposed outfall location, the surficial geology transitions to sand and gravel. The majority of the diffuser survey area is composed of sand and gravel. Table 5.3.3 summarizes the surficial geology along the proposed Caribou Harbour pipeline route.

Point source reflectors interpreted as probable boulders greater than 1 m have been mapped from the sidescan sonar data. The locations of the point source reflectors are included on Enclosures 6 through 9. Boulders may also be present in the shallow sub-surface sediments where sub-bottom Sequence 4 is near the seabed; see Section 5.4.4.

Three areas of bed-forms caused by sediment transport have been identified within the Caribou Harbour survey corridor. These sediment transport features occur in non-cohesive sand produced by currents and or waves. The sediment transport feature locations are included on Enclosures 6 through 9.

The first area is located along the southeast edge of the survey corridor near Gull Spit. The majority of sediment transport features occur within the navigation channel. The proposed pipeline route transects the features between CKP 1.160 and CKP 1.355. These features range from ripples to megaripples with wavelengths of 5 to 10 m and heights of < 0.5 m. They were probably formed as a result of both currents and waves.

Sediment transport features were observed adjacent to the proposed outfall location, see Figure 5.3.6. The sediment transport features within area two occur 160 m southwest of the proposed outfall location between CKP 3.271 and CKP 3.435. The features in this area are interpreted as megaripples with wavelengths of 15 to 10 m and heights of approximately 0.5 m, see Figure 5.3.7. These features were likely formed by currents with a near bed-flow velocity of 40 to 60 cm/s (Amos & King, 1984). The morphology of the megaripples indicates the dominant near bed-flow direction is from southeast to northwest.

The third area is located approximately 75 m north of the proposed outfall location. The proposed pipeline route does not cross this area. The features include a combination of sand waves and megaripples. Sand wave heights range from approximately 1 m to 1.8 m while the megaripples have wavelengths of approximately 10 m and heights ≤ 0.5 m, see Figure 5.3.7. The sand waves and megaripples in this area may have formed by currents with a near bed-flow velocity of 40 to 100 cm/s (Amos & King, 1984). The near bed-flow direction that formed these features was moving in either a northeast or southwest direction.

No sediment transport features were observed at the proposed outfall which may indicate an increase in gravel within the surficial sediments at this location.

Table 5.3.3 – Caribou Harbour Proposed Route Surficial Geology Summary

Start CKP	End CKP	Surficial Geology	Start Water Depth (m)	End Water Depth (m)	Notes
0	0.085	-	-	1.12	Outside of marine survey coverage
0.085	0.167	Sandy Silt	1.12	2.23	
0.167	0.296	Clayey Silt	2.23	2.10	
0.296	0.467	Sandy Silt	2.10	6.57	
0.467	0.667	Silt	6.57	3.05	Nearshore Channel
0.667	1.160	Sand and Gravel	3.05	2.87	
1.159	1.207	Sand	2.87	3.64	
1.207	1.265	Sand and Gravel	3.64	3.30	
1.265	2.175	Sand	3.30	1.58	Gull Spit
2.175	3.016	Silty Sand	1.58	7.95	
3.016	3.106	Sand	7.95	10.74	
3.106	3.178	Silty Sand	10.74	12.74	
3.178	3.604	Sand	12.74	19.04	Outfall Location

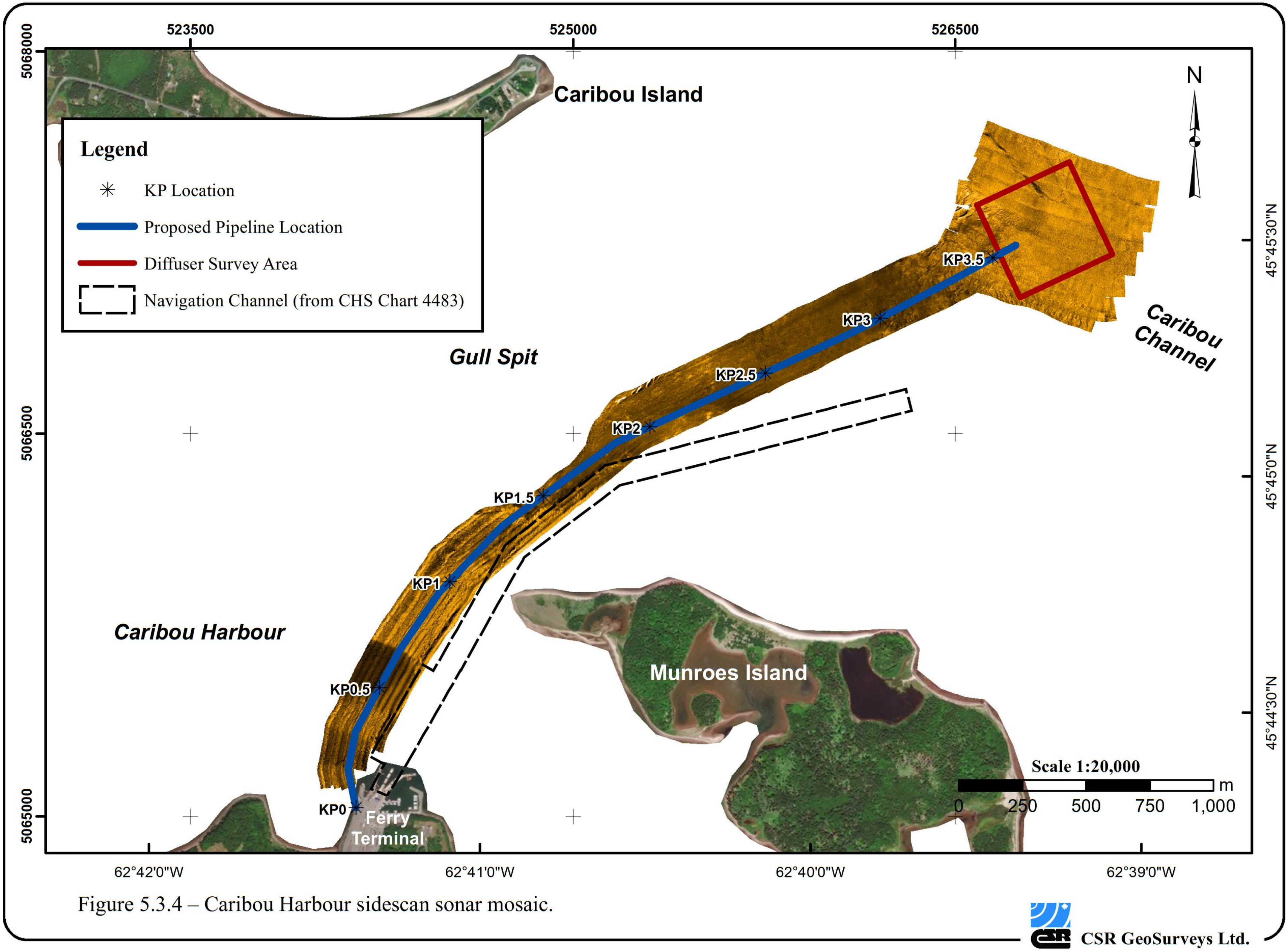

Figure 5.3.4 – Caribou Harbour sidescan sonar mosaic.

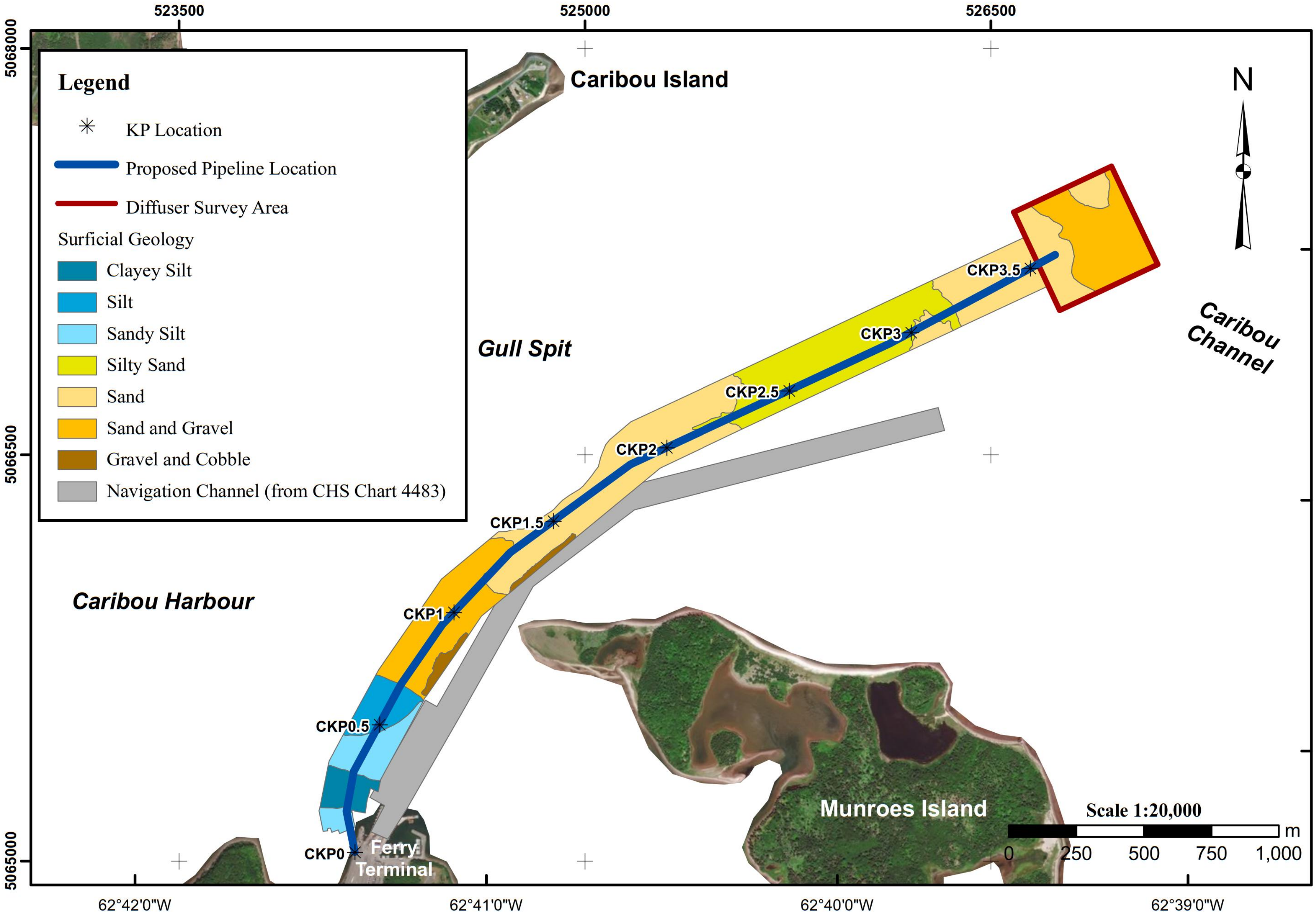

Figure 5.3.5 – Caribou Harbour surficial geology interpretation.

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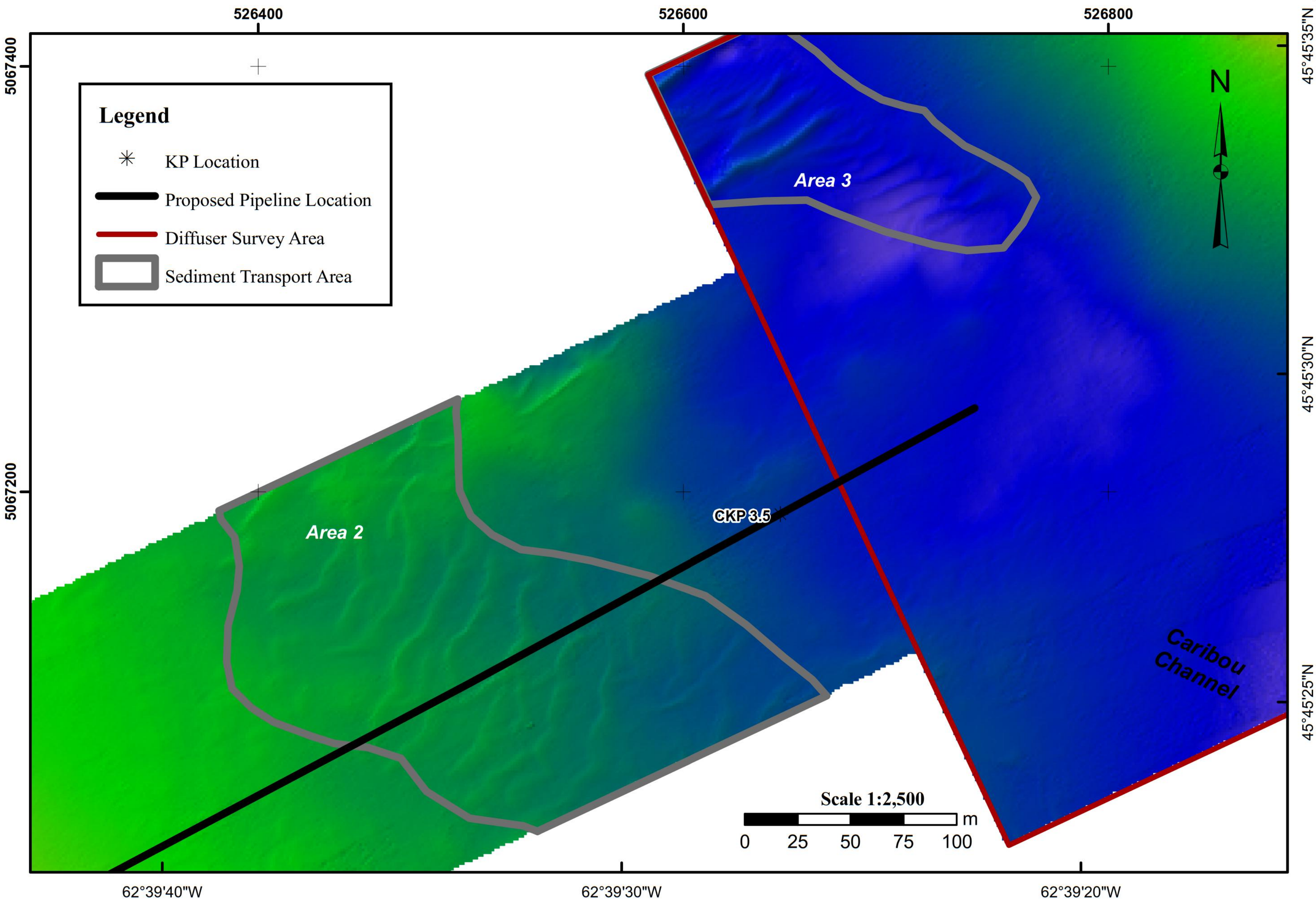

Figure 5.3.6 – Location of sediment transport features adjacent to the outfall.

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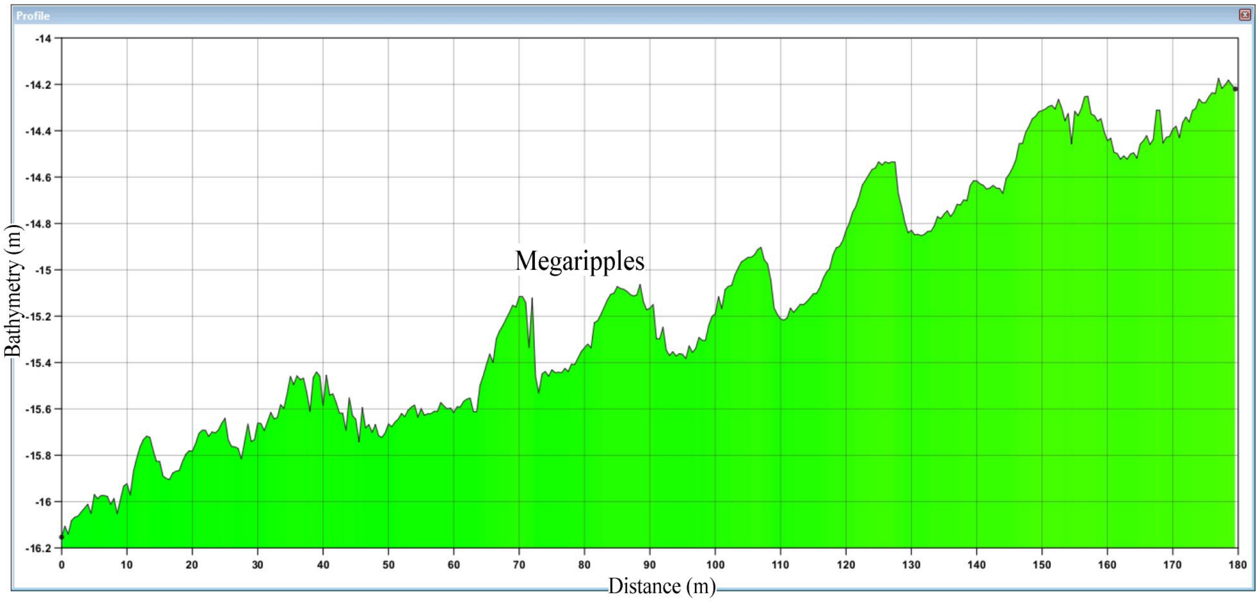
Southeast

Northwest



Southeast

Northwest

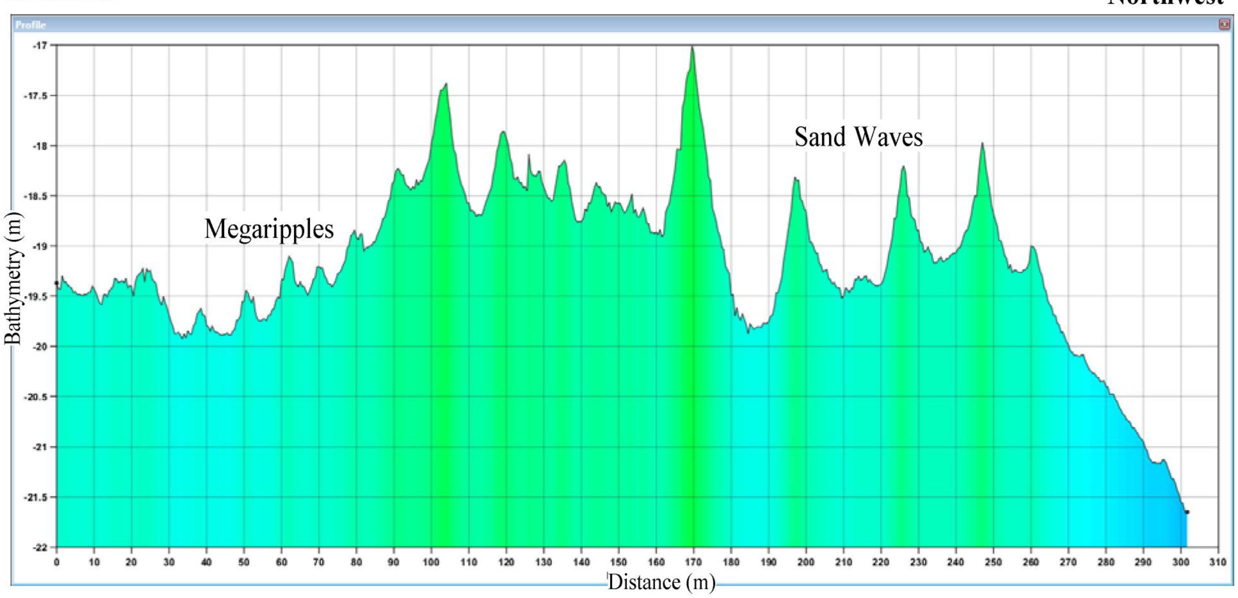


Figure 5.3.7 – Profiles of sediment transport features adjacent to the outfall over Area 2 (top) and Area 3 (bottom).

5.4 SUB-BOTTOM GEOLOGY

The sub-bottom geology of the Pictou Harbour and Caribou Harbour survey corridors were mapped from chirp profiler and single channel seismic reflection (Boomer) data. Mapping of the chirp and boomer sub-bottom datasets were based on analysis of acoustic characteristics and acoustic impedance of the geological sequences present in the seismic records. Vibracore samples were utilized in the interpretation of the sub-bottom geology. Although the proposed maximum trench depth for pipeline installation was 3 m, CSR mapped the complete sub-bottom sequence profiled by the geophysical systems. This was required in order to make correlations of each sub-bottom geological sequence across the survey corridor. CSR also acquired seismic refraction data to support the interpretation of the sub-bottom geology within Caribou Harbour. The seismic refraction data were utilized to map seismic velocities along a portion of the Caribou Harbour route to aid the interpretation of the glacial till-bedrock interface and to provide an indication of rippability for installation planning. The rippability of bedrock is a measure of its ability to be excavated with conventional excavation equipment thereby eliminating blasting of the rock.

5.4.1 Sub-bottom Geological Sequences

Five unique sub-bottom geological sequences have been mapped in the survey corridors. The extent of each sequence along the proposed pipeline routes are included on the route interpreted profiles; see Enclosure 3 (Pictou) and Enclosures 8 and 9 (Caribou). Table 5.4.1 provides details on each sequence.

Table 5.4.1 – Sub-bottom Geological Sequences

Pipeline Route Sub-bottom Sequences	Seismic Reflector	Sequence Description
Sequence 1 – Post glacial sediments	Top – Seabed Bottom – R1, R3	**Pugwash Mud** Sandy mud with 5-50% sand, predominantly silt/clay.
Sequence 2 – Post glacial sediments	Top – Seabed Bottom – R1, R3	**Buctouche Sand & Gravel** Mainly sand with varying percentages of gravel and cobbles.
Sequence 3 – Proglacial sediments	Top – R1, R2 Bottom – R3	**Henry Island Sediments** Proglacial sediment, well developed bedding in some areas.
Sequence 4 – Glacial till	Top – R3 Bottom - AB	**Pomquet Drift** Poorly sorted glacial till consisting of subangular to angular coarse gravel, sand, silt and cobble. Boulders are also present within unit. Can be correlated with Eatonville-Lawrencetown Till mapped locally by Stea & Myers (1990).
Acoustic Basement	AB	**Interpreted Bedrock** Well stratified sandstone and shale

**Sequence names taken from Kranck (1971).*

5.4.2 Sub-bottom Features

Shallow Gas Accumulation

The presence of gas charged sediments within the survey corridors was interpreted from both the chirp and boomer sub-bottom data. The presence of gas charged sediments can accentuate sub-bottom reflectors and cause high amplitude anomalies as well as prevent the penetration of the acoustic energy from the seismic systems, thereby masking the acoustic signal. The origin of the shallow gas in the survey areas cannot be determined from the data collected. The gas could originate from decomposed organic material (biogenic) or from underlying bedrock formations (petrogenic). Shallow gas accumulation is common in marine sediments of the Maritimes and within the Pictou area is probably related to decomposed organic material. The location of the top of shallow gas along the proposed pipeline route is included on the Alignment Sheet interpreted geological profiles.

Acoustic Basement

The acoustic basement is defined as the deepest discernable acoustic reflector mapped from a seismic record. The recognition of the acoustic basement horizon is dependent on the overlying geological units, seismic frequency and energy. Different seismic systems can yield different penetration depths. The acoustic basement mapped from the sub-bottom data was interpreted as either the top of bedrock or boulder rich zone within the lower glacial till sequence. The acoustic basement mapped along the proposed pipeline routes has been included on the route geological profiles; see Enclosure 3 (Pictou) and Enclosures 8 and 9 (Caribou).

5.4.3 Pictou Harbour Sub-bottom Geology

Three major reflectors were identified and mapped in the Pictou Harbour survey corridor; R1, R3 and Acoustic Basement (AB). These reflectors define the sub-bottom geological sequences found along the proposed route. Areas of shallow gas were also identified and mapped over the Pictou Harbour survey corridor. The spatial distribution of the major reflectors, including shallow gas and sub-bottom geological sequences are presented on Enclosure 3: Alignment Sheet 1 - Pictou Harbour. Figure 5.4.2 includes a chirp profiler record with interpreted sub-bottom geology while the location of the chirp record is displayed on Figure 5.4.1.

Sub-bottom Sequence 1 – Post Glacial Sediments

Sequence 1 consists primarily of soft silt and clay with occasional sandy lenses and is interpreted to be Pugwash Mud as defined by Kranck (1971). Shell fragments are also present within Sequence 1. The upper boundary of Sequence 1 is the seabed and the lower boundary is reflector R1.

Sequence 1 is the youngest sub-bottom unit found along the proposed pipeline route in Pictou Harbour and covers the majority of the seabed within the survey corridor. Vibracore samples VC50 through VC54 all intersected Sequence 1. Sequence 1 is exposed at the seabed from PKP 0.281 to PKP 1.415 and ranges in thickness from < 1 m to ≥ 3 m at vibracore locations VC52 and VC53. Areas of shallow gas have been mapped within Sequence 1 from approximately PKP 0.950 to PKP 1.350 resulting in acoustic masking of reflector R1 which defines the bottom of

Sequence 1. Shallow gas may occur at the reflector R1 location over this section of the proposed pipeline route.

The installation of the Pictou Causeway in 1968 effectively obstructed the flow of the West River into Pictou Harbour. This may have caused an increased accumulation of fine-grained sediment (primarily silt) on the seabed within the Pictou Harbour survey corridor and resulted in fine-grained sediment dominating the upper bounds of Sequence 1. Lenses of coarser grained sediment have been intersected at depth within Sequence 1. These lenses are interpreted to be reworked riverbed sediments.

<u>Sub-bottom Sequence 2 – Post Glacial Sediments</u>
Sequence 2 was not observed within the Pictou Harbour survey corridor.

<u>Sub-bottom Sequence 3 – Proglacial Sediments</u>
Sequence 3 consists of proglacial sediments composed of clay, silty sand and gravel (confirmed by vibracore samples and historic boreholes in the area). The deposition of Sequence 3 may be correlated with Henry Island Sediments as defined by Kranck (1971). Henry Island Sediments is an informal term applied to formations of stratified proglacial sediment that overlie Pomquet Drift glacial till and bedrock in river channels over the eastern area of the Northumberland Strait.

The top of Sequence 3 is defined by reflector R1 in Pictou Harbour and is overlain by Sequence 1 along the proposed pipeline route. Sequence 3 occurs along the majority of the proposed pipeline route and reaches its maximum thickness below the old West River channel of approximately 4.5 m at PKP 0.645. The depth below seabed to the top of Sequence 3 is relatively consistent where reflector R1 has been mapped and ranges between 0.5 m and 1.8 m.

Areas of shallow gas mask reflector R3 making it difficult to interpret the bottom of Sequence 3 in some areas.

<u>Sub-bottom Sequence 4 – Glacial Till</u>
Sequence 4 is defined by reflector R3 in the Pictou Harbour survey corridor. R3 represents the top of Sequence 4 which has been interpreted as glacial till (Pomquet Drift) which overlies bedrock. Pomquet Drift consists of poorly sorted, sub-rounded, coarse gravel mixed with varying proportions of finer sediment. The surface layer, less than a metre thick, is generally coarser and better sorted than the sub-surface material (Kranck, 1971). Cobbles and boulders may also occur in this glacial till sequence.

Sequence 4 is overlain by both Sequence 1 and Sequence 3 along the proposed pipeline route in Pictou Harbour. Areas of shallow gas mask reflector R3 making it difficult to interpret the top of Sequence 4 in some areas. Immediately offshore Abercrombie Point between PKP 0.207 and PKP 0.281 Sequence 4 is at or just below seabed. At the north end of the proposed route, where the route meets the Pictou Causeway toe of slope (PKP 1.415), Sequence 4 is approximately 1.0-1.5 m below seabed (VC54). Sequence 4 thickens towards the old West River channel. At the center of the old West River channel, Sequence 4 has been mapped 3 to 6 m below the seabed and has a thickness of 2 to 4 m.

Acoustic Basement

The acoustic basement reflector mapped in the Pictou Harbour survey corridor extends from PKP 0.613 to PKP 0.726. Mapped at a depth below seabed of approximately 7 to 10 m, the acoustic basement is interpreted to be the top of bedrock identified as fractured sandstone and shale from historic borehole logs; see Appendix III. The acoustic basement reflector was not observed in the seismic records outside of the area bounded by PKP 0.613 to PKP 0.724. This is due to limited penetration of the seismic systems within sub-bottom Sequence 4 (glacial till) and masking by shallow gas in the survey area. Although bedrock may not occur within the proposed trench depth of the pipeline route in areas surveyed, it is difficult to interpret the sub-bottom geology beneath Sequence 4. Borehole 16 listed in Appendix III was located onshore Abercrombie Point in the vicinity of PKP 0 and indicates bedrock (likely sandstone and/or shale) was present approximately 2 m below the existing ground surface at the time of drilling (1965).

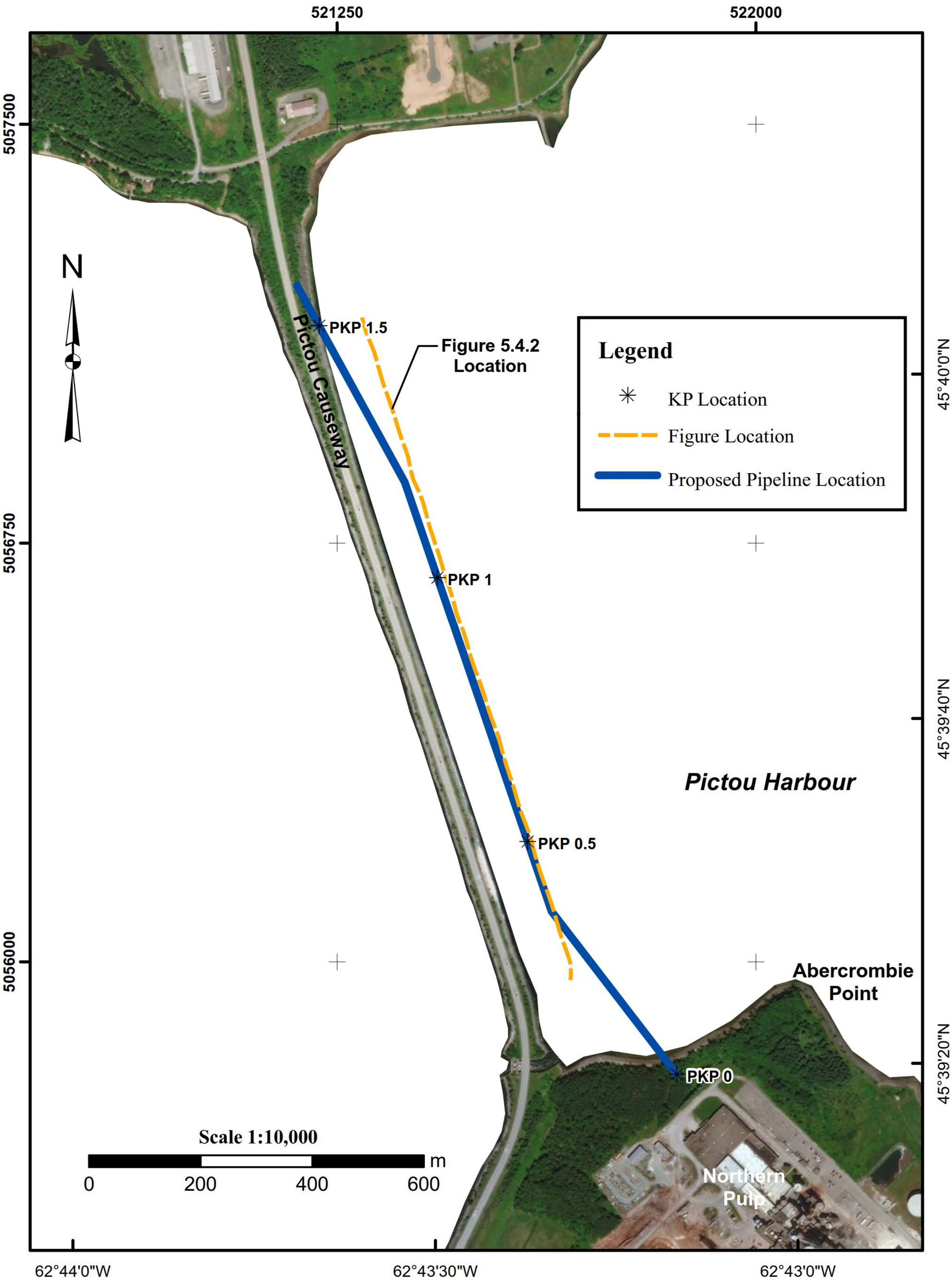


Figure 5.4.1 – Pictou Harbour sub-bottom example figure location.

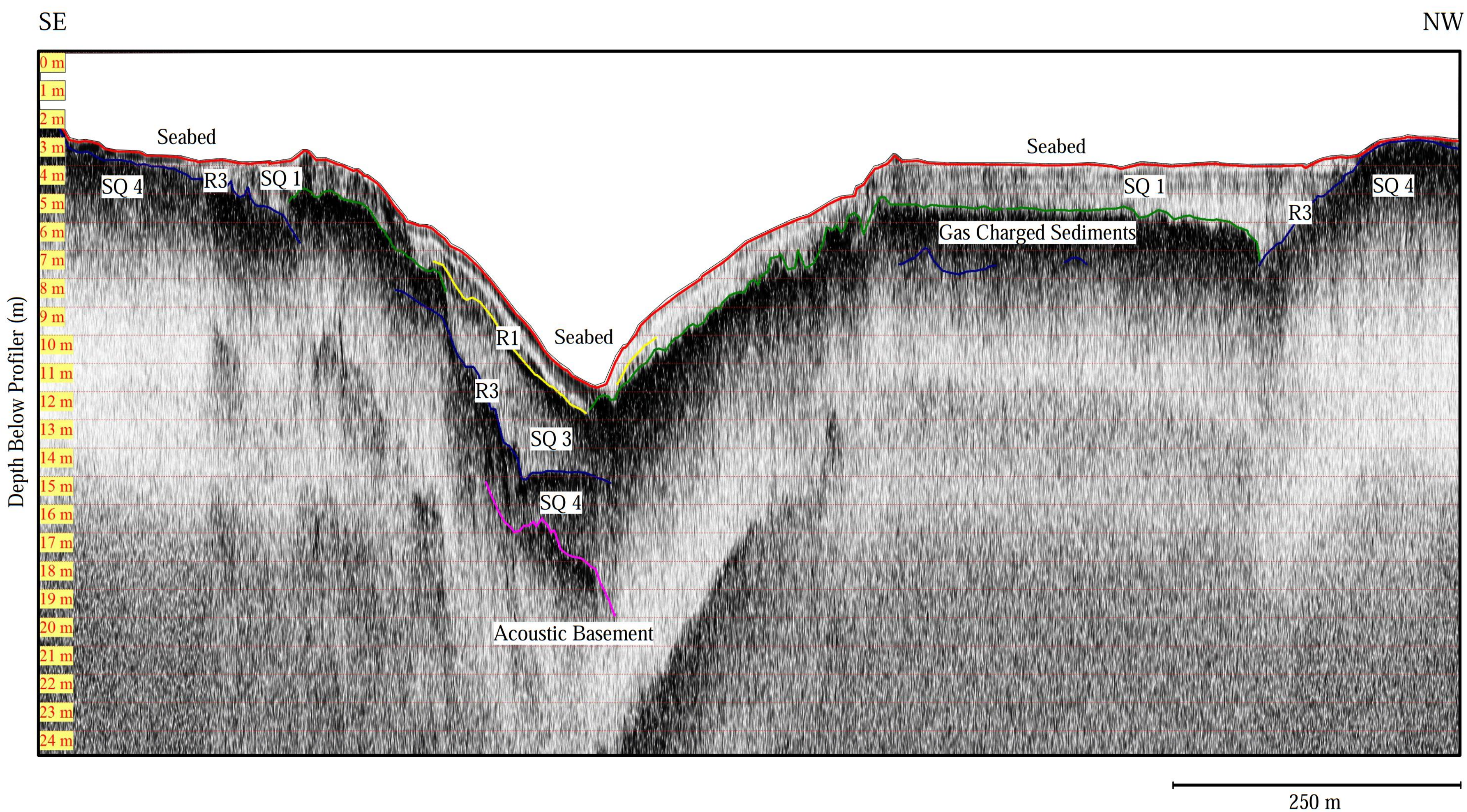


Figure 5.4.2 : Chirp sub-bottom record from Pictou Harbour survey corridor with sub-bottom interpretation. See Figure 5.4.1 for chirp record location.

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5.4.4 Caribou Harbour Sub-bottom Geology

Four major reflectors were identified and mapped in the Caribou Harbour survey corridor; R1, R2, R3 and Acoustic Basement (AB). These reflectors define the sub-bottom geological sequences found along the proposed route. Areas of shallow gas were also identified and mapped over the Caribou Harbour survey corridor. The spatial distribution of the major reflectors, including shallow gas and sub-bottom geological sequences are presented on Enclosure 8: Alignment Sheet 2 - Caribou Harbour Nearshore and Enclosure 9: Alignment Sheet 3 - Caribou Harbour Offshore. Figure 5.4.4 includes a chirp profiler record with interpreted sub-bottom geology of the nearshore while Figure 5.4.5 includes a boomer profiler record of the offshore. The locations of the data examples are displayed on Figure 5.4.3.

<u>Sub-bottom Sequence 1 – Post Glacial Sediments</u>
Sequence 1 consists primarily of soft silt and clay with occasional sandy lenses and is interpreted to be Pugwash Mud as defined by Kranck (1971). Shell fragments are also present within Sequence 1. The upper boundary of Sequence 1 is the seabed and the lower boundary is undefined in Caribou Harbour due to the presence of shallow gas within the sub-surface sediments.

Sequence 1 is a post glacial sediment deposit that occurs in the nearshore area of the Caribou Harbour survey corridor. It is exposed at the seabed from CKP 0.071 to approximately CKP 0.667 where surficial sand and gravel unit occurs. Sequence 1 range in thickness from < 1 m where it pinches out at Sequence 2 to > 4 m. Vibracore samples VC14 to VC16 and VC19 to VC21 all intersect Sequence 1.

<u>Sub-bottom Sequence 2 – Post Glacial Sediments</u>
Sequence 2 is common throughout the Caribou Harbour survey corridor and the majority of the planned trench along the proposed pipeline route occurs within this Sequence. Sequence 2 is bounded at the top by the seabed and at the bottom by reflectors R1 and R3.

Several vibracore samples intersected Sequence 2 including VC1, VC2, and VC3 located in the diffuser survey area. Interpreted to be surficial deposits of Buctouche Sand & Gravel, Sequence 2 ranges in thickness from < 1 m to ≥ 3 m along the proposed pipeline route. The thickest deposits of Sequence 2 are located around Gull Spit and offshore within the Caribou Harbour channel. Thinning of Sequence 2 occurs in areas where reflector R3 (glacial till) is close to the seabed. In some areas of the survey corridor, the surface morphology of Sequence 2 includes sediment transport features resulting from high energy zones dominated by currents.

<u>Sub-bottom Sequence 3a/3b – Proglacial Sediments</u>
Sequence 3 consists of proglacial sediments composed of clay, silty sand and gravel. The deposition of Sequence 3 may be correlated with Henry Island Sediments as defined by Kranck (1971). In the Caribou Harbour survey corridor a distinct reflector or geological boundary (R2) was observed within this Sequence 3. As a result the Sequence has been subdivided into Sequence 3a and Sequence 3b. R1 is the upper boundary of Sequence 3a and R2 is the upper boundary of Sequence 3b. The acoustic characteristics of each sub-sequence are similar with exception of a clay deposit associated with Sequence 3a located between CKP 3.070 and CKP

3.272. In the nearshore section of Caribou Harbour, Sequence 3a appears as thin deposits overlying Sequence 4 (glacial till). Outside Gull Spit at approximately CKP 2.275, Sequence 3 begins to thicken moving offshore as the seabed slopes towards the Caribou Channel reaching a maximum thickness of approximately 7 m at CKP 3.497. At the proposed outfall location, Sequence 3 begins to pinch out between Sequence 2 and Sequence 4 with a thickness of approximately 3 m.

Sub-bottom Sequence 4 – Glacial Till

Sequence 4 is defined by the major reflector R3. R3 represents the top of the sequence which has been interpreted as glacial till (Pomquet Drift). Sequence 4 is overlain by Sequence 2 and 3 in the Caribou Harbour survey corridor. Sequence 4 probably consists of poorly sorted, sub-rounded, coarse gravel mixed with varying proportions of finer sediment. Cobbles and boulders may also be present in this sequence and could be concentrated in the upper sequence as a relict lag deposit. Onshore the glacial till includes a surface boulder layer in some areas and a stony sandy facies on both Abercrombie Point in Pictou Harbour and on Caribou Island adjacent to Gull Spit (Stea & Myers, 1990). The coarse nature of the glacial till made it difficult to interpret the underlying sub-bottom geology. For this reason, it was not possible to map the thickness of Sequence 4.

There are three areas along the proposed pipeline route where Sequence 4 encroaches within the planned trench depth (3 m). These areas have been labelled on the interpreted geological profiles as an area where dredging may be constrained due to the sub-bottom geology and occur at the following locations. The constraint to dredging may include boulder rich glacial till or possibly weathered bedrock.

- CKP 0.725 to CKP 0.982
- CKP 1.018 to CKP 1.263
- CKP 1.738 to CKP 2.214

Vibracore samples VC06, VC09, VC10, VC12 and VC13 intersect Sequence 4 and each sampling attempt met refusal at the upper boundary of the sequence. Sequence 4 samples recovered from VC06 and VC13 were described as gravel, trace cobbles and shells. Samples recovered from VC09 and VC10 included gravel sized fragments of degraded sandstone which may have originated from sub-surface cobble or boulders indicating a possible lag deposit.

Acoustic Basement

The acoustic basement over the proposed pipeline route within Caribou Harbor was mapped through analysis of both chirp and boomer sub-bottom data. The acoustic basement reflector was usually faint and discontinuous. In general, the acoustic basement was very difficult to map through the nearshore section of the proposed pipeline route as a result of gas masking, shallow water multiples in the seismic data, and the presence of Sequence 4 glacial till near the seabed. The acoustic basement was discernable within the boomer sub-bottom data through the offshore section of the route. Although discontinuous the high amplitude reflector between CKP 3.212 and CKP 3.604 appears to correlate with the top of bedrock, see Figure 5.4.5. This correlation is much more difficult between CKP 0.779 and CKP 2.203. Over this section of the proposed pipeline route, seismic refraction was utilized to assist with the depth to bedrock interpretation.

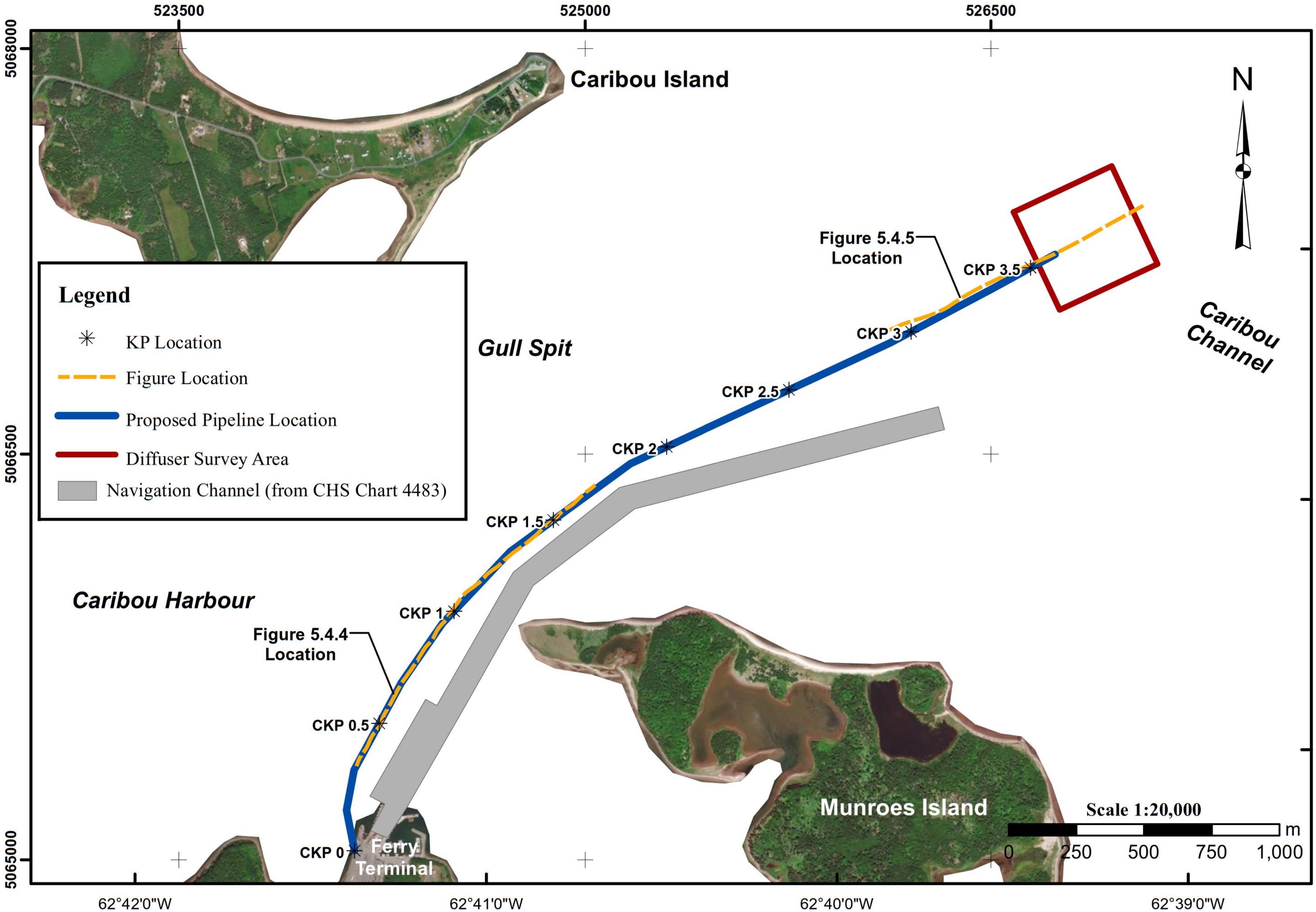

Figure 5.4.3 – Caribou Harbour sub-bottom example figure locations.

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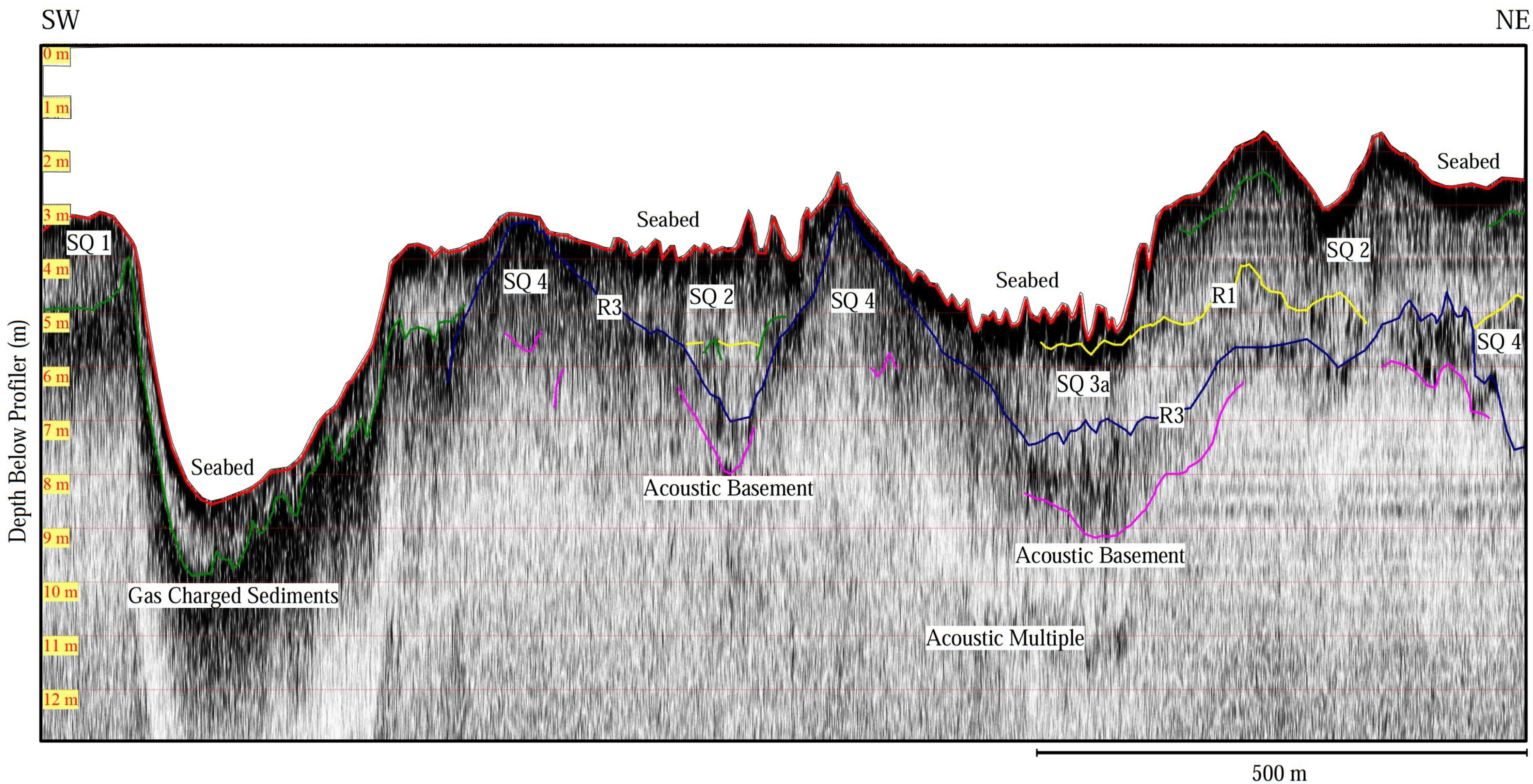

Figure 5.4.4 : Chirp sub-bottom record from Caribou Harbour survey corridor (nearshore) with sub-bottom interpretation. See Figure 5.4.3 for boomer record location.

CSR GeoSurveys Ltd.

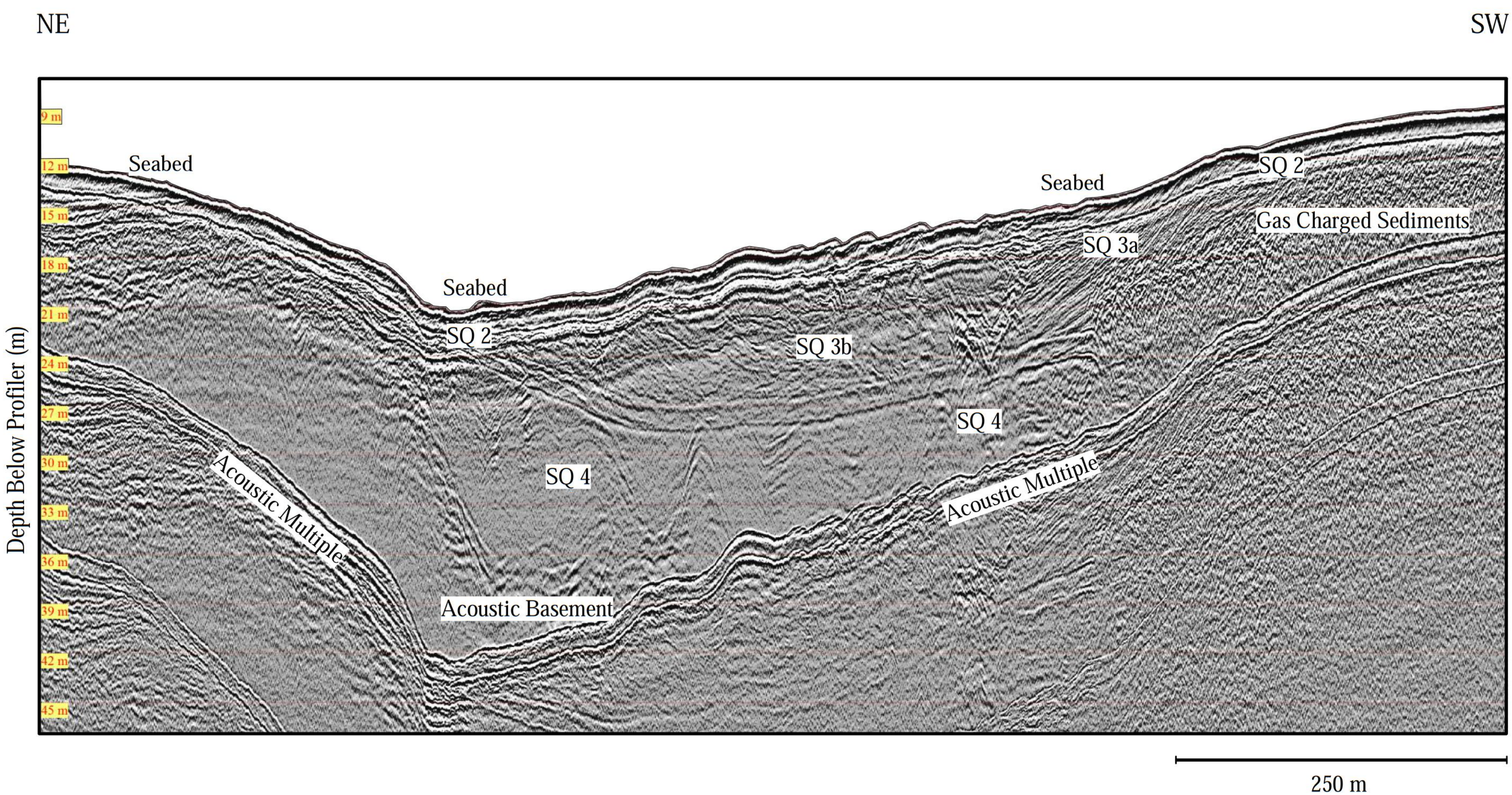

Figure 5.4.5 : Boomer sub-bottom record from Caribou Harbour survey corridor (offshore) with sub-bottom interpretation. See Figure 5.4.3 for boomer record location.

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5.4.5 Seismic Refraction Results

Seismic refraction data collected within the Caribou Harbour survey corridor was processed to generate velocity models of the sub-surface geological horizons. Seismic refraction data were collected along the initial proposed route through the nearshore section of Caribou Harbour between KP 0.250 and KP 2.500 (see Figure 3.8.11).

Figure 5.4.4 presents a seismic refraction model generated from KP 2.0 to KP 2.4. The refraction model indicates bedrock velocities in the range of 2000 m/s to 2700 m/s, typical of sandstone and shale sedimentary rocks. Overlying sediments appear to exhibit velocities in the range of 1600 m/s to 2000 m/s with velocities increasing with depth. It should be noted that the seismic inversion software attempts to produce a smooth model, avoiding sharp vertical changes in velocity that occur at a sediment/competent bedrock interface. As a result, the modelled velocity change between sediment and bedrock can appear more gradational, giving rise to the 2000-2700 m/s velocities observed above the competent bedrock. However, these velocities in the mid 2000 m/s range may be representative of a weathered and/or fractured bedrock zone separating the sediment from the competent bedrock.

Most marine sediments are composed of soft silts, clays and sands that are underlain by glacial till. A typical refraction model would assume that the soft, fine-grained, water saturated sediments would have a similar velocity as water. The velocity difference between the glacial till and bedrock, however, is usually significant. This boundary was resolved using the seismic refraction technique at the Caribou site. The following table represents a descriptive classification of bedrock seismic velocities that can be correlated with RQD (Rock Quality Designation) values.

Table 5.4.2 – Descriptive Classification of Bedrock Seismic Velocities with RQD Values

RQD (%)	Velocity Index	Seismic Velocity (m/sec)	Rock Quality	Seismic Description
0 - 25	0.00 - 0.20	< 2425	Very Poor	Low velocity
25 - 50	0.20 - 0.40	2425-3450	Poor	Low velocity
50 - 75	0.40 - 0.60	3450-4240	Fair	Intermediate
75 - 90	0.60 - 0.80	4240-4850	Good	Sound Rock
90 - 100	0.80 - 1.00	4850-6660	Excellent	Sound Rock

The calculated velocity of bedrock from refraction modelling of the Caribou Harbour data indicates the rock quality designation (RQD) is very poor at the surface indicating a possible weathered zone. The velocities do increase with depth through the bedrock sequence but remain in the range of poor quality rock with an RQD range of 25 - 50.

Although it is apparent from the refraction modelling that competent bedrock does not exist above the proposed trench depth in the areas surveyed, a conservative approach has been taken to account for the possibility of a weathered bedrock zone within the limits of proposed excavation. It is important to note that seismic reflection survey lines were spaced at 20 m metre intervals and one seismic refraction line was acquired. Thus, the depth of bedrock is interpolated in the areas between the surveyed lines. Considering the limits of excavation may be up to 14 m wide and 3 m deep below seabed, it is uncertain whether incompetent bedrock will be encountered during installation of the pipeline. These areas have been labelled on the interpreted geological profiles as an area where dredging may be constrained due to the sub-bottom geology, see Enclosure 8: Alignment Sheet 2 - Caribou Harbour Nearshore and Enclosure 9: Alignment Sheet 3 - Caribou Harbour Offshore.

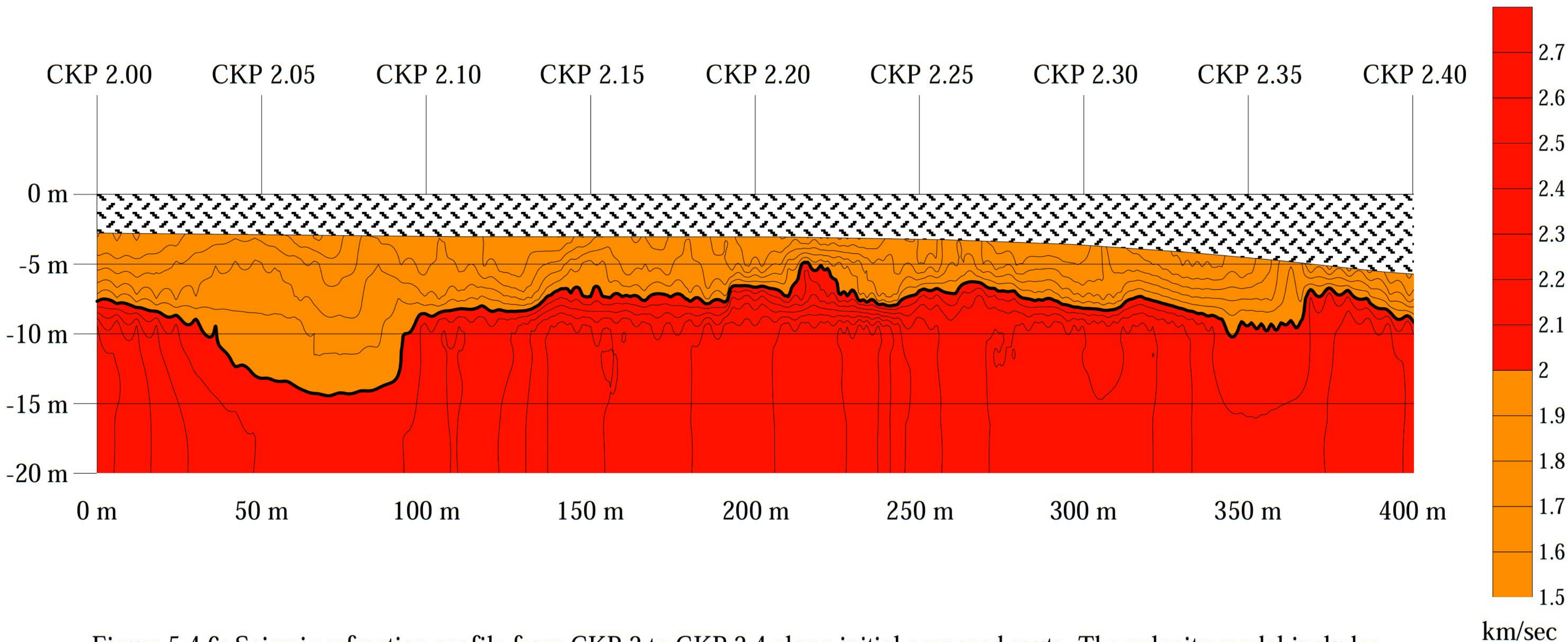
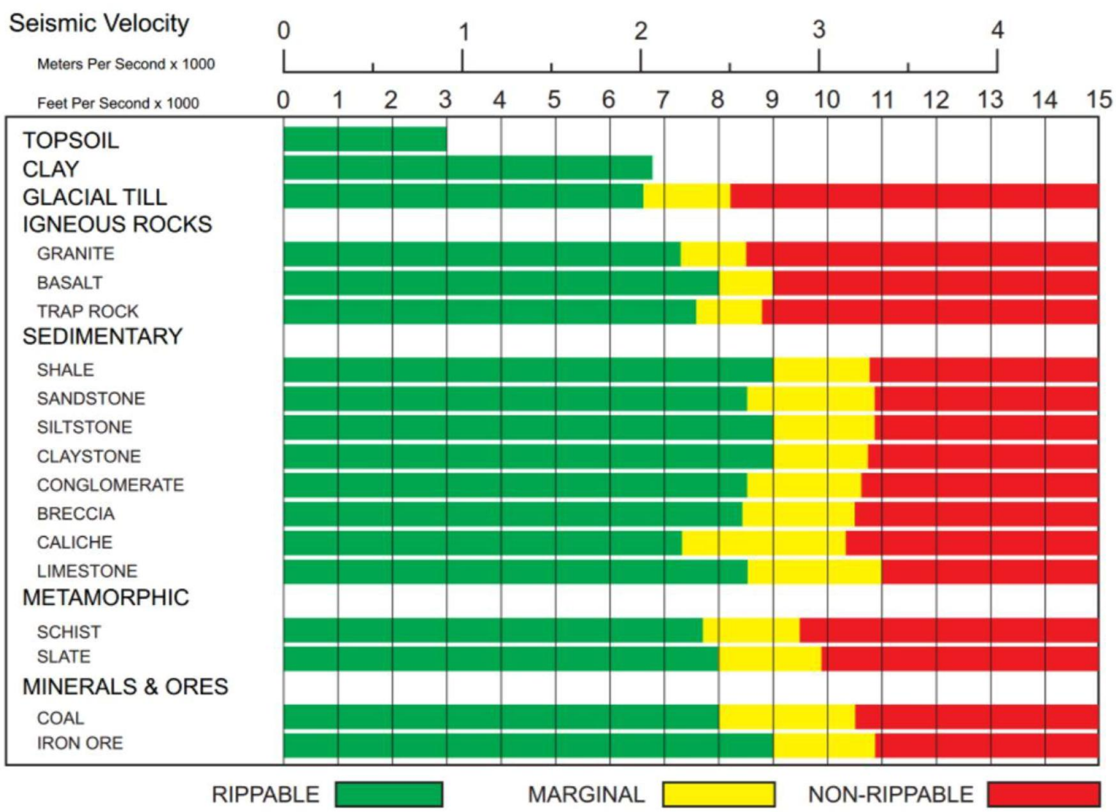


Figure 5.4.6: Seismic refraction profile from CKP 2 to CKP 2.4 along initial proposed route. The velocity model includes the water column (1.4 km/s - 1.5 km/s). Velocities between 1.6 km/s and 2.0 km/s indicate deposits of overburden sediments. Velocites greater than 2.0 km/s indicate the possible presence of very poor to poor quality bedrock. The top of velocity model represents the average water surface at time of data collection.

5.4.6 Glacial Till and Bedrock Rippability

As discussed previously in this report, the glacial till sequence in the Caribou Harbour survey corridor is interpreted to be Pomquet Drift consisting of subangular to angular coarse gravel, sand, silt and cobble. Boulders may also occur within the sequence. Bedrock in the area of Caribou Harbour is expected to be composed of sandstone and/or shale. Table 5.4.3 can be used as a general guide for the evaluation of material rippability and preliminary planning for installation of the proposed pipeline. Seismic velocities of 2000 m/s or less measured from the glacial till sequence fall within the rippable range shown on Table 5.4.3. Seismic velocities of 2000 m/s to 2700 m/s measured from sandstone and/or shale fall within the rippable to marginal range shown on Table 5.4.3. Considering the seismic velocities modelled increase with depth, it is most likely that any bedrock present in the proposed trench limits is weathered and in the rippable range. The rippability of bedrock is a measure of its ability to be excavated with conventional excavation equipment thereby eliminating blasting of the rock.

Table 5.4.3 – Seismic Velocities with Rippability Guidelines.



** See Moustafa, S., 2015, Assessment of Excavatability in Sedimentary Rocks Using Shallow Seismic Refraction Method.*

5.5 ICE SCOUR

Within the Northumberland Strait, ice scouring is the process whereby ice ridges contact the seabed forming linear gouges in the seabed sediments. This scouring process has long been recognised as a potential hazard to sub-sea installations.

The extent and thickness of Northumberland Strait ice is influenced by winter temperatures, severity and duration of storms as well as wind direction. Strong winds can cause ice to fracture and pile up into ridges by compression or shear in the ice cover and are typically found in the shear zone between the landfast ice and the drift or pack ice. Subsequent movement of these ridges can cause their keels to scour the seabed sediments.

The scour depth parameter is perhaps the most important measurement in estimating the minimum trenching depths required for a pipeline installation. Scour depth is a variant parameter, depending on a number of factors including size of the scouring ice keel, scour age, amount of infill, bathymetry, physiographic location and the geotechnical soil conditions. The scour depth parameter represents a measurement that is derived from the acoustic data at some time after the passage of the ice keel. As a result, these values are considered minimum values. For example, upon scouring, some immediate sediment backfill may take place, especially in sandy or silty sediment. Subsequent to this, the scour may become infilled by hydrodynamic reworking, normal sedimentation, bioturbation or by additional scouring by other ice keels. Scours in clay and silt will typically infill or degrade slower than scours in areas of sand. Scours in cohesive clay and silt will also tend to maintain their shape while scours in sand will experience some infill immediately due to the lack of sediment cohesion. The degree of sediment transport within the area contributes significantly to scour degradation and the amount of infill that occurs.

The ice scour survey conducted by CSR was conducted in early spring soon after the break-up of ice in the Northumberland Strait. This was the best time to survey in order to identify and measure the ice scours before they degrade.

5.5.1 Ice Scour Mapping

During this study ice scour features were identified through a detailed examination of multibeam and sidescan sonar data acquired during the 2019 geophysical survey in order to characterize those ice scours that could pose the greatest risk to the pipeline. The survey areas included the Pictou corridor (Figure 3.8.1), Caribou corridor (Figure 3.8.7) and regional lines outside of Caribou Harbour (Figure 3.8.15).

The centerline of each ice scour was digitized and databased within ArcGIS according to the following mapping methodology.

- All ice scours observed within the processed multibeam data.
- Ice scours observed within the sidescan sonar data with scour width > 1 metre.

Bathymetry
Bathymetry was extracted from the processed sounding data at each ice scour location. The bathymetry values stored in the database represent the minimum and maximum water depth of the unscoured seabed.

Scour Depth
Scour depth was measured from the unscoured seabed datum for scours with a depth ≥ 0.2 m. The maximum scour depth was recorded in metres by the interpreter over the deepest location observed along the track of each ice scour event. If the ice scour has been infilled the depth measurement is to the top of the sediment infill.

Scour Length
Scour length was measured in metres and represents true length for scours where both endpoints were observed on the geophysical data, but is less than the true scour length for events which extend beyond the edge of sidescan sonogram or the swath of the multibeam.

Scour Width
Scour width was measured in metres from berm crest to berm crest, perpendicular to the long axis of the scour.

Orientation
Orientation is the bearing of the scour referenced to Grid North and expressed by convention between 0 and 179 degrees inclusive. Orientation does not imply scouring direction. Scour direction can only be determined if the termination is observed.

5.5.2 Ice Scour Analysis

The locations of ice scours mapped during this study within the survey corridors are included on the Enclosures which accompany this report. Figure 5.5.1 includes the spatial distribution of ice scours observed within the Pictou survey corridor. The spatial distribution of ice scours observed over the Caribou survey corridor and along regional survey lines are displayed on Figures 5.5.2 and 5.5.3. These figures also include the multibeam sonar and sidescan sonar data reviewed for ice scours during this study. The location of ice scours within the nearshore Caribou survey corridor from CKP 0.1 to CKP 0.5 and CKP 0.6 to CKP 1.1 are presented on Figures 5.5.4 and 5.5.5 respectively.

One-hundred and forty-six (146) ice scours were identified from the geophysical data acquired in 2019. Thirteen (13) ice scours occur within the Pictou survey corridor while 133 ice scours were observed within the Caribou area. The histograms displayed on Figure 5.5.6 include the ice scour distributions according to bathymetry, scour depth, and scour width. Figure 5.5.7 includes the distribution of scour length and a rose diagram illustrating scour orientation. Figures 5.5.6 and 5.5.7 include the combined ice scour populations (n=146) observed within Pictou and Caribou.

The ice scours observed within the Pictou Harbour survey corridor all occur offshore of Abercrombie Point within water depths ranging from 2 m to 3 m. The ice scours are 1 m to 3 m wide, 11 m to 59 m long with the majority having a north-south orientation. Twelve of the ice scours had depths < 0.2 m. One ice scour had a maximum scour depth of 0.3 m. This scour was 2 m wide, 14 m long, and had an orientation of 161 degrees.

The ice scours observed within the Caribou area occur within water depths ranging from 1 m to 9 m. Ice scour length ranges from 2 m to 260 m with a mean length of 45 m. Ice scour width ranges from 1 m to 6 m with a mean width of 2 m. Ice scour orientation is generally controlled by water depth with the majority of ice scours parallel to the bathymetry contours. No ice scours were observed within the area of the proposed diffuser.

Spatially, the observed Caribou ice scour population occurs within two main areas. Eighty-eight (88) ice scours occur within Caribou Harbour in water depths ranging 1 m to 9 m and 42 ice scours occur east of Caribou Island in water depths ranging from 5 m to 8 m. Two ice scours were observed approximately 800 m north of Munroes Island in 6 m to 7 m water depth and one ice scour occurs 1.5 km northeast of the diffuser in 6 m to 7 m water depth. The maximum water depth ice scours were observed was 9 m.

Of the 133 ice scours observed in the Caribou area only 15 had a scour depth ≥ 0.2 m with a maximum recorded depth of 0.4 m. The ice scour population with scour depth ≥ 0.2 m occurs in water depths ranging from 1 m to 6 m, are 1.3 m to 5.4 m wide, and 5 m to 260 m long. Fourteen (14) of the ice scours with scour depth ≥ 0.2 m occur within Caribou Harbour and one occurs east of Caribou Island. Two (2) ice scours had a recorded scour depth of 0.4 m and occur in the nearshore Caribou survey corridor northwest of the ferry terminal in 2 m to 3 m water depth between CKP 0.2 and CKP 0.3. The age of the ice scours is not known but they were likely formed during the winter of 2018/2019.

Within the nearshore Caribou Harbour area west of Munroes Island between CKP 1.0 and CKP 1.1 the seabed includes an area that may have been disturbed as a result of ice grounding, see Figure 5.5.8. The area is approximately 70 m by 100 m and includes small pit features that have a maximum depth of 0.7 m. The water depth within this area ranges from 2 to 3 m and the surficial sediments are sand and gravel. The age of the features is not known.

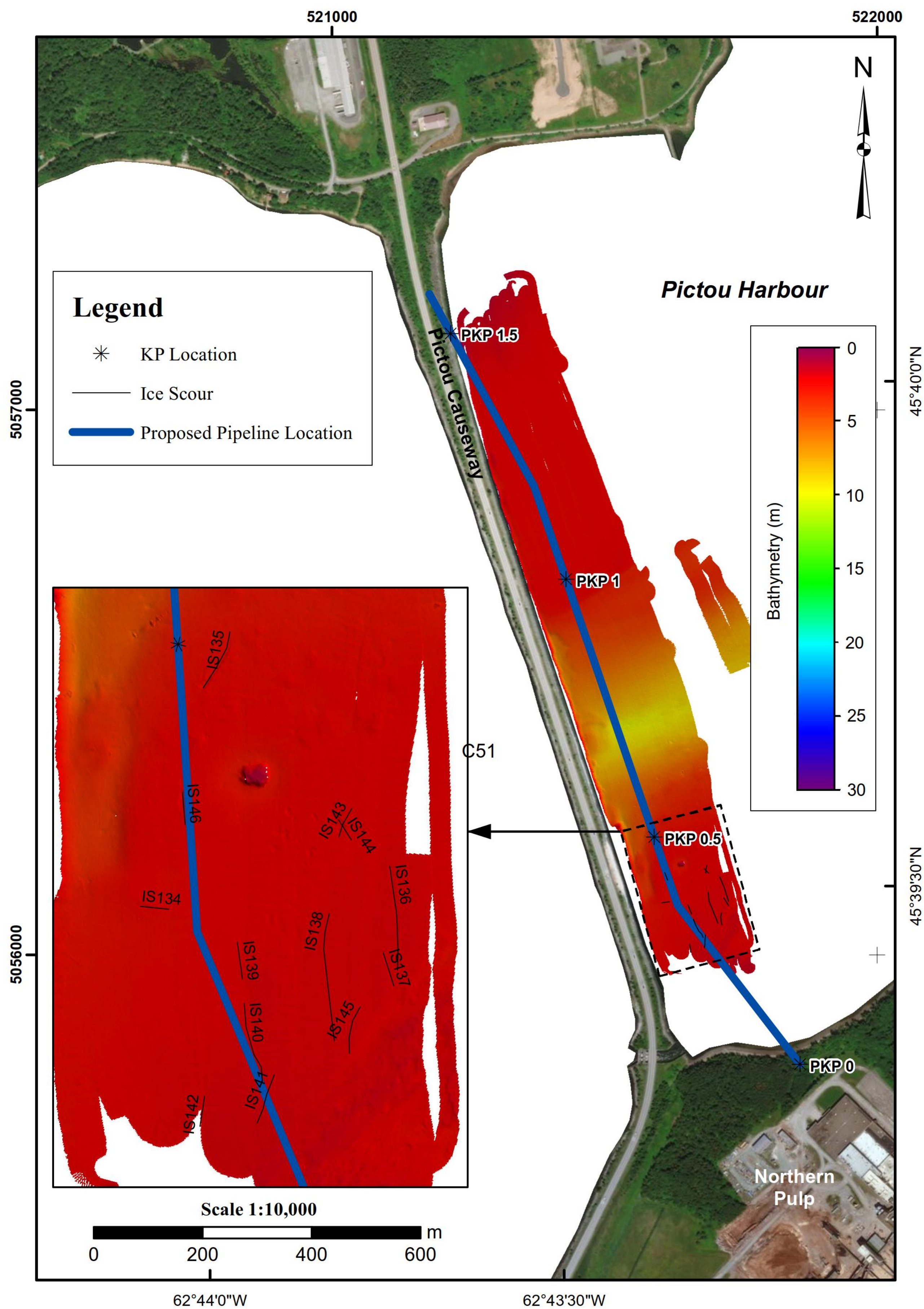


Figure 5.5.1 – Spatial distribution of ice scours observed within the Pictou survey corridor.

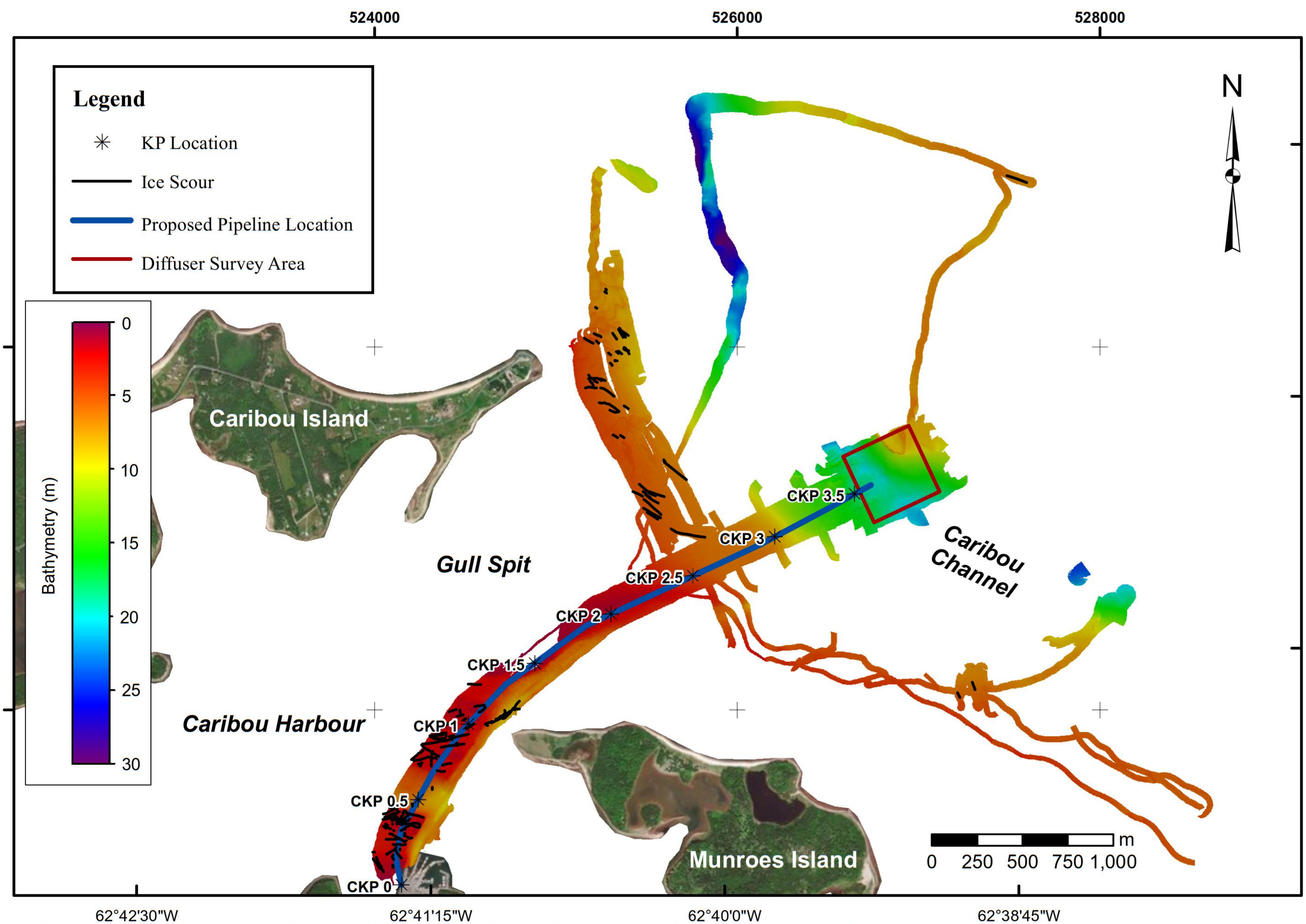


Figure 5.5.2 – Spatial distribution of ice scours observed within the Caribou survey corridor and along regional survey lines over multibeam sonar data reviewed during this study

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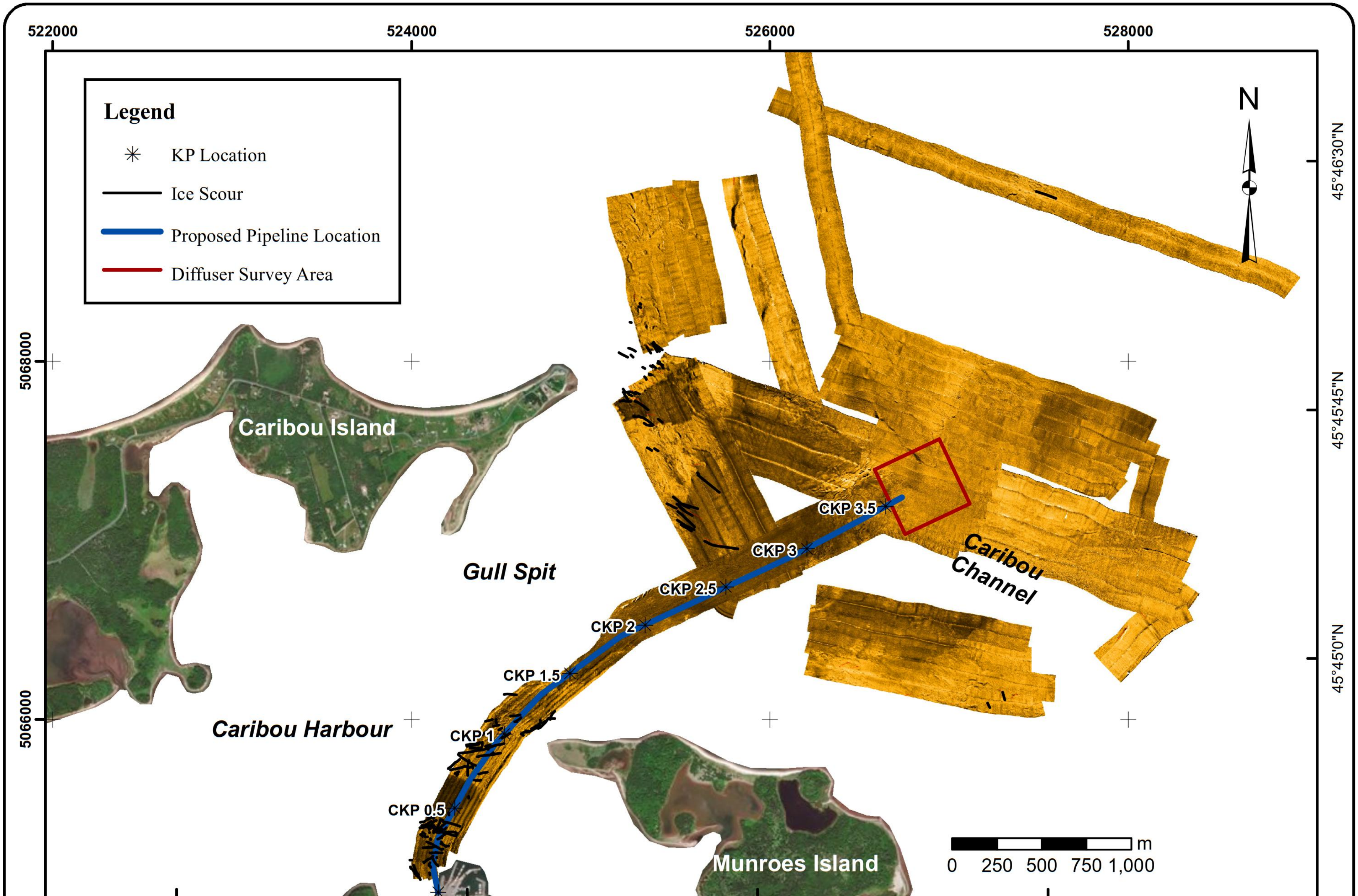

Figure 5.5.3 – Spatial distribution of ice scours observed within the Caribou survey corridor and along regional survey lines over sidescan sonar data reviewed during this study.

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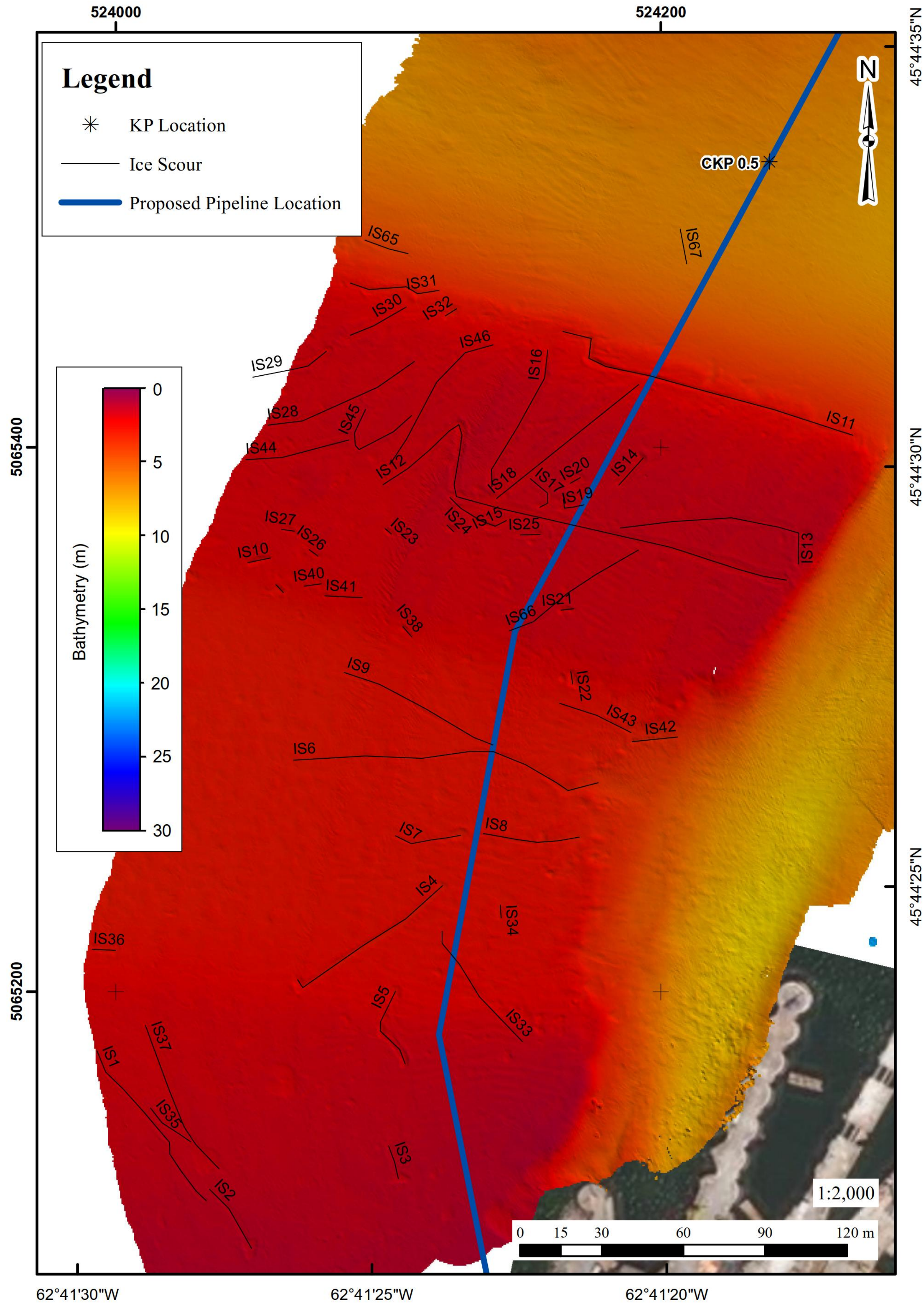


Figure 5.5.4 – Spatial distribution of ice scours observed between CKP 0.1 and CKP 0.5, northwest of the Caribou ferry terminal.

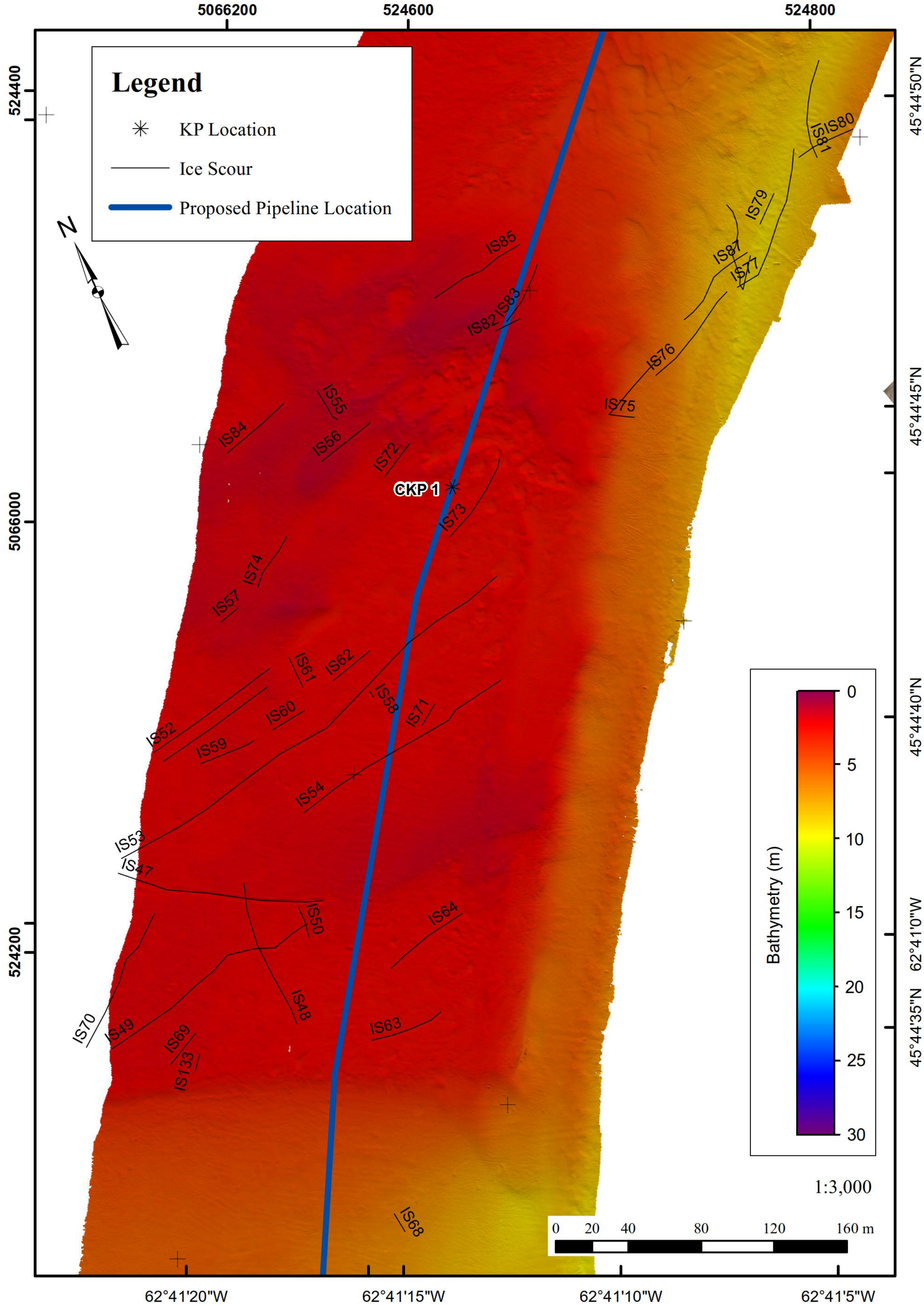
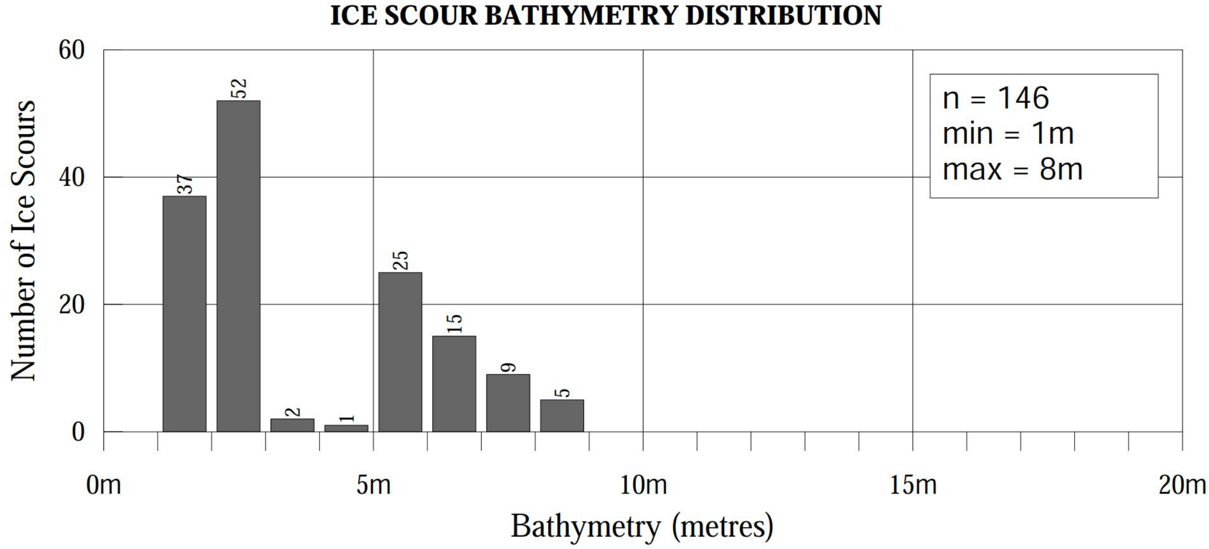
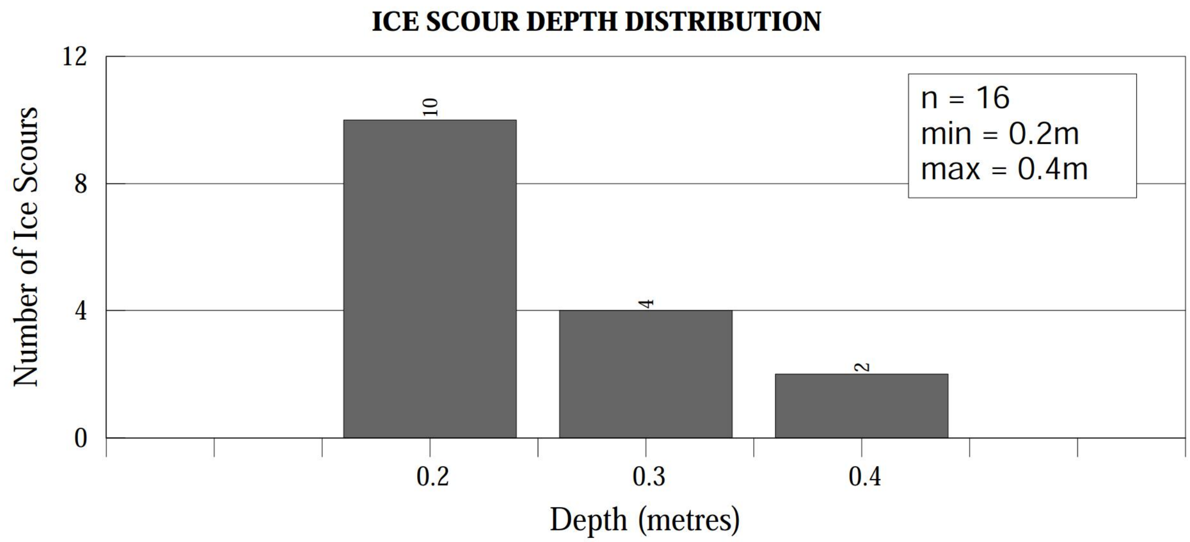


Figure 5.5.5 – Spatial distribution of ice scours observed between CKP 0.6 and CKP 1.1.





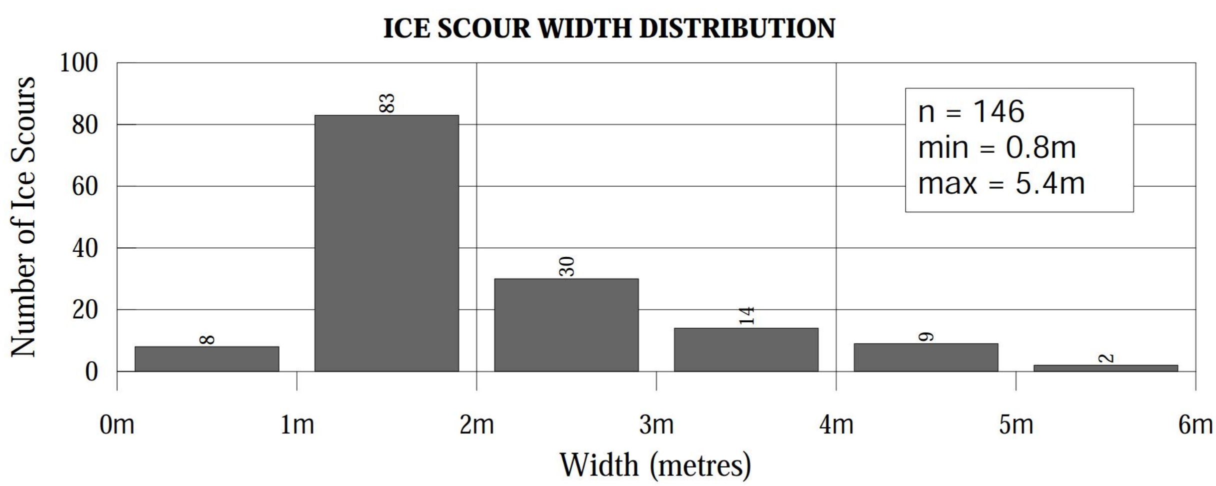
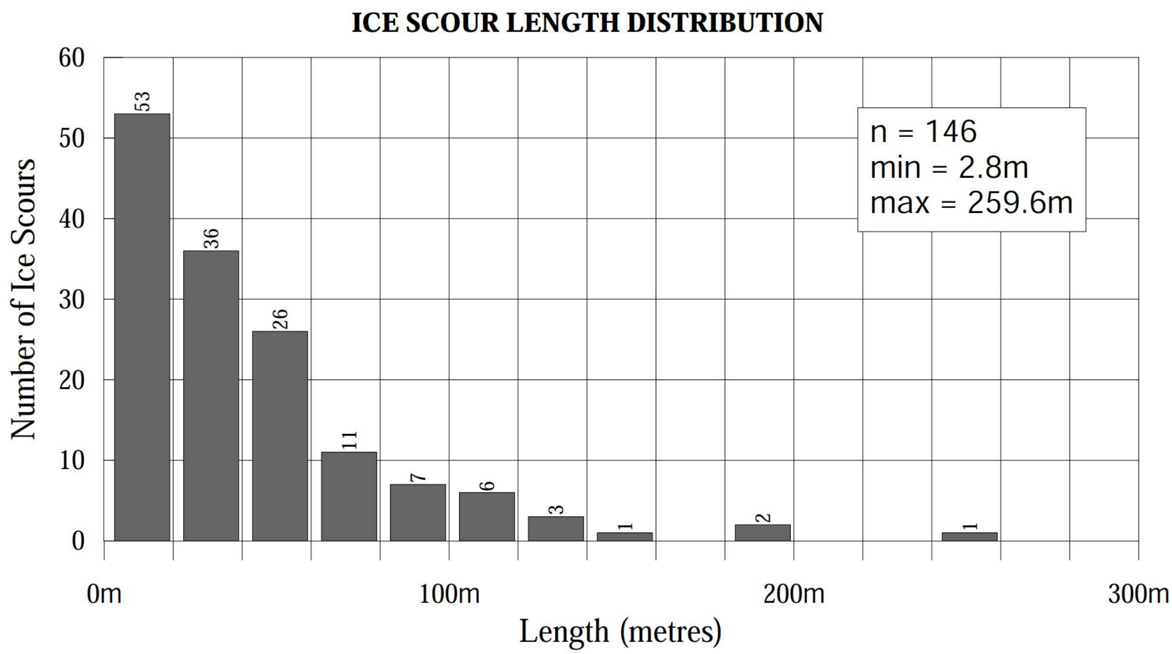


Figure 5.5.6 - Histograms showing the distribution of ice scour events according to bathymetry (top), scour depth (middle), and scour width (bottom).



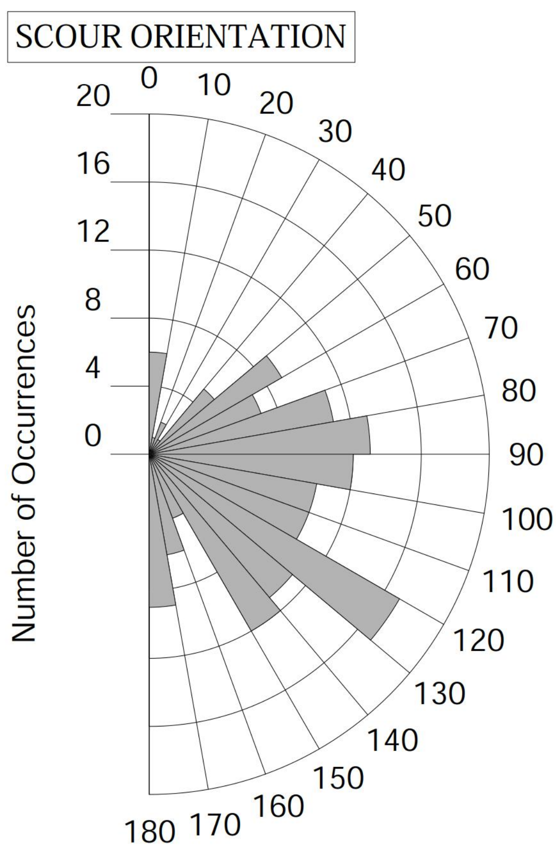


Figure 5.5.7 - Histogram showing the distribution of ice scour events according to length (top) and rose diagram illustrating ice scour orientation (bottom).

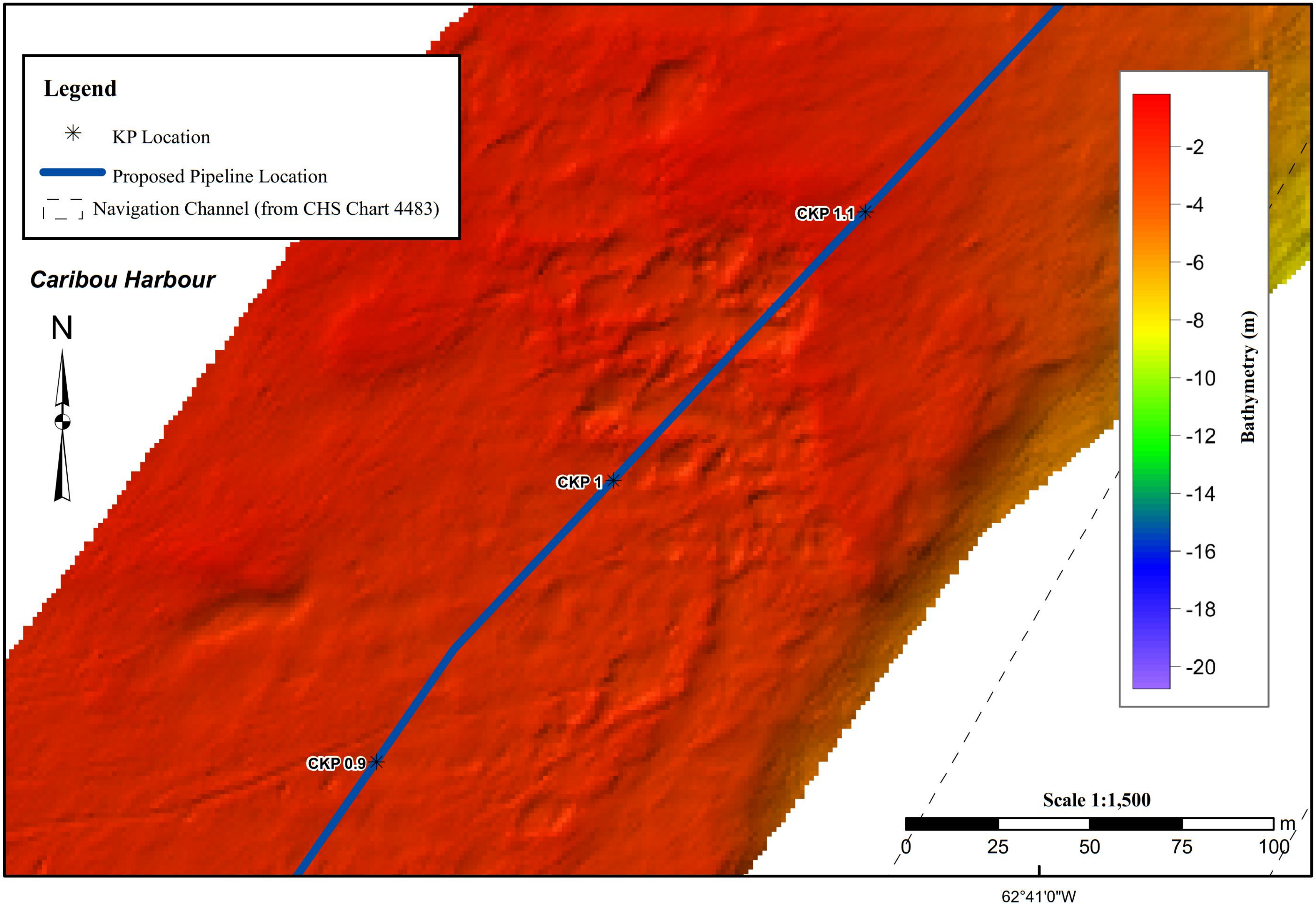


Figure 5.5.8 – Probable area of ice grounding located between CKP 1.0 and CKP 1.1.

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5.6 Anthropogenic Features

For the purpose of this report, anthropogenic features can be defined as contacts identified at or below the seabed within the survey corridor that originated from human activity. CSR utilized both sidescan sonar data and marine magnetometer data to identify anthropogenic features in the survey corridors. Examples of anthropogenic features mapped during the marine geophysical survey include old pile timbers, mooring blocks/chains and rock piles. Anthropogenic features mapped from the sidescan sonar data have been coded with an ID prefix C. Magnetic anomalies mapped from the magnetometer data have been coded with and ID prefix M. All sidescan sonar contacts and magnetic anomalies have been included with our surficial geology interpretation on Enclosure 2 (Pictou) and Enclosures 6 and 7 (Caribou).

CSR provided all sidescan sonar data and magnetic anomalies mapped from marine geophysical data to Stantec for detailed analysis by a marine archaeologist. Sonograms of each sonar contact identified by CSR are included in Appendix IV.

Results from the analysis completed by a marine archaeologist have been provided in a separate Stantec report.

Stantec Consulting Ltd., 2019b. Archaeological Review of Marine Geophysical Data – Pictou Harbour and Caribou Harbour Pipeline Corridors. Final Report, 2019. Prepared for CSR GeoSurveys Ltd., Porter's Lake, NS and submitted to Northern Pulp Nova Scotia Corporation, New Glasgow, NS. Stantec File: 121621877

5.6.1 Sidescan Sonar Contacts

Pictou Harbour Sonar Contacts

In total, 43 sidescan sonar contacts representing possible anthropogenic features on the seabed were mapped in the Pictou Harbour survey corridor; see Figure 5.6.1. CSR identified 42 of these targets through analysis of the geophysical data. Review by the marine archaeologist identified 1 additional sidescan sonar contact. Details on all sidescan sonar contacts mapped in the Pictou Harbour survey corridor are listed in Table 5.6.1.

Table 5.6.1 – Pictou Harbour Sidescan Contacts

Target	Position		Width (m)	Length (m)	CSR Classification	Associated Magnetic Target
	Northing	Easting				
C1	5055969	521607	0.19	4.93	Linear feature; probable timber	n/a
C2	5055980	521594	0.35	5.99	Linear feature; probable timber	n/a
C3	5055982	521601	0.52	5.67	Linear feature; probable timber	n/a
C4	5055984	521627	0.15	5.11	Linear feature; probable timber	n/a
C5	5055989	521593	0.65	4.78	Linear feature; probable timber	n/a
C6	5055993	521626	0.11	1.49	Linear feature; probable timber	n/a
C7	5055999	521590	0.65	3.04	Linear feature; probable timber	n/a
C8	5056002	521641	1.14	2.27	Linear feature; probable timber	n/a

Target	Position		Width	Length	CSR Classification	Associated
C9	5056003	521586	0.44	2.84	Linear feature; probable timber	n/a
C10	5056014	521606	0.56	6.88	Linear feature; probable timber	n/a
C11	5056018	521584	0.59	3.13	Linear feature; probable timber	n/a
C12	5056037	521576	0.53	3.23	Linear feature; possible timber	n/a
C13	5056043	521597	0.50	2.10	Linear feature; possible timber	n/a
C14	5056047	521596	0.53	3.10	Linear feature; possible timber	n/a
C15	5056058	521579	0.38	6.57	Linear feature; probable timber	n/a
C16	5056065	521587	0.27	4.95	Linear feature; probable timber	n/a
C17	5056070	521579	0.38	12.79	Linear feature; probable timber	n/a
C18	5056077	521568	0.96	2.35	Linear feature; possible timber	n/a
C19	5056080	521576	0.36	1.55	Linear feature; possible timber	n/a
C20	5056082	521570	0.21	1.77	Linear feature; possible timber	n/a
C21	5056087	521565	0.56	6.42	Linear feature; possible timber	n/a
C22	5056099	521581	0.27	4.68	Linear feature; possible timber	n/a
C23	5056101	521577	0.44	9.93	Linear feature; possible timber	n/a
C24	5056105	521574	0.62	3.36	Linear feature; probable timber	n/a
C25	5056144	521560	0.39	5.62	Linear feature; probable timber	n/a
C26	5056162	521548	0.38	4.86	Linear feature; possible timber	n/a
C27	5056170	521568	2.25	19.38	Linear feature; possible debris	n/a
C29	5056174	521550	0.37	6.96	Linear feature; probable timber	n/a
C30	5056188	521612	0.72	2.08	Rectangular feature; possible debris	M14, M15, M16, M23, M24
C31	5056194	521546	0.27	1.76	Linear feature; probable timber	n/a
C32	5056206	521545	1.09	5.68	Linear feature; possible timber	n/a
C33	5056215	521571	1.61	2.86	Rectangular feature; possible debris	M10
C34	5056224	521581	3.42	10.59	Linear feature; probable debris	M10
C35	5056226	521535	0.34	1.89	Linear feature; possible timber	n/a
C36	5056230	521526	0.17	6.35	Linear feature; possible timber	n/a
C37	5056235	521526	0.47	2.49	Linear feature; possible timber	n/a
C38	5056243	521533	0.22	4.34	Linear feature; probable timber	n/a
C39	5056247	521535	0.29	2.79	Linear feature; probable timber	n/a
C40	5056247	521531	0.23	3.42	Linear feature; probable timber	n/a
C41	5056253	521591	0.30	7.86	Linear feature; possible timber	n/a
C42	5056330	521647	2.88	13.33	Rectangular feature; possible debris	n/a
C43	5056910	521326	0.65	0.96	Point source, possible vertical timber	n/a

Target	Position		Width	Length	CSR Classification	Associated
C51	5056172	521643	13.50	15.50	Cobble pile; rock dump or possible ballast	n/a

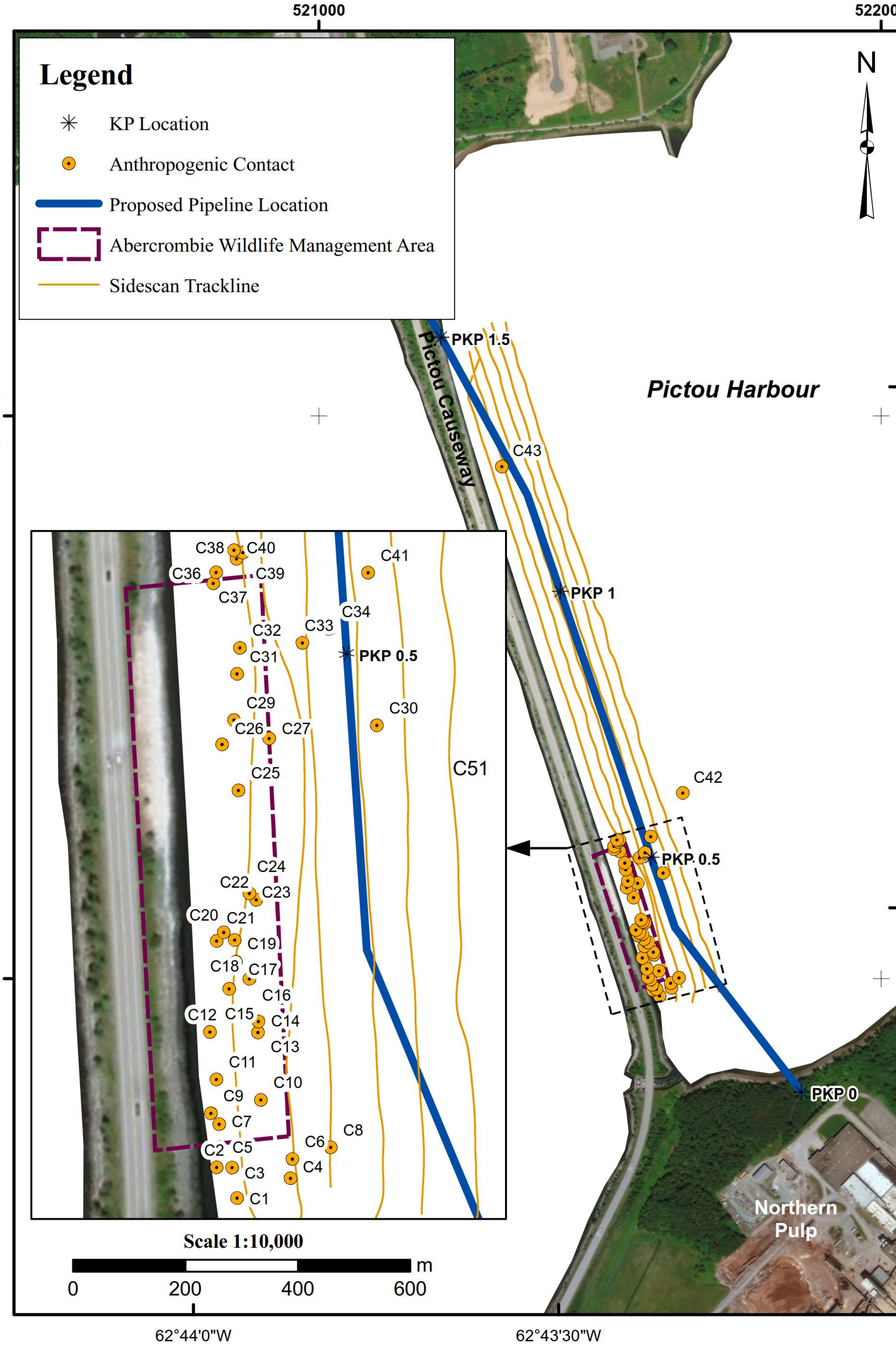

Figure 5.6.1 – Pictou Harbour sidescan sonar contact locations.

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Caribou Harbour Sonar Contacts

In total, 7 sidescan sonar contacts representing possible anthropogenic features on the seabed were mapped in the Caribou Harbour survey corridor; see Figure 5.6.2. CSR identified 5 of these targets through analysis of the geophysical data. Review by the marine archaeologist identified 2 additional sidescan sonar contacts. Details on all sidescan sonar contacts mapped in the Caribou Harbour survey corridor are listed in Table 5.6.2.

Table 5.6.2 – Caribou Harbour Sidescan Contacts

Target	**Position**		**Width (m)**	**Length (m)**	**CSR Classification**	**Associated Magnetic Target**
	Northing	**Easting**				
C44	5066053	524727	2.03	4.51	Linear feature; possible debris	n/a
C45	5066069	524726	1.96	2.64	Rectangular feature; possible debris	M35
C46	5066214	524922	1.03	6.19	Linear feature; possible debris	n/a
C47	5066718	525650	0.35	11.51	Linear feature; probable timber	n/a
C48	5066729	525663	2.67	13.63	Linear feature; probable timber	n/a
C49	5067059	527149	12.75	16.50	Stantec Identified: semi-circular or “v-shaped” rock formation	n/a
C50	5067126	527194	10.75	26.25	Stantec Identified: linear rock formation with associated linear channel	n/a

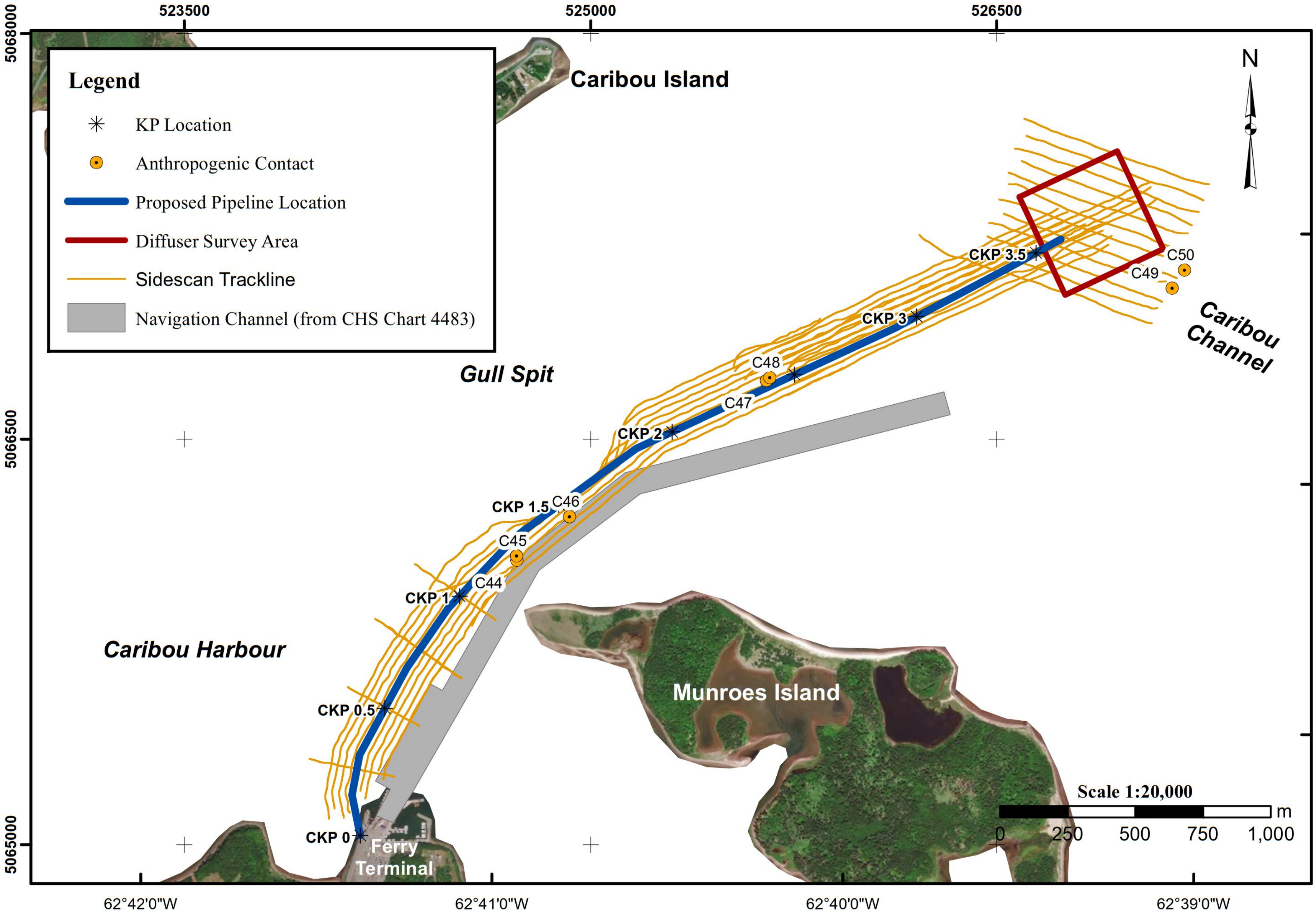

Figure 5.6.2 – Caribou Harbour sidescan sonar contact locations.

5.6.2 Magnetic Anomalies

Pictou Harbour Magnetic Anomalies
In total, 31 magnetic anomalies were mapped in the Pictou Harbour survey corridor; see Figure 5.6.3. Where possible, magnetic anomalies were correlated with sidescan sonar contacts and/or other magnetic anomalies. Details on all magnetic anomalies mapped in the Pictou Harbour survey corridor are listed in Table 5.6.3.

Table 5.6.3 – Pictou Harbour Magnetic Anomalies

Target	Position		Peak Spread (nT)	Distance (m)	Class*	Description	Possible Associations
	Northing	Easting					
M1	5056395	521576	53.93	25.65	M	-	-
M2	5056326	521603	185.98	30.27	MC	-	-
M3	5056300	521612	181.42	35.99	MC	-	-
M4	5056240	521630	170.73	38.94	MC	-	-
M5	5056264	521623	170.73	38.84	MC	-	-
M6	5056219	521636	266.93	41.76	MC	-	-
M7	5056095	521614	293.16	6	M	-	-
M8	5056131	521601	26.78	12.03	D	-	-
M9	5056164	521591	53.2	30.7	MC	-	-
M10	5056218	521575	325.77	17.85	M	Possible pile	C34, C33
M11	5056250	521558	68.36	58.95	MC	-	-
M12	5056287	521592	136.48	29.48	M	-	-
M13	5056256	521602	543.57	44.86	MC	-	-
M14	5056226	521611	149.36	20.6	MC	-	M15, M16, M23, M24, C30
M15	5056211	521617	66.37	20.1	MC	-	M14, M16, M23, M24, C30
M16	5056197	521621	100.26	14.02	MC	-	M14, M15, M23, M24, C30
M17	5056157	521570	271.06	45.69	D	-	M25
M18	5056233	521546	72.41	42.3	D	-	M27
M19	5056393	521497	38.82	41.86	D	-	-
M20	5056440	521480	28.24	55.88	D	-	M28
M21	5056834	521353	24.36	9.22	M	-	-
M22	5057082	521273	73.28	4.44	M	-	-
M23	5056195	521602	1082.48	6.84	D	-	M14, M15, M16, M24, C30
M24	5056181	521605	2055.39	9.99	D	-	M14, M15, M16, M23, C30

Target	Position		Peak Spread (nT)	Distance (m)	Class*	Description	Possible Associations
M25	5056159	521565	125.77	30.76	D	-	M17
M26	5056184	521557	98.78	35.49	M	-	-
M27	5056232	521542	28.34	35.25	MC	-	M18
M28	5056439	521477	16.48	32.26	D	-	M20
M29	5056310	521500	333.27	90.42	D	Large anomaly	-
M30	5056484	521444	96.65	34.92	D	-	-
M31	5056298	521564	122.46	28.51	D	-	-
* M = monopole; D = dipole, MC = multicomponent							

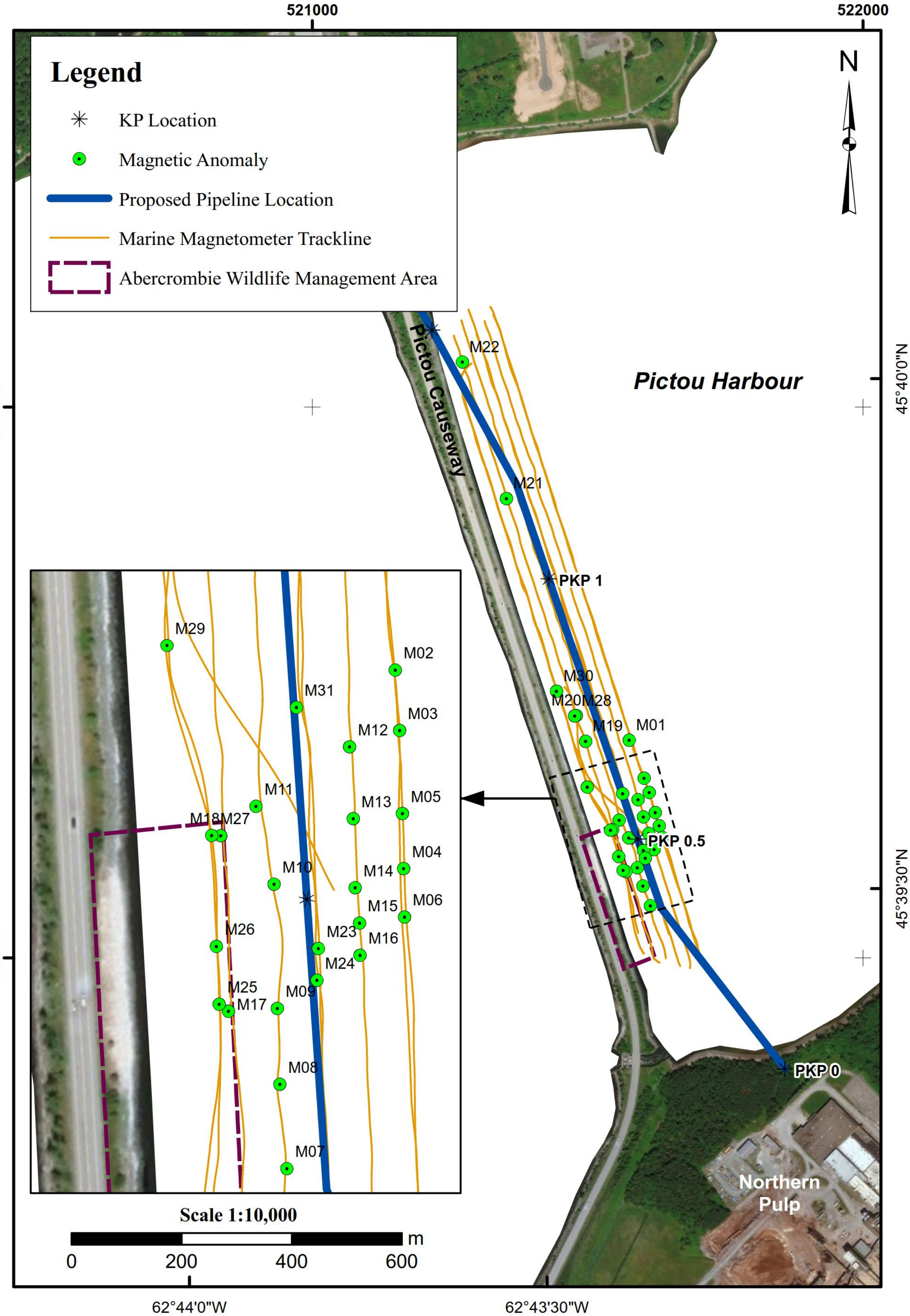

Figure 5.6.3 – Pictou Harbour magnetic anomaly locations.

Caribou Harbour Magnetic Anomalies

In total, 7 magnetic anomalies were mapped in the Caribou Harbour survey corridor; see Figure 5.6.4. Where possible, magnetic anomalies were correlated with sidescan sonar contacts and/or other magnetic anomalies. Details on all magnetic anomalies mapped in the Caribou Harbour survey corridor are listed in Table 5.6.4.

Table 5.6.4 – Caribou Harbour Magnetic Anomalies

Target	Position		Peak Spread (nT)	Distance (m)	Class*	Description	Possible Associations
	Northing	Easting					
M32	5066268	524937	212.62	22.13	M	Possible buoy	-
M33	5066170	524818	12.1	16.03	M	-	-
M34	5066332	524986	270.08	13.22	M	-	-
M35	5066069	524730	18.14	65	D	Possible buoy	C45
M37	5066105	524767	10.75	31.7	M	Possible buoy	-
M38	5066633	525431	62.6	12.26	MC	-	-
M39	5066936	526081	3.92	16.54	M	-	-
* M = monopole; D = dipole, MC = multicomponent							

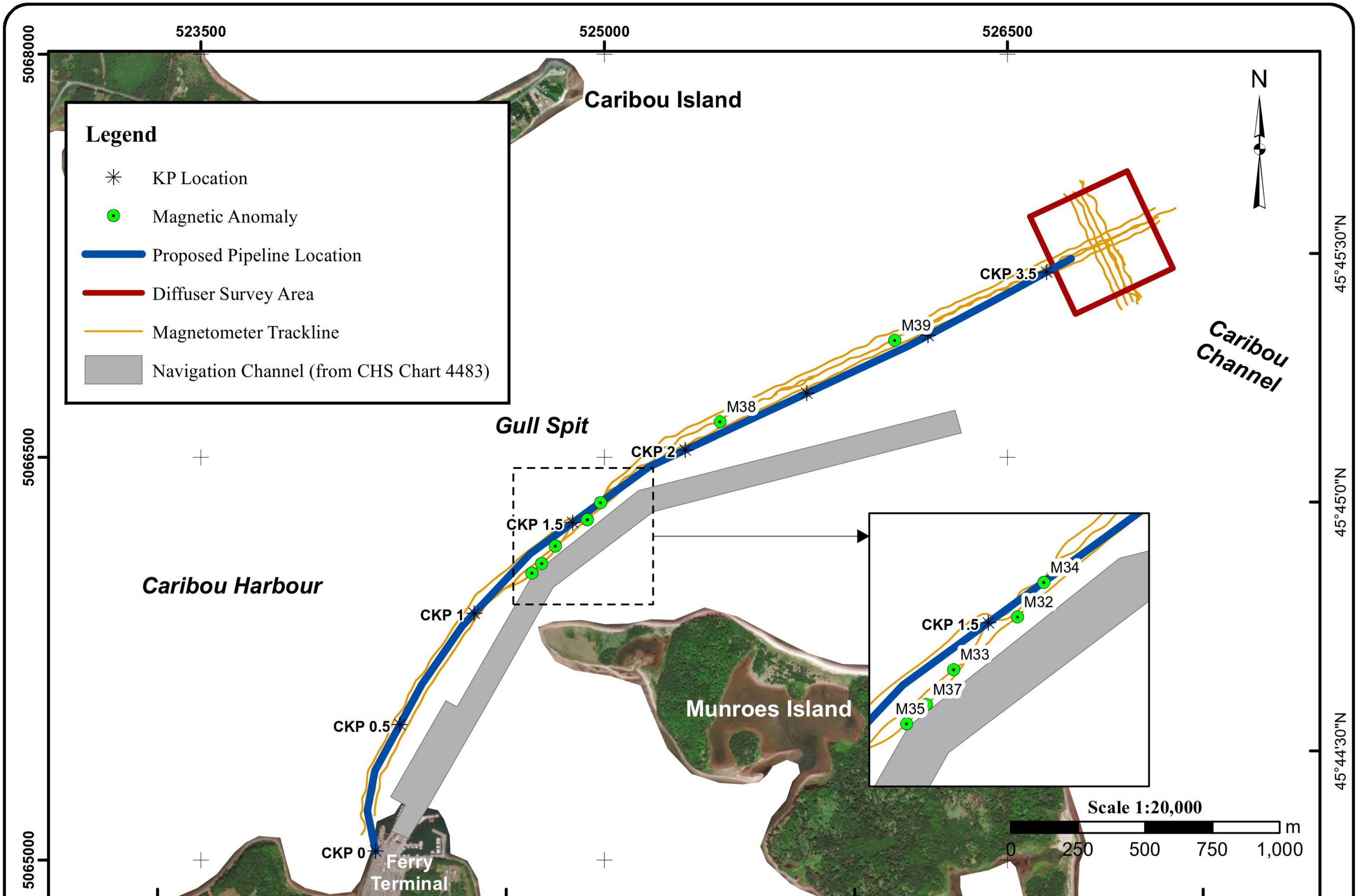

Figure 5.6.4 – Caribou Harbour magnetic anomaly locations.

CSR GeoSurveys Ltd.

5.7 Harbour Bottom Video Analysis

Analysis of the harbour bottom video collected in the Pictou Harbour and Caribou Harbour survey corridors included three main objectives:

1. The underwater video was utilized by CSR to visually ground truth seabed sediment types to support the surficial geology interpretation.
2. The underwater video was utilized by a marine archaeologist (Stantec) to examine anthropogenic seabed anomalies identified in the Pictou Harbour and Caribou Harbour survey corridors; see Section 5.6.
3. The underwater video was utilized by a marine scientist (Stantec) to analyze and map the benthic habitats (flora and fauna) within the Pictou Harbour and Caribou Harbour survey corridors.

Results from CSR's analysis of the underwater video supported the surficial geology interpretations presented on Enclosure 2 (Pictou) and Enclosures 6 and 7 (Caribou).

Results from the analysis and mapping efforts completed by the marine scientist have been provided in a separate report provided by Stantec.

Stantec Consulting Ltd., 2019a. Underwater Benthic Habitat Survey of Caribou Harbour and Pictou Harbour Pipeline Corridors. Final Report, 2019. Prepared for CSR GeoSurveys Ltd., Porter's Lake, NS and submitted to Northern Pulp Nova Scotia Corporation, New Glasgow, NS. Stantec File: 121621877

6.0 SUMMARY

A new wastewater treatment plant is being proposed to replace the Boat Harbour system. The treated effluent from the new facility is proposed to be discharged into the Northumberland Strait outside Caribou Harbour. Two sections of the proposed pipeline route are located in marine areas; Pictou Harbour and Caribou Harbour. CSR GeoSurveys was contracted by NPNS to conduct marine geophysical, geotechnical and harbour bottom video investigations to gain an understanding of the bathymetry, geology, surficial features, benthic habitats and possible archeological resources within the Pictou Harbour and Caribou Harbour survey corridors.

Survey operations were conducted during April and May 2019 with CSR's survey vessel *SeaQuest* and Huntley's Sub-Aqua Construction vessel *Nova Endeavor*. Survey equipment utilized included multibeam sonar, sidescan sonar, marine magnetometer, boomer shallow seismic system, chirp sub-bottom profiler, seismic refraction system and an underwater video system. Grab samples were also collected to aid the surficial interpretation. Vibracores were collected to support the geotechnical and environmental testing of sediments.

The Pictou Harbour survey corridor parallels the Pictou Causeway from Abercrombie Point to the northern end of the Pictou Causeway. The Pictou Harbour survey corridor was approximately 1.5 km in length and approximately 200 m wide.

The Caribou Harbour survey corridor extends from the ferry terminal located on the southern shoreline of Caribou Harbour to the proposed outfall location in the Northumberland Strait. The survey corridor was approximately 3.6 km long and 200 m wide. The Caribou Harbour survey also included a 400 m x 400 m area over the proposed outfall location.

The geophysical data were referenced to NAD83 (CSRS) horizontal datum and projected to UTM Zone 20 coordinates. The vertical datum for the project was Chart Datum (LLWLT).

Kilometre Postings (KP) were generated for the Pictou Harbour proposed pipeline route from the start location on Abercrombie Point (PKP 0) to the Pictou Causeway (PKP 1.582). Kilometre Postings were also generated for the Caribou Harbour proposed pipeline route from the start location near the ferry terminal (CKP 0) to the outfall location in the Northumberland Strait (CKP 3.604).

<u>Bathymetry</u>
Bathymetry data were processed by CSR and corrected to Chart Datum. Bathymetric contours were generated at 1 m intervals and are presented on Enclosure 1 and 3 (Pictou) and Enclosures 4, 5, 8 and 9 (Caribou).

The bathymetry of the Pictou Harbour proposed pipeline route is relatively flat and shallow immediately offshore of Abercrombie Point. The old West River channel is located between PKP 0.460 and PKP 0.965 with a maximum depth of 9.9 m. The remainder of the proposed pipeline route occurs over a flat shallow seabed until reaching the Pictou Causeway toe at PKP 1.415.

The bathymetry of the Caribou Harbour proposed pipeline route ranges from 0.22 m to 19.06 m. Between CKP 0.100 and CKP 0.400 the seabed is generally flat with water depths ranging between 1.15 m and 2.75 m. The proposed pipeline route transects a channel within Caribou Harbour between CKP 0.400 and CKP 0.675 with a maximum depth of 6.8 m. North of the channel, water depths remain very shallow as the proposed route approaches and crosses Gull Spit. At CKP 2.270, the seabed begins to deepen as the proposed route follows a gradual slope towards the Caribou Channel to the end of the proposed route at CKP 3.604 (outfall location) where the water depth is 19.04 m below Chart Datum or 20.2 m below Mean Water Level.

Surficial Geology

The sidescan sonar data were processed and 0.2 m resolution mosaics were created for the Pictou Harbour and Caribou Harbour survey corridors. The processed data were interpreted visually to identify and map surficial geological boundaries and seabed features. The size, shape, homogeneity, apparent relief and acoustic returns were used to map surficial units and identify seabed surficial features including ice scours and anthropogenic seabed contacts. To support the interpretation, grab samples, vibracores and underwater video were correlated with the geophysical data. The surficial boundaries, seabed features, and sonar contacts mapped from the sidescan sonar data have been included on Enclosure 2 and 3 (Pictou) and Enclosures 6, 7, 8 and 9 (Caribou).

The surficial geology of the Pictou Harbour survey corridor is dominated by an extensive area of silt with local areas of cobble and boulders interpreted as outcropping glacial till.

The surficial geology of the Caribou Harbour survey corridor is dominated by extensive areas of silty sand, sand, and sand/gravel. An area of finer grained sediments including clayey silt, silt and sandy silt occurs nearshore. From CKP 0.667 to CKP 3.178 the seabed within the survey corridor is composed of sand, silty sand and sand/gravel. The surficial geology from CKP 3.178 to the proposed pipeline outfall location (CKP 3.604) is composed primarily of sand.

Three areas of bed-forms caused by sediment transport have been identified within the Caribou Harbour survey corridor. These sediment transport features occur in non-cohesive sand produced by currents and or waves. Sediment transport features observed adjacent to the proposed outfall location include megaripples and sand waves. These features were likely formed by currents with near bed-flow velocity of 40 to 100 cm/s (Amos & King, 1984). The near bed-flow direction that formed these features was moving in either a northeast or southwest direction. No sediment transport features were observed at the proposed outfall which may indicate an increase in gravel within the surficial sediments at this location.

Sub-bottom Geology

The sub-bottom geology in the Pictou Harbour and Caribou Harbour survey corridors were mapped from chirp profiler, boomer sub-bottom and seismic refraction data. All sub-bottom data were interpreted using established seismo-stratigraphic techniques. Identification of geological sequences was based on the internal characteristics of each sequence and correlation with the vibracore sampling.

Four major reflectors, R1 through R3 and Acoustic Basement, were identified and mapped from the sub-bottom data along the proposed pipeline routes. Areas of shallow gas were also mapped from the sub-bottom data. The seismic reflectors were correlated with vibracores and historic boreholes (in Pictou). Based on this analysis, CSR identified four main sub-bottom geological sequences. The spatial distribution of these sequences is included on the route profiles presented on Enclosure 3 (Pictou) and Enclosures 8 and 9 (Caribou).

Three major reflectors were identified and mapped in the Pictou Harbour survey corridor. These reflectors define the sub-bottom geological sequences found along the proposed route. Sequence 1 consists primarily of soft silt and clay with occasional sandy lenses. Sequence 2 was not observed within the Pictou Harbour survey corridor. Sequence 3 consists of proglacial sediments composed of clay, silty sand and gravel. Sequence 4 has been interpreted as glacial till consisting of poorly sorted, sub-rounded, coarse gravel mixed with finer sediment. Cobbles and boulders may also occur in this glacial till sequence. The acoustic basement reflector mapped in the Pictou Harbour survey corridor extends from PKP 0.613 to PKP 0.726 and is interpreted to be the top of bedrock.

Four major reflectors were identified and mapped in the Caribou Harbour survey corridor. Sequence 1 consists primarily of soft silt and clay with occasional sandy lenses. Sequence 2 is common throughout the Caribou Harbour survey corridor and is composed of sand & gravel. Sequence 3 consists of proglacial sediments composed of clay, silty sand and gravel. In the Caribou Harbour survey corridor a distinct reflector was observed within Sequence 3. As a result the Sequence has been subdivided into Sequence 3a and Sequence 3b. Sequence 4 has been interpreted as glacial till consisting of poorly sorted, sub-rounded, coarse gravel with finer sediment. Cobbles and boulders may also occur in this sequence and could be concentrated in the upper sequence as a relict lag deposit. Onshore the glacial till includes a surface boulder layer in some areas and a stony sandy facies. The coarse nature of the glacial till made it difficult to interpret the underlying sub-bottom geology.

The acoustic basement over the proposed pipeline route within Caribou Harbor was mapped through analysis of both chirp and boomer sub-bottom data. The acoustic basement reflector was usually faint and discontinuous. The acoustic basement was discernable within the boomer sub-bottom data over the offshore section of the route. In general, the acoustic basement was difficult to map over the nearshore section of the proposed pipeline route as a result of shallow gas, shallow water multiples in the seismic data, and the presence of Sequence 4 glacial till near the seabed. As a result, seismic refraction data was collected in this area to aid in the interpretation of the depth to bedrock.

The seismic refraction data indicates bedrock velocities in the range of 2000 m/s to 2700 m/s, typical of sandstone and shale. Overlying sediments appear to exhibit velocities in the range of 1600 m/s to 2000 m/s with velocities increasing with depth. Velocities in the mid 2000 m/s range may be representative of a weathered and/or fractured bedrock zone. The calculated velocity of bedrock from refraction modelling indicates the rock quality is very poor at the surface indicating a possible weathered zone. The velocities increase with depth through the bedrock sequence but remain in the range of poor quality rock.

Dredging Constraints

There are 3 main areas along the proposed Caribou Harbour pipeline route where Sequence 4 (glacial till) encroaches within the planned trench depth (3 m). Also, since the limits of excavation may be up to 14 m wide and 3 m below seabed, it is uncertain whether bedrock will be encountered during installation of the pipeline. These areas have been labelled on the interpreted geological profiles as an area where dredging may be constrained due to the sub-bottom geology and occur at the following locations.

- CKP 0.725 to CKP 0.982
- CKP 1.018 to CKP 1.263
- CKP 1.738 to CKP 2.214

The glacial till sequence in the Caribou Harbour survey corridor is interpreted to be Pomquet Drift consisting of subangular to angular coarse gravel, sand, silt and cobble. Boulders may also occur within the sequence. Bedrock in the area of Caribou Harbour is expected to be sandstone and shale. Seismic velocities of 2000 m/s to 2700 m/s measured from the glacial till and bedrock fall within the rippable to marginal rippable range. Considering the seismic velocities modelled increase with depth, it is most likely that bedrock in the proposed trench limits is likely weathered and in the rippable range. The rippability of bedrock is a measure of its ability to be excavated with conventional excavation equipment thereby eliminating blasting of the rock.

Ice Scour

Within the Northumberland Strait, ice scouring is the process whereby ice ridges contact the seabed forming linear gouges in the seabed sediments. The extent and thickness of Northumberland Strait ice is influenced by winter temperatures, severity and duration of storms as well as wind direction. Strong winds can cause ice to fracture and pile up into ridges by compression or shear in the ice cover and are typically found in the shear zone between the landfast ice and the drift or pack ice. Subsequent movement of these ridges can cause their keels to scour the seabed sediments. The scour depth parameter is perhaps the most important measurement in estimating the minimum trenching depths required for a pipeline installation.

During this study ice scour features were identified through an examination of multibeam and sidescan sonar data acquired during the 2019 geophysical survey in order to characterize those ice scours that could pose the greatest risk to the pipeline.

One-hundred and forty-six ice scours were identified from the geophysical data acquired in 2019. Thirteen ice scours occur within the Pictou survey corridor while 133 ice scours were observed within the Caribou area.

The ice scours observed within the Pictou Harbour survey corridor all occur offshore of Abercrombie Point within water depths ranging from 2 m to 3 m. These ice scours were 1 m to 3 m wide, 11 m to 59 m long with the majority having a north-south orientation. The deepest ice scour observed was 0.3 m.

The ice scours observed within the Caribou area occur within water depths ranging from 1 m to 9 m. Ice scour length ranges from 2 m to 260 m with a mean length of 45 m. Ice scour width ranges from 1 m to 6 m with a mean width of 2 m. Ice scour orientation is generally controlled by water depth with the majority of ice scours parallel to the bathymetric contours. No ice scours were observed within the area of the proposed diffuser. Spatially, the observed Caribou ice scour population occurs within two main areas. Eighty-eight ice scours occur within Caribou Harbour in water depths ranging 1 m to 9 m and 42 ice scours occur east of Caribou Island in water depths ranging 5 m to 8 m. Of the 133 ice scours observed in the Caribou area only 15 had a scour depth ≥ 0.2 m with a maximum recorded depth of 0.4 m. The age of the ice scours is not known but they were likely formed during the winter of 2018/2019.

Within the nearshore Caribou Harbour area west of Munroes Island between CKP 1.0 and CKP 1.1 the seabed includes an area that may have been disturbed as a result of ice grounding. The area is approximately 70 m by 100 m and includes small pit features that have a maximum depth of 0.7 m. The water depth within this area ranges from 2 to 3 m and the surficial sediments are sand and gravel. The age of the features is not known.

Sonar Contacts & Magnetic Anomalies

CSR utilized both sidescan sonar data and marine magnetometer data to identify anthropogenic features in the survey corridors. Examples of anthropogenic features mapped during the marine geophysical survey include old pile timbers, mooring blocks/chains and rock piles. CSR provided all sidescan sonar data and magnetic anomalies mapped from marine geophysical data to Stantec for detailed analysis by a marine archaeologist. The sonar contacts and magnetic anomalies have been included on Enclosure 2 and 3 (Pictou) and Enclosures 6, 7, 8 and 9 (Caribou).

In total, 43 sidescan sonar contacts representing possible anthropogenic features on the seabed were mapped in the Pictou Harbour survey corridor while 7 sidescan sonar contacts were mapped in the Caribou Harbour survey corridor.

Seven magnetic anomalies were mapped in the Caribou Harbour survey corridor while 31 were mapped in the Pictou Harbour survey corridor. Where possible, magnetic anomalies were correlated with sidescan sonar contacts and/or other magnetic anomalies.

Underwater Video

A harbour bottom video investigation was conducted to analyze the benthic habitat, ground truth seabed sediment types to support the surficial geology interpretation, and to examine anthropogenic seabed contacts present in the Pictou Harbour and Caribou Harbour survey corridors.

7.0 RECOMMENDATIONS

CSR recommends the following work be considered to further support the engineering, design and installation of the proposed pipeline.

During the final engineering design an ice scour assessment could be conducted to model the ice scour contact frequency and define the maximum depth of ice scouring. This study may result in refinement of the trench design depth and reduce the volume of excavated material if it is determined that a 3 m trench is not required in all areas.

Pictou Harbour

1. Removal of seabed debris identified within the construction footprint of the proposed pipeline route.
2. Pre-lay clearance survey along the proposed route using sidescan sonar, magnetometer, video (remotely operated video) and possible grapnel drag conducted immediately prior to the installation to ensure the route is free of obstructions.

Caribou Harbour

1. Ground truth sidescan sonar contacts C47 and C48. These contacts are responsible for a minor route deviation in the offshore area of Caribou Harbour. If the contacts are not culturally significant, the route could be adjusted back to its original position.
2. Geotechnical boreholes at select areas of uncertainty to examine the rippability of glacial till and possible weathered bedrock within the limits of the proposed installation trench. The benefits resulting from the geotechnical boreholes may include refinement of the trench design to reduce the volume of excavated material. Geotechnical information from the glacial till and possible bedrock may indicate that the trench walls can be redesigned at an angle greater than the planned 30% grade, minimizing the trench footprint. The geotechnical information could assist to refine the equipment selected for installation.
3. Pre-lay clearance survey along the proposed route using sidescan sonar, magnetometer, video (remotely operated video) and possible grapnel drag conducted immediately prior to the installation to ensure the route is free of obstructions.

8.0 REFERENCES

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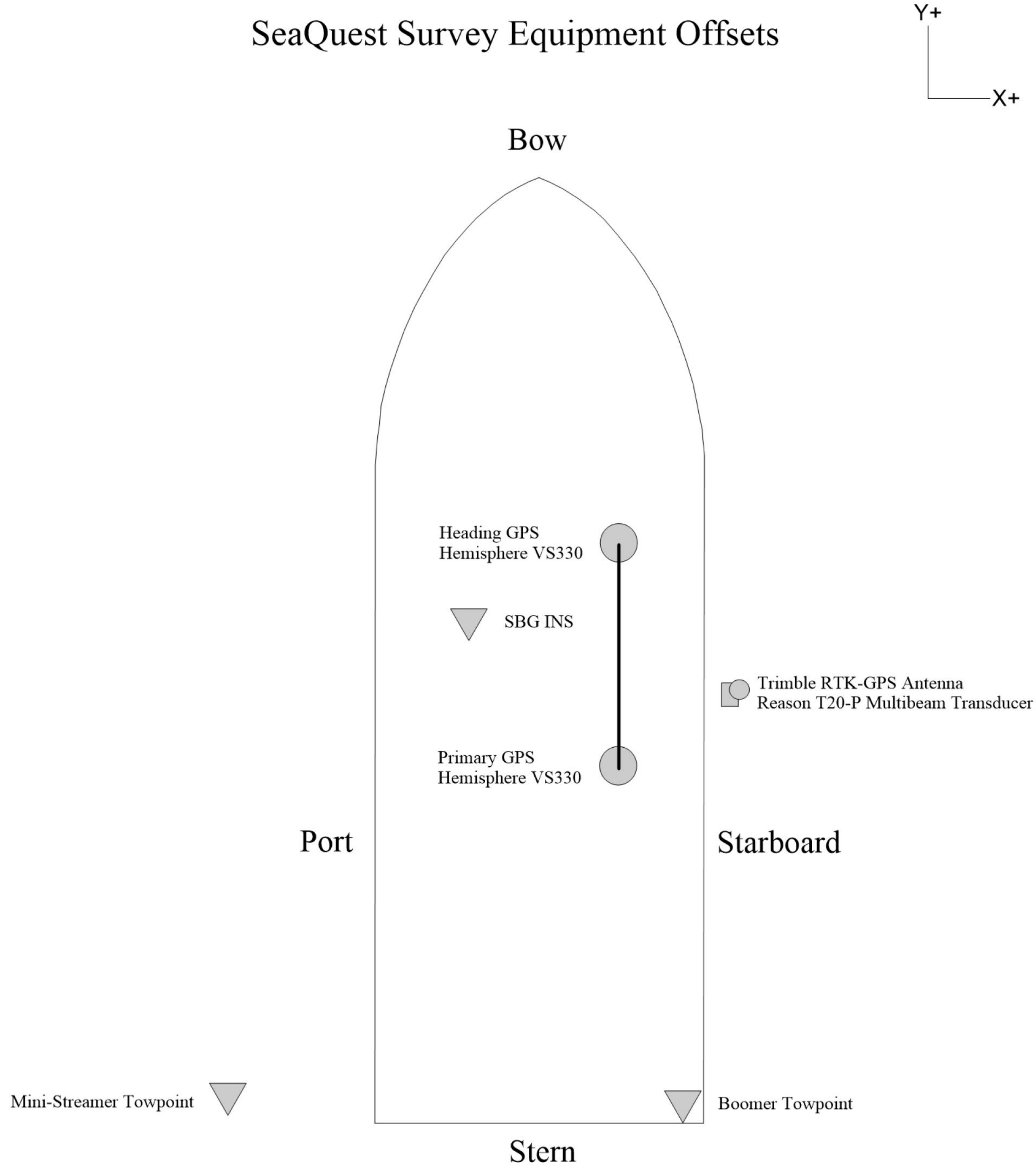
APPENDIX I
VESSEL OFFSETS

SeaQuest Survey Equipment Offsets

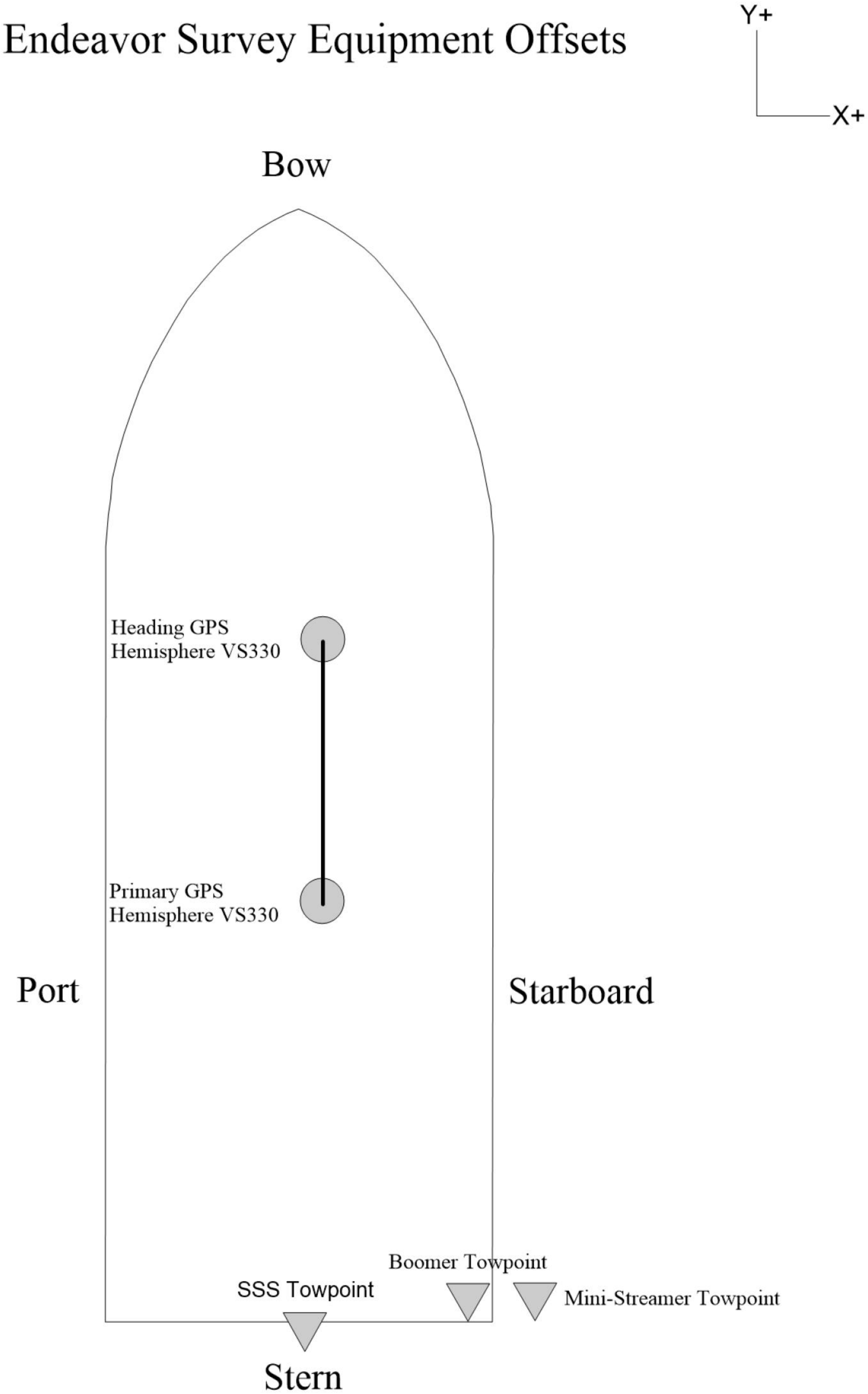


Boomer Systems Offsets (m)			
System	X	Y	Z
Hemisphere Primary Antenna	0.00	0.00	-
Hemisphere Secondary Antenna	0.00	2.00	-
Boomer Towpoint	0.70	-1.68	-
Boomer with Layback	0.70	-12.68	-
Mini-Streamer Towpoint	-2.78	-1.68	-
Mini-Streamer with Layback	-2.78	-12.68	-

Multibeam Systems Offsets (m)			
System	X	Y	Z
Trimble RTK-GPS Antenna	1.60	-0.60	1.58
SBG INS	0.00	0.00	0.00
T20-P Multibeam Transducer	1.50	-0.65	-1.25

Plan view and vessel offsets of the CSR GeoSurveys vessel *SeaQuest.*

Nova Endeavor Survey Equipment Offsets



Boomer Systems Offsets (m)			
System	X	Y	Z
Hemisphere Primary Antenna	0.00	0.00	-
Hemisphere Secondary Antenna	0.00	2.00	-
Boomer Towpoint	2.50	-6.90	-
Boomer with Layback	7.50	-31.90	-
Mini-Streamer Towpoint	3.50	-6.90	-
Mini-Streamer with Layback	2.50	-31.90	-

Sidescan Sonar System Offsets (m)			
System	X	Y	Z
Sidescan Sonar	0.00	-6.90	4.00
Hemisphere Primary Antenna	0.00	0.00	0.00
Hemisphere Secondary Antenna	0.00	2.00	0.00

Plan view and vessel offsets of the Huntley Sub-Aqua Construction vessel *Nova Endeavor*.

CSR GeoSurveys Ltd.

APPENDIX II
FINAL VIBRACORE LOGS AND TEST RESULTS

Stantec

Stantec Consulting Ltd.
102-40 Highfield Park Drive, Dartmouth NS B3A 0A3

July 26, 2019
File: 121621877

Attention: Mr. Glen Gilbert
CSR GeoSurveys Ltd.
341 Myra Road
Porters Lake NS B3E 1G2

Dear Mr. Gilbert,

Reference: Summary of Vibrocore Observations and Laboratory Testing
Proposed Northern Pulp Outfall, Pictou County, NS

As requested, Stantec Consulting Ltd. provided field and laboratory inspection and testing services as part of the collection of the vibrocore samples taken along the proposed outfall route in Pictou County. The services included visual classification of the material retrieved, laboratory testing on selected samples, and the preparation of this summary letter.

Stantec personnel were on board the vessel during the vibrocore collection program. The program took place between April 27 and May 5, 2019. During the collection of the vibrocores, our personnel made observations on the material collected in the vibrocores and recorded the location of the core.

Following completion of the field program, the samples were returned to our Dartmouth laboratory, where the cores were extruded and more detailed classification took place. Following the visual classification, samples of the material were selected for laboratory testing which included moisture content determinations, grain size analyses, Atterberg limits, and pocket penetrometer readings. The results of the laboratory testing are appended to this letter.

Our summary of the subsurface conditions encountered in the vibrocores is provided in the attached summary table.

Geotechnical recommendations for use in the design and construction of the proposed outfall will be provided under a separate cover at a later date.

We trust this is all the information that is required at this time. If you have any questions or require any additional information, please do not hesitate to contact the undersigned at your convenience.

Regards,

Stantec Consulting Ltd.

James S. Mitchell, P.Eng., PMP
Managing Principal, Geotechnical
Phone: 902 468 0421
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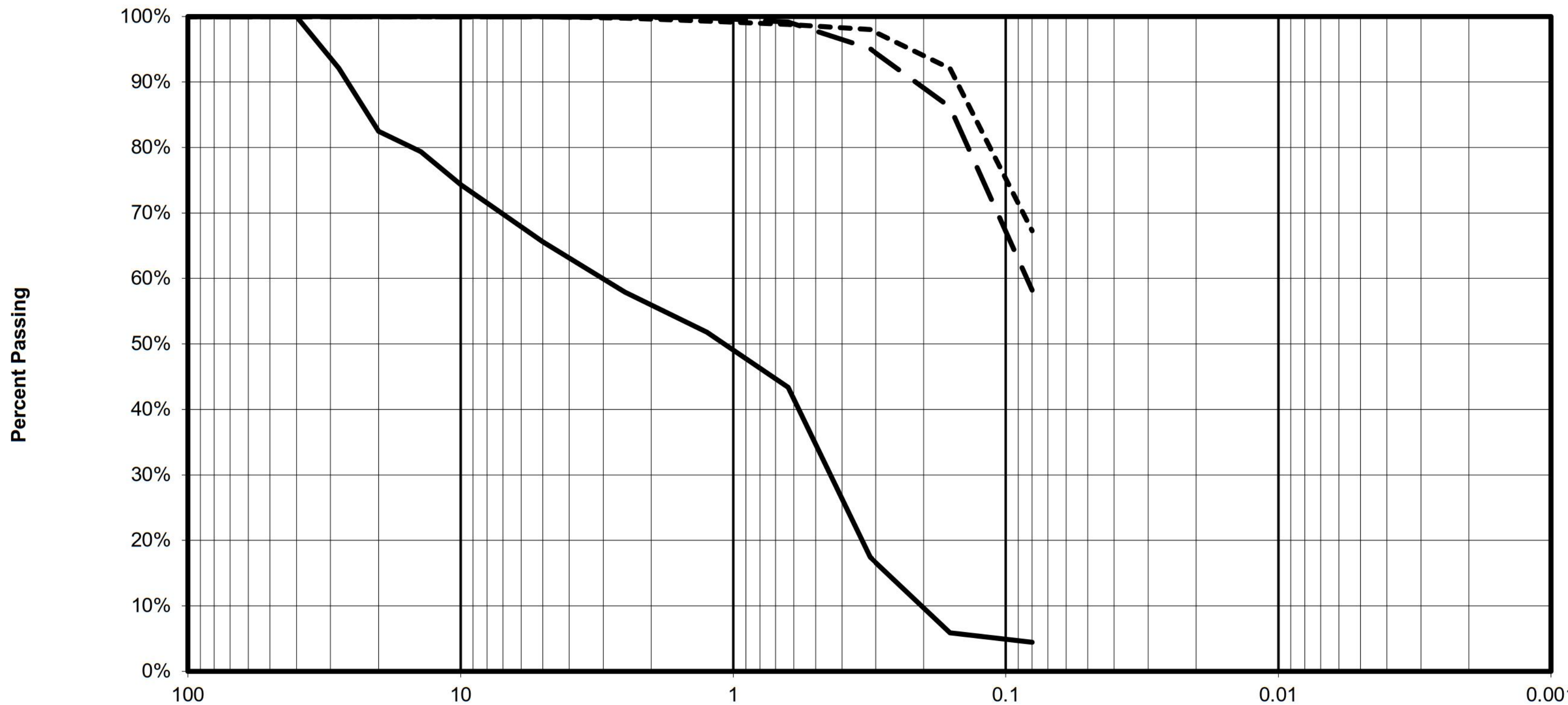
Attachments: Grain Size Analyses
Vibrocore Summary Table
Vibrocore Moisture Contents

jm v:\1216\active\121621xxx\121621877\7_reports\geotechnical\let_jsm_drm_gg_20190726.docx

Approved: JSM



Grain Size in Millimetres

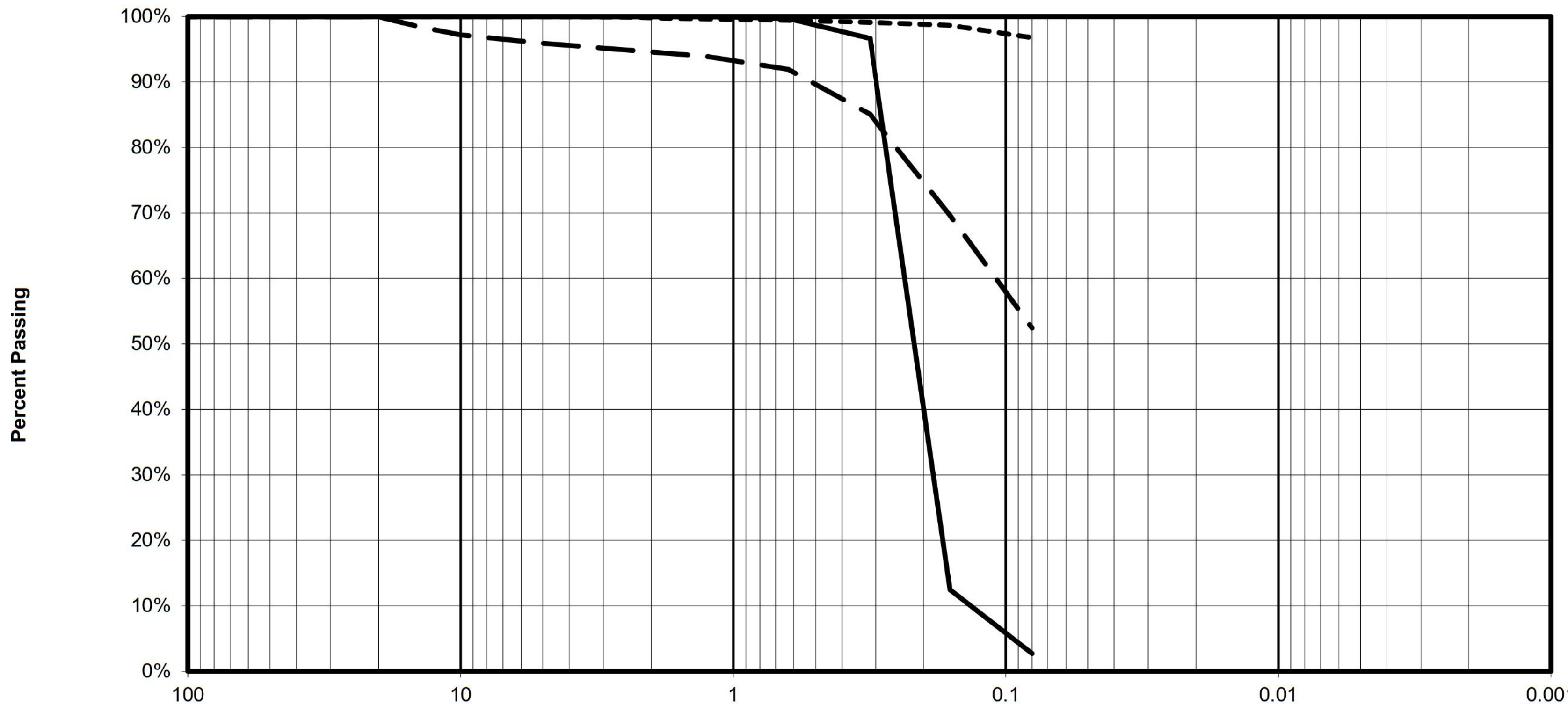
Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System ASTM D 2487/2488

Curve	BOREHOLE/TESTPIT	SAMPLE	DEPTH (m)	Soil Fractions			Soil Description
				Gravel	Sand	Silt/Clay	
———	VC-01	BS4	0.66 - 0.91	34%	61%	4%	Sand with gravel
— — ·	VC-02	BS4	1.2 - 2.2	0%	42%	58%	Sandy silt
- - - -	VC-05	BS2	0.2 - 1.2	0%	33%	67%	Sandy silt

Job No.: 121621877

Approved: JSM



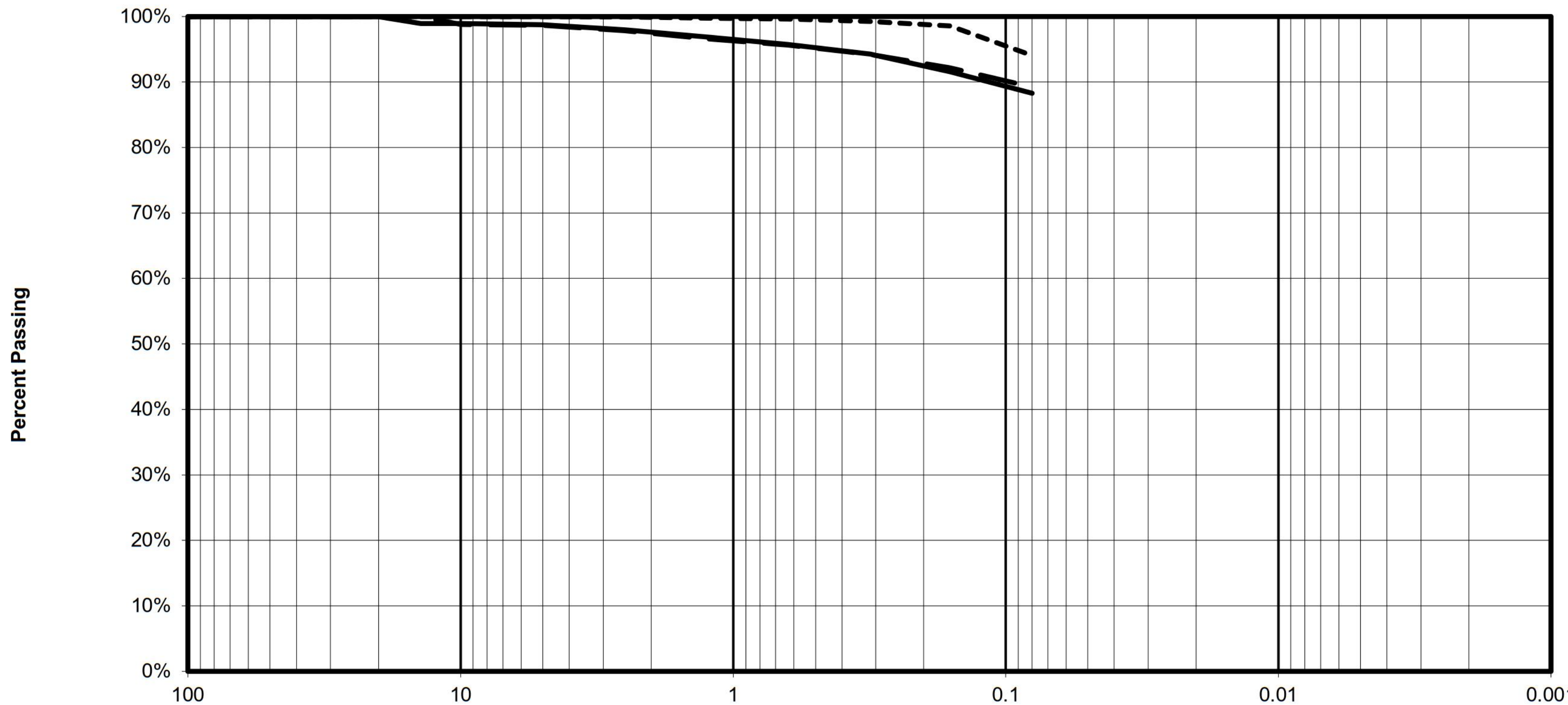
Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System ASTM D 2487/2488

Curve	BOREHOLE/TESTPIT	SAMPLE	DEPTH (m)	Soil Fractions			Soil Description
				Gravel	Sand	Silt/Clay	
———	VC-8A	BS2	0.5 - 1.1	0%	97%	3%	Sand
— — ·	VC-12	BS2	1.1 - 1.3	4%	43%	52%	Sandy silt
- - - -	VC-14	BS2	1.5 - 1.9	0%	3%	97%	Organic silt

Job No.: 121621877

Approved: JSM



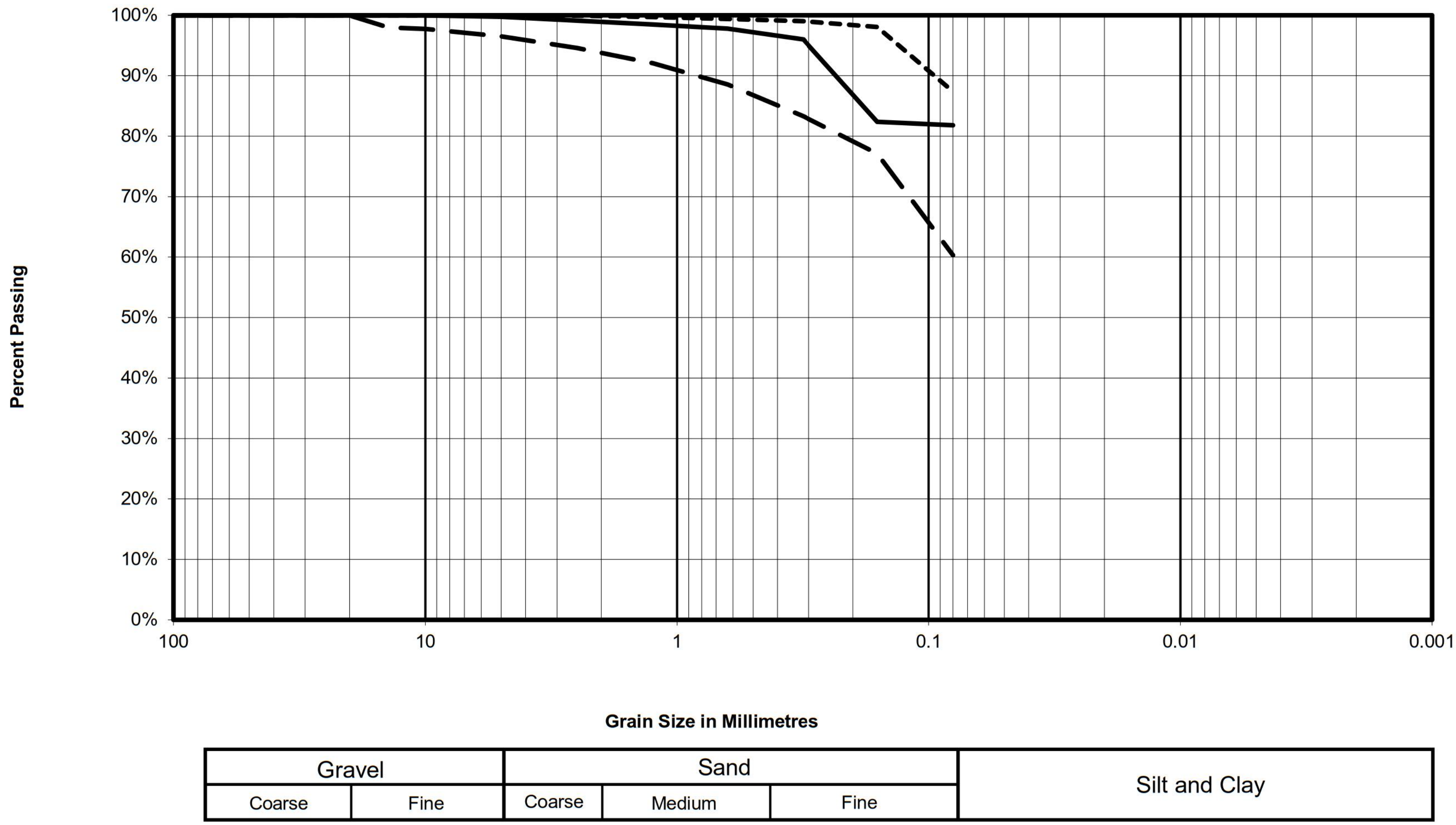
Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification System ASTM D 2487/2488

Curve	BOREHOLE/TESTPIT	SAMPLE	DEPTH (m)	Soil Fractions			Soil Description
				Gravel	Sand	Silt/Clay	
———	VC-16	BS3	1.4 - 2.4	1%	10%	88%	Organic silt
— — ·	VC-19	BS2	1.4 - 2.4	1%	9%	89%	Silt
- - - -	VC-20	BS2	2.5 - 3.5	0%	6%	94%	Organic silt

Job No.: 121621877

Approved: JSM



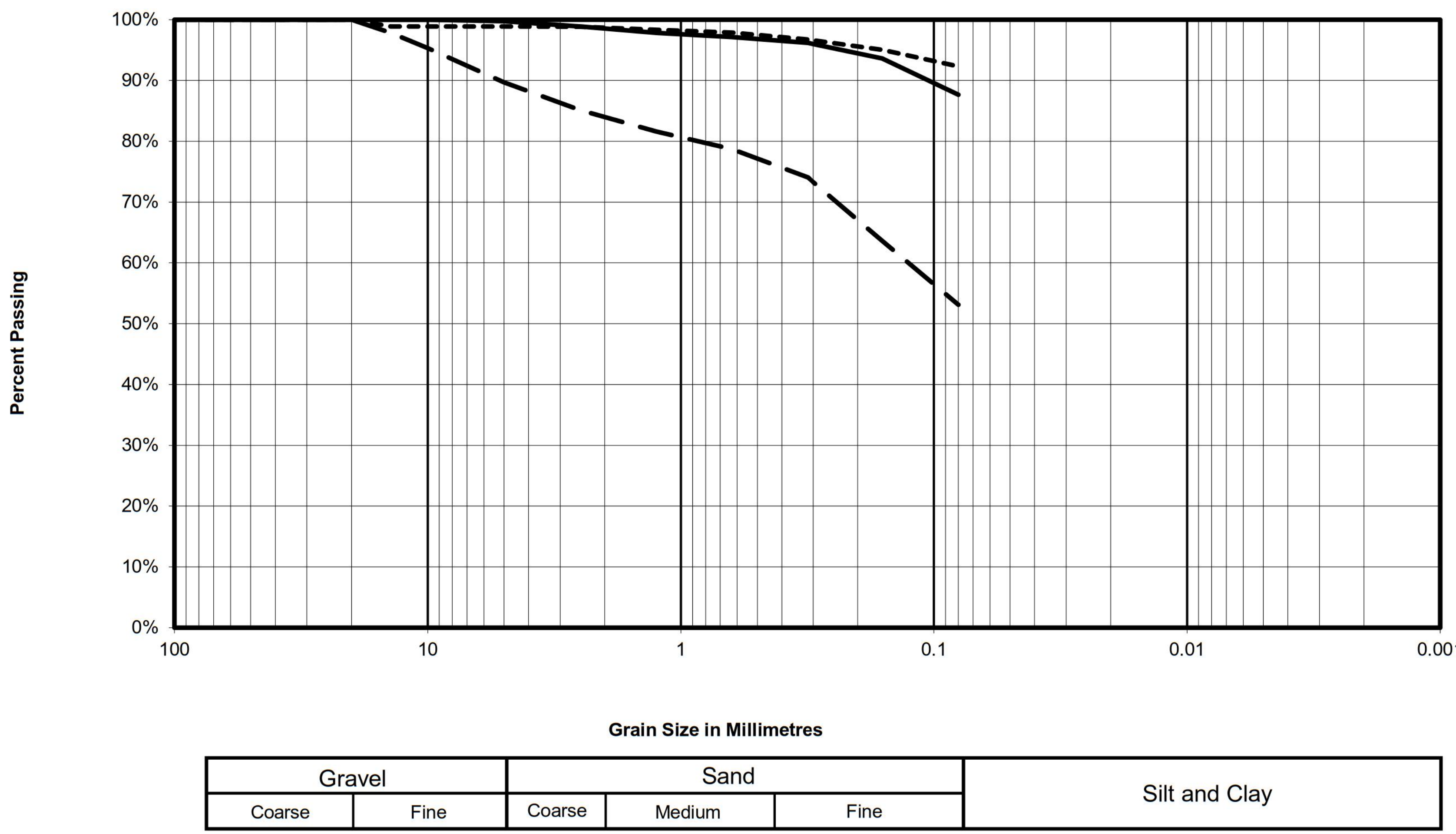
Unified Soil Classification System ASTM D 2487/2488

Curve	BOREHOLE/TESTPIT	SAMPLE	DEPTH (m)	Soil Fractions			Soil Description
				Gravel	Sand	Silt/Clay	
———	VC-21	BS2	2.5 - 3.5	0%	18%	82%	Sandy silt
— — ·	VC-22	BS5 & 6	2.45 - 3.45	3%	36%	60%	Sandy organic silt
- - - -	VC-23	BS6	2.3 - 2.7	0%	13%	87%	Clay

Stantec

Job No.: 121621877

Approved: JSM



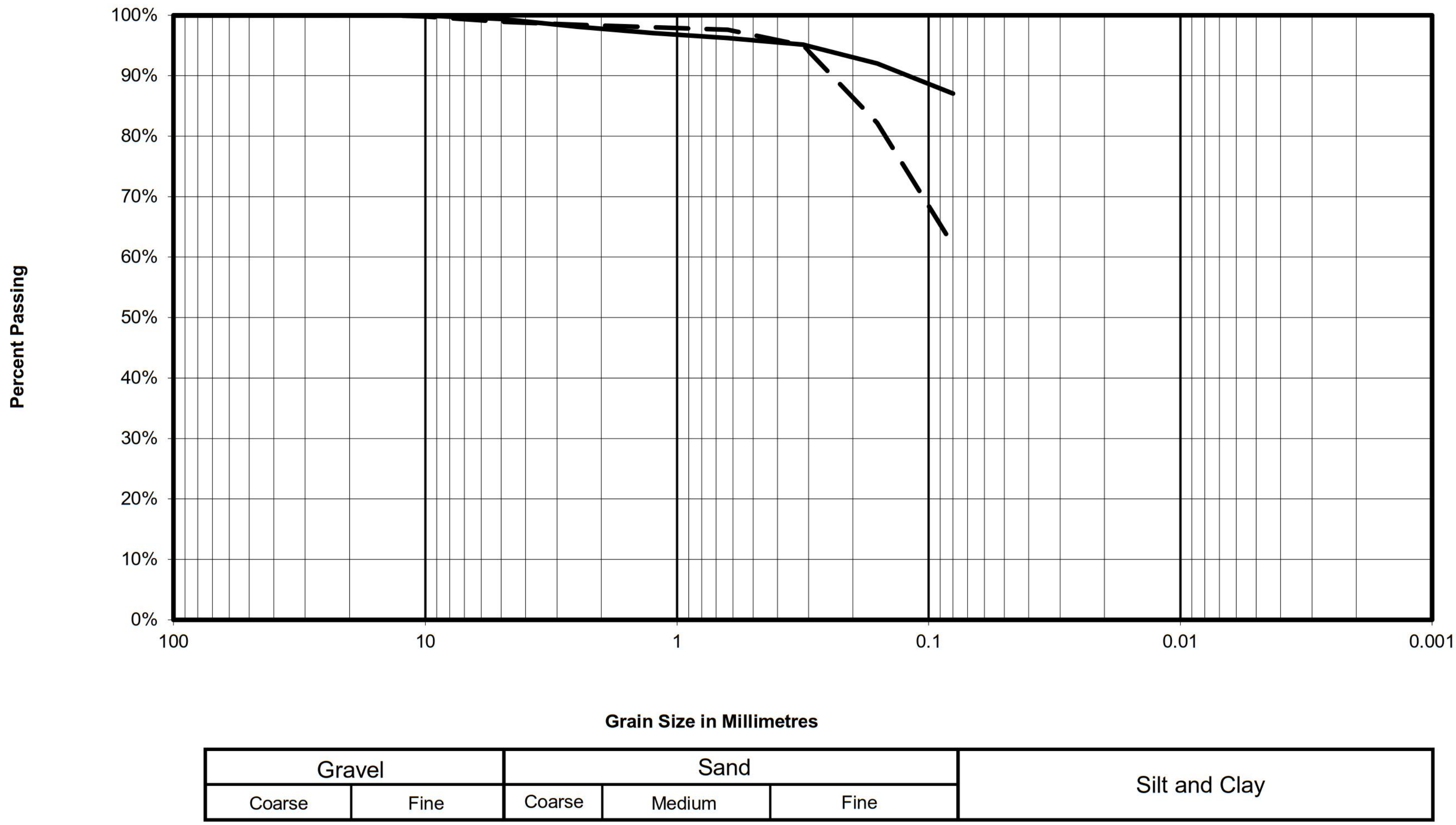
Unified Soil Classification System ASTM D 2487/2488

Curve	BOREHOLE/TESTPIT	SAMPLE	DEPTH (m)	Soil Fractions			Soil Description
				Gravel	Sand	Silt/Clay	
———	VC-50	BS7	2.0 - 2.2	0%	12%	88%	Organic silt
— — ·	VC-51	BS1	0.25 - 1.0	10%	37%	53%	Sandy silt
- - - -	VC-52	BS3	1.3 - 2.2	1%	7%	92%	Organic silt

Stantec

Job No.: 121621877

Approved: JSM



Unified Soil Classification System ASTM D 2487/2488

Curve	BOREHOLE/TESTPIT	SAMPLE	DEPTH (m)	Soil Fractions			Soil Description
				Gravel	Sand	Silt/Clay	
———	VC-53	BS3	1.5 - 2.2	1%	12%	87%	Organic silt
— — ·	VC-54	BS4	1.0 - 1.4	1%	37%	62%	Sandy silt

Job No.: 121621877

Vibrocore Summary Table

Vibrocore #	UTM Location Coordinate		Depth (m)	Description	Undrained Shear Strength (kPa)
	Easting	Northing			
VC-01	526868.6	5067312.2	0 – 0.5	Brown medium to fine sand	
			0.5 – 0.66	Brown silty sand	
			0.66 – 0.91	Brown sand with gravel, trace shells	
VC-02(c)	526907.3	5067189.0	0 – 0.8	Light grey to brown sand	
			0.8 – 1.1	Brown silty clay	20
			1.1 – 2.2	Brown sandy silt	
VC-03(b)	526662.6	5067227.4	0 – 0.5	Brown sand, some gravel	
VC-04(b)	526502.1	5067135.2	0 – 2.4	Grey to brown sand, with shells and gravel	
VC-05	526241.6	5067015.1	0 – 0.2	Brown silty sand	
			0.2 – 2.2	Reddish brown sandy silt, black organic matter	10
VC-06	524574.9	5066004.0	0 – 0.3	Grey to brown sand with gravel, trace cobbles and shells	
VC-07	525931.2	5066867.9	0 – 1.45	Brown silty sand, shells	
VC-08	525663.0	5066734.9	0.0 – 0.5	Brown sand	
			0.5 – 1.1	Brown sand	
VC-09	525401.0	5066622.3	0 – 0.35	Brown sand	
			0.35 – 0.67	Brown gravel with sand, trace shells	
VC-10(b)	525156.9	5066482.7	0 – 0.4	Brown sand	
			0.4 – 0.65	Brown sand with gravel	
VC-11	524783.0	5066168.4	0.0 – 0.3	Brown sand	
			0.3 – 1.5	Grey silt, some organics matter	20
VC-12	524555.7	5065980.4	0 – 0.4	Black/grey silty sand, shells	
			0.4 – 1.6	Red sandy silt	
VC-13	524405.3	5065768.1	0 – 0.35	Gravel, trace sand and cobbles	
VC-14	524261.6	5065548.3	0 – 0.9	Black to brown organic silt	
			0.9 – 1.4	Black organic silt	
			1.4 – 1.9	Black organic silt	
			1.9 – 2.5	Black organic silt	3
VC-15	524178.8	5065386.3	0 – 2.5	Grey silt with sand, some organic matter	7
VC-16	524131.9	5065255.1	0 – 1.4	Brown clayey silt, some shells	3 – 5
			1.4 – 2.4	Grey organic silt	
VC-18	524964.8	5066289.0	0 – 0.8	Brown sand, trace silt	
VC-19	524125.0	5065136.5	0 – 3.4	Brown to grey silt, some organic matter	5 – 16
VC-20	524151.9	50656327.1	0 – 0.9	Brown sandy silt	5
			0.9 – 3.5	Grey organic silt, occasional shells, and gravel	5 – 10
VC-21	524225.2	5065466.1	0 – 1.5	Dark brown sandy silt occasional black organic matter	0
			1.5 – 4.3	Brown sandy silt, occasional organic matter	0
VC-22	524322.9	5065654.7	0 – 2.25	Brown sandy silt, trace shells and organic matter	3 – 8
			2.25 – 3.0	Grey sandy organic silt	13
			3.0 – 3.45	Grey sandy organic silt	14

Vibrocore Summary Table

Vibrocore #	UTM Location Coordinate		Depth (m)	Description	Undrained Shear Strength (kPa)
	Easting	Northing			
VC-23	526960.8	5066910.0	0 – 0.8	Brown silty sand to fine sand	10 – 20
			0.8 – 2.1	Grey silty sand	10
			2.1 – 3.2	Grey clay	3 – 50
VC-50(c)	521567.2	5056172.2	0 – 0.2	Brown silt	
			0.2 – 1.4	Grey silty sand	
			1.4 – 3.3	Grey to black organic silt, occasional shells	8 – 13
VC-51(b)	524172.7	5056386.4	0 – 3.0	Reddish brown sandy silt, some gravel below 1.0 m.	10
VC-52(b)	521389.9	5056656.0	0 – 3.15	Grey organic silt, occasional shells	1 – 2
VC-53	521309.0	5056899.1	0 – 3.15	Grey organic silt, trace shells	1 – 6
VC-54	521267.0	5057061.5	0 – 0.1	Brown silt	
			0.1 – 2.5	Grey sandy silt, shells at bottom	15
			2.5 – 2.6	Brown silty sand	

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Stantec

Project Name: Northern Pulp Outfall

Project Number: 121621877

Task: 200

Client: CSR Geosurveys Ltd.

Sample Identification	Moisture Content, %
VC-01, BS3	15.1
VC-01, BS4, 0.66-0.91 m	12.4
VC-2, BS4, 1.2-2.2 m	21.1
VC-2C, BS1, 0-0.8 m	13.5
VC-2C, BS2, 0.5-1.1 m	83.5
VC-04, BS1, 0.3-0.6 m	18.1
VC-05, BS2, 0.2-1.2 m	44.4
VC-07, BS1, 0.15-1.45 m	37.9
VC-8A, BS2, 0.5-1.1 m	23.9
VC-09, BS2, 0.35-0.67 m	9.6
VC-10B, BS2, 0.4-0.65 m	15.0
VC-11, BS4, 1.0-1.5 m	55.5
VC-12, BS2, 1.1-1.3 m	16.0
VC-14, BS1, 1.1-1.3 m	78.3
VC-14, BS2, 1.5-1.9 m	78.1
VC-15, BS4, 1.5-2.5 m	70.5
VC-16, BS2, 0.8-1.4 m	80.2
VC-16, BS3, 1.4-2.4 m	96.9
VC-18, BS1, 0-0.8 m	17.2
VC-19, BS2, 1.4-2.4 m	87.5
VC-20, BS1, 1.5-2.5 m	86.8
VC-20, BS2, 2.5-3.5 m	78.4
VC-21, BS2, 2.5-3.5 m	54.6
VC-21, BS3, 1.5-2.5 m	82.0
VC-22, BS2, 1.45-2.25 m	62.4
VC-22, BS5 & 6, 2.45-3.45 m	60.6
VC-23, BS2, 0.3-0.6 m	31.1
VC-23, BS3, 0.8-1.1 m	26.6
VC-23, BS6, 2.3-2.7 m	49.6

Sample Identification	Moisture Content, %
VC-50, BS4, 0.85-1.2 m	97.8
VC-50, BS7, 2.0-2.2 m	68.6
VC-51, BS1, 0.25-1.0 m	18.1
VC-52, BS2, 0.8-1.3 m	104.1
VC-52, BS3, 1.3-2.2 m	95.8
VC-53, BS3, 1.5-2.2 m	115.3
VC-54, BS3, 0.4-1.0 m	79.1
VC-54, BS4, 1.0-1.4 m	15.0

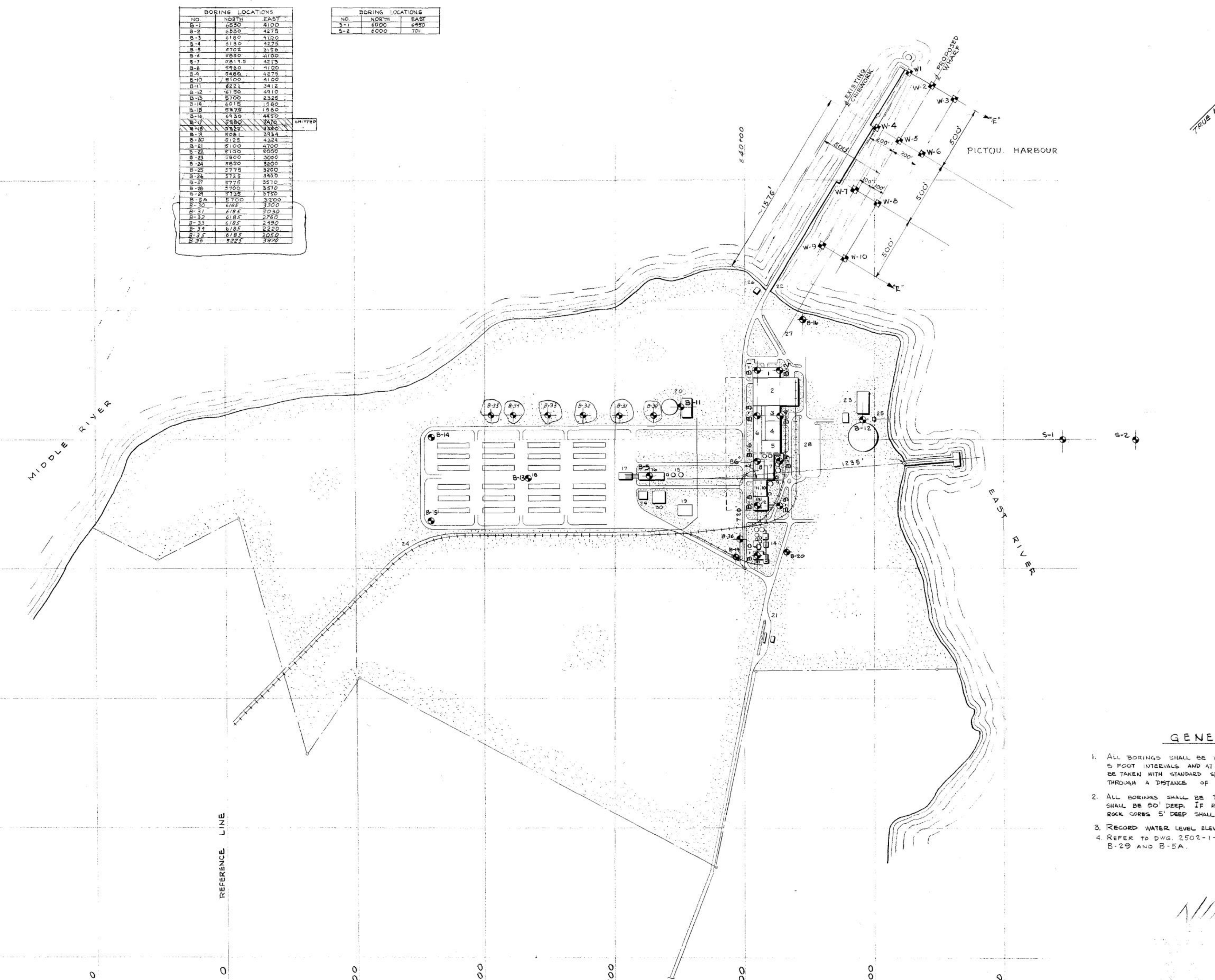
Reviewed By: S. Aldous

Date: June 10, 2019

APPENDIX III
PICTOU HARBOUR BOREHOLE INFORMATION

BORING LOCATIONS		
NO.	NORTH	EAST
B-1	6530	4100
B-2	6530	4275
B-3	6180	4100
B-4	6180	4275
B-5	5702	3156
B-6	5830	4100
B-7	5819.5	4213
B-8	5980	4100
B-9	5480	4275
B-10	5100	4100
B-11	6221	3412
B-12	6150	4910
B-13	5700	2325
B-14	6015	1580
B-15	5375	1580
B-16	6930	4450
~~B-17~~	~~5880~~	~~3470~~	OMITTED
~~B-18~~	~~5322~~	~~3560~~	"
B-19	5081	3934
B-20	5125	4324
B-21	5100	4700
B-22	5100	5000
B-23	5800	3000
B-24	5850	3200
B-25	5775	3200
B-26	5735	3400
B-27	5775	3570
B-28	5700	3570
B-29	5735	3750
B-5A	5700	3200
B-30	6185	3300
B-31	6185	3030
B-32	6185	2760
B-33	6185	2490
B-34	6185	2220
B-35	6185	2050
B-36	5225	3970

BORING LOCATIONS		
NO.	NORTH	EAST
S-1	6000	6950
S-2	6000	7011



—LEGEND—

1 OFFICES
2 WAREHOUSE
3 STORES
4 SHOPS
5 MILL OFFICES
6 PULP DRYER
7 BROWN STOCK
8 BLEACH PLANT
9 CONTINUOUS DIGESTER
10 EVAPORATORS
11 RECOVERY BOILER
12 TURBINE GENERATOR
13 POWER BOILER
14 CAUSTICIZING
15 CHIP SILOS
16 WOOD ROOM
17 LOG POND
18 WOOD YARD
19 PURCHASED POWER SUBSTATION
20 WATER TREATMENT
21 GATE HOUSE, SCALE & SCALE HOUSE
22 DOCK
23 WASTE WATER
24 WATER LINE
25 EFFLUENT LINE
26 SALT WATER PUMP HOUSE
27 OFFICE PARKING
28 MILL PARKING
29 EMERGENCY BARK STORAGE
30 EMERGENCY CHIP STORAGE

GENERAL NOTES

1. ALL BORINGS SHALL BE WASH BORINGS WITH SAMPLES TAKEN AT 5 FOOT INTERVALS AND AT EVERY CHANGE IN STRATA. SAMPLES SHALL BE TAKEN WITH STANDARD SPLIT SPOON WITH 140 POUND WEIGHT FALLING THROUGH A DISTANCE OF 30 INCHES.
2. ALL BORINGS SHALL BE 30' DEEP EXCEPT B-1, B-7, & B-10 WHICH SHALL BE 50' DEEP. IF ROCK IS ENCOUNTERED BEFORE SPECIFIED DEPTH, ROCK CORES 5' DEEP SHALL BE TAKEN.
3. RECORD WATER LEVEL ELEVATIONS IN ALL HOLES 24 HOURS AFTER COMPLETION.
4. REFER TO DWG. 2502-1-1-0501 FOR LAYOUT OF BORINGS B-21 THRU B-29 AND B-5A.

NIFR

THIS ORIGINAL DRAWING IS RELEASED TO THE CLIENT ________ DATE
CHAS. T. MAIN INTERNATIONAL, INC. ASSUMES NO RESPONSIBILITY FOR ANY SUBSEQUENT REVISIONS TO THIS DRAWING.
CHAS. T. MAIN INTERNATIONAL, INC. ________

THIS DRAWING HAS BEEN MICROFILMED

SCANNED

0 300 600 900 1200 1500 1800 2100
SCALE OF FEET · 1" = 300'

DRAWING NUMBER	REFERENCE
2502-1-1-0504	BORING RECORD
2502-1-1-0503	BORING RECORD
2502-1-1-0502	BORING RECORD
2502-1-1-0501	PLAN

DATE	ISSUED FOR	NO.	REVISIONS	DATE	APPROVED
9-28-65	INFORMATION	A	B-5A ADDED	9-28-65	EJF ECS
8-20-65	INFORMATION		WAS DWG # 2502-1-1-0501	8-20-65	EJF ECS
5-20-65	REF-ECN 1	—		5-20-65	EJF

IN CHARGE W. J. LESSARD | DATE MADE 4-26-65 | CHECKED ECS
PROJ. MGR. C. H. ANDERSON | DRAWN R.R.F. | APPROVED

SCOTT MARITIMES PULP, LIMITED
ABERCROMBIE PT., NOVA SCOTIA.
SULPHATE PULP MILL

CHAS. T. MAIN INTERNATIONAL, INC.
BOSTON, MASSACHUSETTS · CHARLOTTE, NORTH CAROLINA · U.S.A.

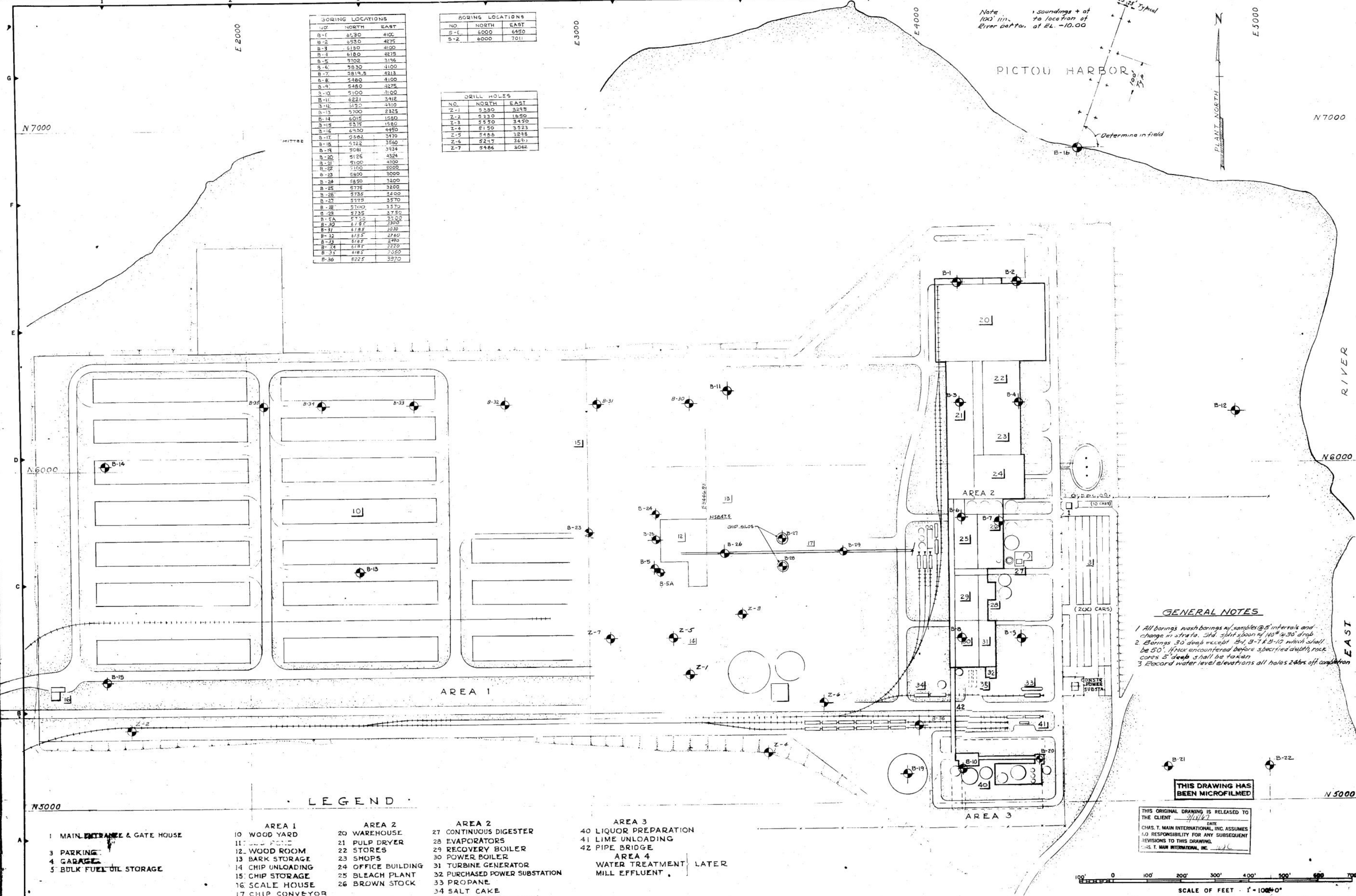
LICENSED TO PRACTICE PROVINCE OF NOVA SCOTIA 1965 APENS
COMMONWEALTH OF MASSACHUSETTS WILFRED MC HALL No. C 2465 REGISTERED PROFESSIONAL ENGINEER

DEPT. NO. 1 - MILL PROPERTY
AREAS 1, 2, 3 & 4

CIVIL
MILL SITE
SOIL EXPLORATION

CLIENT. JOB DEPT. DWG. NO.	REV.
2502-1-1-0500	A

44-132



BORING LOCATIONS		
NO.	NORTH	EAST
B-1	6530	4100
B-2	6530	4275
B-3	6180	4100
B-4	6180	4275
B-5	5702	3196
B-6	5830	4100
B-7	5819.5	4213
B-8	5480	4100
B-9	5480	4275
B-10	5100	4100
B-11	6221	3412
B-12	6150	4910
B-13	5700	2325
B-14	6015	1580
B-15	5375	1580
B-16	6930	4450
B-17	5382	3470
B-18	5322	3560
B-19	5081	3934
B-20	5125	4324
B-21	5100	4700
B-22	5100	5000
B-23	5800	3000
B-24	5850	3200
B-25	5775	3200
B-26	5735	3400
B-27	5775	3570
B-28	5700	3570
B-29	5735	3750
B-5A	5730	3200
B-30	6185	3300
B-31	6185	3030
B-32	6185	2760
B-33	6185	2490
B-34	6185	2220
B-35	6185	2050
B-36	5225	3970

BORING LOCATIONS		
NO.	NORTH	EAST
S-1	6000	6450
S-2	6000	7011

DRILL HOLES		
NO.	NORTH	EAST
Z-1	5380	3295
Z-2	5230	1650
Z-3	5550	3450
Z-4	5150	3523
Z-5	5488	3248
Z-6	5245	3690
Z-7	5486	3062

GENERAL NOTES

1 All borings wash borings w/ samples @ 5' intervals and change in strata. Std. split spoon w/ 140# @ 30" drop
2. Borings 30' deep except B-1, B-7 & B-10 which shall be 50'. If rock encountered before specified depth, rock cores 5' deep shall be taken
3 Record water level elevations all holes 24hrs. aft. completion

LEGEND

1 MAIN ~~ENTRANCE~~ & GATE HOUSE
3 PARKING
4 GARAGE
5 BULK FUEL OIL STORAGE

AREA 1
10 WOOD YARD
11 [illegible]
12 WOOD ROOM
13 BARK STORAGE
14 CHIP UNLOADING
15 CHIP STORAGE
16 SCALE HOUSE
17 CHIP CONVEYOR

AREA 2
20 WAREHOUSE
21 PULP DRYER
22 STORES
23 SHOPS
24 OFFICE BUILDING
25 BLEACH PLANT
26 BROWN STOCK

AREA 2
27 CONTINUOUS DIGESTER
28 EVAPORATORS
29 RECOVERY BOILER
30 POWER BOILER
31 TURBINE GENERATOR
32 PURCHASED POWER SUBSTATION
33 PROPANE
34 SALT CAKE
35 FUEL OIL DAY TANKS

AREA 3
40 LIQUOR PREPARATION
41 LIME UNLOADING
42 PIPE BRIDGE

AREA 4
WATER TREATMENT } LATER
MILL EFFLUENT

SCOTT MARITIMES PULP, LIMITED
ABERCROMBIE PT. NOVA SCOTIA
SULPHATE PULP MILL

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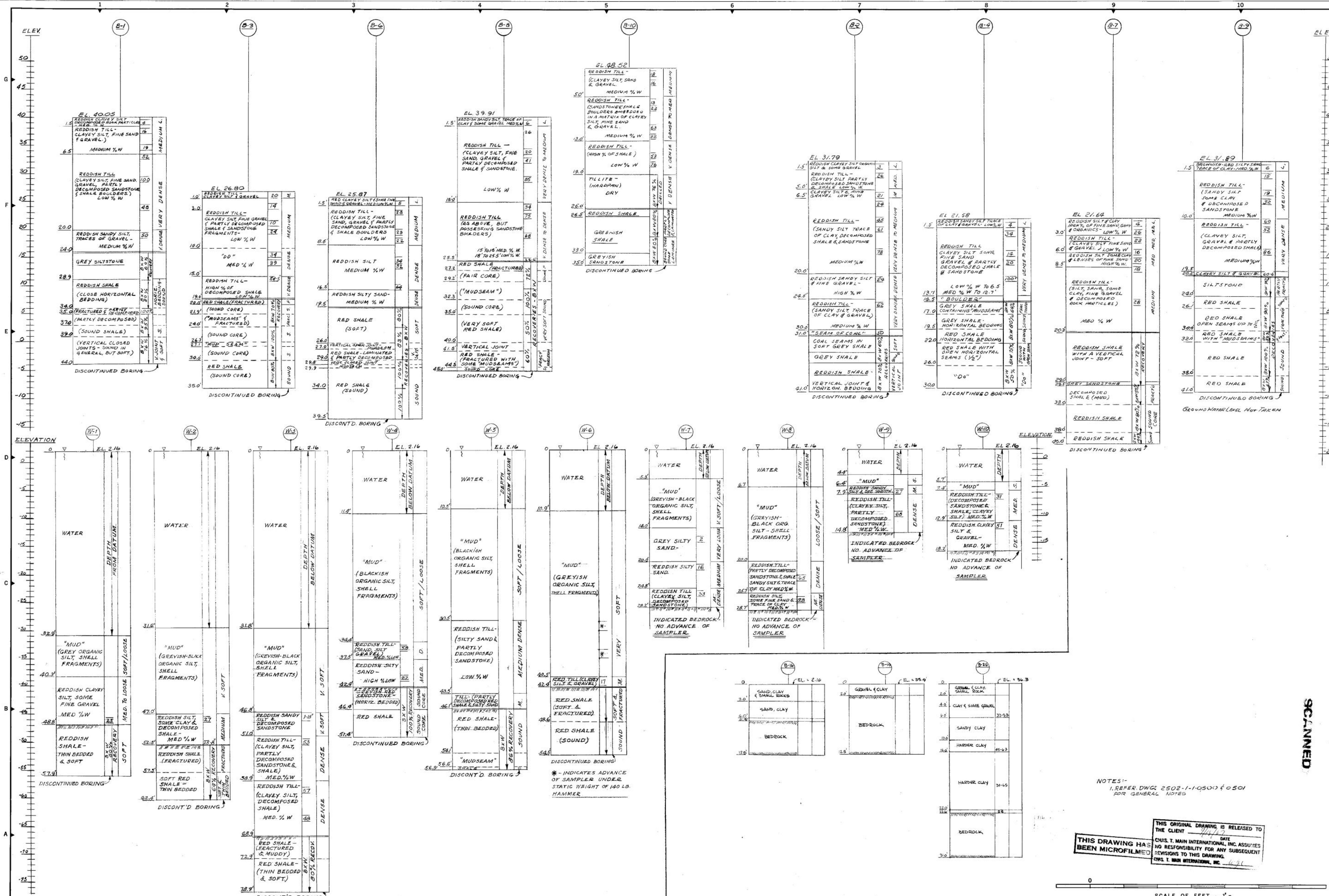
DEPT. NO. 1 - MILL PROPERTY
AREAS 1, 2, 3 & 4

CIVIL
MILL SITE
SOIL EXPLORATION

CLIENT JOB DEPT
2502 - 1 - 1 -0501

IN CHARGE W. J. LESSARD
PROJ. MGR. C. H. ANDERSON
DRAWING NUMBER | REFERENCE | DATE | ISSUED FOR | NO. | REVISIONS | DATE | APPROVED



DRAWING NUMBER	REFERENCE
2502-1-1-0504	BORING RECORD
2502-1-1-0502	BORING RECORD
2502-1-1-0501	PLAN
2502-1-1-0500	PLAN

DATE	ISSUED FOR	NO.	REVISIONS	DATE	APPROVED
9-28-65	INFORMATION	B	NOTE ADDED	9-28-65	EJF ECS
8-20-65	Information	A	As encircled	8-20-65	EJF ECS
5-28-65	Reference				
5-20-65	REF. ECN 1			5-20-65	EJF
3-26-65	Information				
3-15-65	Information				

IN CHARGE W. J. LESSARD — DATE MADE 3-15-65 — CHECKED ECS
PROJ. MGR. C. H. ANDERSON — DRAWN AMK-JHC — APPROVED

SCOTT MARITIMES PULP, LIMITED
ABERCROMBIE PT. NOVA SCOTIA
SULPHATE PULP MILL

CHAS. T. MAIN INTERNATIONAL, INC.
BOSTON, MASSACHUSETTS · CHARLOTTE, NORTH CAROLINA · U.S.A.

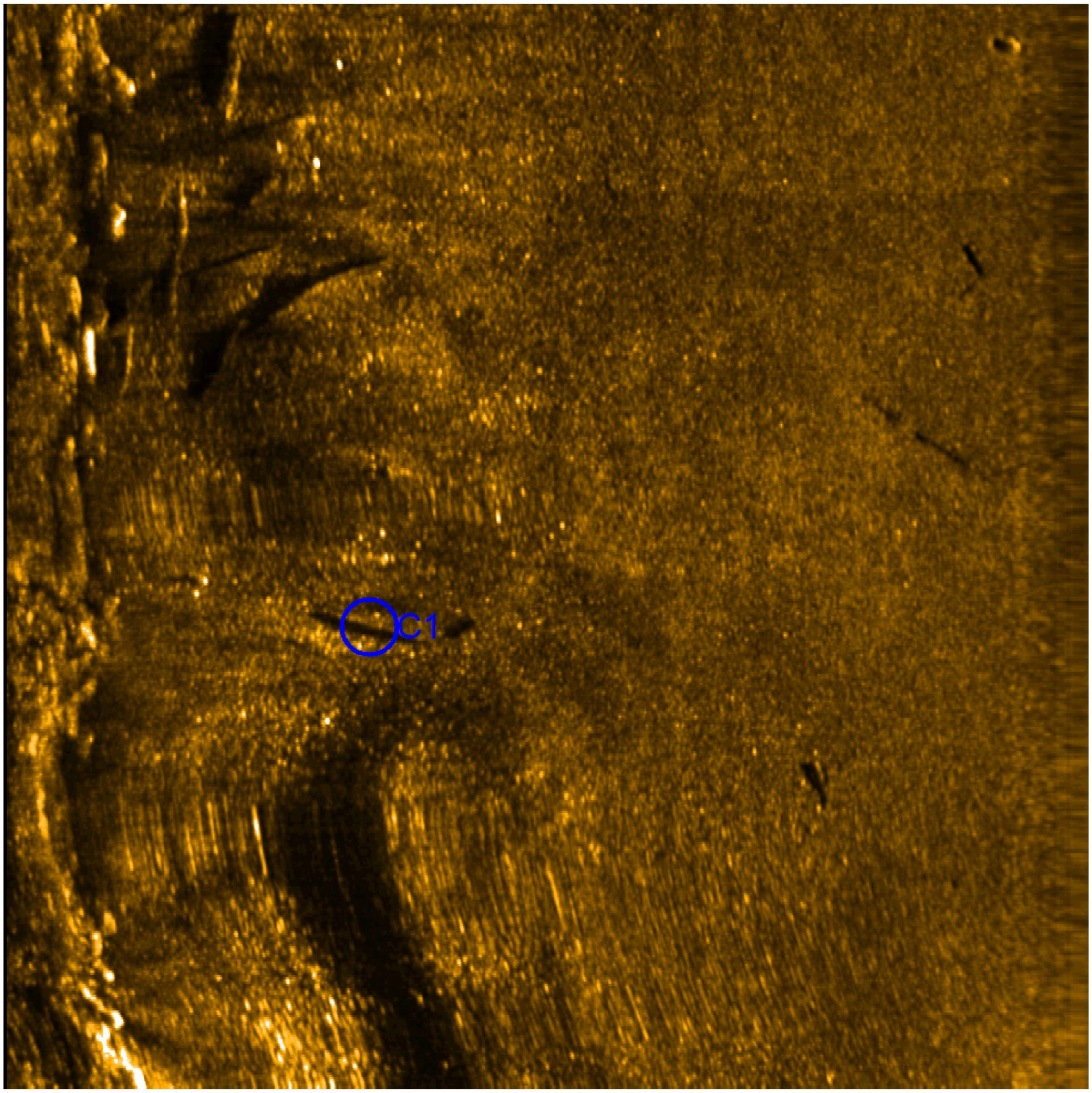
LICENSED TO PRACTICE PROVINCE OF NOVA SCOTIA 1965 APENS
WILFRED M. HALE REGISTERED PROFESSIONAL ENGINEER

DEPARTMENT No. 1 - MILL PROPERTY
AREAS 1, 2, 3 & 4

CIVIL
BORING RECORD - SHEET 2

CLIENT	JOB	DEPT.	DWG. NO.	REV.
2502	1	1	0503	B

APPENDIX IV
SIDESCAN SONAR CONTACTS



C1

Position

521607 E 5055969 N

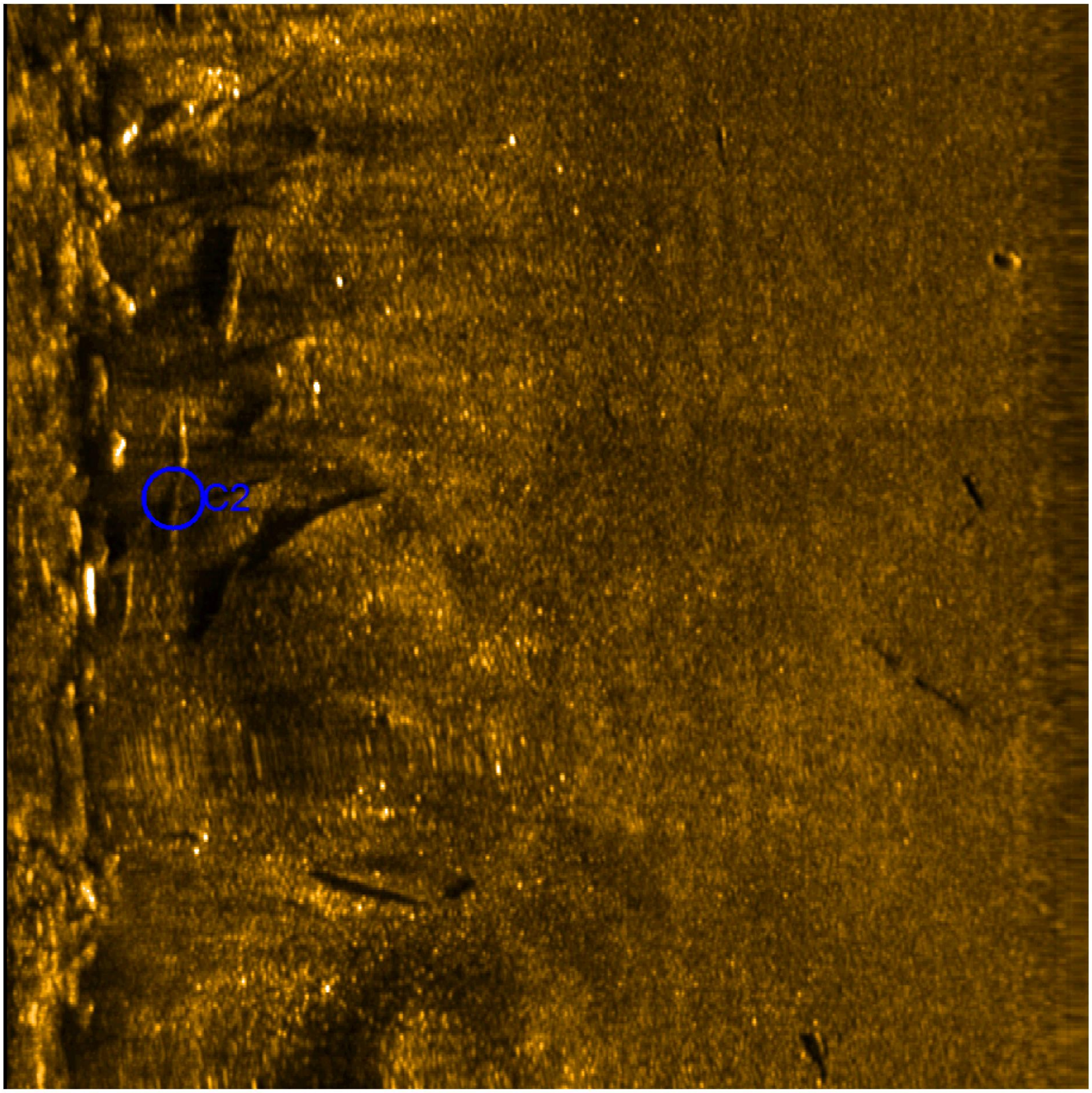
Dimensions and attributes

Target Width: 0.19 Meters

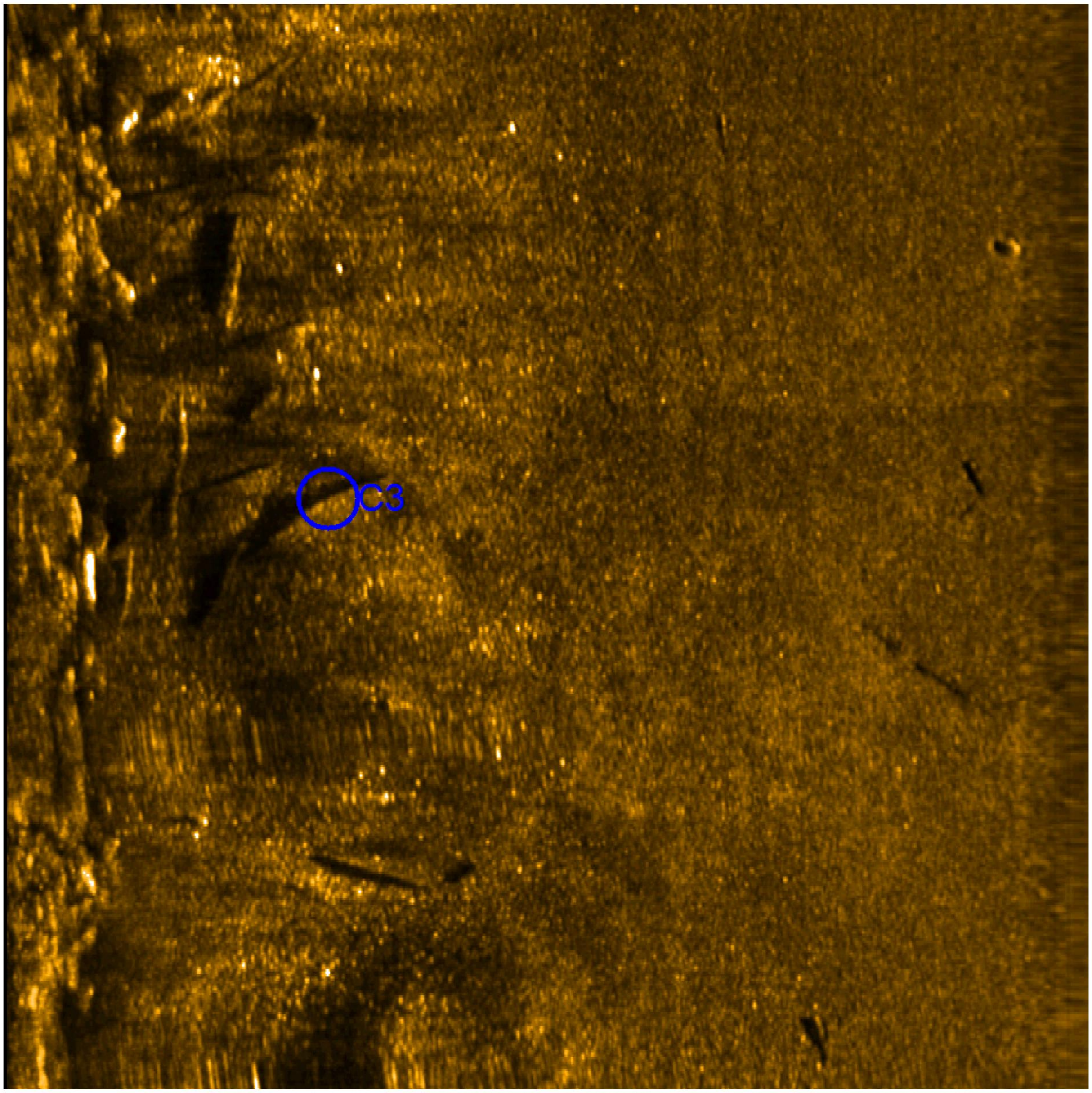
Target Length: 4.93 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C2	Dimensions and attributes
Position 521594 E 5055980 N	Target Width: 0.35 Meters Target Length: 5.99 Meters Classification1: Linear Feature Classification2: Probable Timber



C3

Position

521601 E   5055982 N

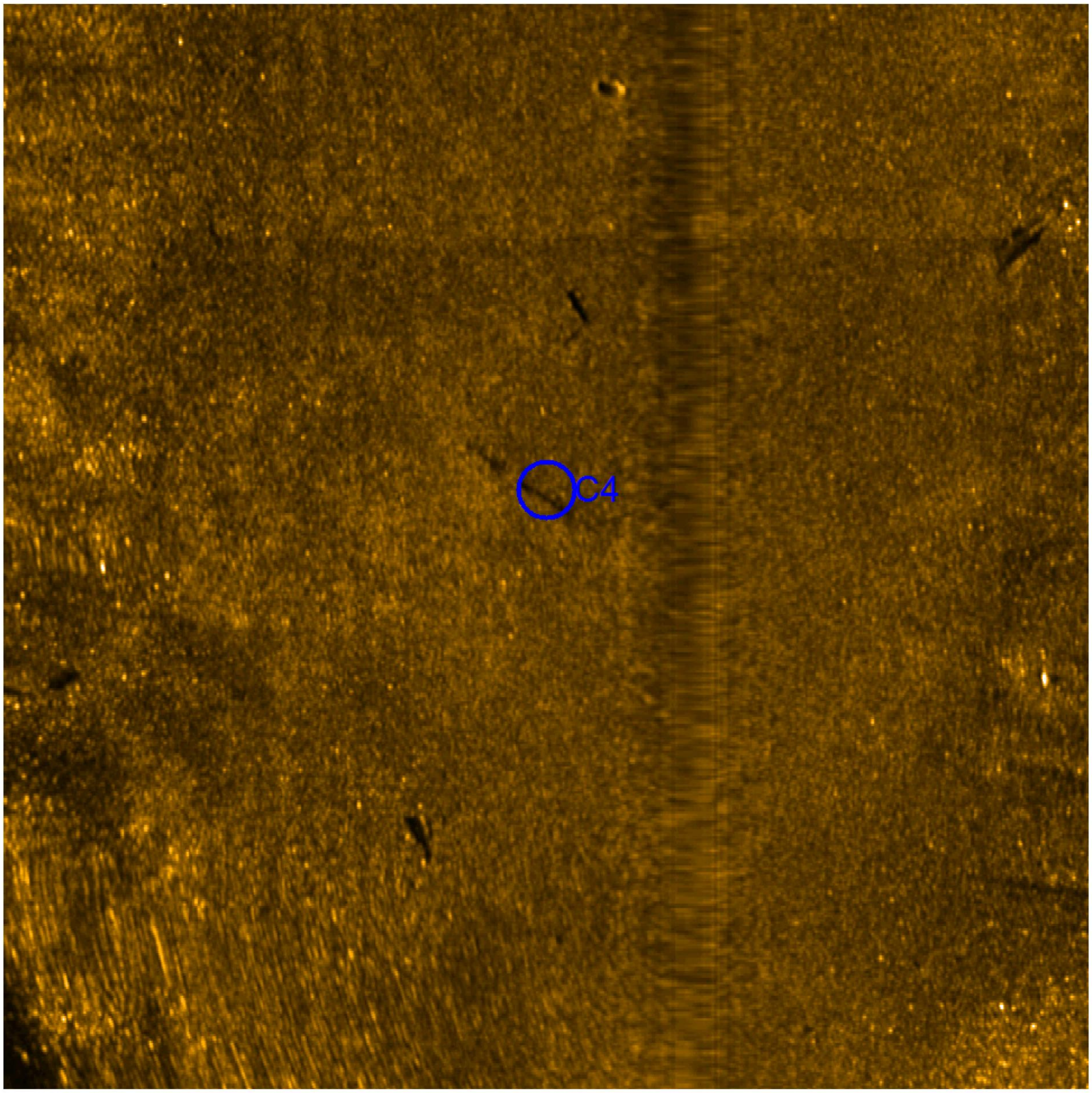
Dimensions and attributes

Target Width: 0.52 Meters

Target Length: 5.67 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C4

Position
521627 E   5055984 N

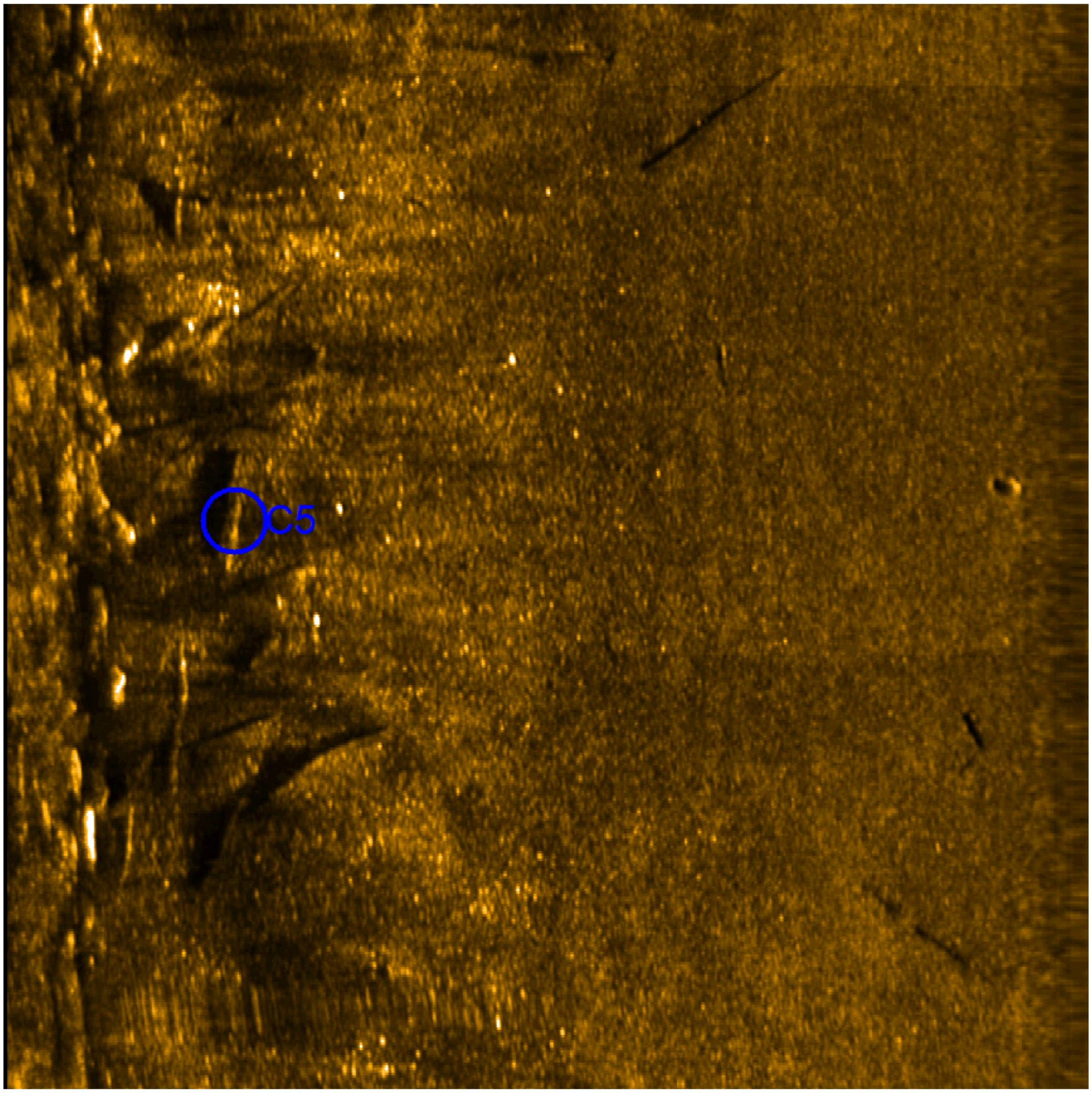
Dimensions and attributes

Target Width: 0.15 Meters

Target Length: 5.11 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C5

Position

521593 E 5055989 N

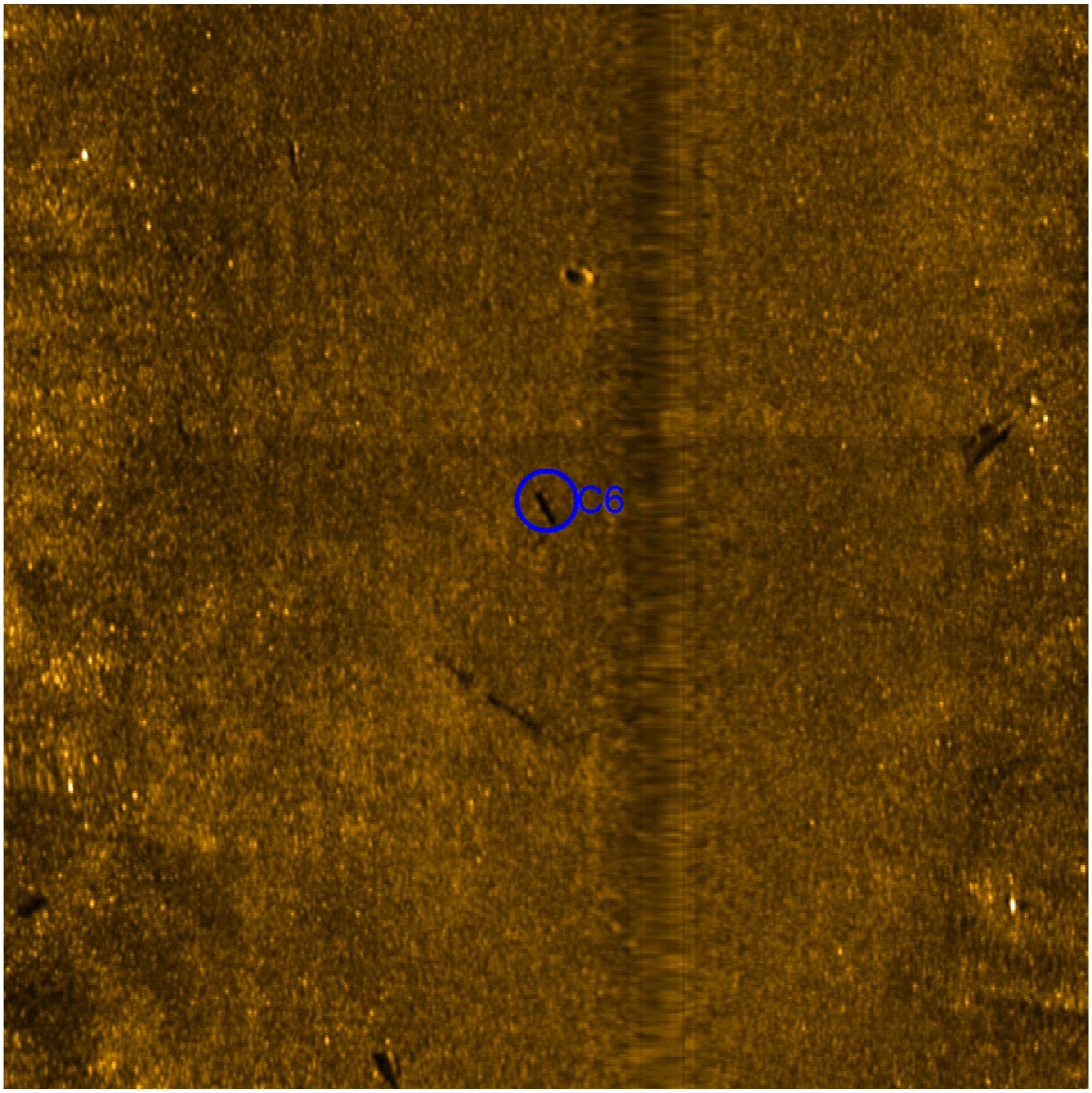
Dimensions and attributes

Target Width: 0.65 Meters

Target Length: 4.78 Meters

Classification1: Linear Feature

Classification2: Possible Timber



C6

Position
521626 E   5055993 N

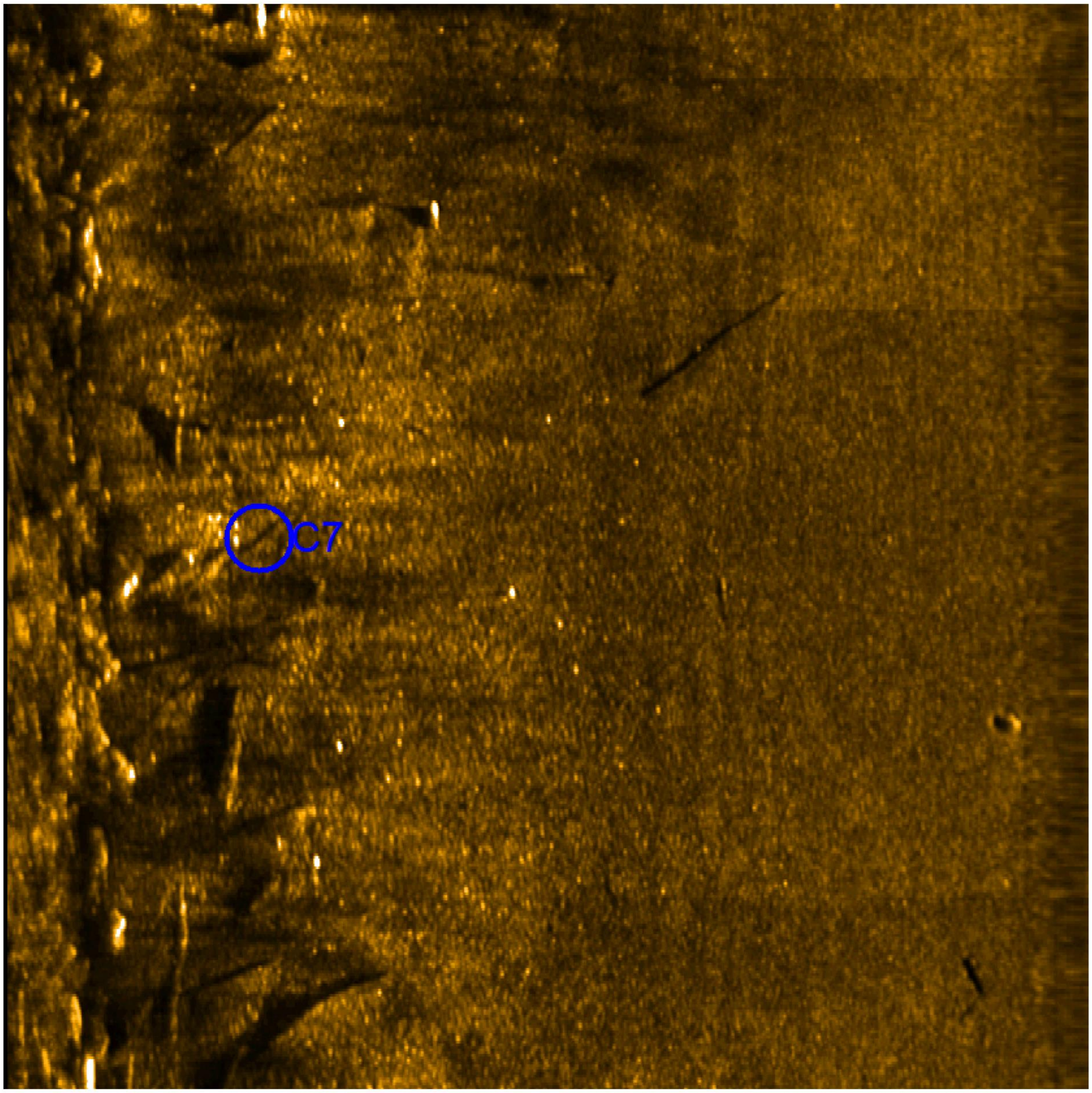
Dimensions and attributes

Target Width: 0.11 Meters

Target Length: 1.49 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C7

Position

521590 E   5055999 N

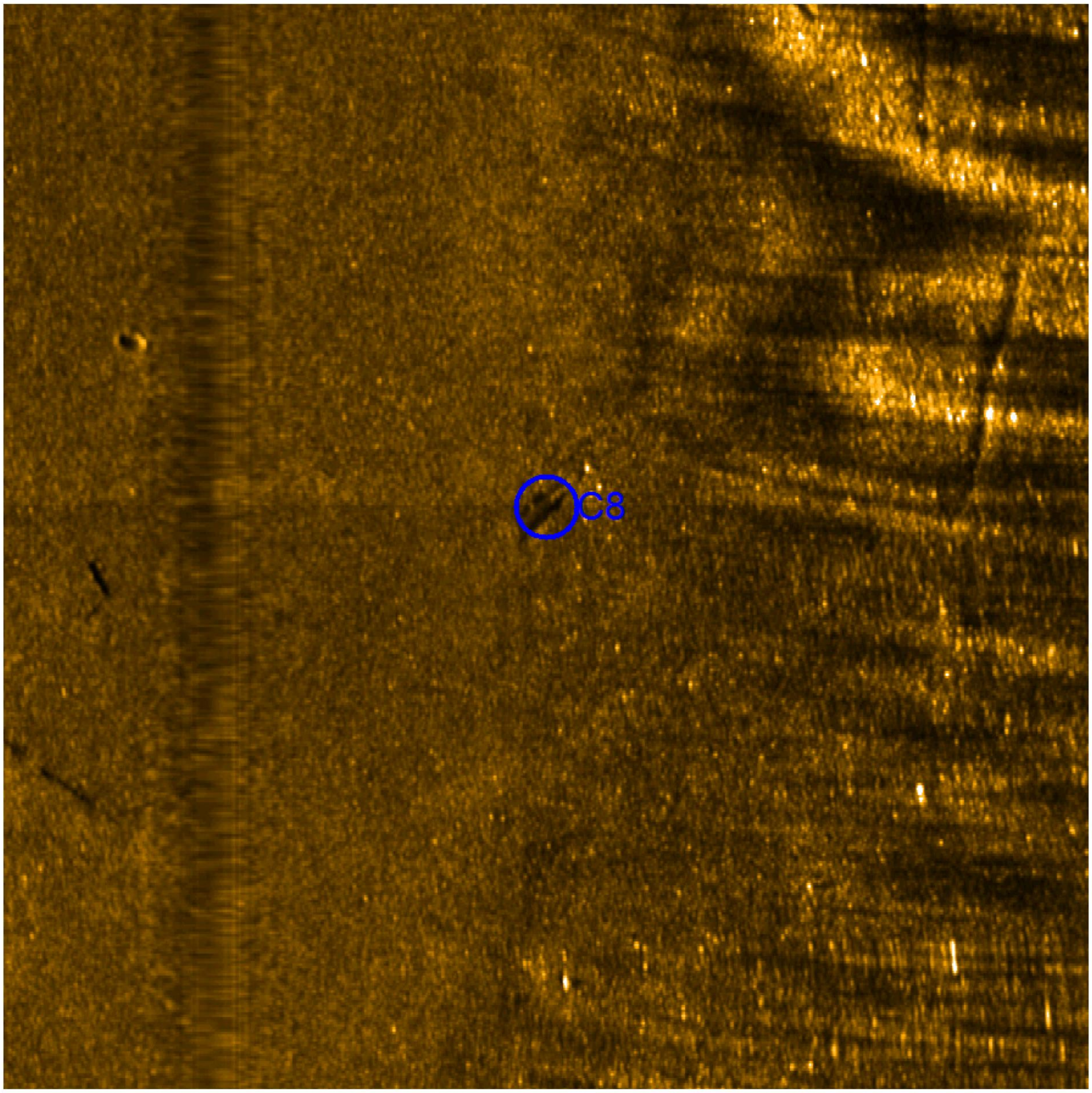
Dimensions and attributes

Target Width: 0.65 Meters

Target Length: 3.04 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C8

Position

521641 E   5056002 N

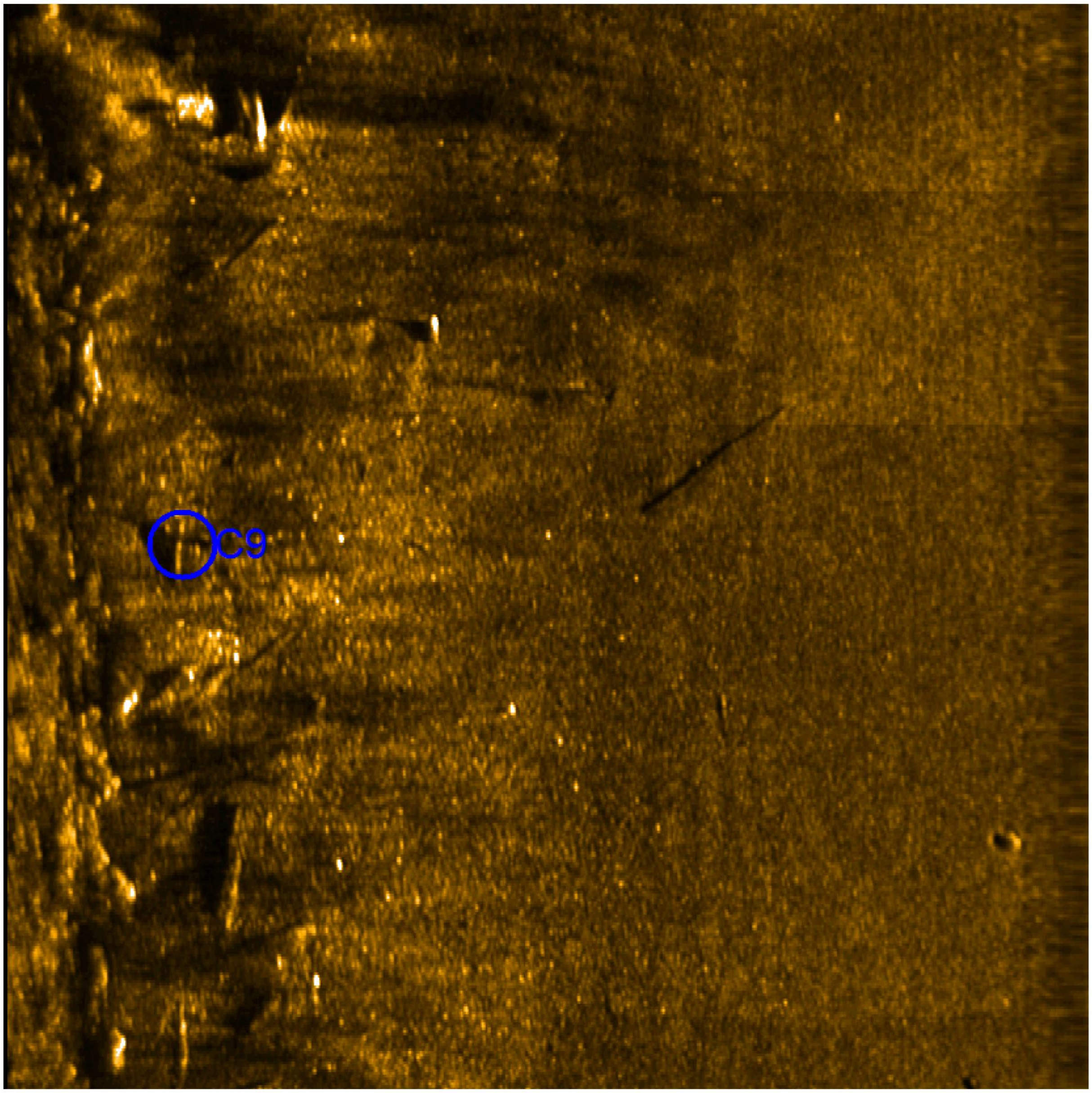
Dimensions and attributes

Target Width: 1.14 Meters

Target Length: 2.27 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C9

Position

521586 E   5056003 N

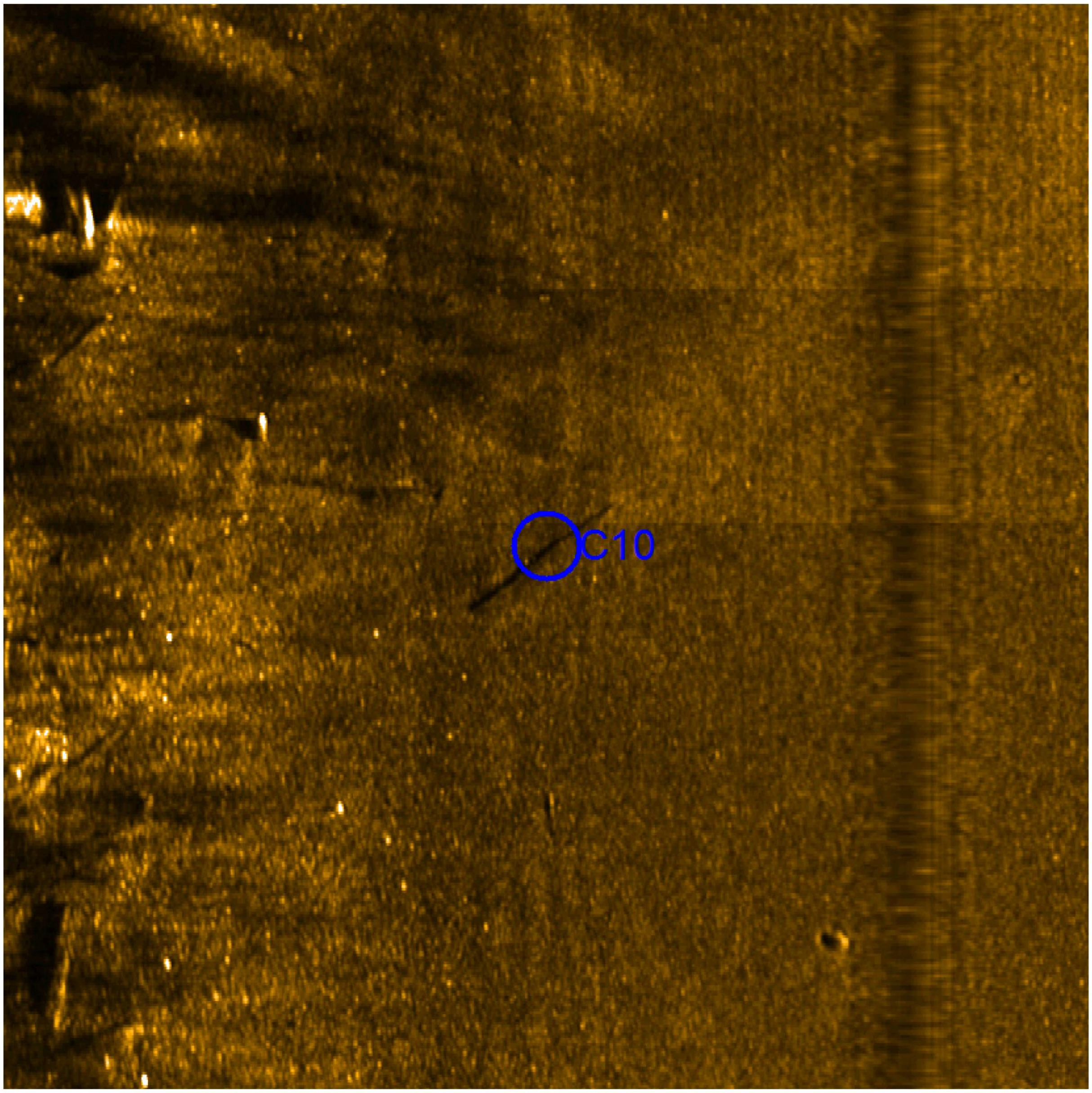
Dimensions and attributes

Target Width: 0.44 Meters

Target Length: 2.84 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C10

Position

521606 E   5056014 N

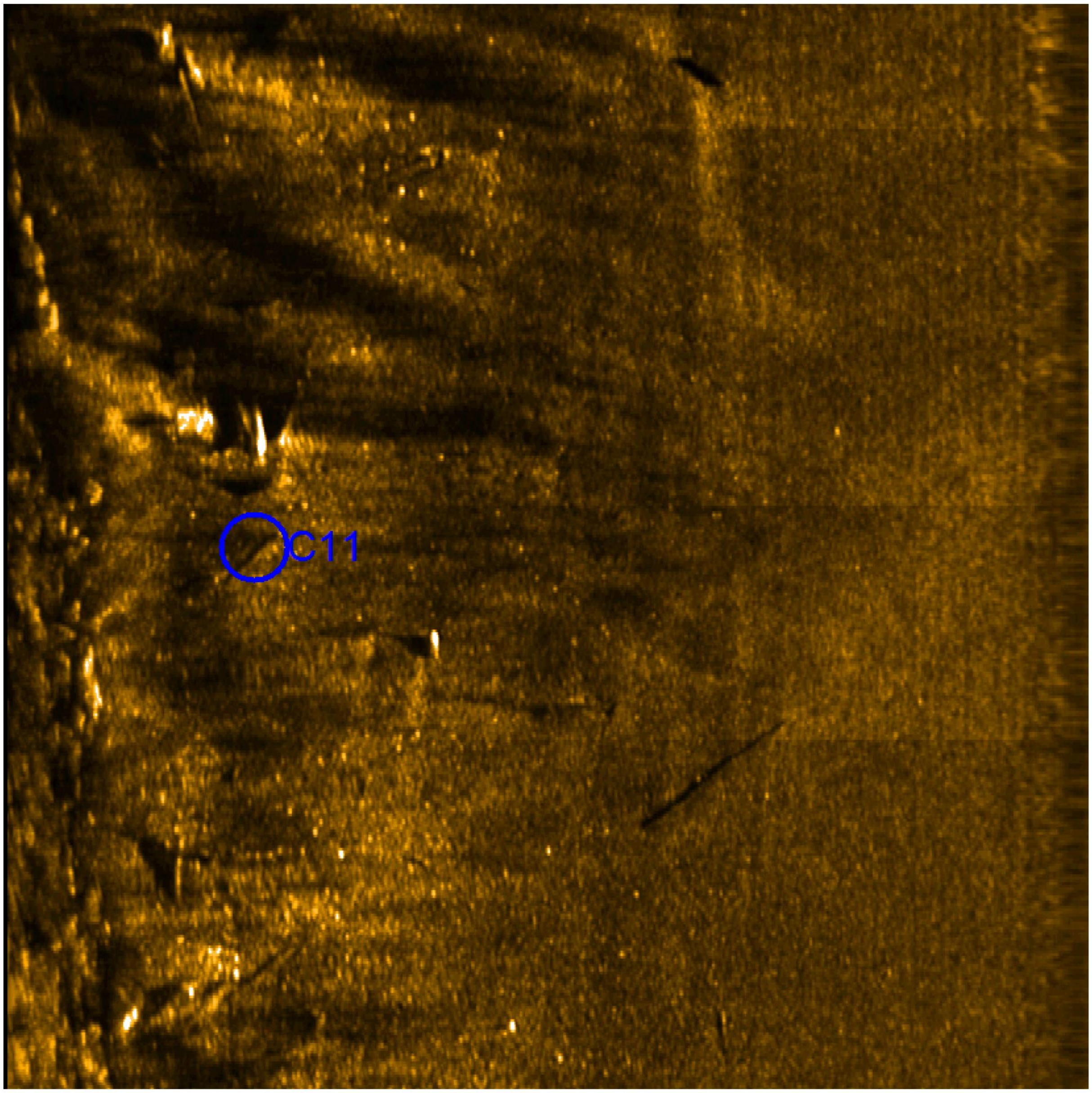
Dimensions and attributes

Target Width: 0.56 Meters

Target Length: 6.88 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C11

Position
521584 E   5056018 N

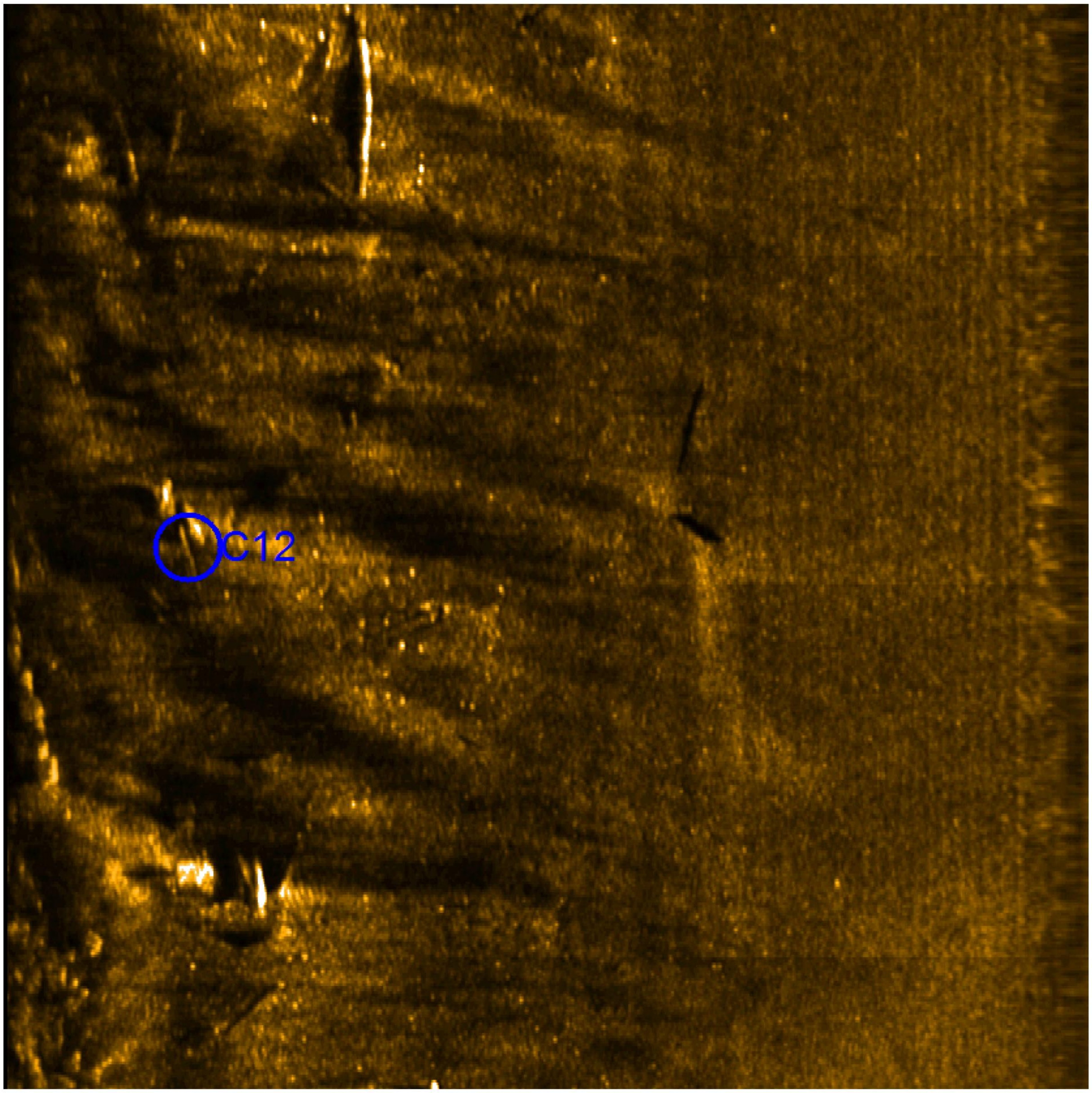
Dimensions and attributes

Target Width: 0.59 Meters

Target Length: 3.13 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C12

Position

521576 E   5056037 N

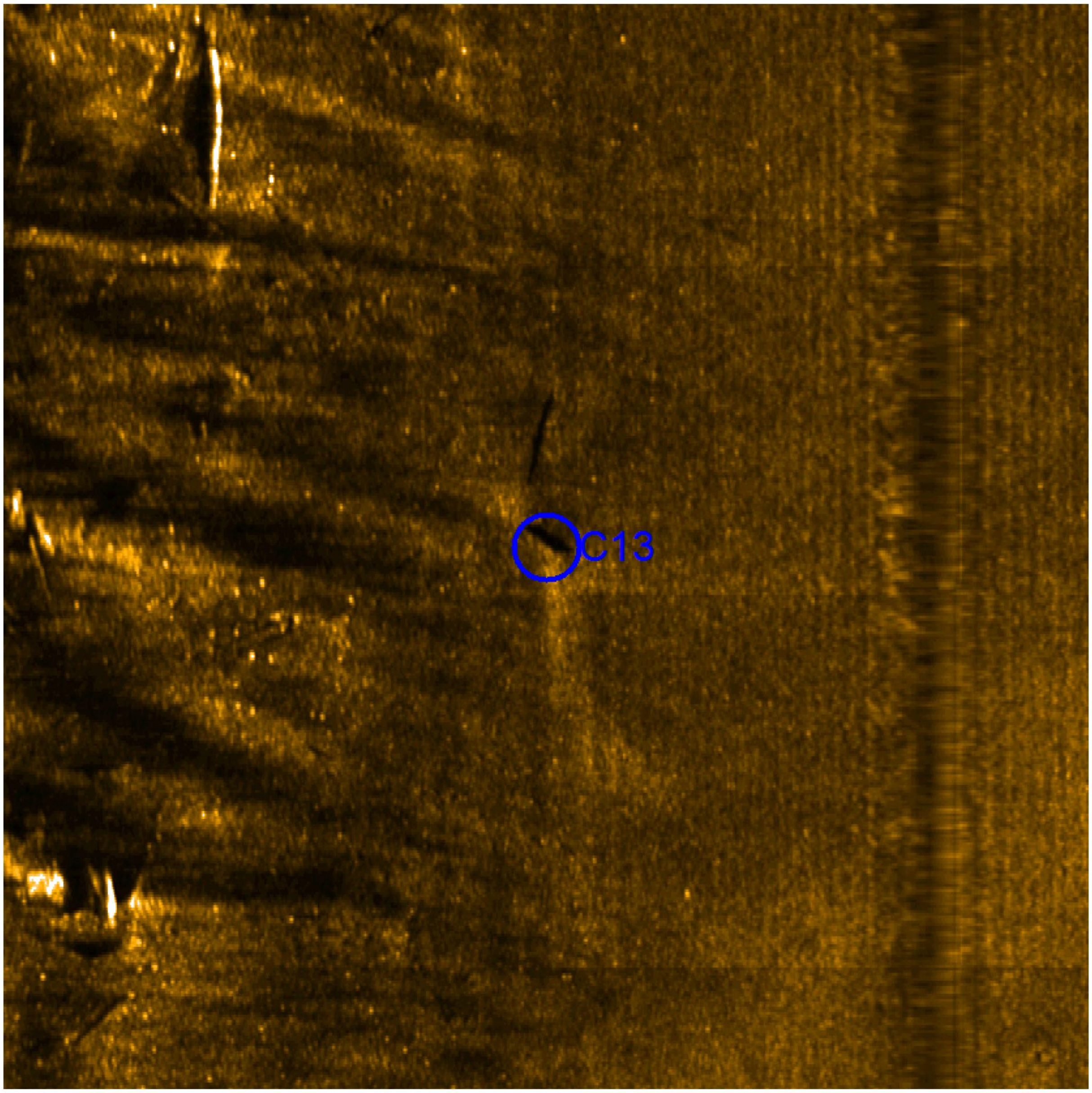
Dimensions and attributes

Target Width: 0.53 Meters

Target Length: 3.23 Meters

Classification1: Linear Feature

Classification2:



C13

Position

521597 E   5056043 N

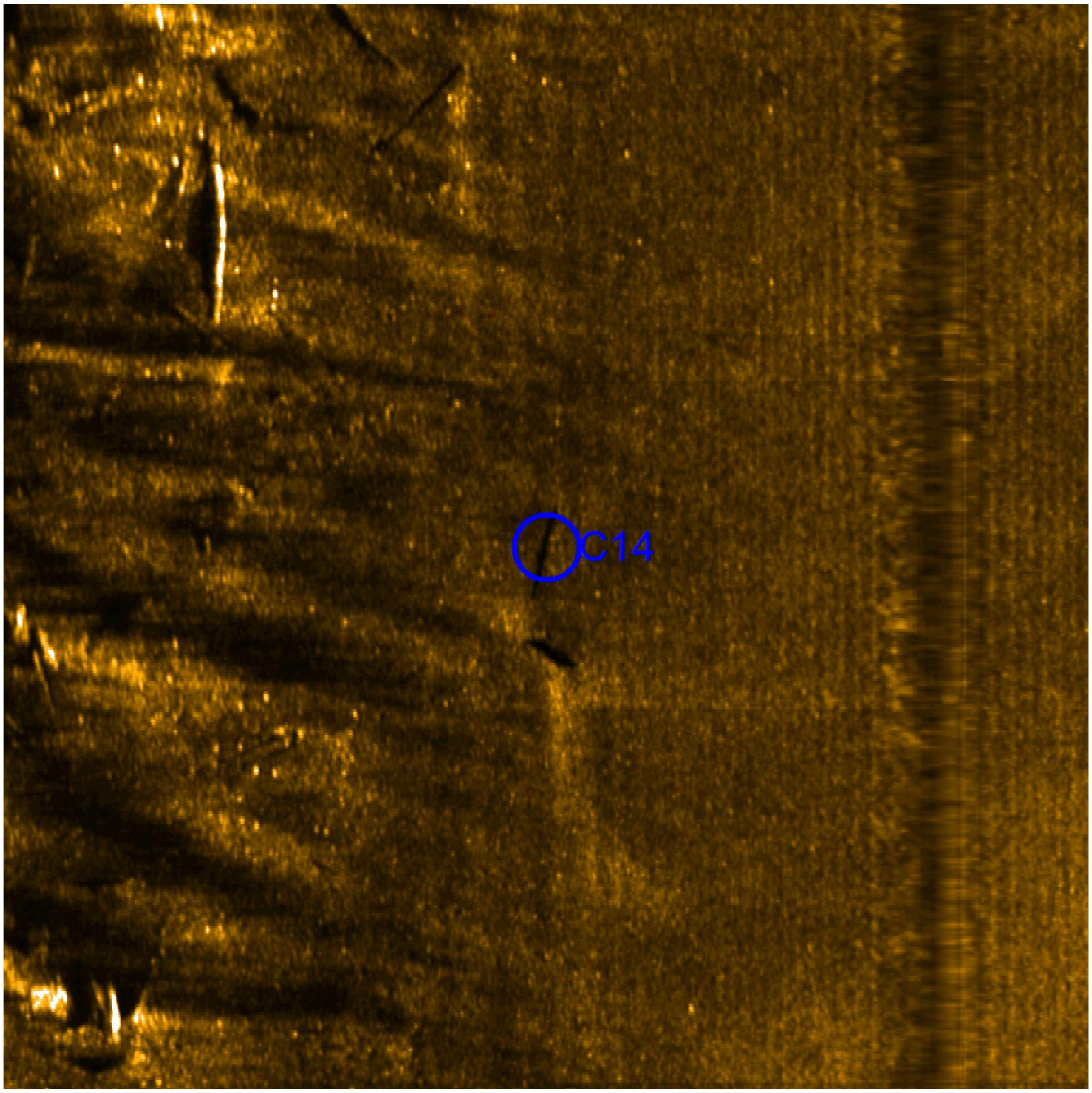
Dimensions and attributes

Target Width: 0.50 Meters

Target Length: 2.10 Meters

Classification1: Linear Feature

Classification2: Possible Timber



C14

Position

521596 E 5056047 N

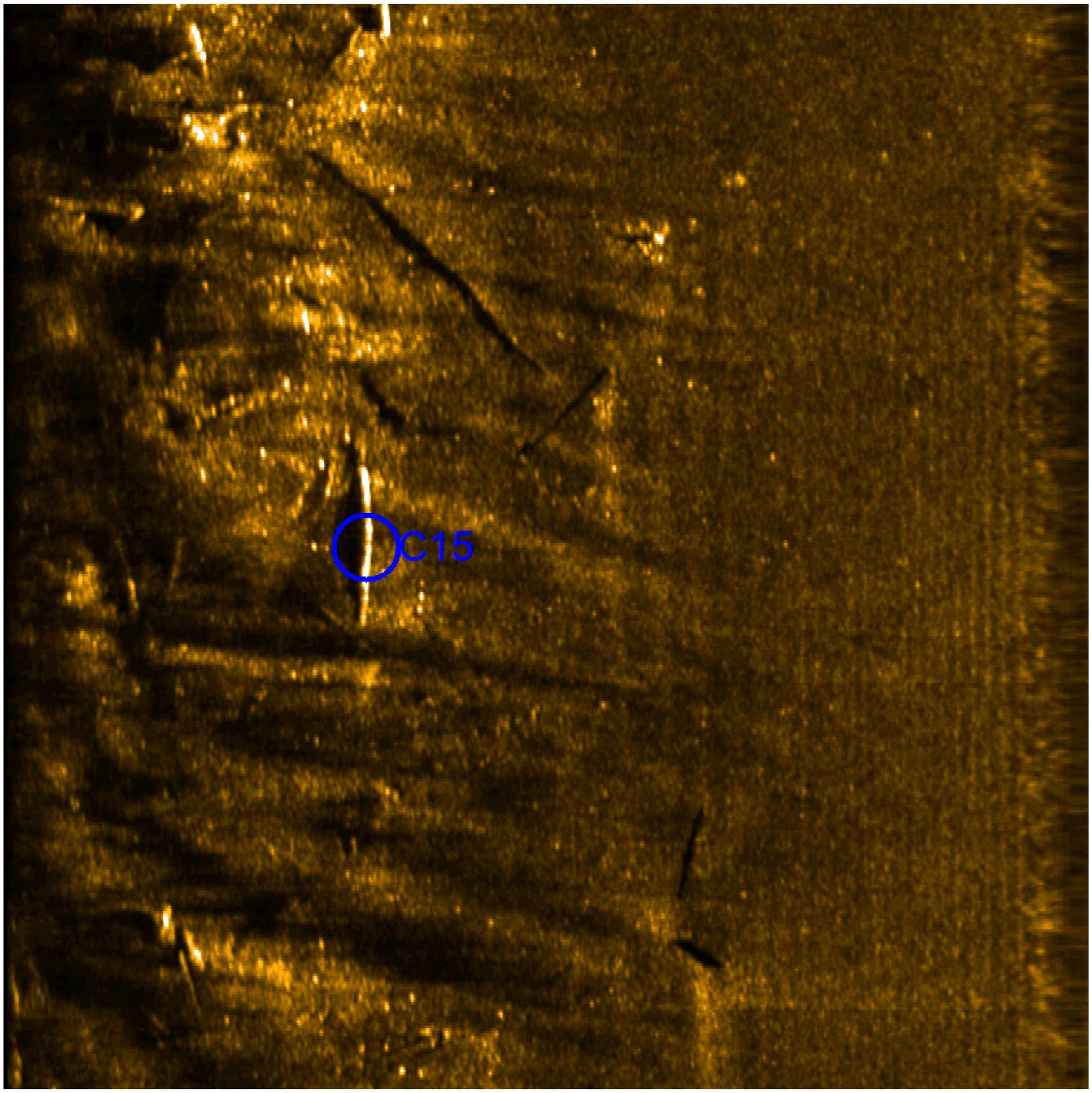
Dimensions and attributes

Target Width: 0.53 Meters

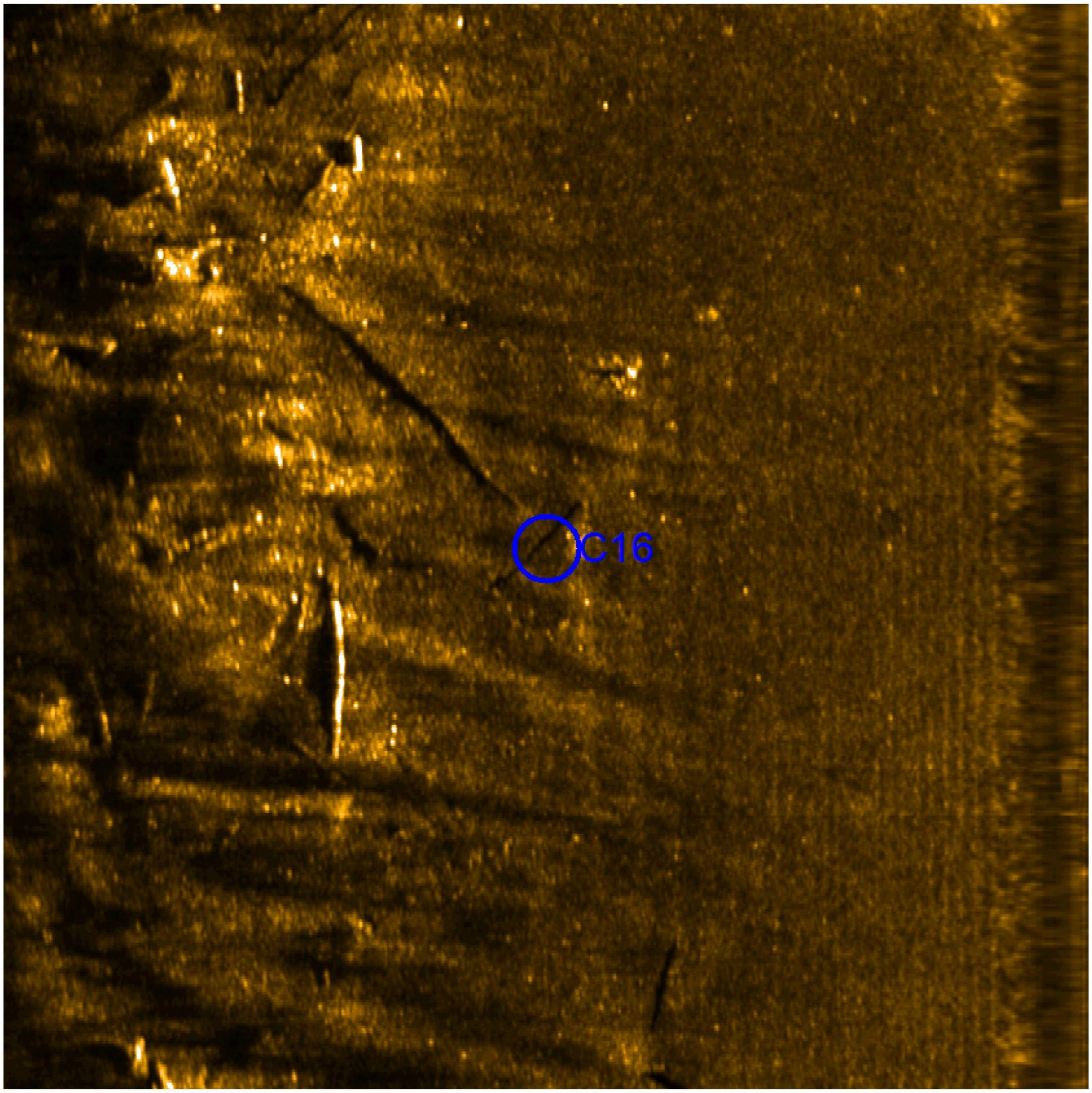
Target Length: 3.10 Meters

Classification1: Linear Feature

Classification2: Possible Timber



C15	Dimensions and attributes
Position 521579 E 5056058 N	Target Width: 0.38 Meters Target Length: 6.57 Meters Classification1: Linear Feature Classification2: Probable Timber



C16

Position

521587 E 5056065 N

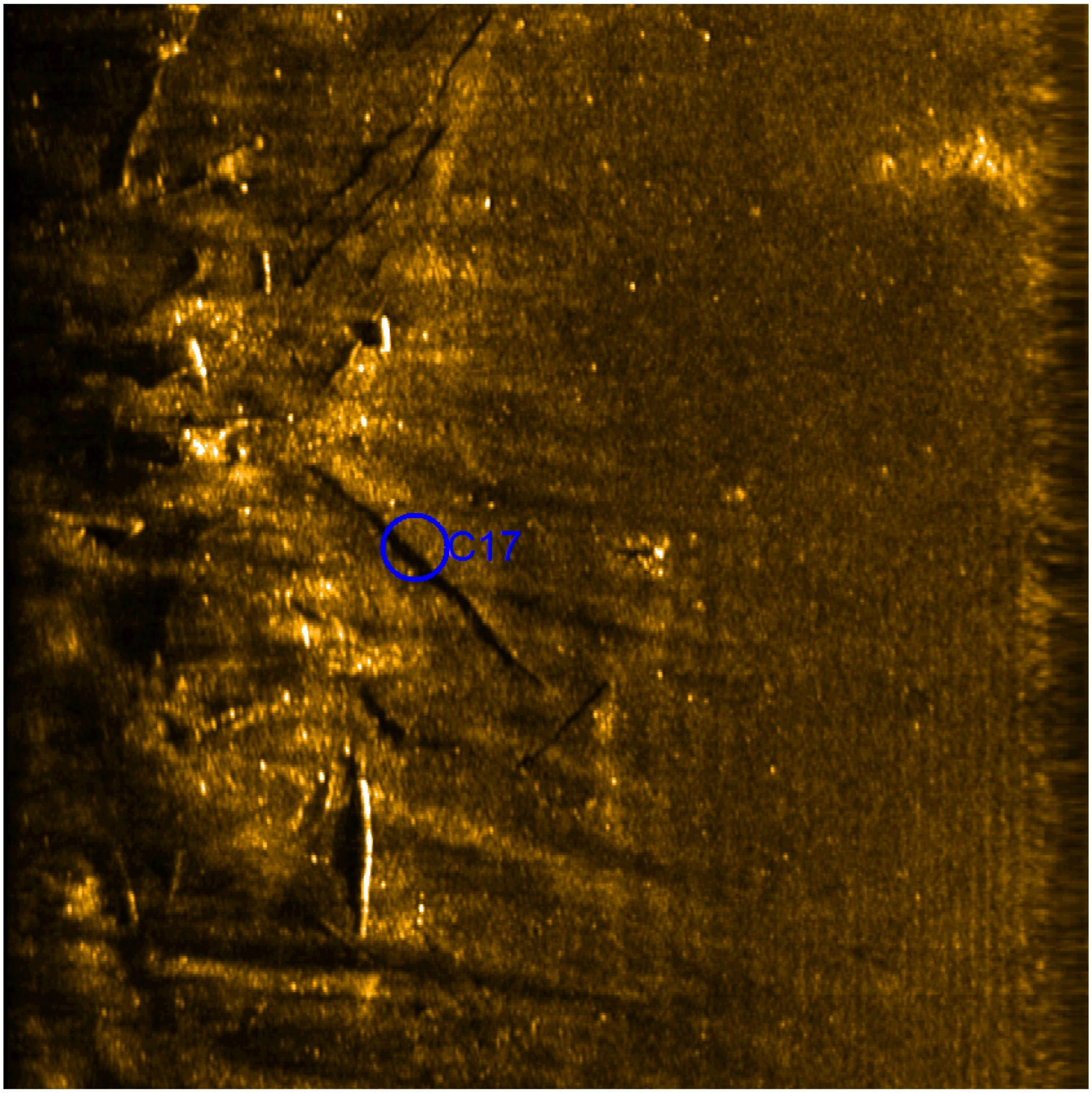
Dimensions and attributes

Target Width: 0.27 Meters

Target Length: 4.95 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C17

Position

521579 E   5056070 N

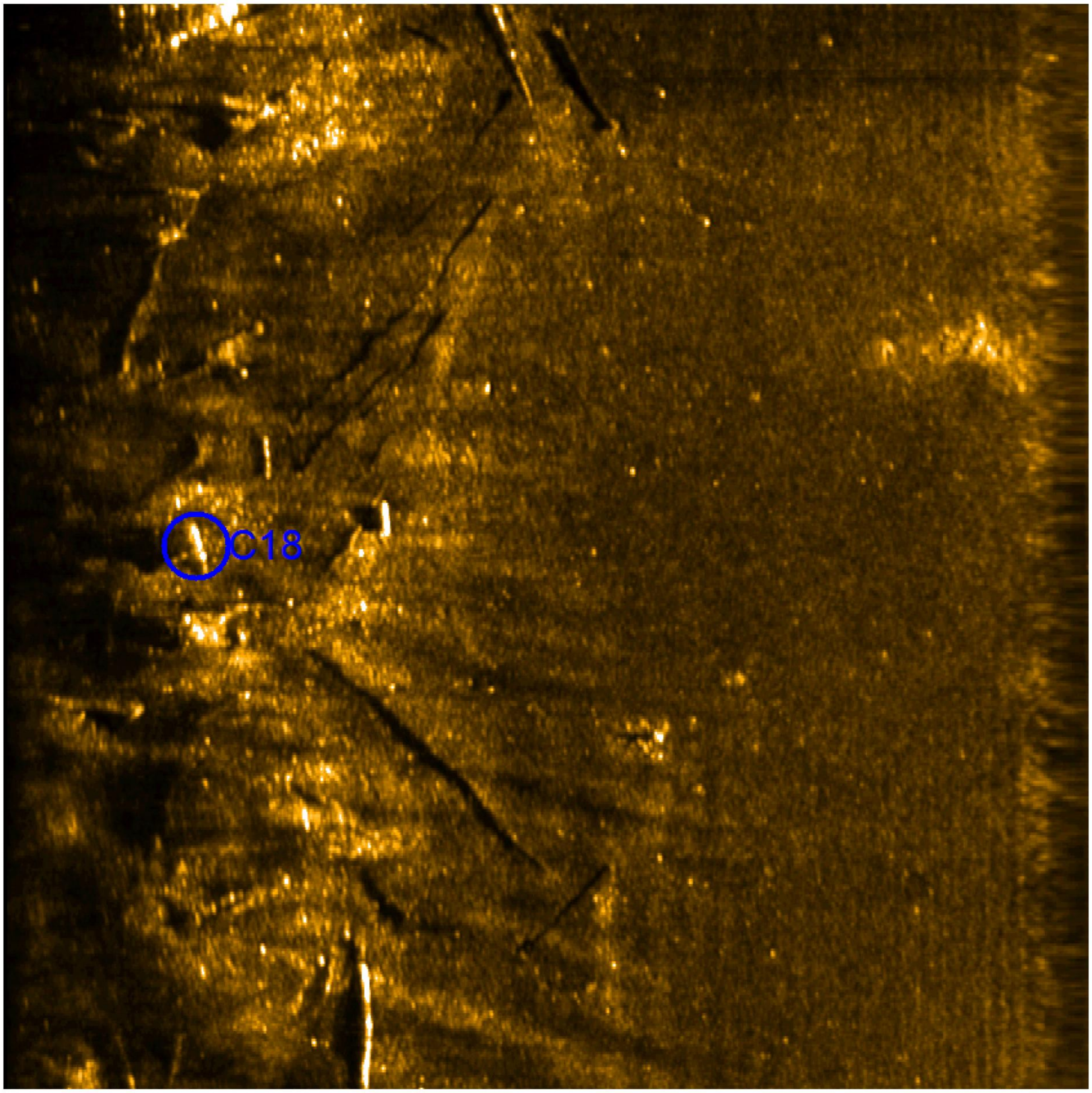
Dimensions and attributes

Target Width: 0.38 Meters

Target Length: 12.79 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C18

Position

521568 E   5056077 N

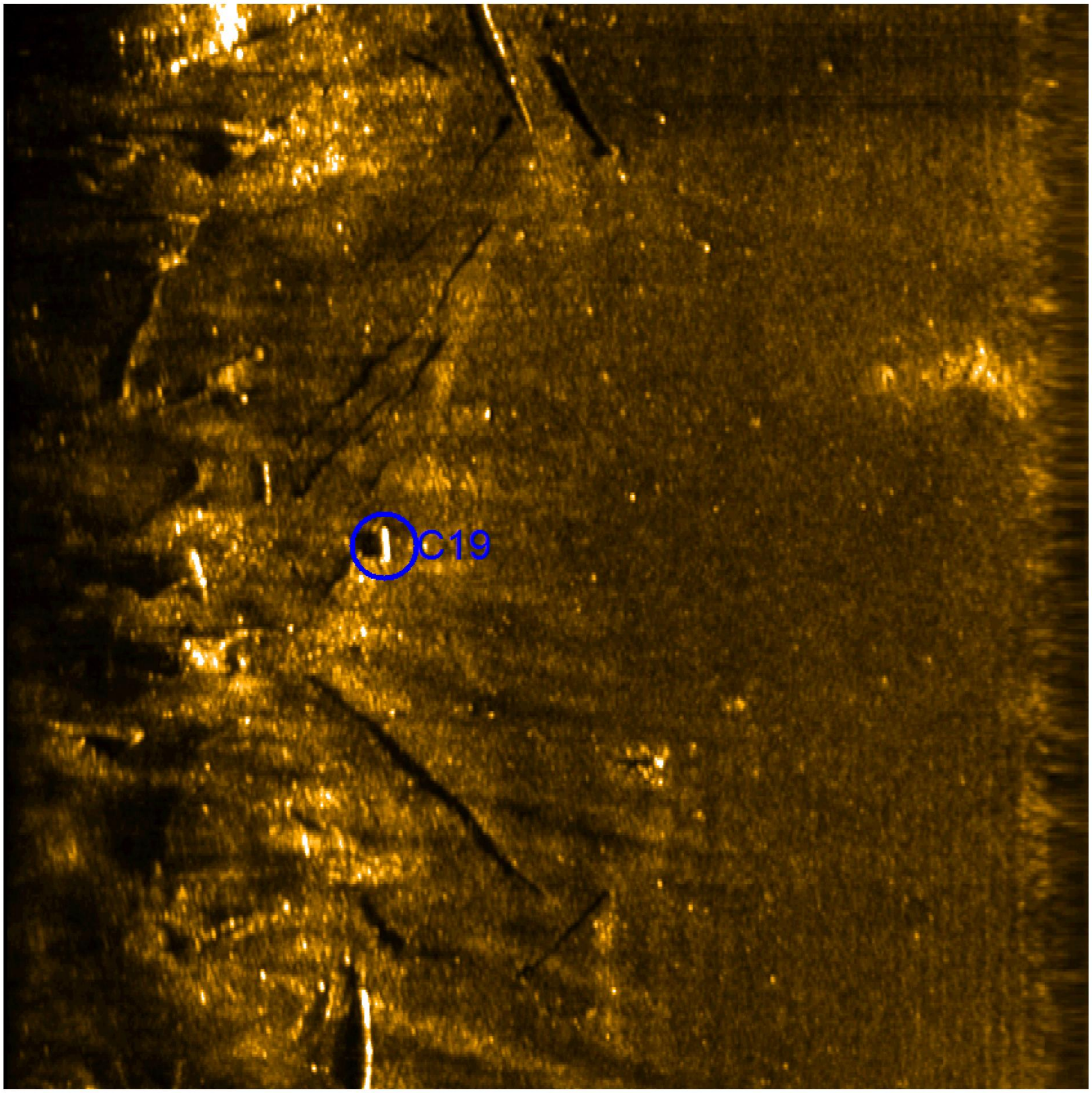
Dimensions and attributes

Target Width: 0.96 Meters

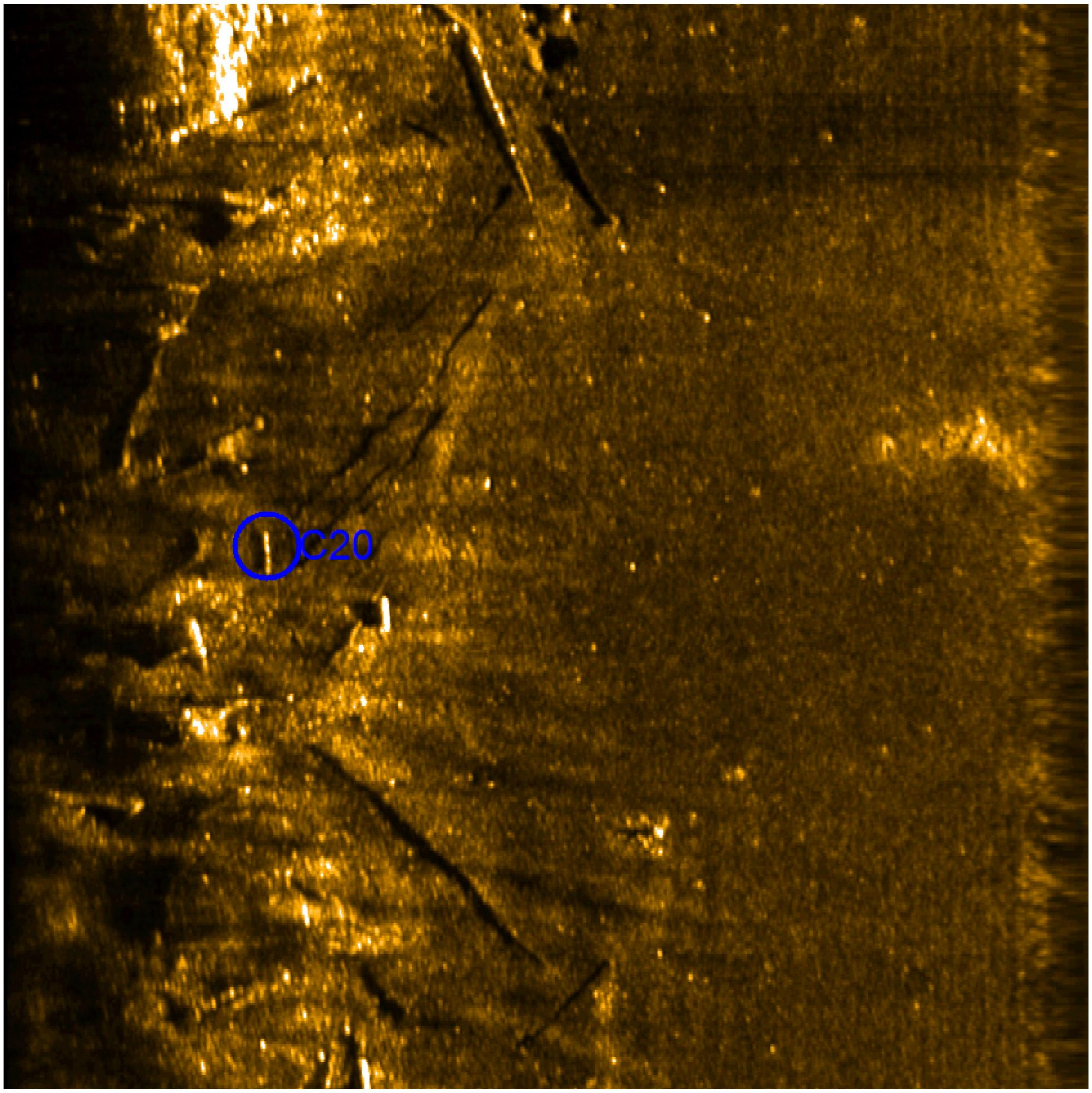
Target Length: 2.35 Meters

Classification1: Linear Feature

Classification2: Possible Timber



C19	Dimensions and attributes
Position 521576 E 5056080 N	Target Width: 0.36 Meters Target Length: 1.55 Meters Classification1: Linear Feature Classification2: Possible Timber



C20

Position
521570 E   5056082 N

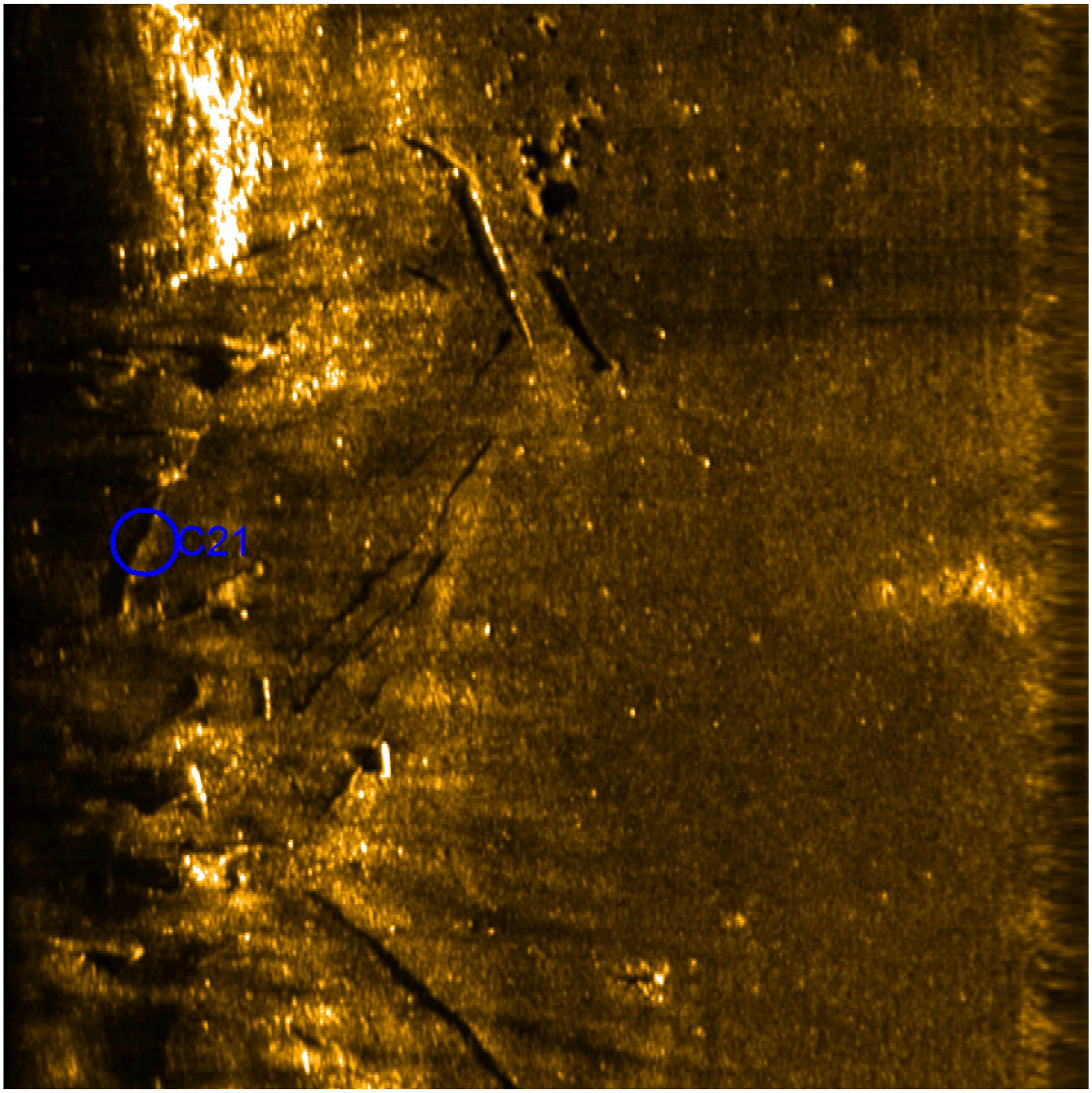
Dimensions and attributes

Target Width: 0.21 Meters

Target Length: 1.77 Meters

Classification1: Linear Feature

Classification2: Possible Timber



C21

Position
521565 E   5056087 N

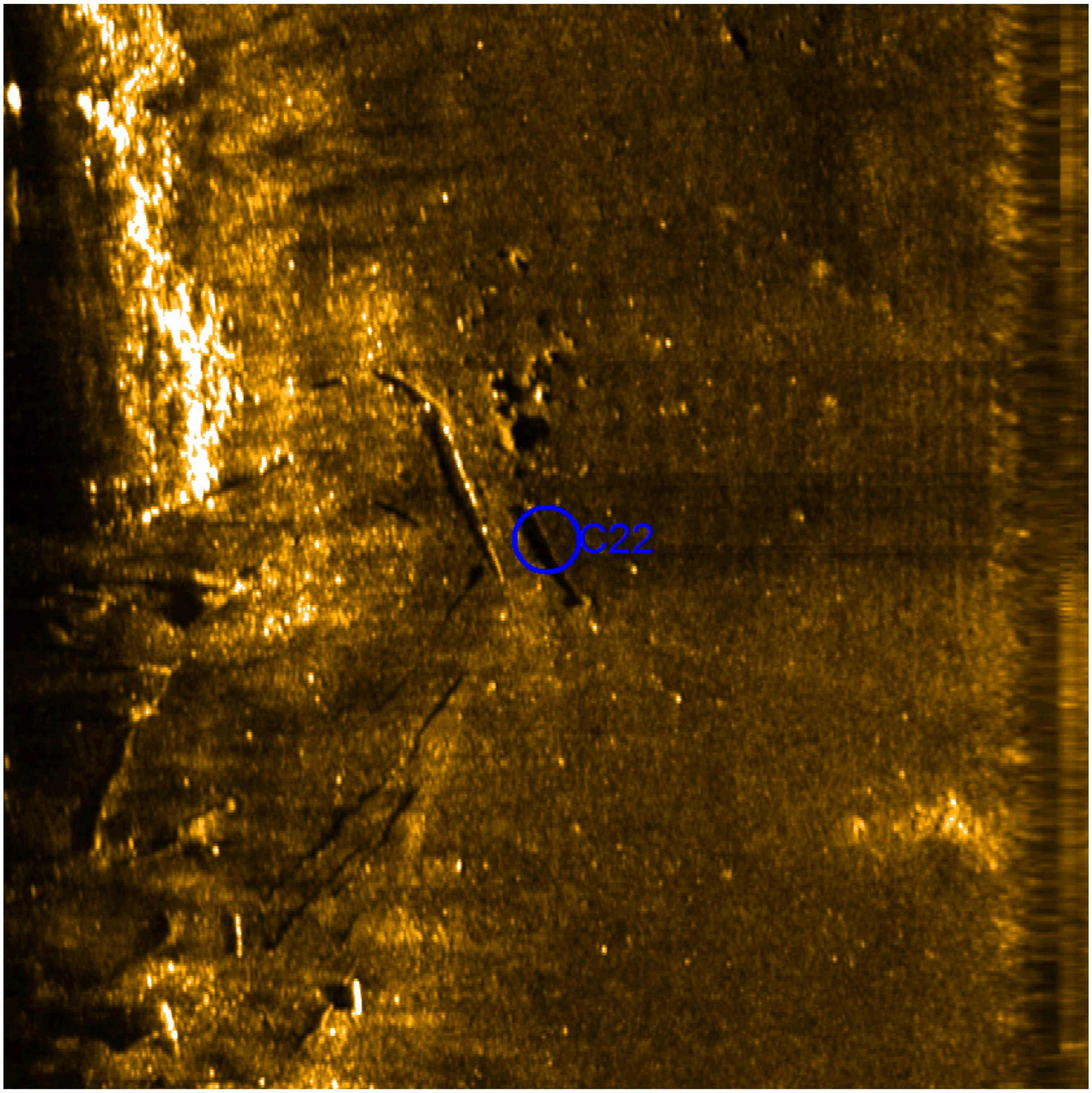
Dimensions and attributes

Target Width: 0.56 Meters

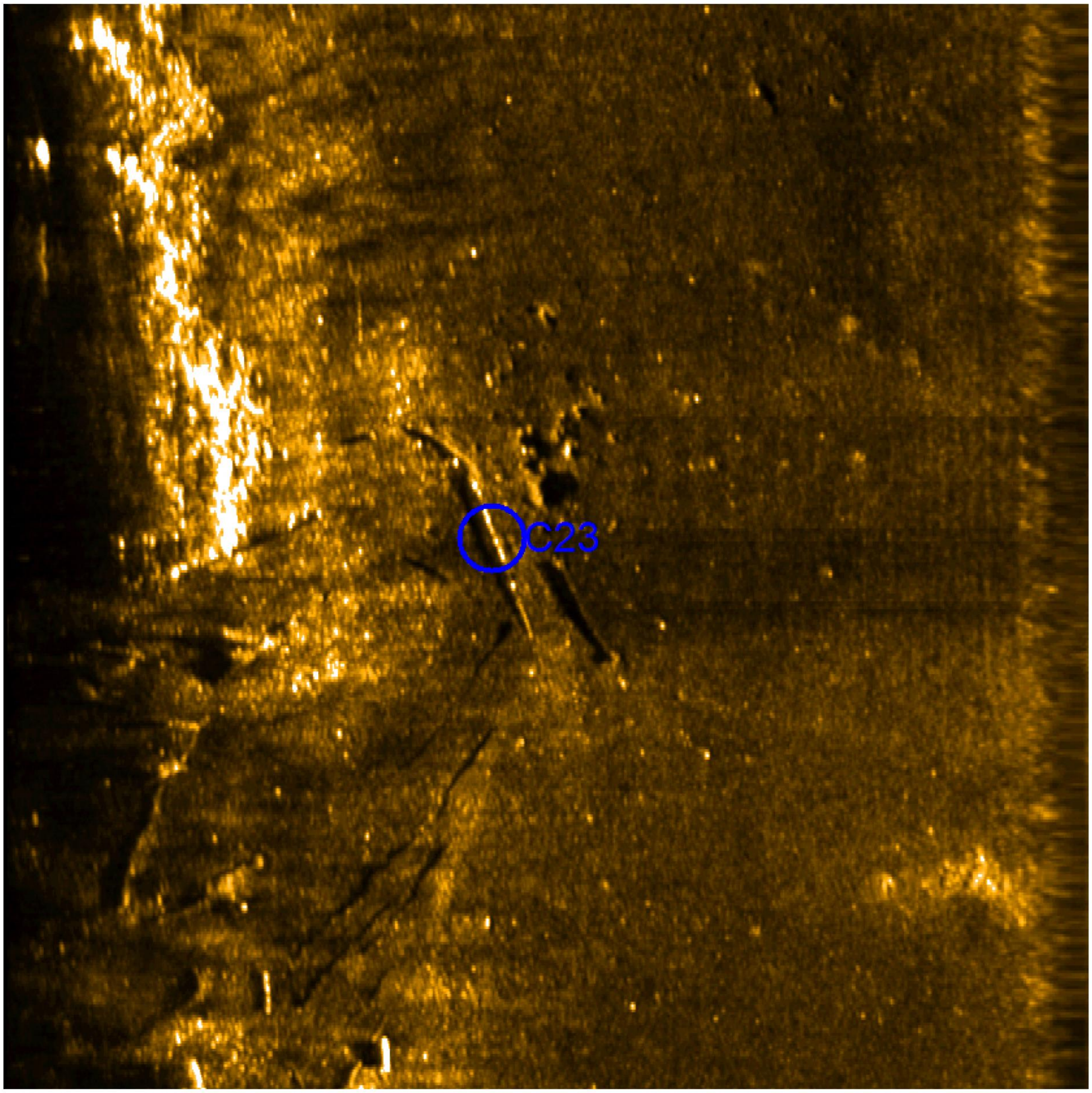
Target Length: 6.42 Meters

Classification1: Linear Feature

Classification2: Possible Timber



C22	Dimensions and attributes
Position 521581 E 5056099 N	Target Width: 0.27 Meters Target Length: 4.68 Meters Classification1: Linear Feature Classification2: Possible Timber



C23

Position
521577 E   5056101 N

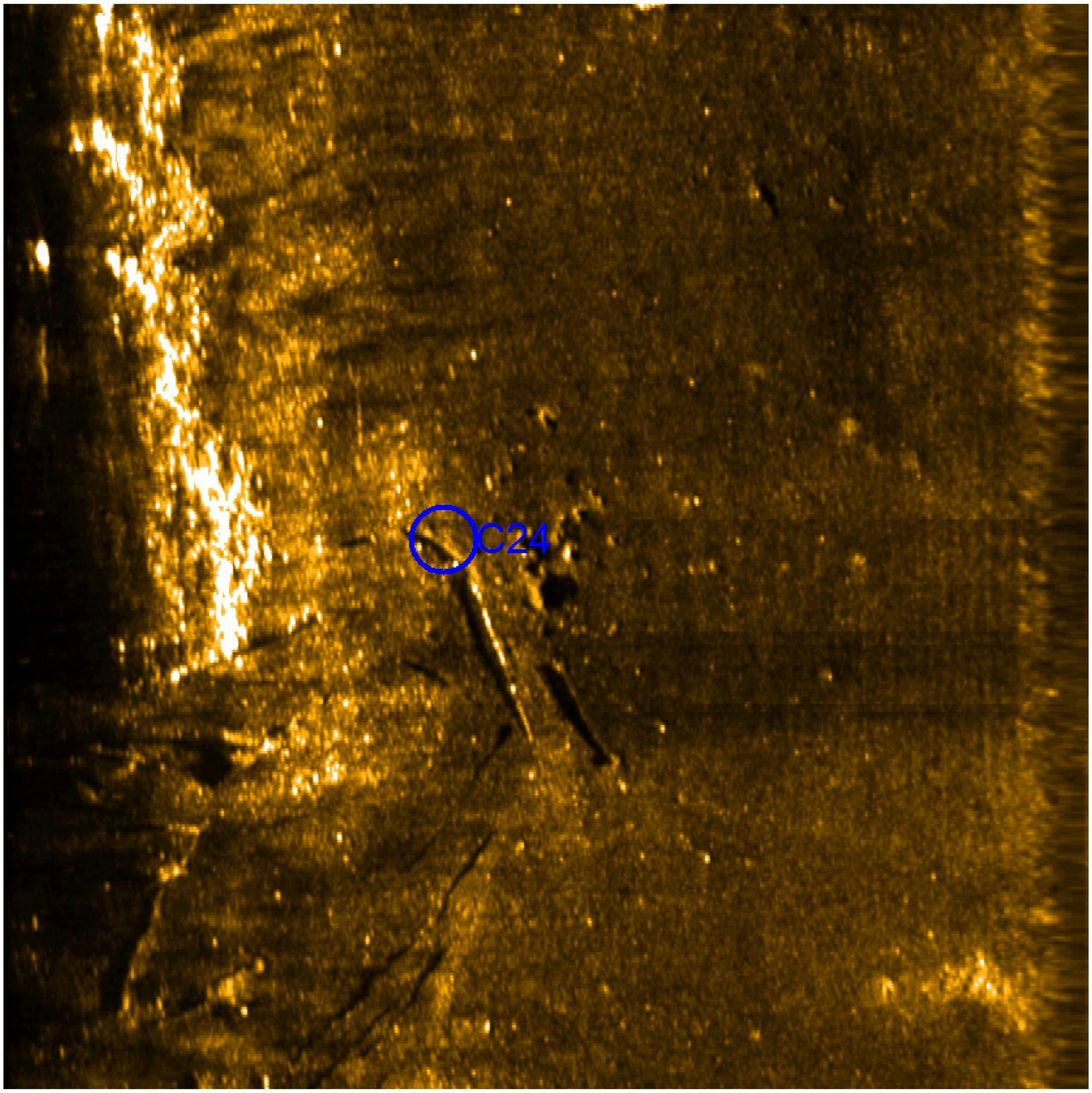
Dimensions and attributes

Target Width: 0.44 Meters

Target Length: 9.93 Meters

Classification1: Linear Feature

Classification2: Possible Timber



C24

Position

521574 E 5056105 N

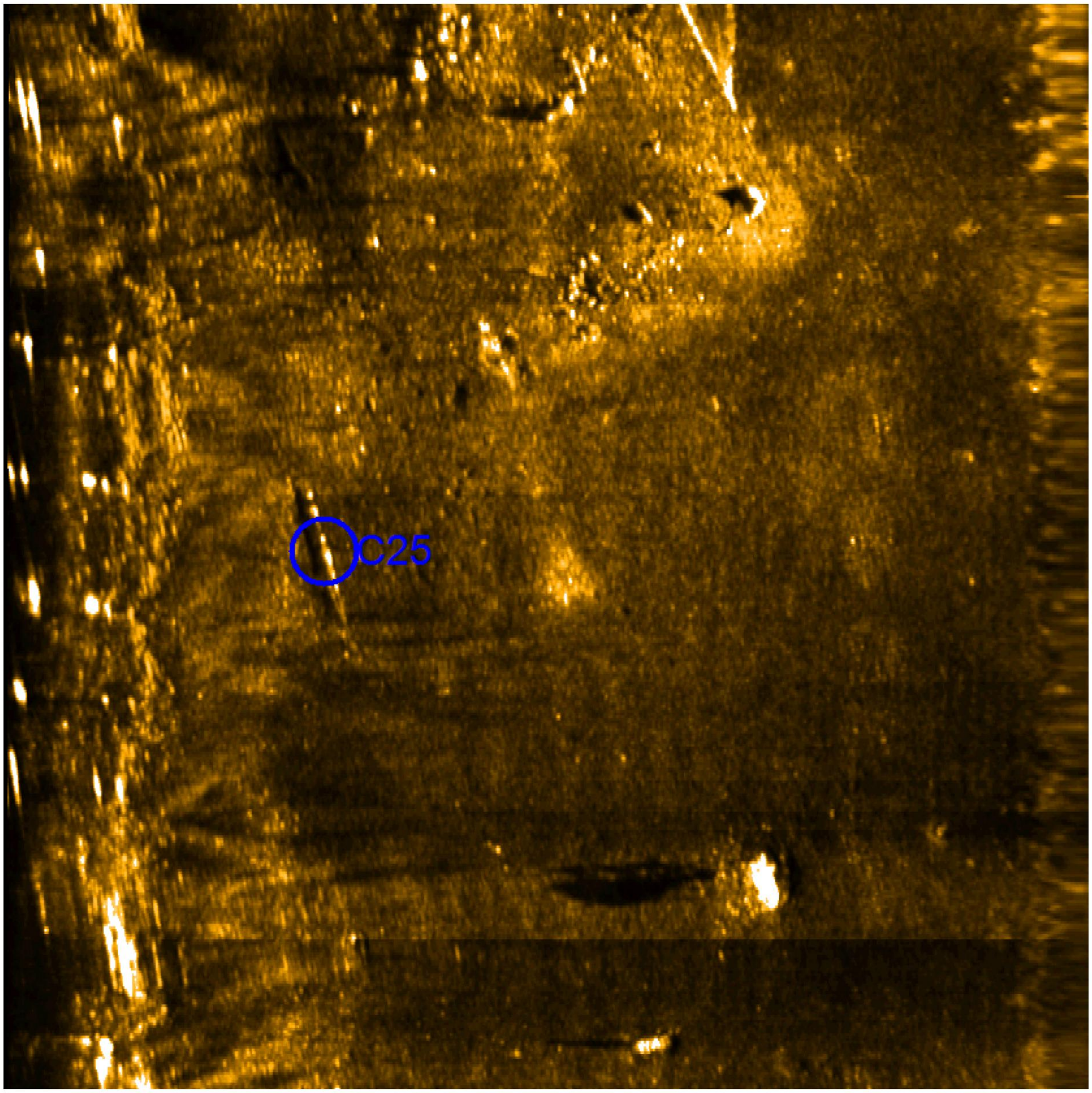
Dimensions and attributes

Target Width: 0.62 Meters

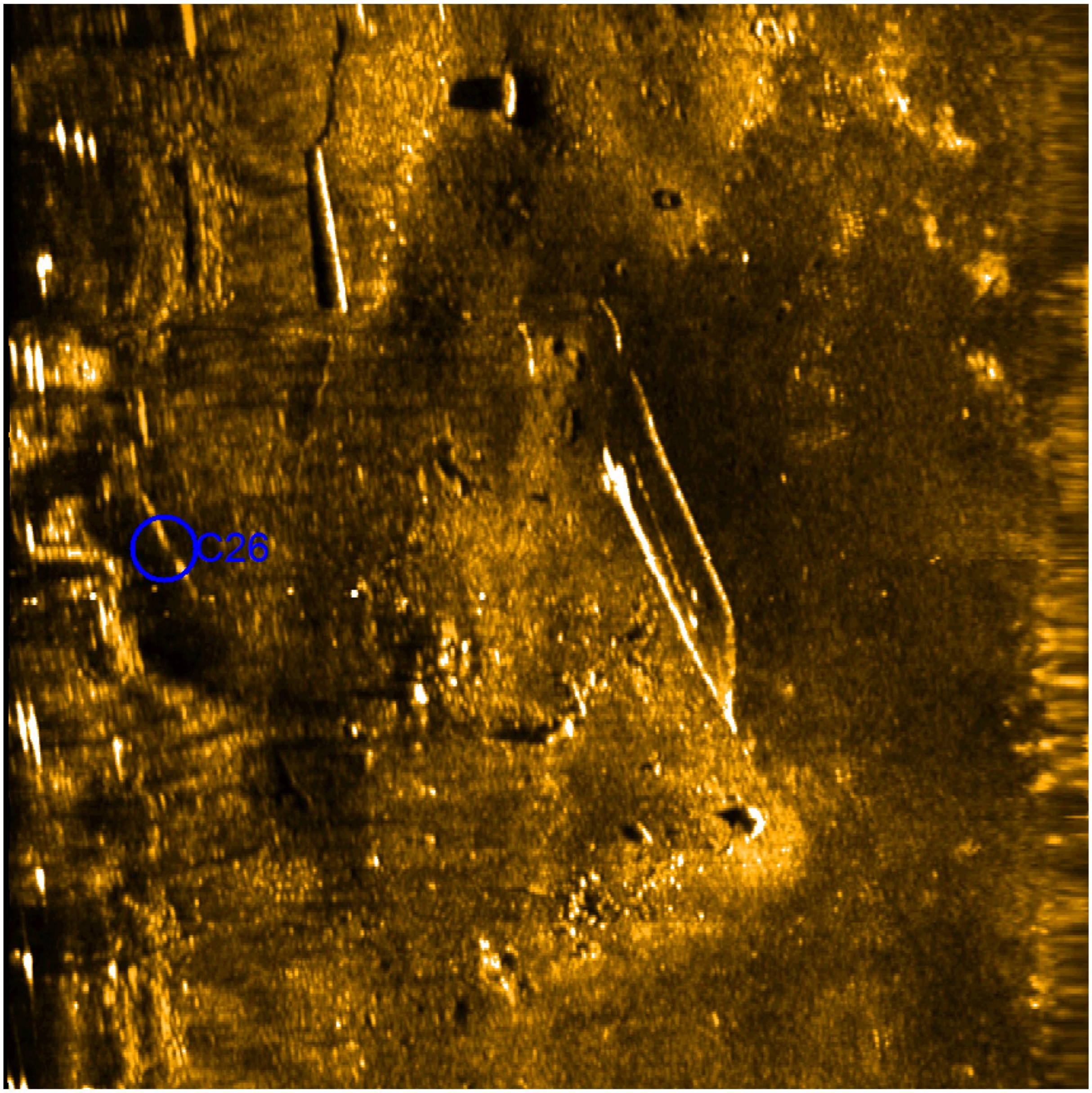
Target Length: 3.36 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C25	Dimensions and attributes
Position 521560 E 5056144 N	Target Width: 0.39 Meters Target Length: 5.62 Meters Classification1: Linear Feature Classification2: Probable Timber



C26

Position

521548 E   5056162 N

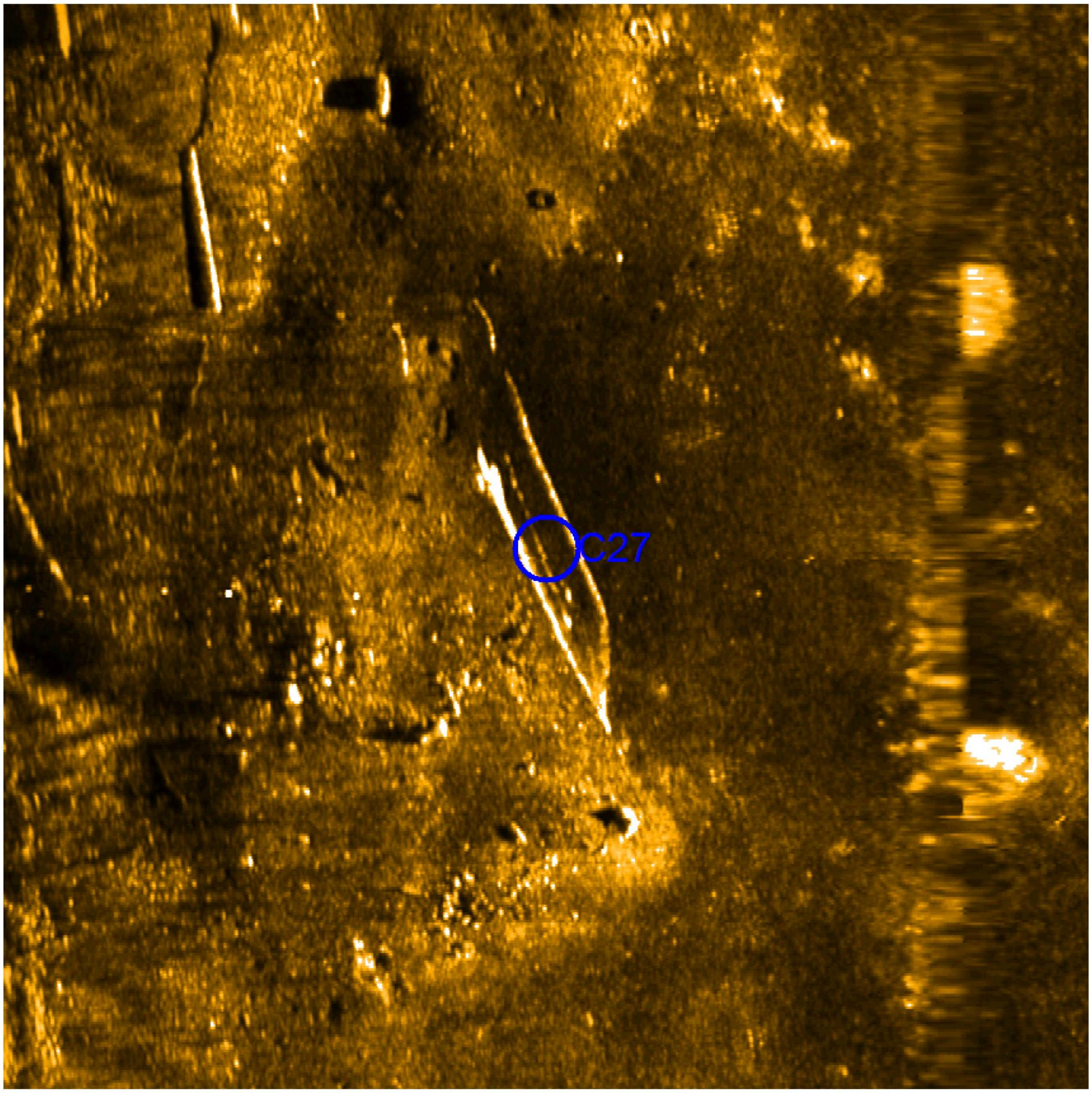
Dimensions and attributes

Target Width: 0.38 Meters

Target Length: 4.86 Meters

Classification1: Linear Feature

Classification2: Possible Timber



C27

Position
521568 E   5056170 N

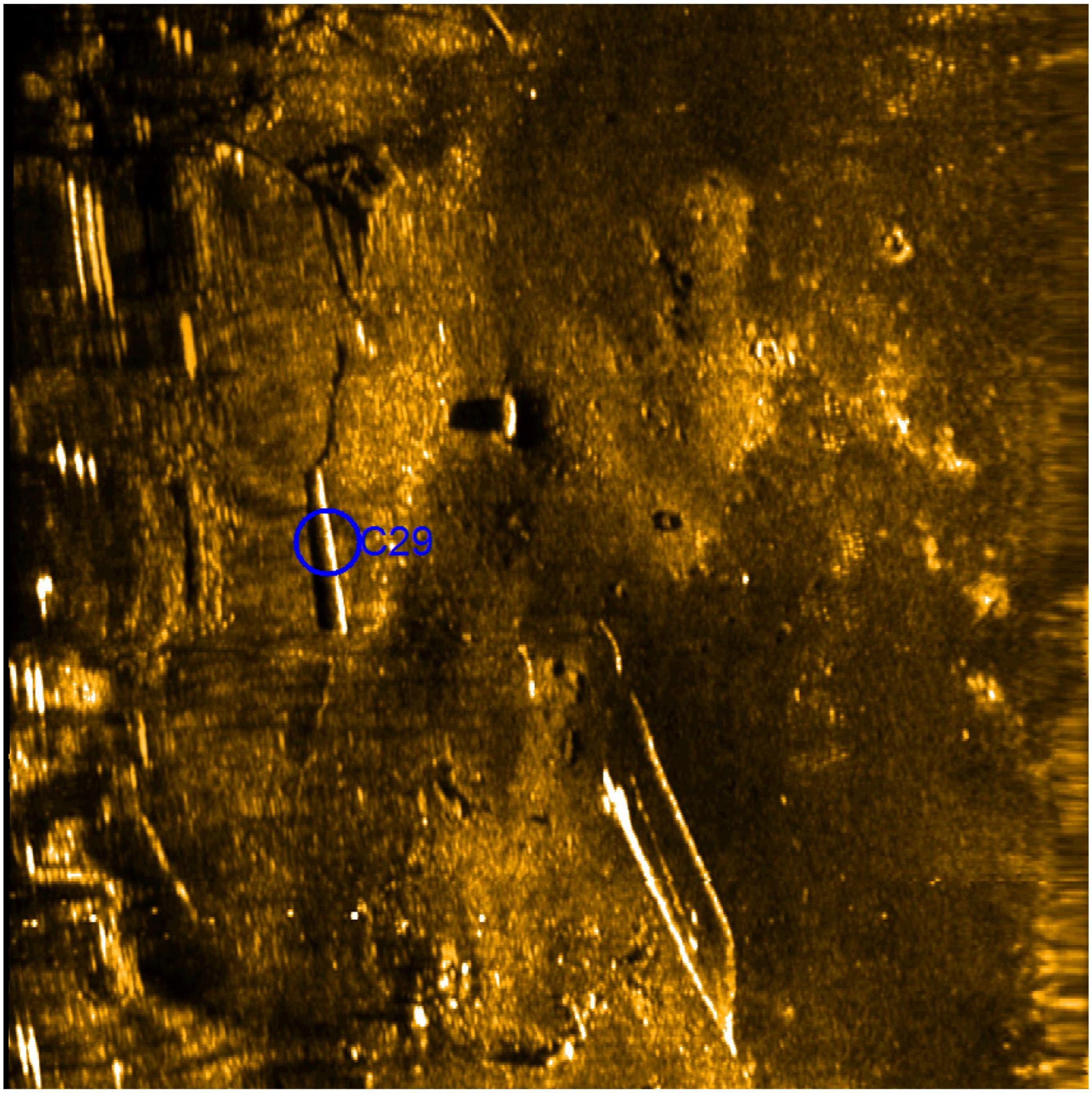
Dimensions and attributes

Target Width: 2.25 Meters

Target Length: 19.38 Meters

Classification1: Linear Feature

Classification2: Possible Debris



C29

Position
521550 E   5056174 N

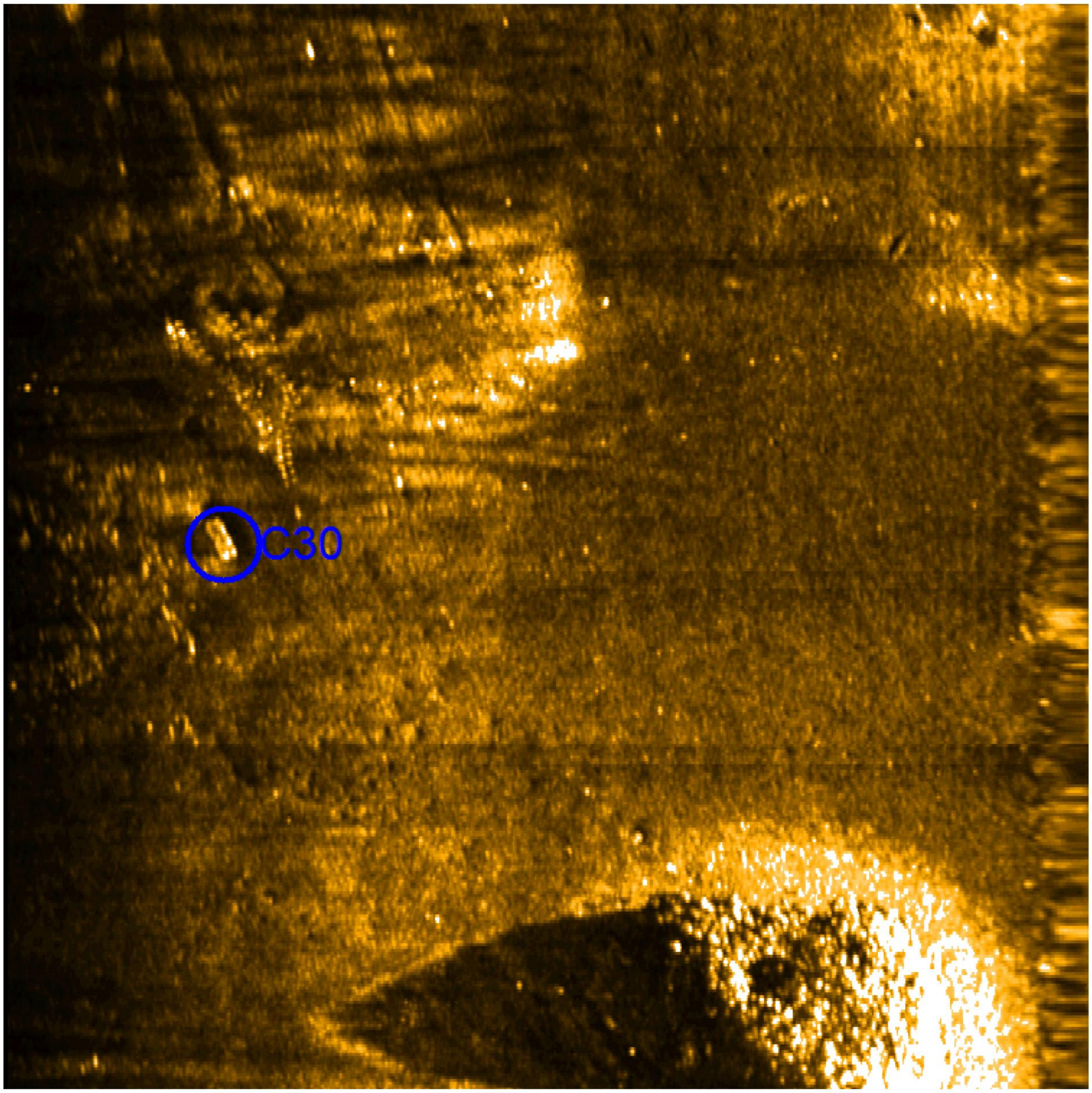
Dimensions and attributes

Target Width: 0.37 Meters

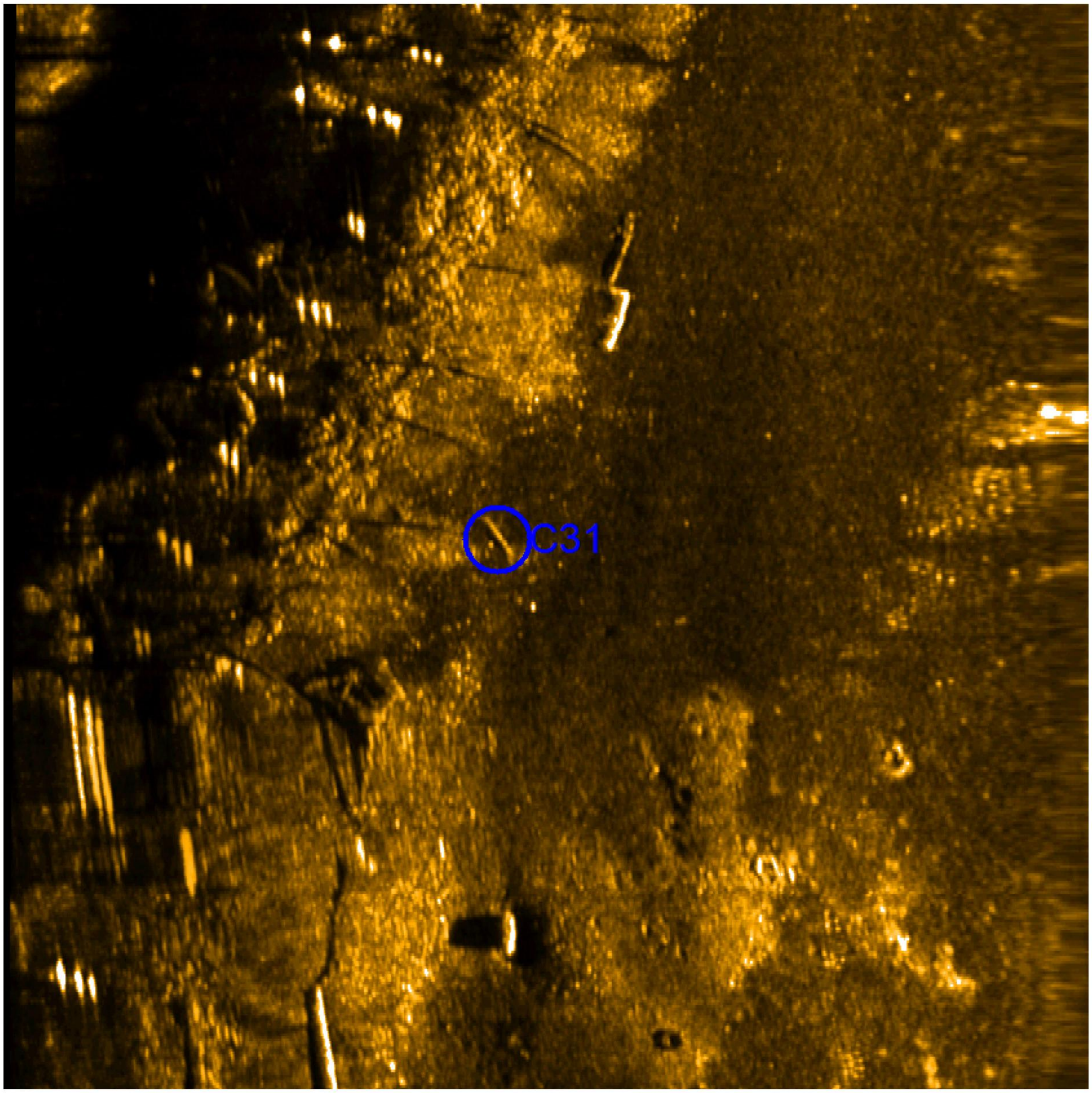
Target Length: 6.96 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C30	Dimensions and attributes
Position 521612 E 5056188 N	Target Width: 0.72 Meters Target Length: 2.08 Meters Classification1: Rectangular Feature Classification2: Possible Debris



C31

Position

521546 E   5056194 N

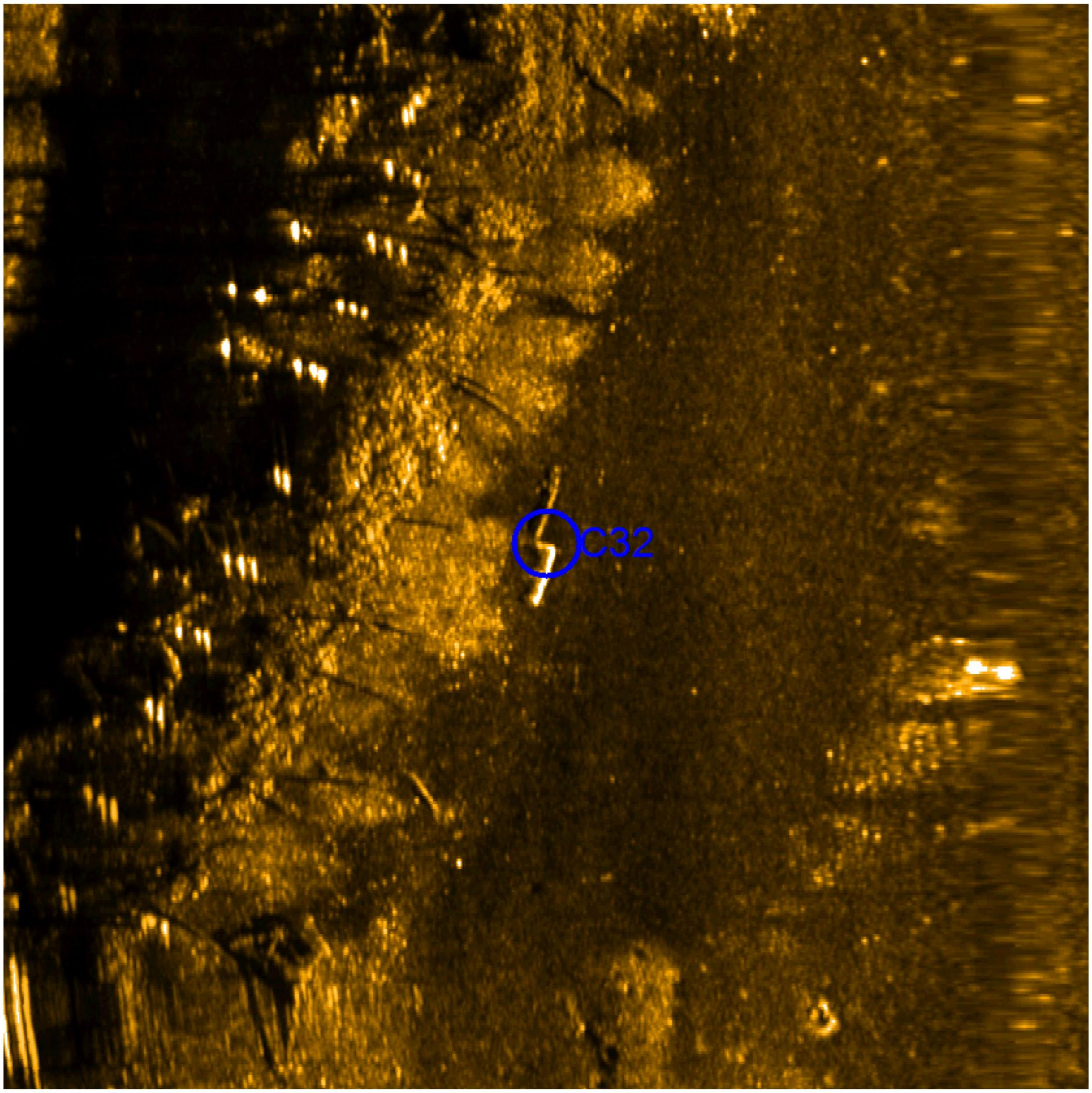
Dimensions and attributes

Target Width: 0.27 Meters

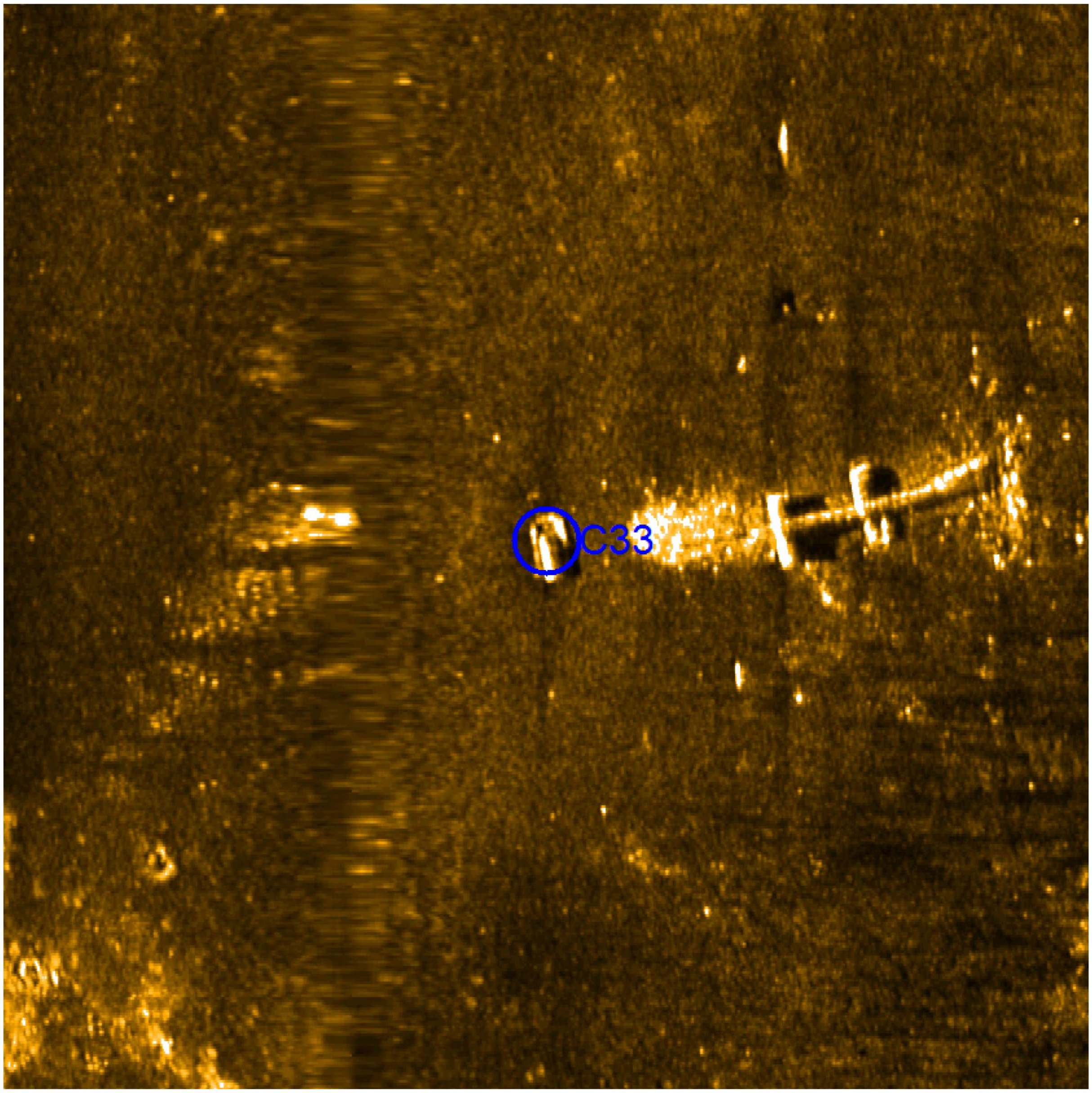
Target Length: 1.76 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C32	Dimensions and attributes
Position 521545 E 5056206 N	Target Width: 1.09 Meters Target Length: 5.68 Meters Classification1: Linear Feature Classification2: Possible Timber



C33

Position

521571 E 5056215 N

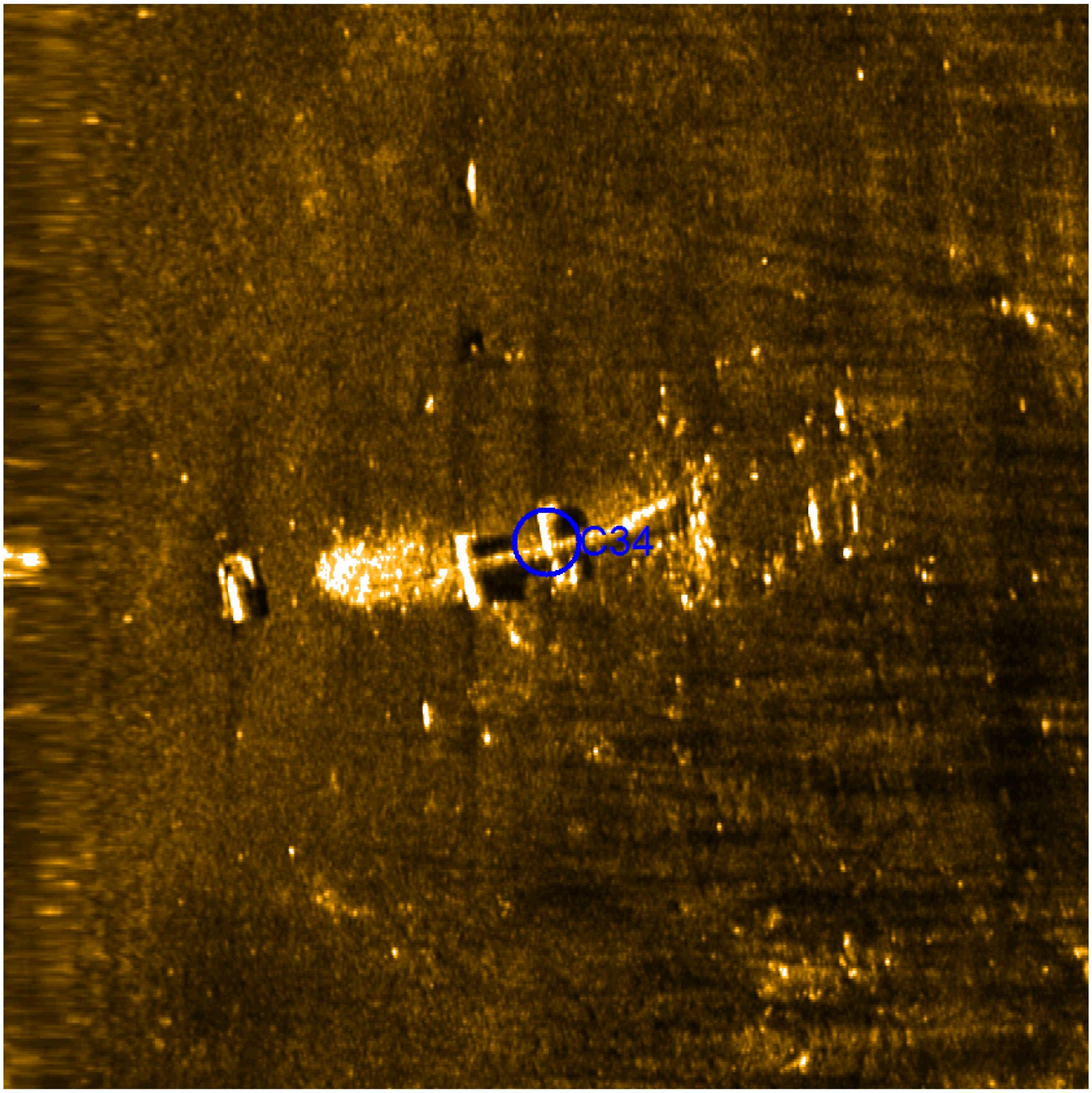
Dimensions and attributes

Target Width: 1.61 Meters

Target Length: 2.86 Meters

Classification1: Rectangular Feature

Classification2: Possible Debris



C34

Position

521581 E 5056224 N

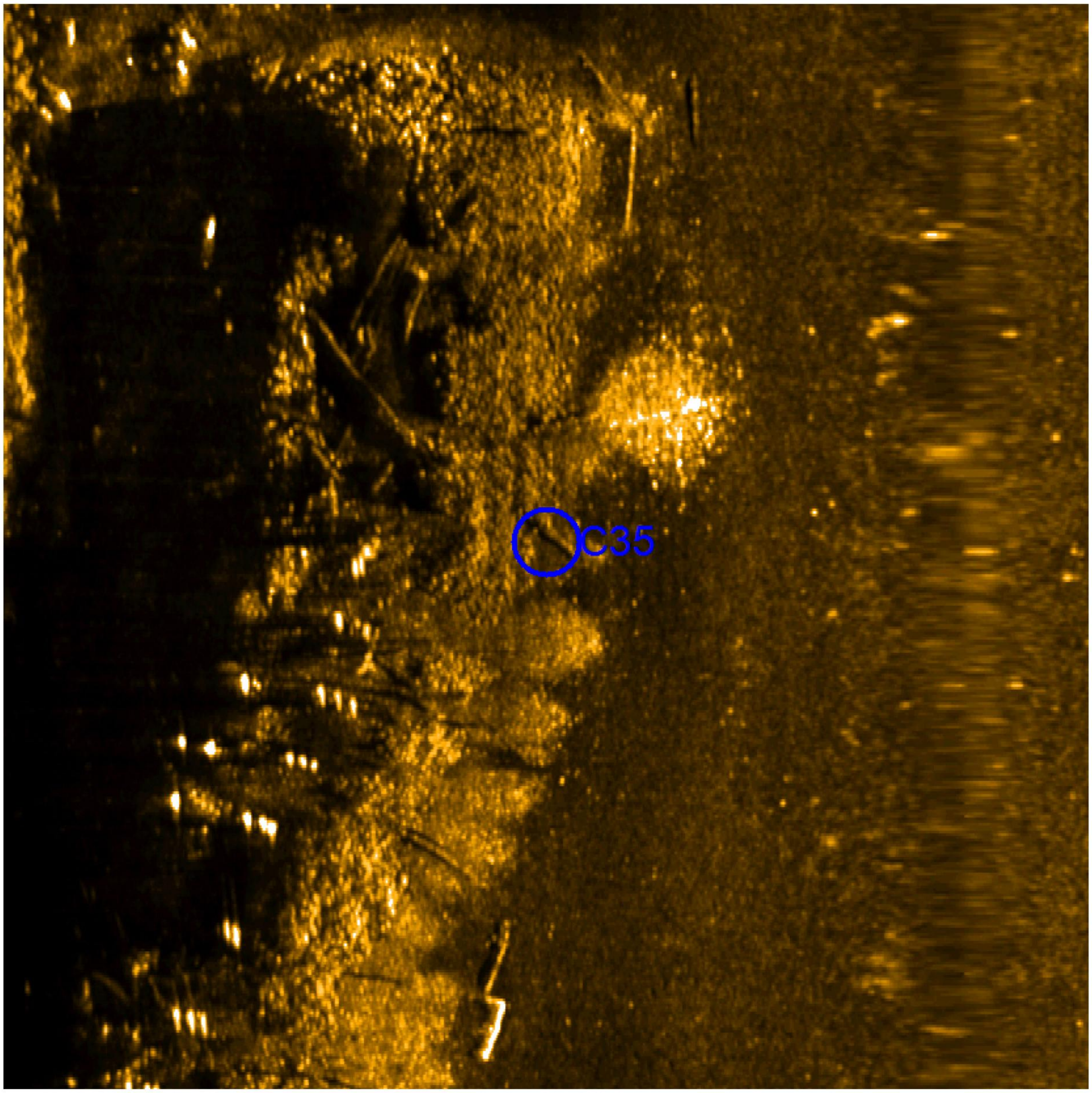
Dimensions and attributes

Target Width: 3.42 Meters

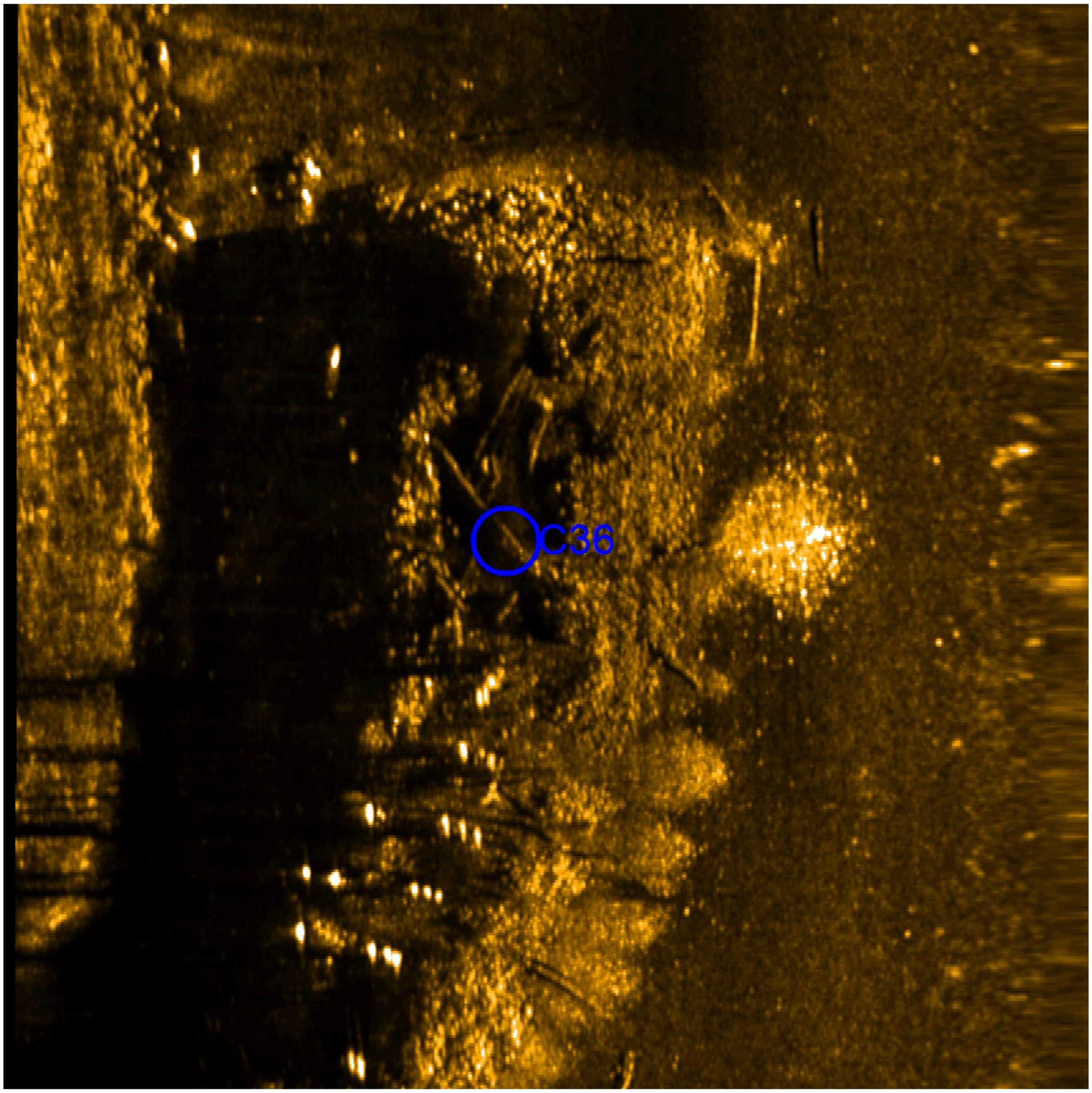
Target Length: 10.59 Meters

Classification1: Linear Feature

Classification2: Probable Debris



C35	Dimensions and attributes
Position 521535 E 5056226 N	Target Width: 0.34 Meters Target Length: 1.89 Meters Classification1: Linear Feature Classification2: Possible Timber



C36

Position

521526 E   5056230 N

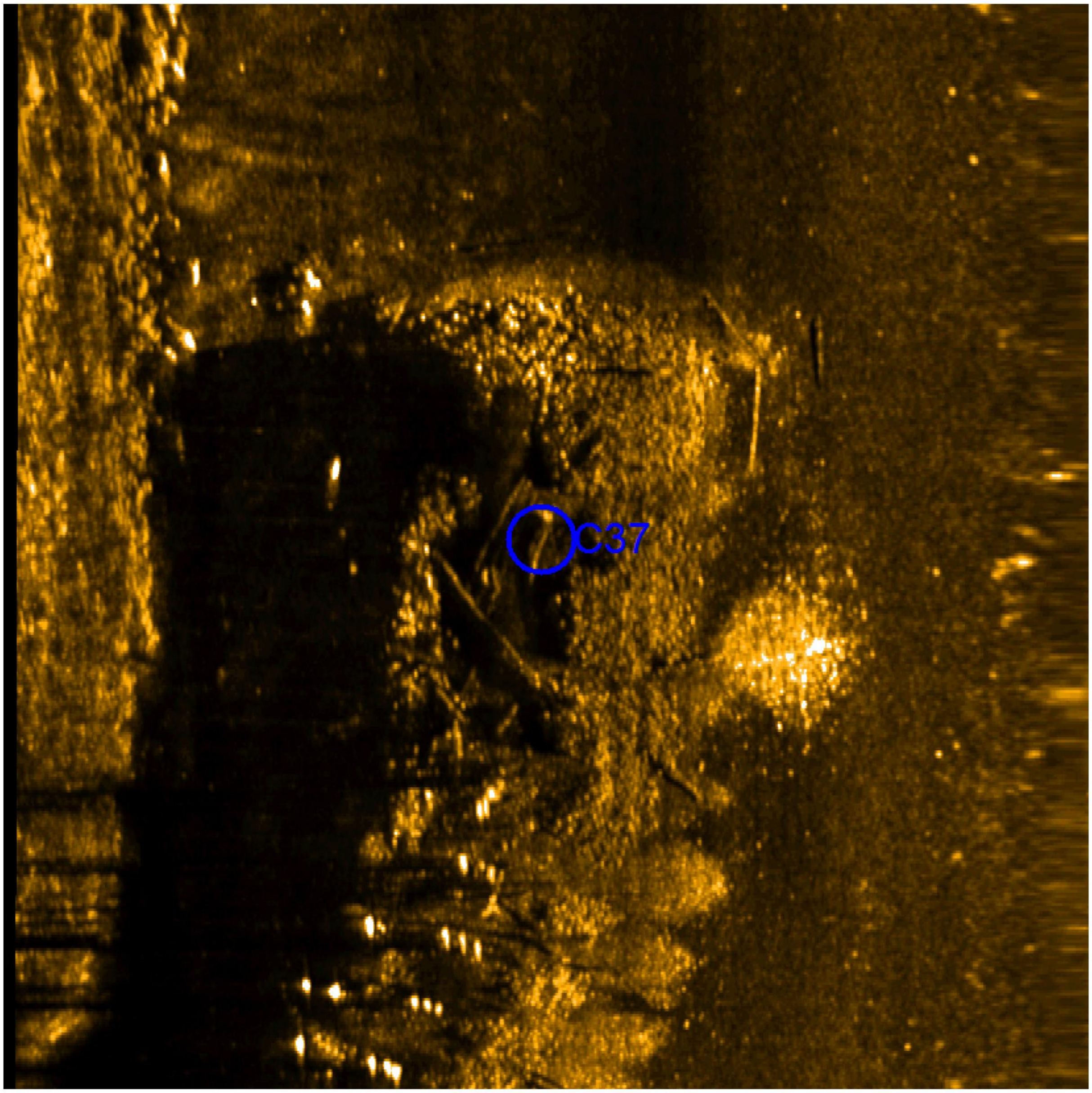
Dimensions and attributes

Target Width: 0.17 Meters

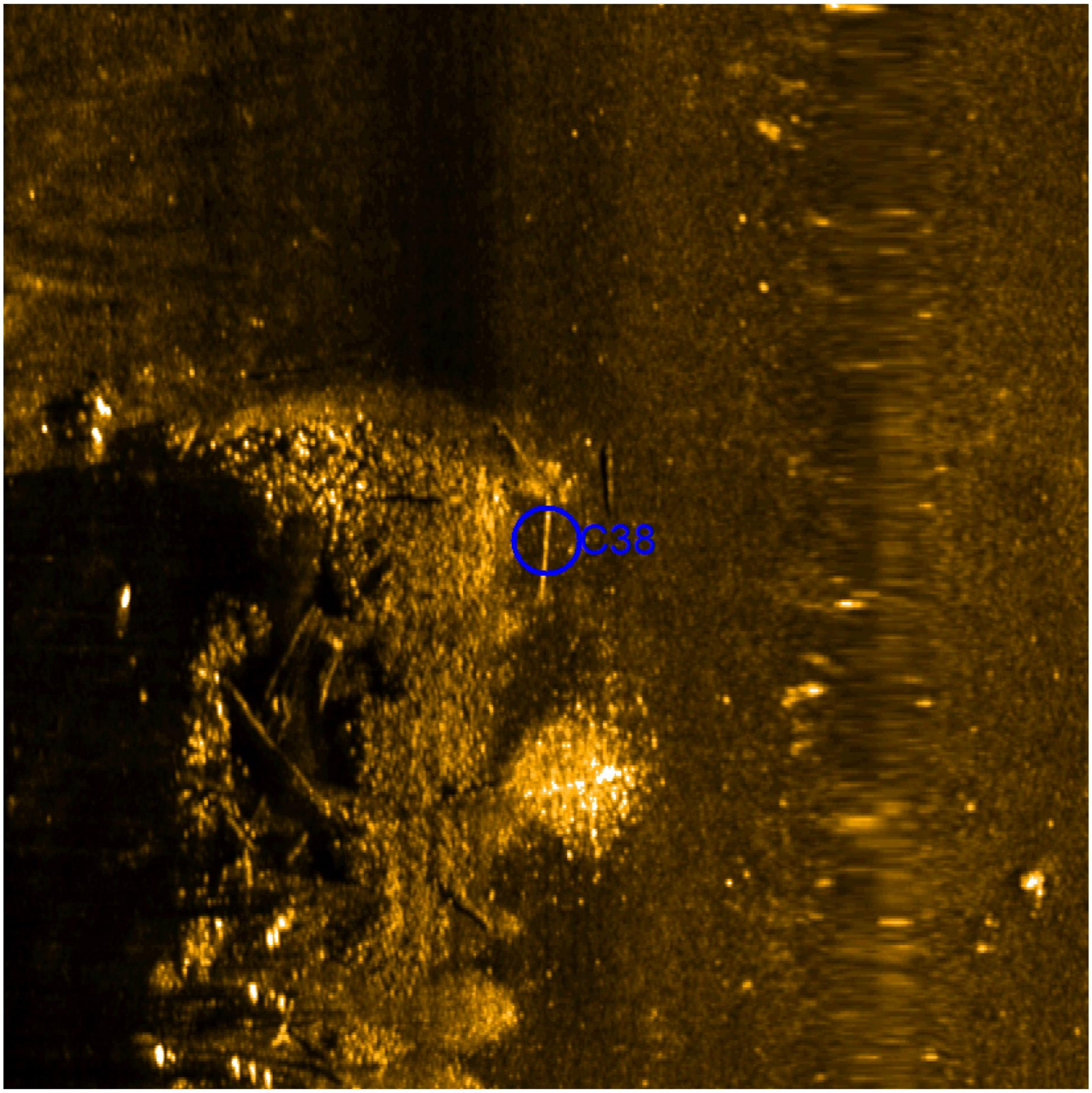
Target Length: 6.35 Meters

Classification1: Linear Feature

Classification2: Possible Timber



C37	Dimensions and attributes
Position 521526 E 5056235 N	Target Width: 0.47 Meters Target Length: 2.49 Meters Classification1: Linear Feature Classification2: Possible Timber



C38

Position
521533 E   5056243 N

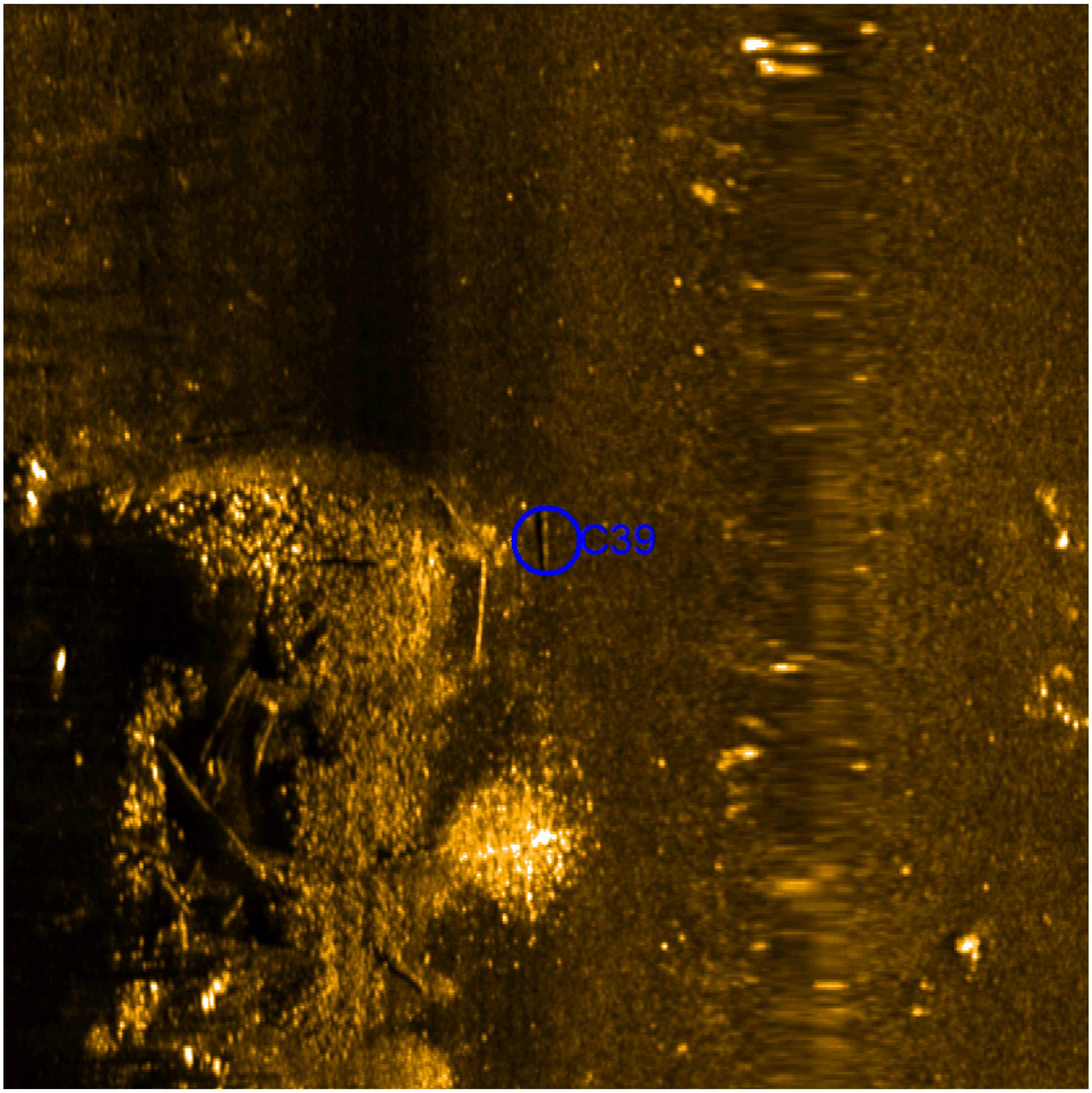
Dimensions and attributes

Target Width: 0.22 Meters

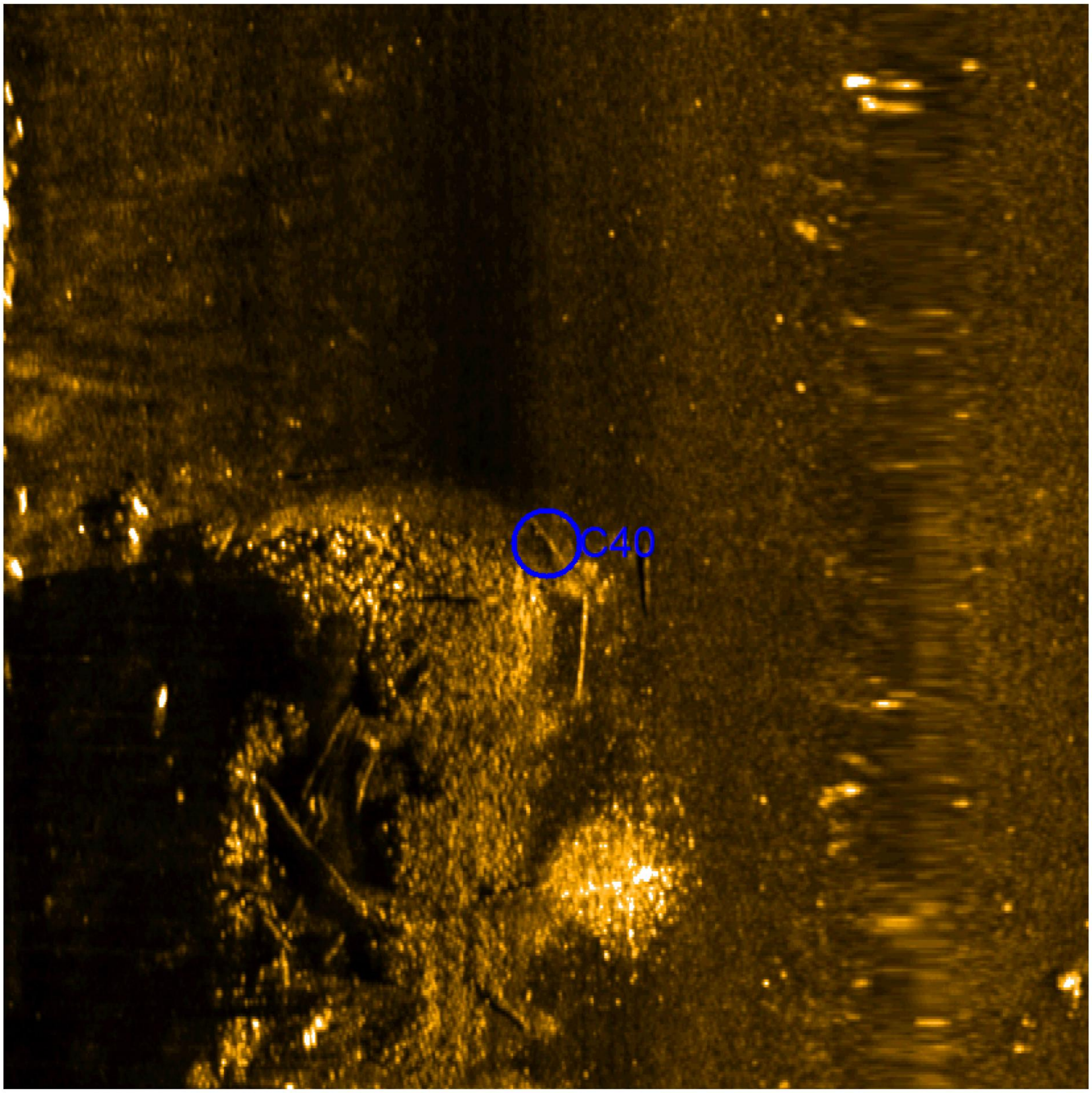
Target Length: 4.34 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C39	Dimensions and attributes
Position 521535 E 5056247 N	Target Width: 0.29 Meters Target Length: 2.79 Meters Classification1: Linear Feature Classification2: Probable Timber



C40

Position
521531 E   5056247 N

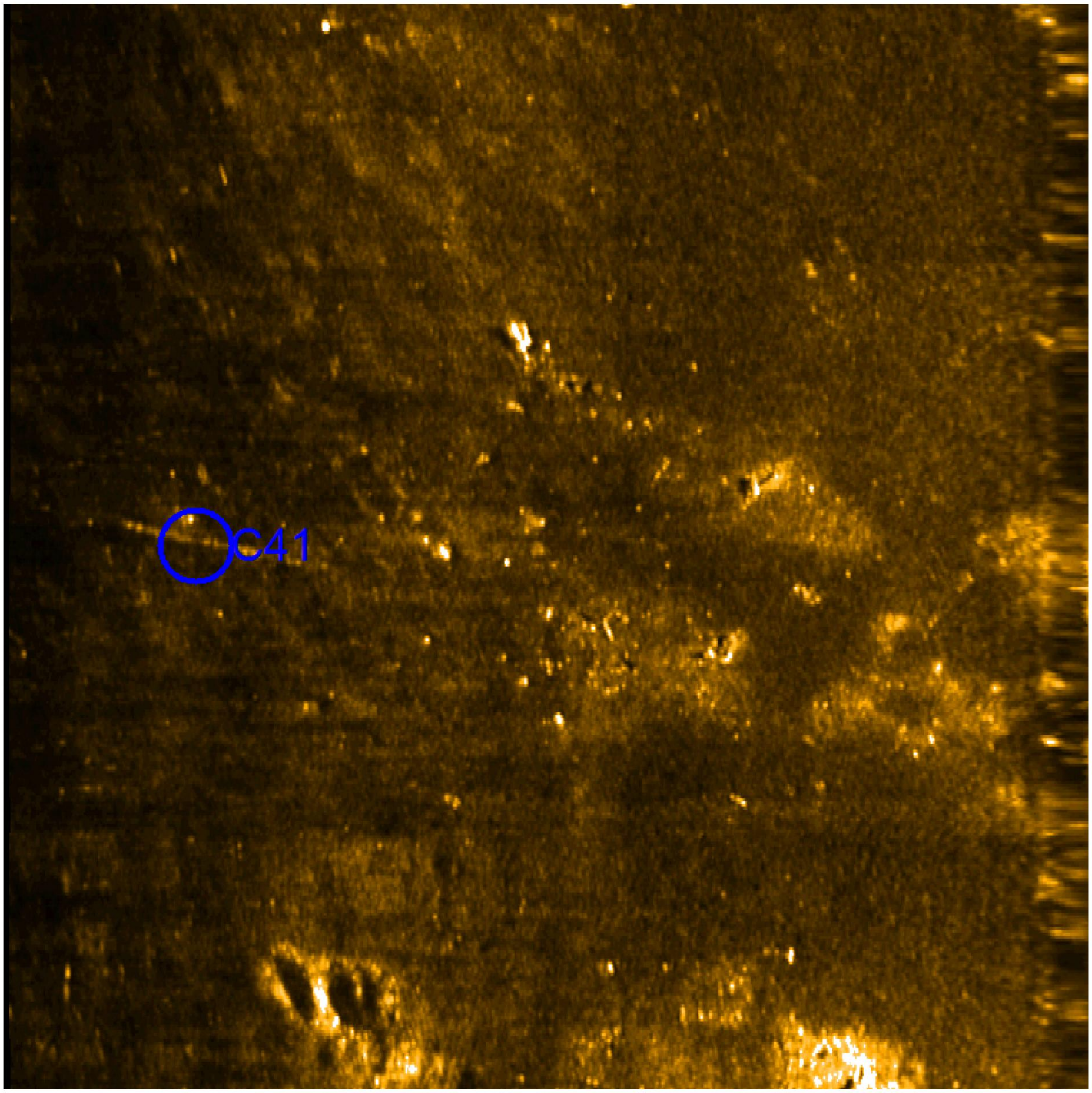
Dimensions and attributes

Target Width: 0.23 Meters

Target Length: 3.42 Meters

Classification1: Linear Feature

Classification2: Probable Timber



C41

Position

521591 E 5056253 N

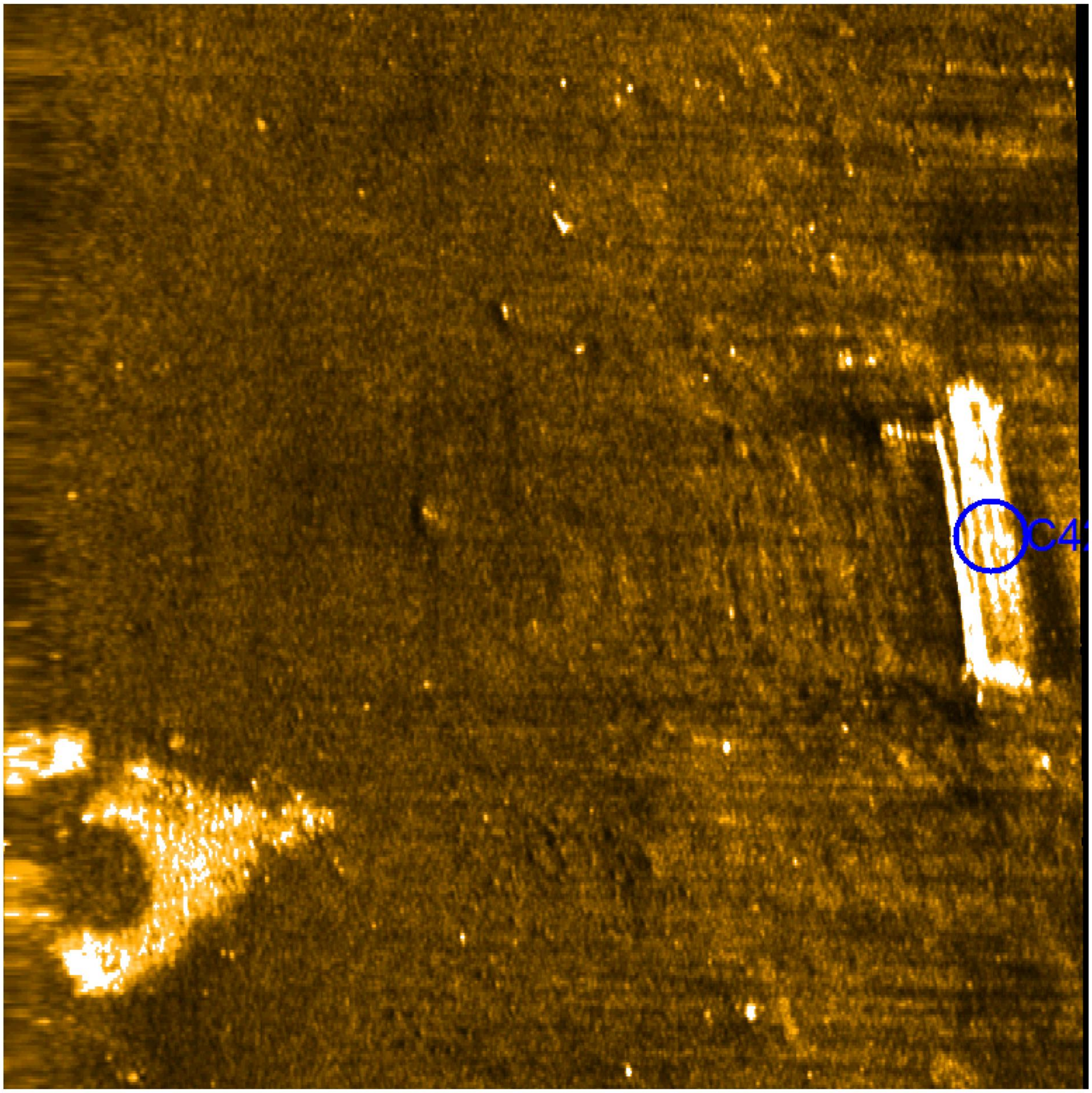
Dimensions and attributes

Target Width: 0.30 Meters

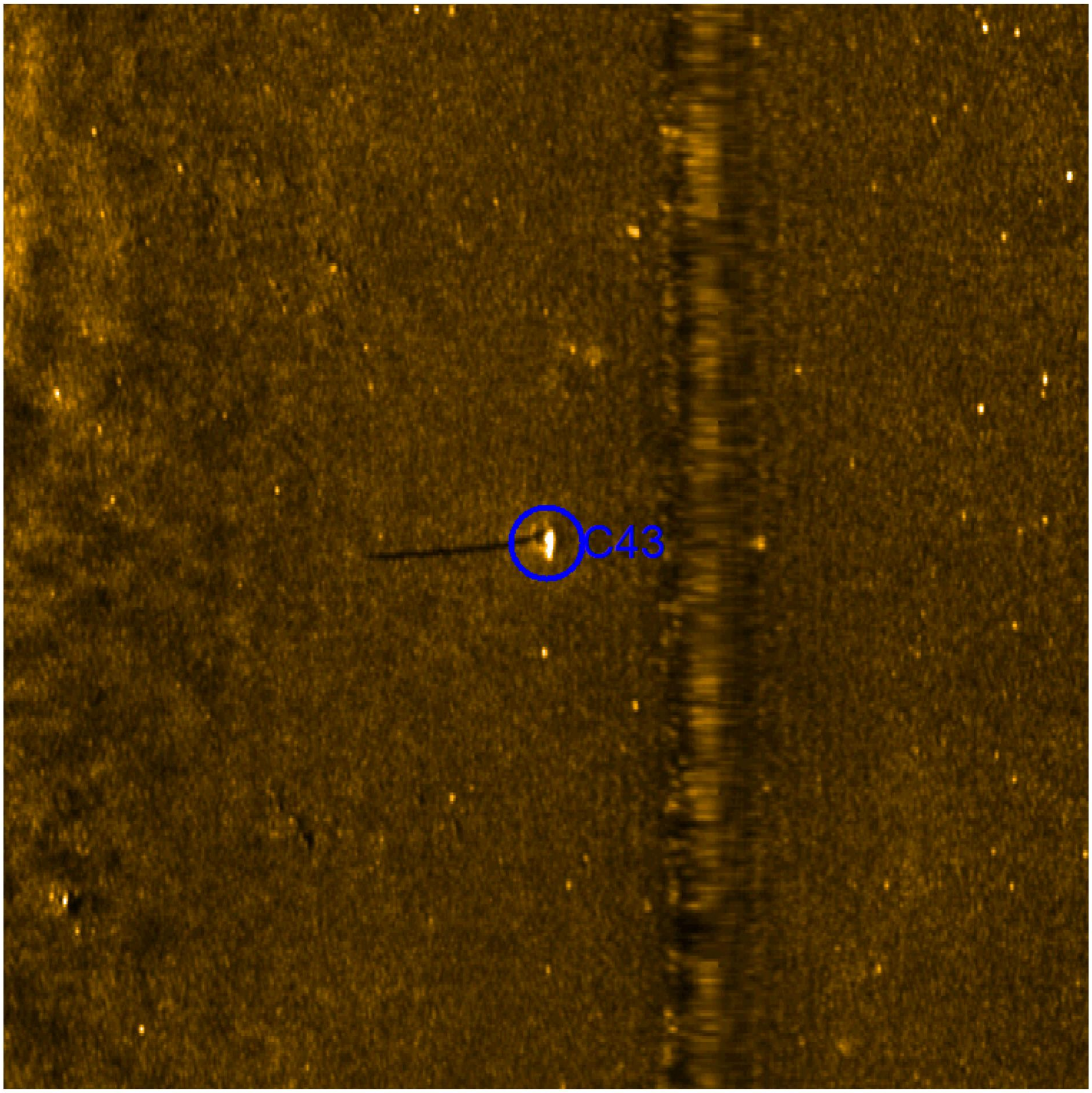
Target Length: 7.86 Meters

Classification1: Linear Feature

Classification2: Possible Timber



C42 Position 521647 E 5056330 N	Dimensions and attributes Target Width: 13.33 Meters Target Length: 2.88 Meters Classification1: Rectangular Feature Classification2: Possible Debris



C43

Position
521326 E   5056910 N

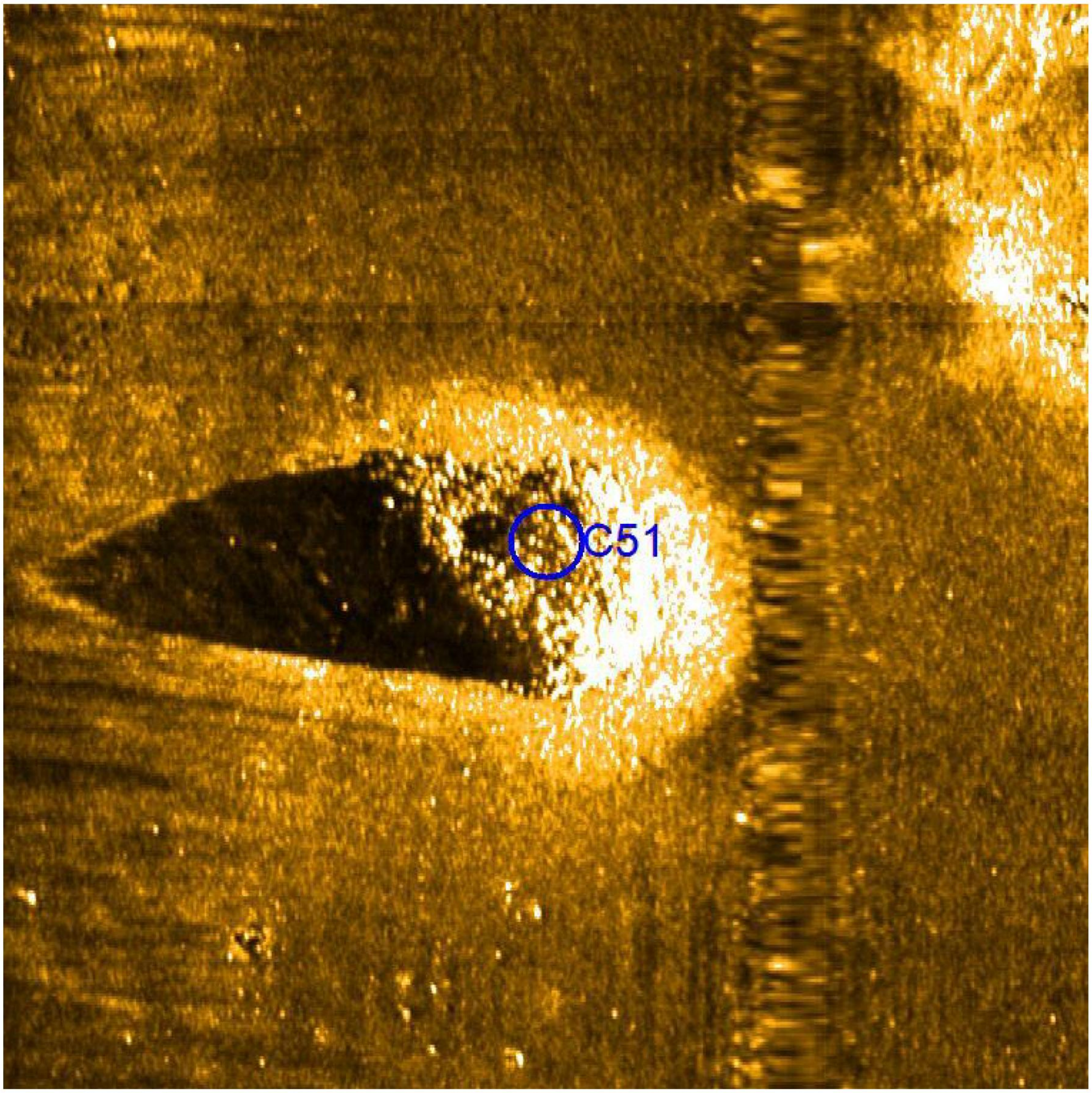
Dimensions and attributes

Target Width: 0.65 Meters

Target Length: 0.96 Meters

Classification1: Point Source

Classification2: Possible Vertical Timber



C51

Position

521643 E 5056172 N

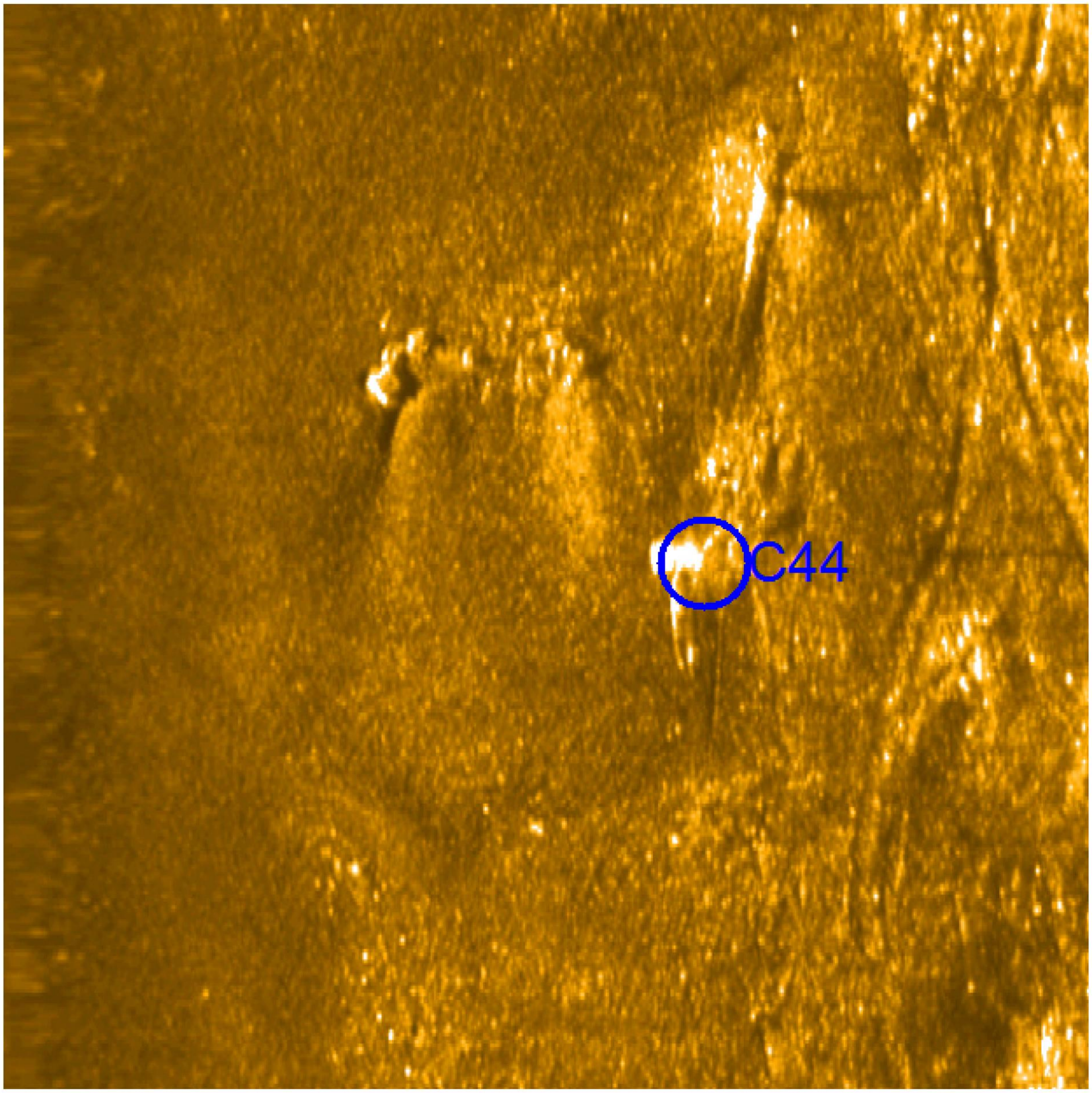
Dimensions and attributes

Target Width: 13.50 Meters

Target Length: 15.50 Meters

Classification1: Circular Feature

Classification2: Rock dump, possible ballast



C44

Position

524727 E   5066053 N

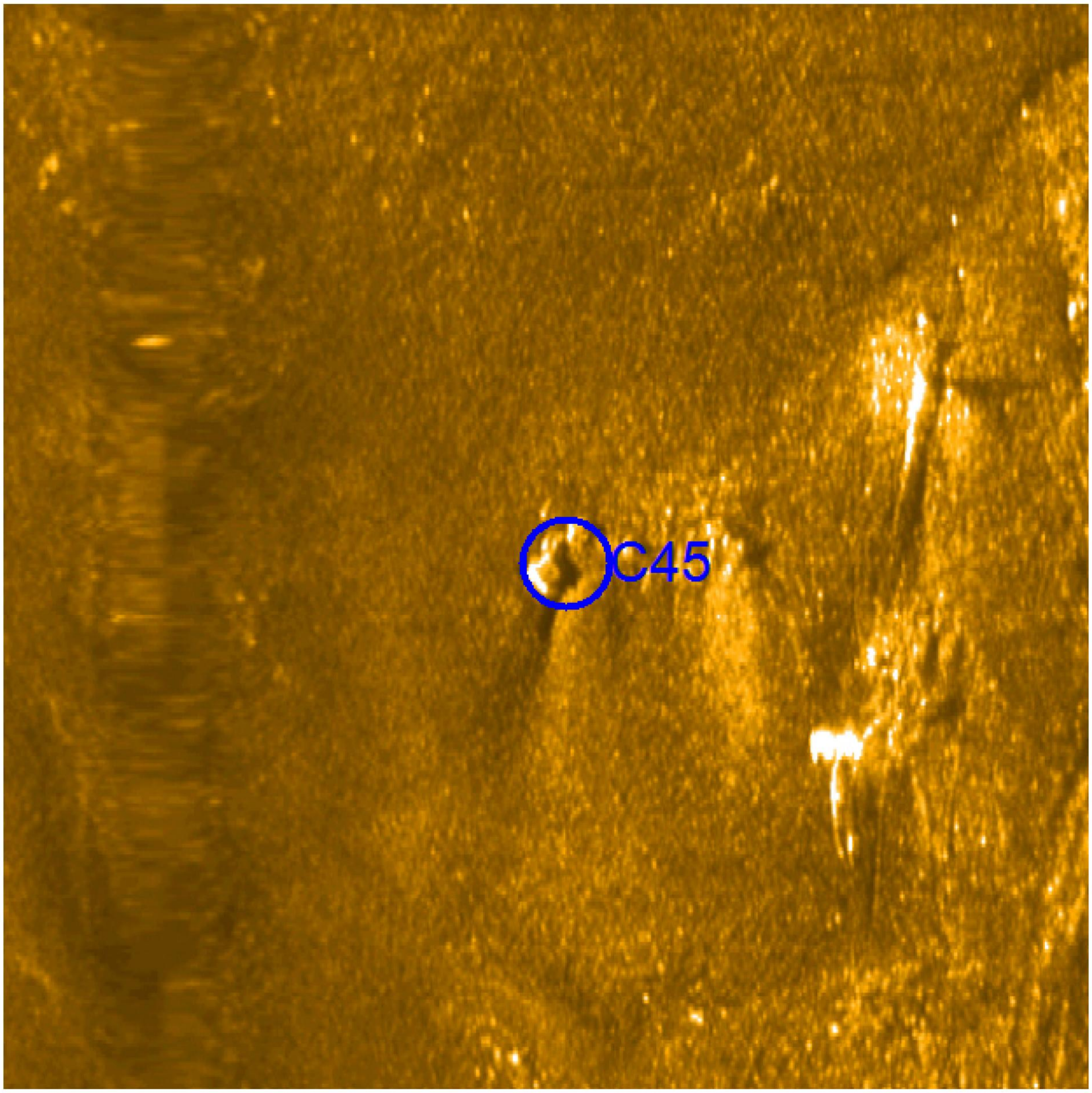
Dimensions and attributes

Target Width: 2.03 Meters

Target Length: 4.51 Meters

Classification1: Linear Feature

Classification2: Possible Debris



C45

Position
524726 E   5066069 N

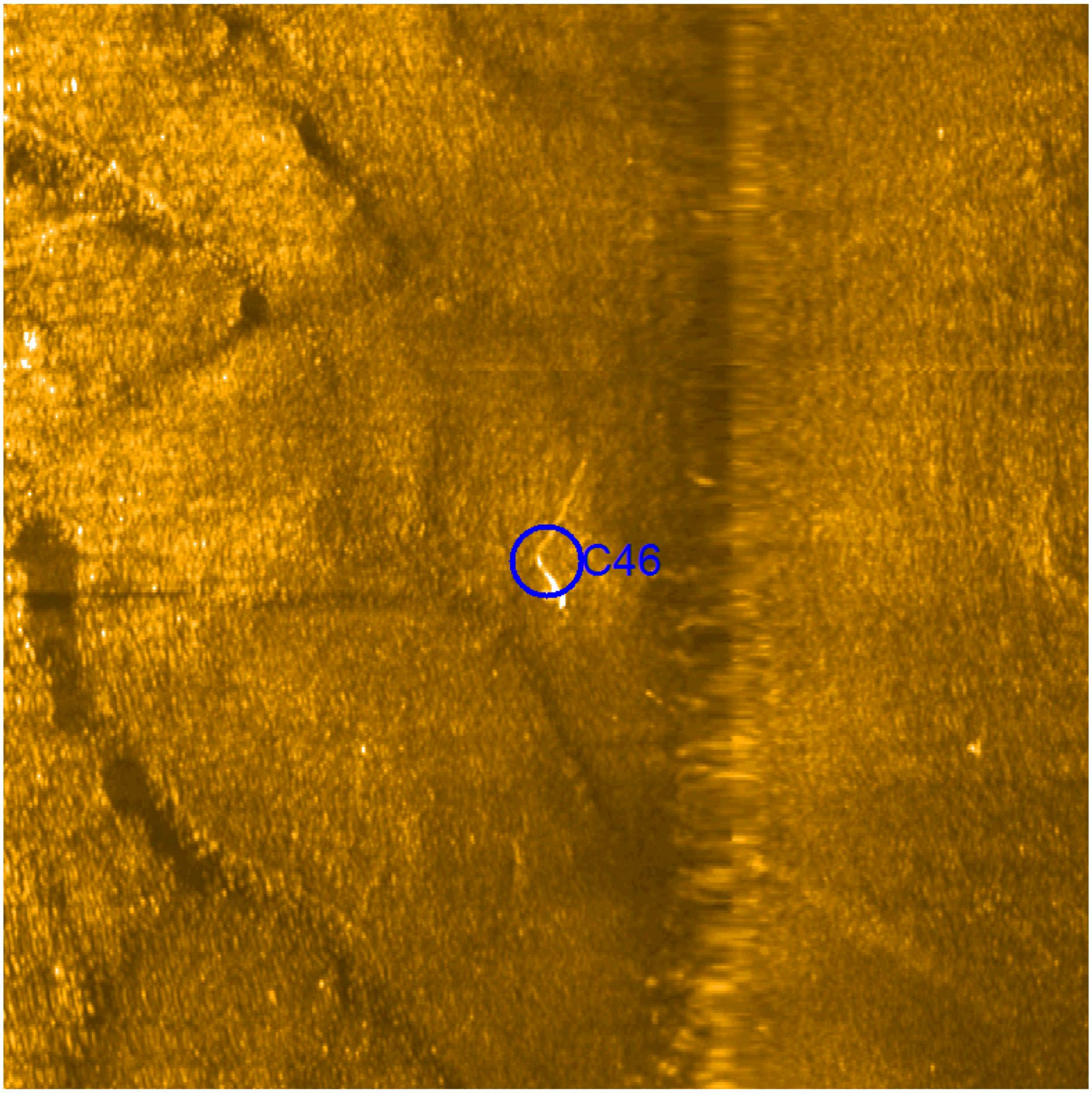
Dimensions and attributes

Target Width: 1.96 Meters

Target Length: 2.64 Meters

Classification1: Rectangular Feature

Classification2: Possible Debris, possibly related to Mag anomaly M35



C46

Position

524922 E   5066214 N

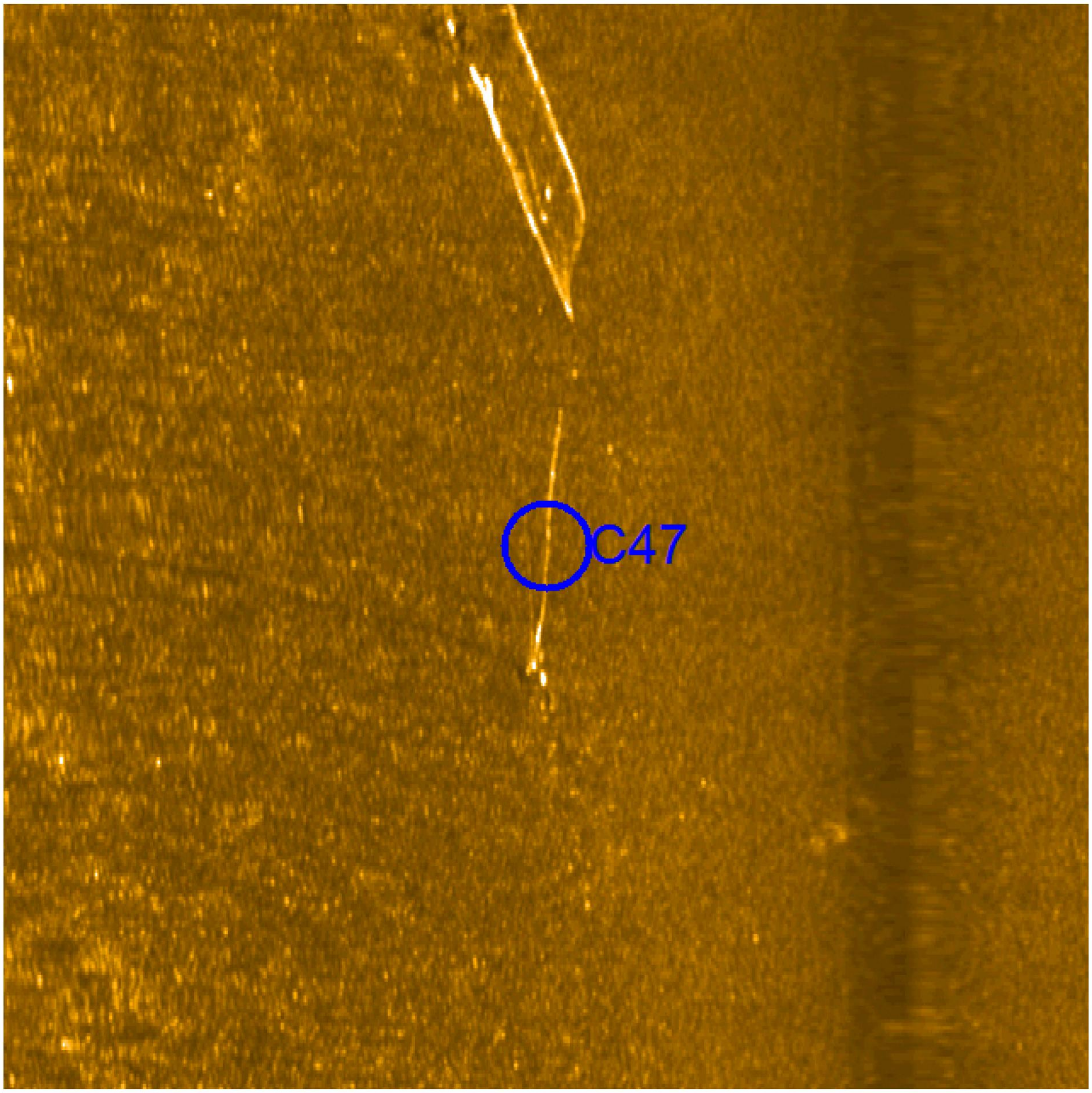
Dimensions and attributes

Target Width: 1.03 Meters

Target Length: 6.19 Meters

Classification1: Linear Feature

Classification2: Possible Debris



C47

Position
525650 E 5066718 N

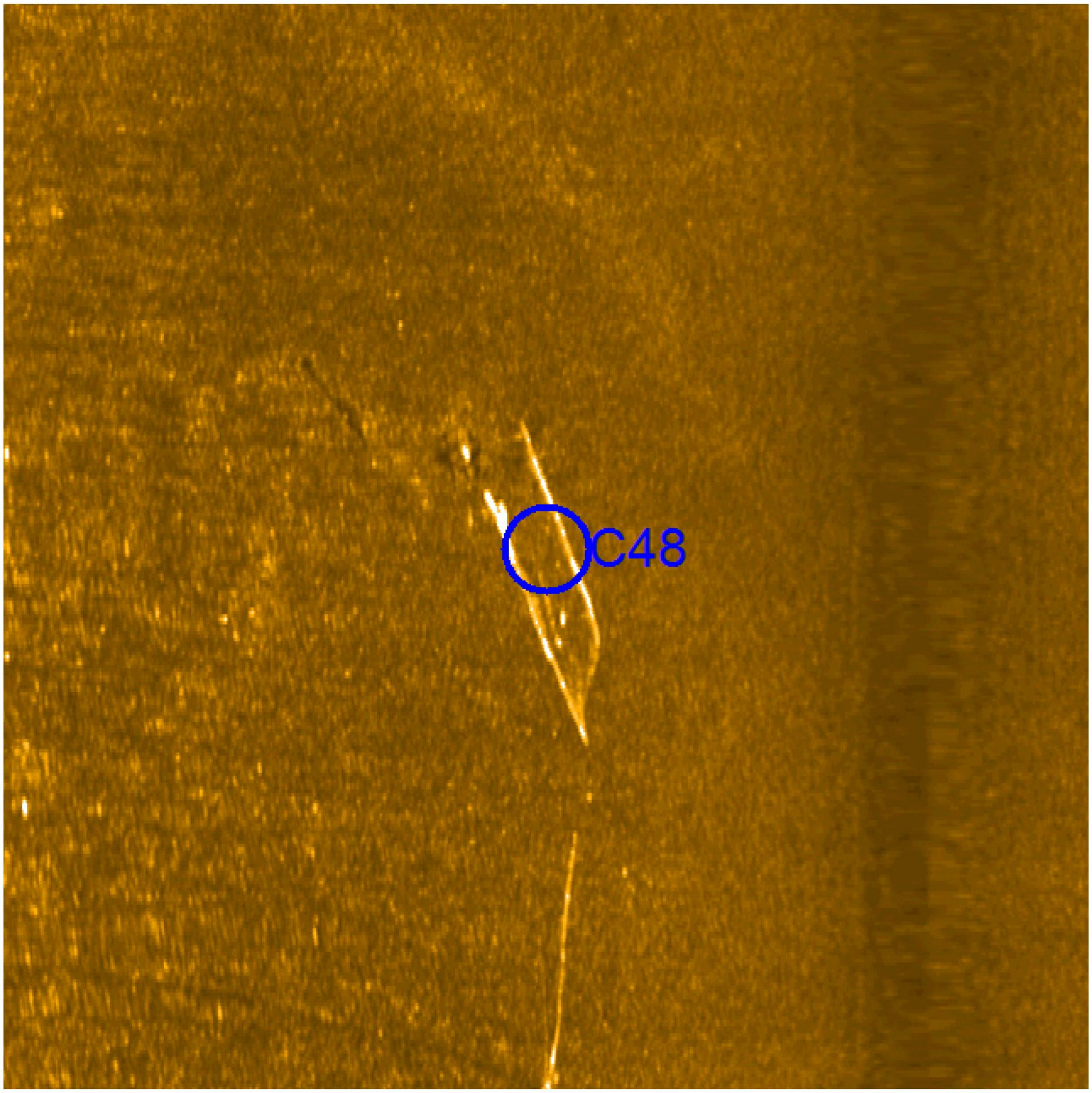
Dimensions and attributes

Target Width: 0.35 Meters

Target Length: 11.51 Meters

Classification1: Linear Feature

Classification2: Possible Debris



C48

Position
525663 E   5066729 N

Dimensions and attributes

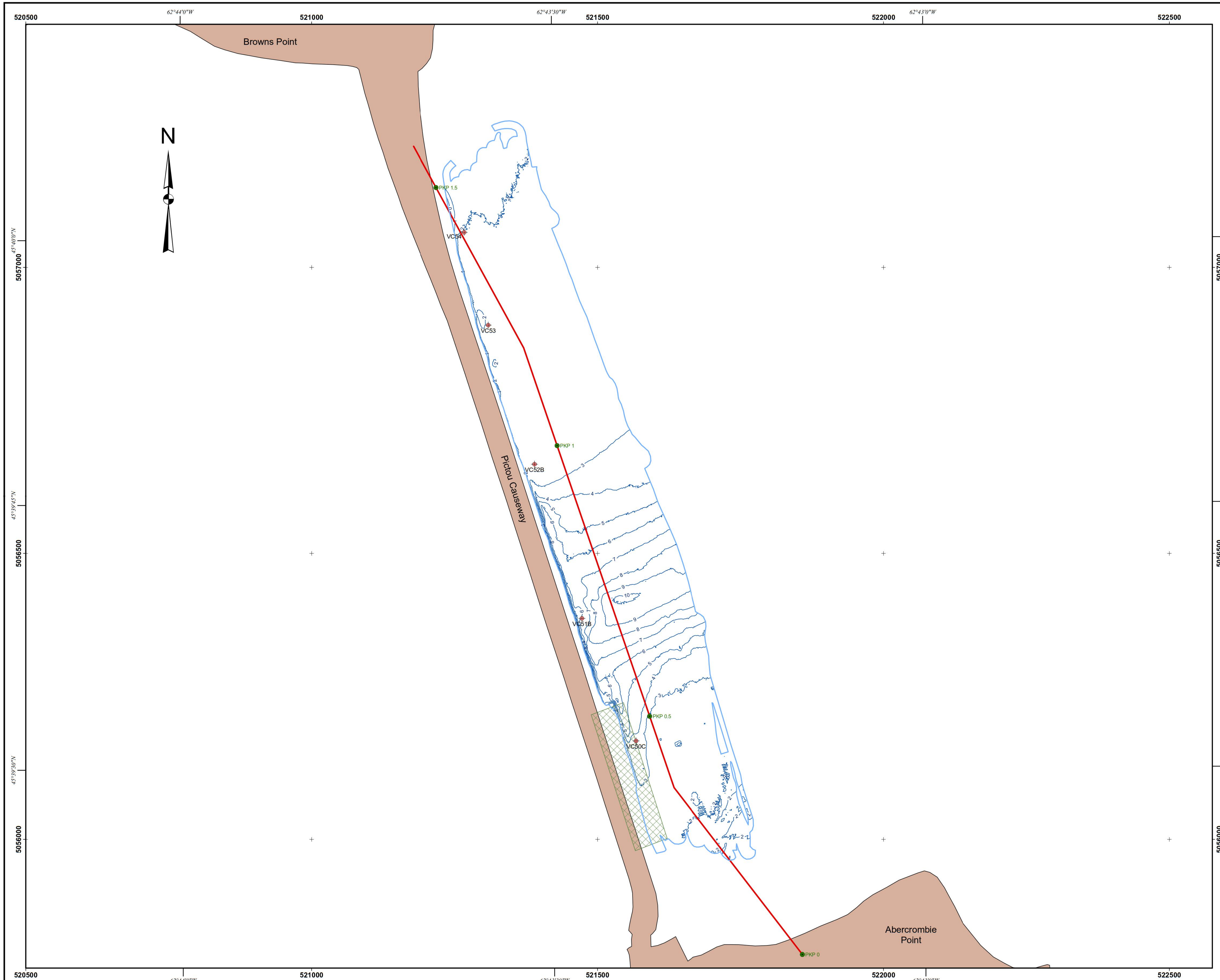
Target Width: 2.67 Meters

Target Length: 13.63 Meters

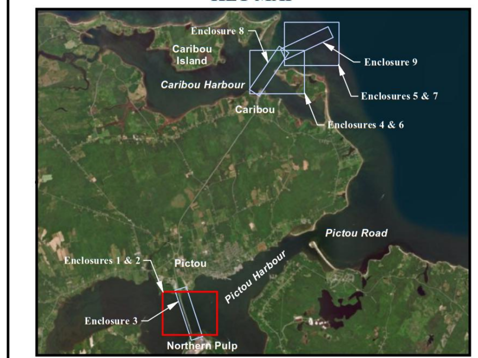
Classification1: Linear Feature

Classification2: Possible Debris

ENCLOSURES



KEY MAP



LEGEND

- Proposed pipeline route
- Abercrombie Wildlife Management Area
- Bathymetric contour (1 m intervals)
- Bathymetric contour extent
- Adjacent map sheet
- Vibracore location
- KP Location

NOTES

FIELD SURVEY

CSR GeoSurveys Ltd. conducted geophysical and geotechnical surveys during April and May, 2019.

SURVEY EQUIPMENT

Vessel:	SeaQuest / Nova Endeavor
Positioning System:	Trimble 5700/5800, Hemisphere R110 DGPS
Positioning/Heading System:	Hemisphere VS-330 GNSS SBG Ekinox D
Multibeam Echosounder:	Teledyne-RESON T-20P (200-400 kHz)
Motion Sensor:	SBG Ekinox D
Sound Velocity:	Teledyne-RESON Odom Digibar
Tide Gauge:	RTK Tides - CAN NET
Sidescan Sonar System:	Klein 3000 (100 kHz and 500 kHz)
Sub-bottom Systems:	Klein 3310 Chirp (2-8 kHz) EG&G 240 Boomer System
Seismic Refraction:	Pro-Seismic 24 channel marine cable with Geometrics Geode Seismic Recorder
Grab Sampler:	Van Veen Petite Ponar
Vibracore System:	Rossfelder P-3C Vibracorer
Survey Navigation System:	Hypack
Multibeam Acquisition System:	Hysweep & Teledyne-RESON Seabat UI
Sonar Acquisition System:	SonarPro

BASEMAP

Horizontal Datum:	NAD83 CSRS
Projection:	Universal Transverse Mercator (Zone 20N)
Vertical Datum:	Chart Datum (LLWLT)
Horizontal Scale:	1:2500
Units:	Metres

BACKGROUND

The shoreline was digitized from CHS charts 443701, 448301 and 448302 and is considered approximate.

The Abercrombie Wildlife Management Area outline was obtained online at https://geonova.novascotia.ca.

PREPARED FOR

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1:2,500

0 25 50 100 150 200 250 300 m

CSR GeoSurveys Ltd.
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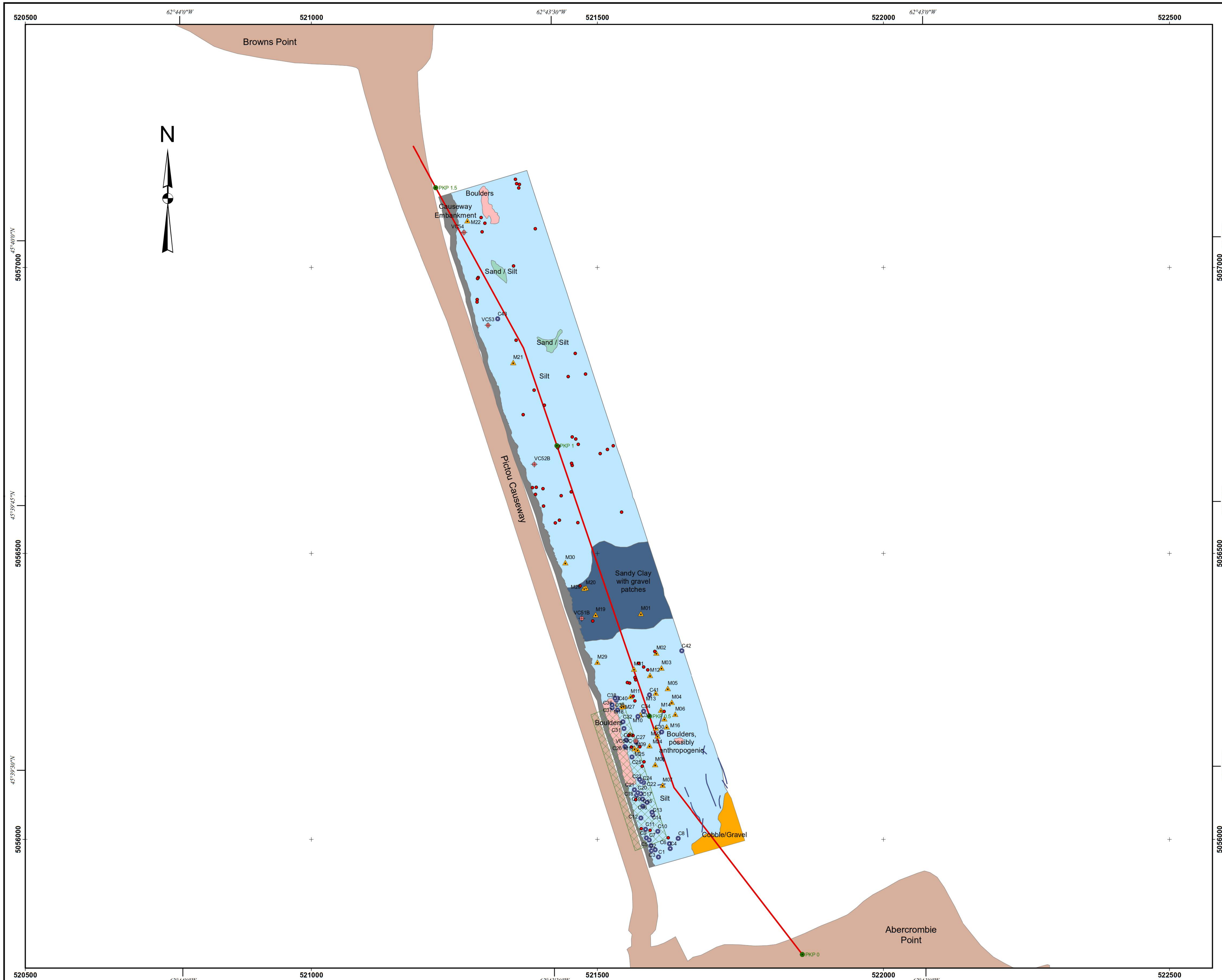
Canada B3E 1G2
Tel: (902) 827-4200 Fax: (902) 827-2002
Email: info@csr-marine.com

ENGINEERING AND ENVIRONMENTAL GEOPHYSICS

2019 Geophysical and Geotechnical Survey
Pictou Bathymetry Map
North-Up Map Sheet 1
Enclosure 1

REV	DATE	REMARK	INTERPRETED BY	COMPILED BY	CHECKED BY
0	Aug 8, 2019	Draft	MS	MW	PC
1	Aug 16, 2019	Draft	MS	MW	PC
2	Aug 23, 2019	Final	MS	MW	PC

SCALE: 1:2500	PROJECTION: UTM 20
CSR PROJECT # : 1806	FILE: CSR1806_BAT_ENC_1_20190823



KEY MAP

LEGEND

- Proposed pipeline route
- Adjacent map sheet
- Ice scour
- Vibracore location
- Grab sample location
- Magnetic anomaly location
- Anthropogenic contact
- Point source reflector (probable boulder > 1m dia.)
- KP Location
- Abercrombie Wildlife Management Area

Surficial Geology

- Causeway Embankment
- Boulders
- Cobble / Gravel
- Sand / Silt
- Silt
- Sandy Clay
- Sediment transport features

NOTES

FIELD SURVEY

CSR GeoSurveys Ltd. conducted geophysical and geotechnical surveys during April and May, 2019.

SURVEY EQUIPMENT

Vessel:	SeaQuest / Nova Endeavor
Positioning System:	Trimble 5700/5800, Hemisphere R110 DGPS
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Vibracore System:	Rossfelder P-3C Vibracorer
Survey Navigation System:	Hypack
Multibeam Acquisition System:	Hysweep & Teledyne-RESON Seabat UI
Sonar Acquisition System:	SonarPro

BASEMAP

Horizontal Datum:	NAD83 CSRS
Projection:	Universal Transverse Mercator (Zone 20N)
Vertical Datum:	Chart Datum (LLWLT)
Horizontal Scale:	1:2500
Units:	Metres

BACKGROUND

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1:2,500

0 25 50 100 150 200 250 300 m

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Email: info@csr-marine.com

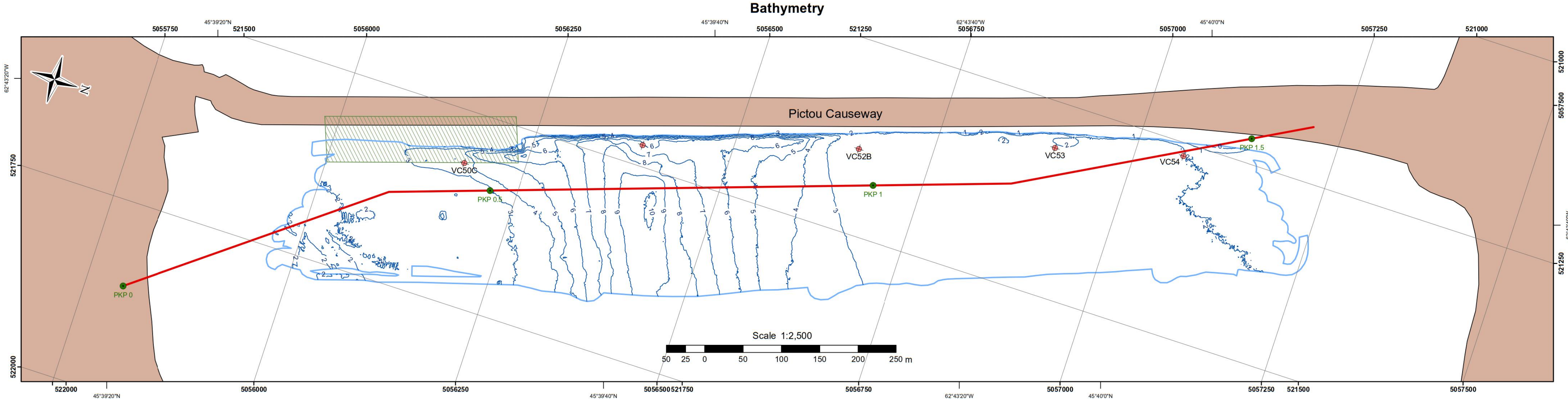
ENGINEERING AND ENVIRONMENTAL GEOPHYSICS

2019 Geophysical and Geotechnical Survey
Pictou Harbour Surficial Geology Map
North-Up Map Sheet 2
Enclosure 2

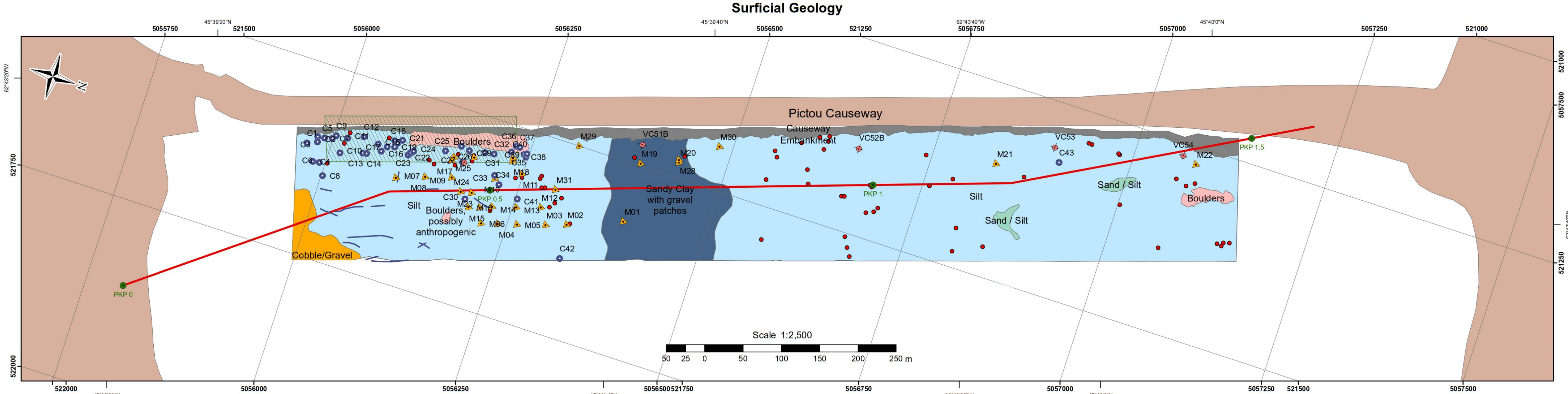
REV	DATE	REMARK	INTERPRETED BY	COMPILED BY	CHECKED BY
0	Aug 8, 2019	Draft	LM MS	MW	PC
1	Aug 16, 2019	Draft	LM MS	MW	PC
2	Aug 23, 2019	Final	LM MS	MW	PC

SCALE: 1:2500	PROJECTION: UTM 20
CSR PROJECT # : 1806	FILE: CSR1806_SURF_ENC_2_20190823

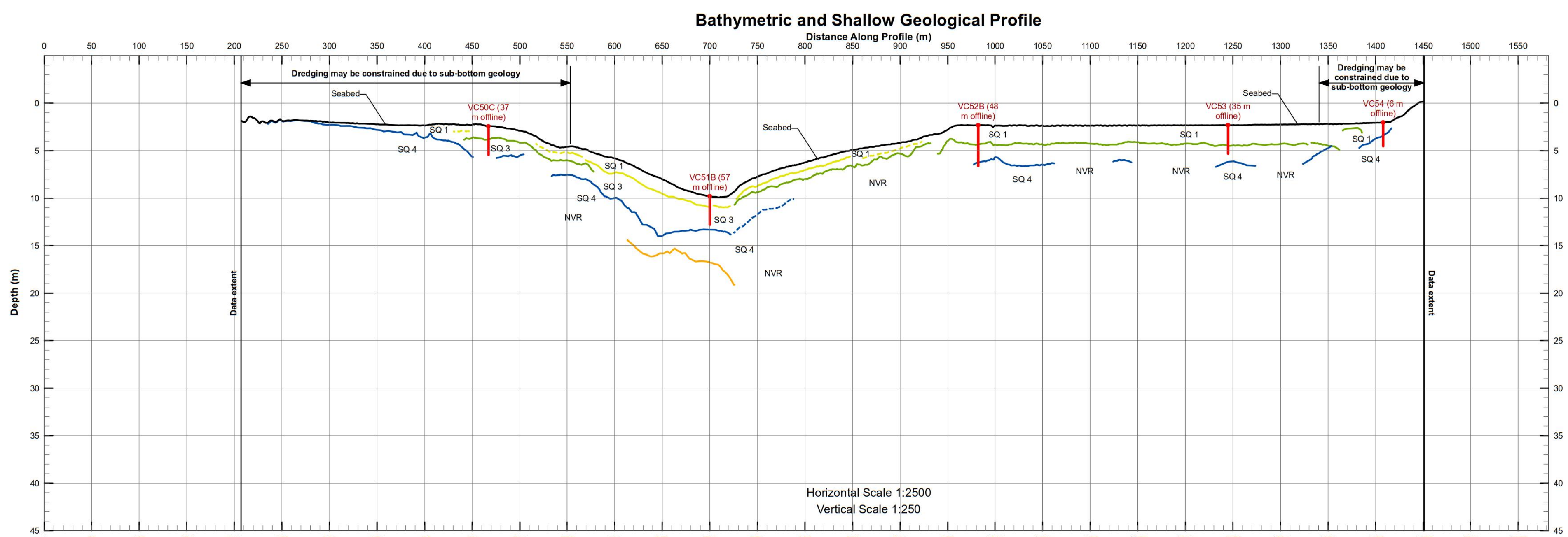
Bathymetry



Surficial Geology



Bathymetric and Shallow Geological Profile



KEY MAP

BATHYMETRY LEGEND

- Proposed pipeline route
- Bathymetric contour (1 m intervals)
- Bathymetric contour extent
- Adjacent map sheet
- KP Location
- Vibracore location
- Grab sample location
- Abercrombie Wildlife Management Area

SURFICIAL GEOLOGY LEGEND

- Proposed pipeline route
- Ice scour
- Adjacent map sheet
- Vibracore location
- Grab sample location
- Magnetic anomaly location
- Anthropogenic contact
- Point source reflector (probable boulder > 1m dia.)
- KP Location
- Abercrombie Wildlife Management Area

Surficial Geology

- Causeway Embankment
- Boulders
- Cobble / Gravel
- Sand / Silt
- Silt
- Sandy Clay
- Sediment transport features

PROFILE LEGEND

Sub-bottom Reflectors

- R1 -Top of proglacial sediments (SQ 3a)
- R2 -Top of proglacial sediments (SQ 3b)
- R3 -Top of glacial till (SQ 4)
- Top of clay (SQ 3a)
- Bottom of clay (SQ 3a)
- AB - Acoustic basement
- Top of shallow gas

Sub-bottom Sequences

- Sequence 1 = SQ 1
- Sequence 2 = SQ 2
- Sequence 3a = SQ 3a
- Sequence 3b = SQ 3b
- Sequence 4 = SQ 4
- NVR = No Visible Reflector

Note: Solid line indicates data 0 to 20 m from proposed route. Dashed line indicates data 20 to 35 m from proposed route. See report for detailed information on sub-bottom reflectors and geological sequences.

NOTES

FIELD SURVEY

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SURVEY EQUIPMENT

Vessel:	SeaQuest / Nova Endeavor
Positioning System:	Trimble 5700/5800, Hemisphere R110 DGPS
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Motion Sensor:	SBG Ekinox D
Sound Velocity:	Teledyne-RESON Odom Digibar
Tide Gauge:	RTK Tides - CAN NET
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Sub-bottom Systems:	Klein 3310 Chirp (2-8 kHz) EG&G 240 Boomer System
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Vibracore System:	Rossfelder P-3C Vibracorer
Survey Navigation System:	Hypack
Multibeam Acquisition System:	Hysweep & Teledyne-RESON Seabat UI
Sonar Acquisition System:	SonarPro

BASEMAP

Horizontal Datum:	NAD83 CSRS
Projection:	Universal Transverse Mercator (Zone 20N)
Vertical Datum:	Chart Datum (LLWLT)
Horizontal Scale:	1:2500
Units:	Metres

BACKGROUND

The shoreline was digitized from CHS charts 443701, 448301 and 448302 and is considered approximate.

The Abercrombie Wildlife Management Area outline was obtained online at https://geonova.novascotia.ca.

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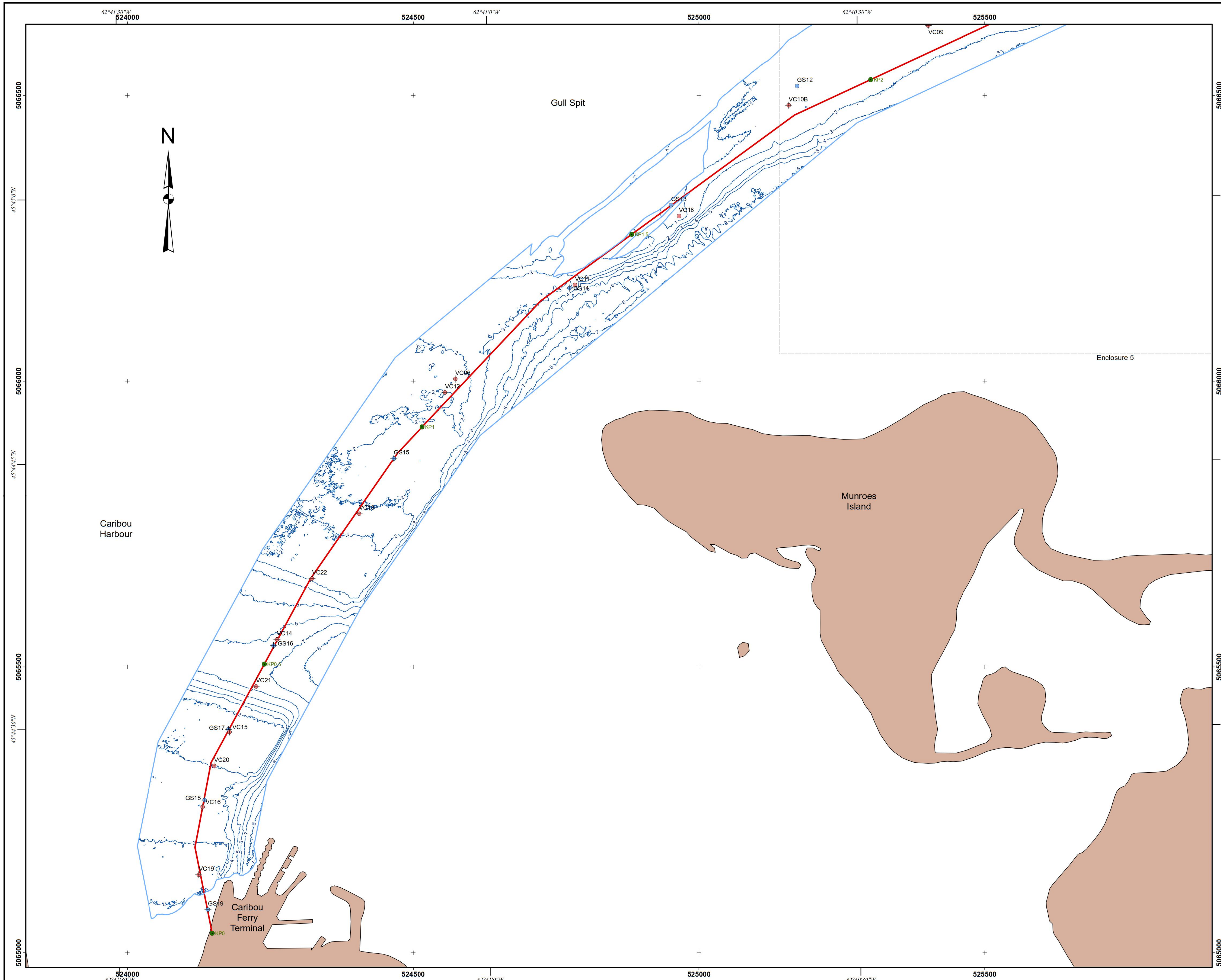
ENGINEERING AND ENVIRONMENTAL GEOPHYSICS

2019 Geophysical and Geotechnical Survey
Pictou Harbour
Alignment Sheet 1
Enclosure 3

REV	DATE	REMARK	INTERPRETED BY	COMPILED BY	CHECKED BY
0	Aug. 14, 2019	Draft	AD MS LM CT	MW	PC
1	Aug 23, 2019	Final	AD MS LM CT	MW	PC

SCALE: 1:2500	PROJECTION: UTM 20
CSR PROJECT # : 1806	FILE: CSR1806_Align_ENC_3_20190823



KEY MAP

LEGEND

- Proposed pipeline route
- Bathymetric contour (1 m intervals)
- Bathymetric contour extent
- Adjacent map sheet
- Vibracore location
- Grab sample location
- KP Location
- Abercrombie Wildlife Management Area

NOTES

FIELD SURVEY

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Survey Navigation System:	Hypack
Multibeam Acquisition System:	Hysweep & Teledyne-RESON Seabat UI
Sonar Acquisition System:	SonarPro

BASEMAP

Horizontal Datum:	NAD83 CSRS
Projection:	Universal Transverse Mercator (Zone 20N)
Vertical Datum:	Chart Datum (LLWLT)
Horizontal Scale:	1:2500
Units:	Metres

BACKGROUND

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1:2,500

0 25 50 100 150 200 250 300 m

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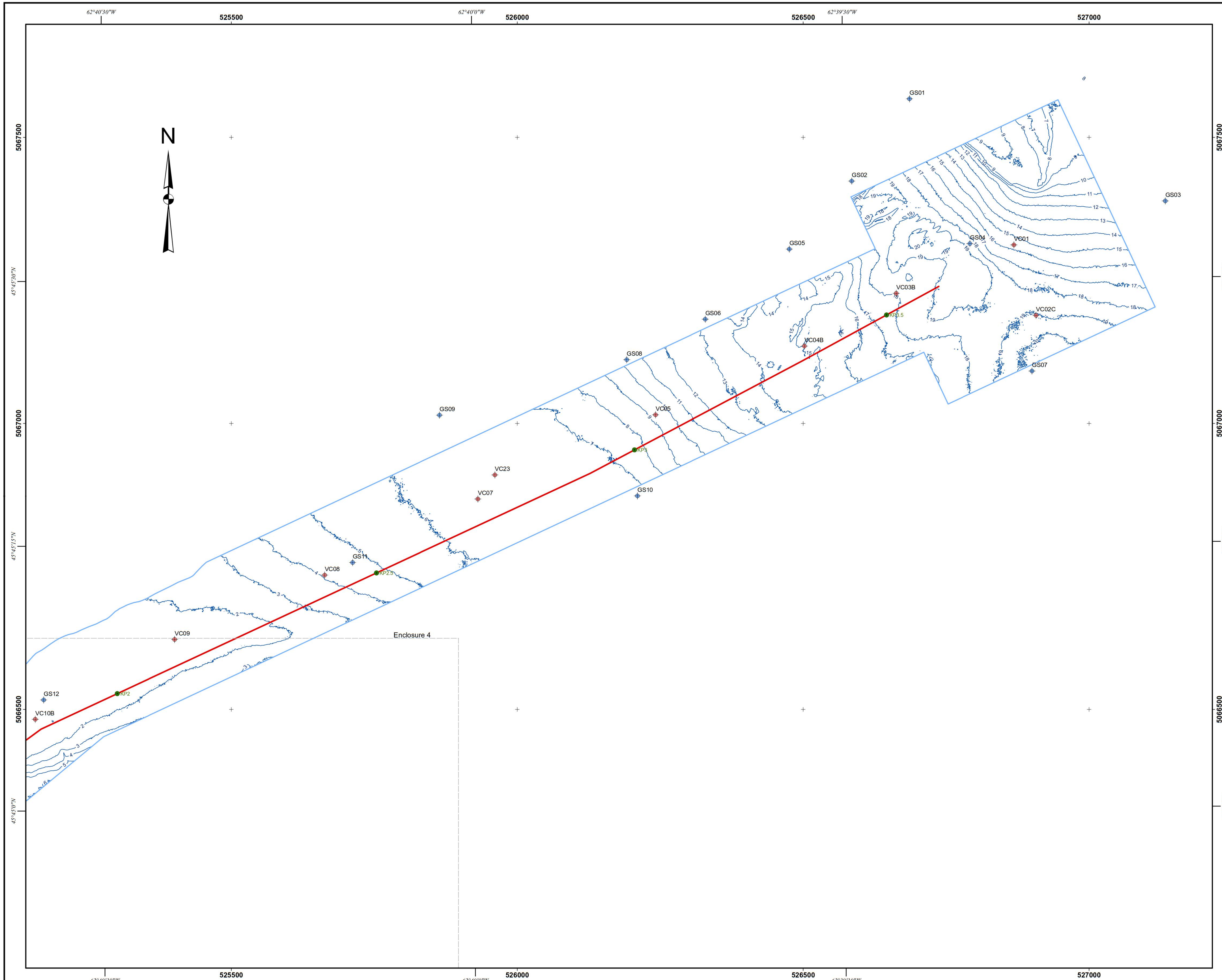
ENGINEERING AND ENVIRONMENTAL GEOPHYSICS

2019 Geophysical and Geotechnical Survey
Caribou Harbour Nearshore Bathymetry Map
North-Up Map Sheet 3
Enclosure 4

REV	DATE	REMARK	INTERPRETED BY	COMPILED BY	CHECKED BY
0	Aug 8, 2019	Draft	MS	MW	PC
1	Aug 16, 2019	Draft	MS	MW	PC
2	Aug 23, 2019	Final	MS	MW	PC

SCALE: 1:2500	PROJECTION: UTM 20
CSR PROJECT # : 1806	FILE: CSR1806_BAT_ENC_4_20190823



KEY MAP

LEGEND

- Proposed pipeline route
- Bathymetric contour (1 m intervals)
- Bathymetric contour extent
- Adjacent map sheet
- Vibracore location
- Grab sample location
- KP Location
- Abercrombie Wildlife Management Area

NOTES

FIELD SURVEY

CSR GeoSurveys Ltd. conducted geophysical and geotechnical surveys during April and May, 2019.

SURVEY EQUIPMENT

Vessel:	SeaQuest / Nova Endeavor
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Motion Sensor:	SBG Ekinox D
Sound Velocity:	Teledyne-RESON Odom Digibar
Tide Gauge:	RTK Tides - CAN NET
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Survey Navigation System:	Hypack
Multibeam Acquisition System:	Hysweep & Teledyne-RESON Seabat UI
Sonar Acquisition System:	SonarPro

BASEMAP

Horizontal Datum:	NAD83 CSRS
Projection:	Universal Transverse Mercator (Zone 20N)
Vertical Datum:	Chart Datum (LLWLT)
Horizontal Scale:	1:2500
Units:	Metres

BACKGROUND

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The Abercrombie Wildlife Management Area outline was obtained online at https://geonova.novascotia.ca.

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1:2,500

0 25 50 100 150 200 250 300 m

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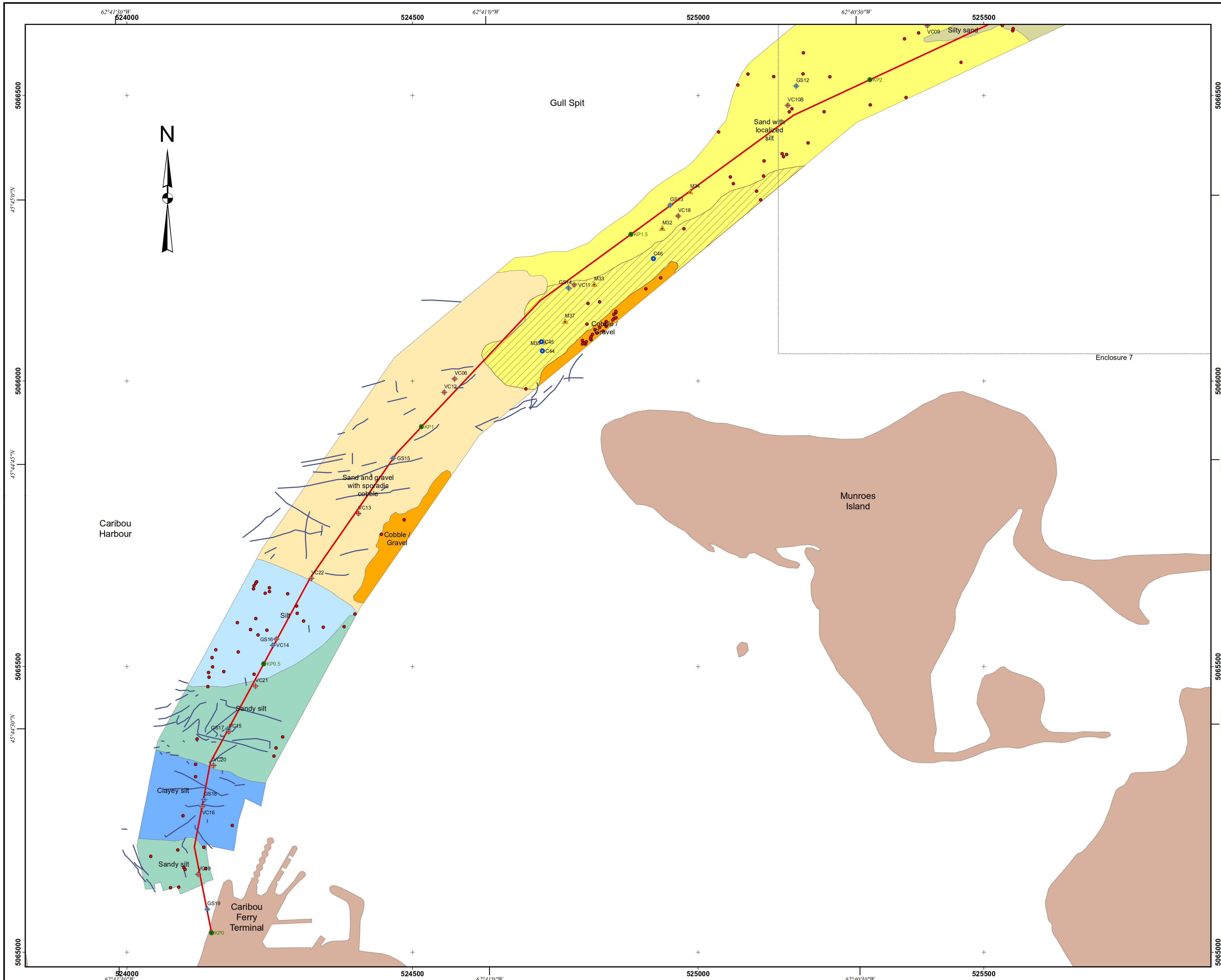
Email: info@csr-marine.com

ENGINEERING AND ENVIRONMENTAL GEOPHYSICS

2019 Geophysical and Geotechnical Survey
Caribou Harbour Offshore Bathymetry Map
North-Up Map Sheet 4
Enclosure 5

REV	DATE	REMARK	INTERPRETED BY	COMPILED BY	CHECKED BY
0	Aug 8, 2019	Draft	MS	MW	PC
1	Aug 16, 2019	Draft	MS	MW	PC
2	Aug 23, 2019	Final	MS	MW	PC

SCALE: 1:2500	PROJECTION: UTM 20
CSR PROJECT # : 1806	FILE: CSR1806_BAT_ENC_5_20190823



KEY MAP

LEGEND

- Proposed pipeline route
- Adjacent map sheet
- Ice scour
- Vibracore location
- Grab sample location
- Magnetic anomaly location
- Anthropogenic contact
- Point source reflector (probable boulder > 1m dia.)
- KP Location
- Abercrombie Wildlife Management Area

Surficial Geology

- Cobble / Gravel
- Sand and Gravel
- Sand
- Silty Sand
- Sandy Silt
- Silt
- Clayey Silt
- Sediment transport features

NOTES

FIELD SURVEY

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Vibracore System:	Rossfelder P-3C Vibracorer
Survey Navigation System:	Hypack
Multibeam Acquisition System:	Hysweep & Teledyne-RESON Seabat UI
Sonar Acquisition System:	SonarPro

BASEMAP

Horizontal Datum:	NAD83 CSRS
Projection:	Universal Transverse Mercator (Zone 20N)
Vertical Datum:	Chart Datum (LLWLT)
Horizontal Scale:	1:2500
Units:	Metres

BACKGROUND

The shoreline was digitized from CHS charts 443701, 448301 and 448302 and is considered approximate.

The Abercrombie Wildlife Management Area outline was obtained online at https://geonova.novascotia.ca.

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1:2,500

0 25 50 100 150 200 250 300 m

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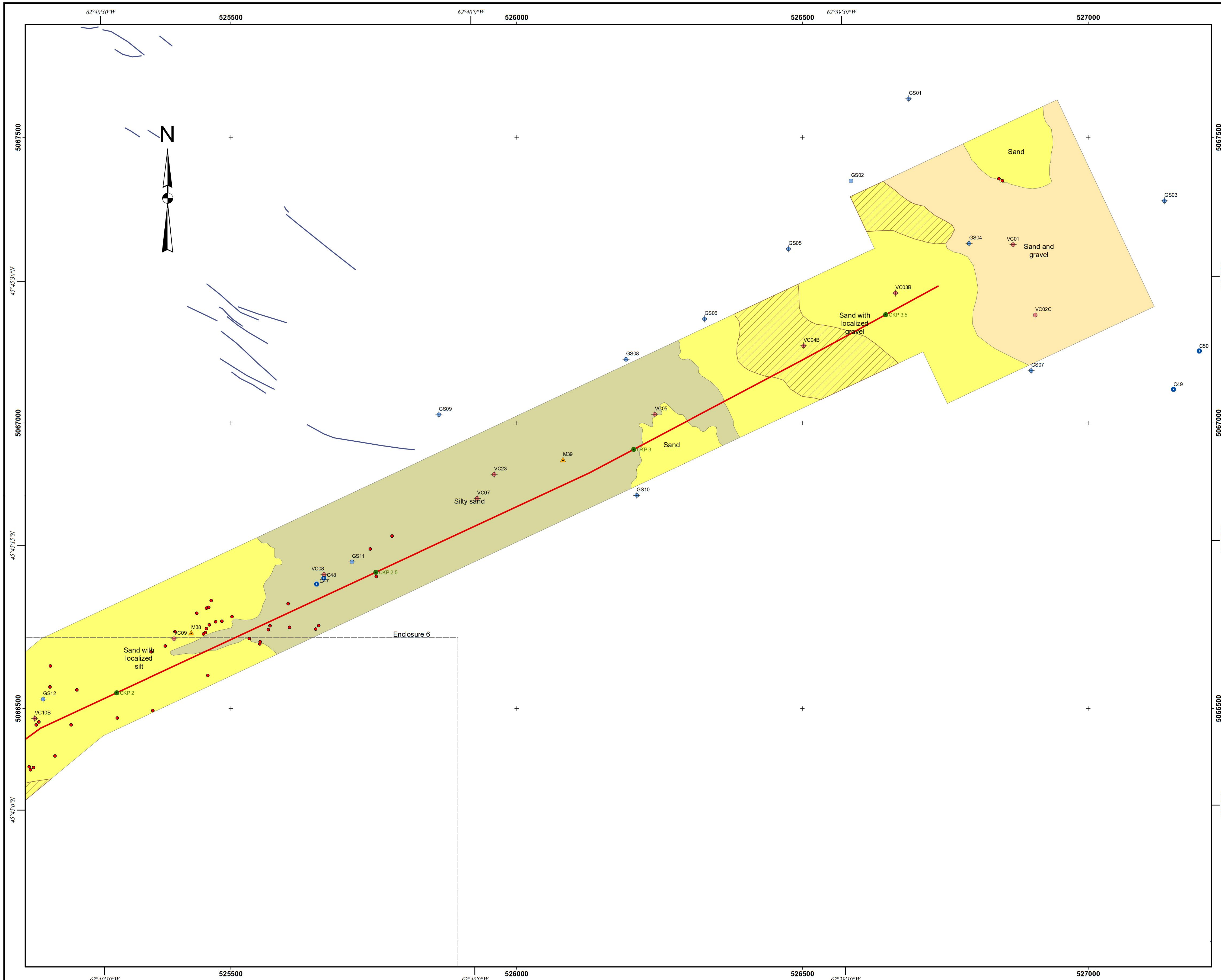
ENGINEERING AND ENVIRONMENTAL GEOPHYSICS

2019 Geophysical and Geotechnical Survey
Caribou Harbour Nearshore Surficial Geology Map
North-Up Map Sheet 5
Enclosure 6

REV	DATE	REMARK	INTERPRETED BY	COMPILED BY	CHECKED BY
0	Aug 8, 2019	Draft	LM MS	MW	PC
1	Aug 16, 2019	Draft	LM MS	MW	PC
2	Aug 23, 2019	Final	LM MS	MW	PC

SCALE: 1:2500	PROJECTION: UTM 20
CSR PROJECT # : 1806	FILE: CSR1806_SURF_ENC_6_20190823



KEY MAP

LEGEND

- Proposed pipeline route
- Adjacent map sheet
- Ice scour
- Vibracore location
- Grab sample location
- Magnetic anomaly location
- Anthropogenic contact
- Point source reflector (probable boulder > 1m dia.)
- KP Location
- Abercrombie Wildlife Management Area

Surficial Geology

- Cobble / Gravel
- Sand and Gravel
- Sand
- Silty Sand
- Sandy Silt
- Silt
- Clayey Silt
- Sediment transport features

NOTES

FIELD SURVEY

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SURVEY EQUIPMENT

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Sound Velocity:	Teledyne-RESON Odom Digibar
Tide Gauge:	RTK Tides - CAN NET
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Grab Sampler:	Van Veen Petite Ponar
Vibracore System:	Rossfelder P-3C Vibracorer
Survey Navigation System:	Hypack
Multibeam Acquisition System:	Hysweep & Teledyne-RESON Seabat UI
Sonar Acquisition System:	SonarPro

BASEMAP

Horizontal Datum:	NAD83 CSRS
Projection:	Universal Transverse Mercator (Zone 20N)
Vertical Datum:	Chart Datum (LLWLT)
Horizontal Scale:	1:2500
Units:	Metres

BACKGROUND

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1:2,500

0 25 50 100 150 200 250 300 m

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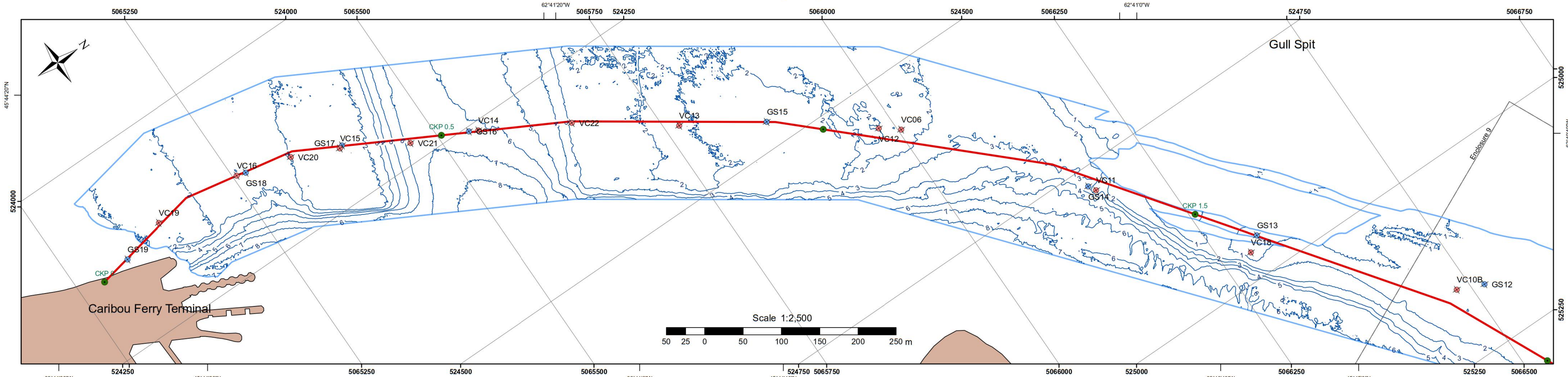
ENGINEERING AND ENVIRONMENTAL GEOPHYSICS

2019 Geophysical and Geotechnical Survey Caribou Harbour Offshore Surficial Geology Map North-Up Map Sheet 6 Enclosure 7

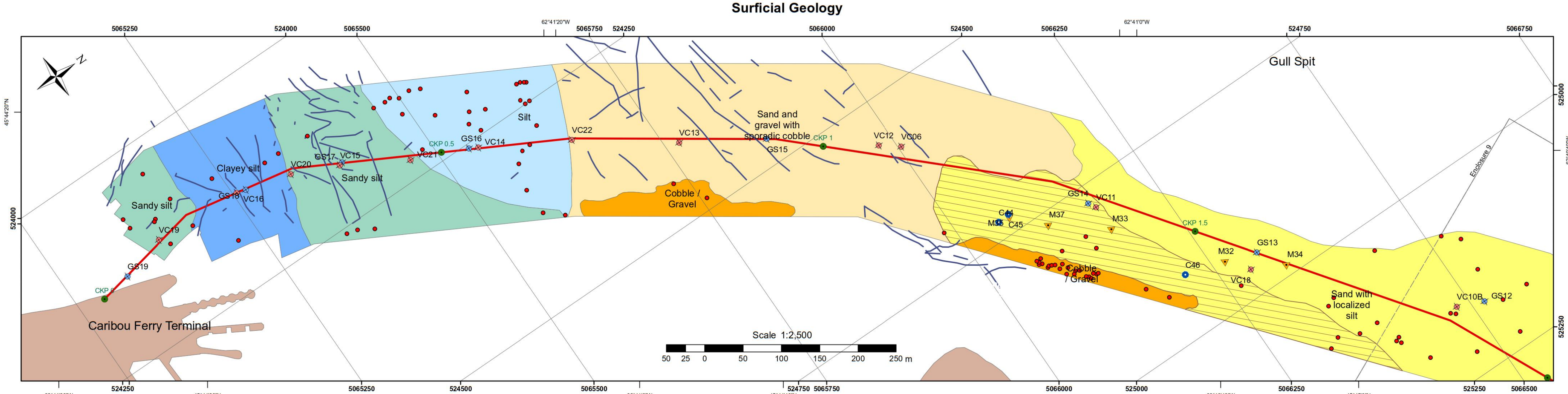
REV	DATE	REMARK	INTERPRETED BY	COMPILED BY	CHECKED BY
0	Aug 8, 2019	Draft	LM MS	MW	PC
1	Aug 16, 2019	Draft	LM MS	MW	PC
2	Aug 23, 2019	Final	LM MS	MW	PC

SCALE: 1:2500	PROJECTION: UTM 20
CSR PROJECT # : 1806	FILE: CSR1806_SURF_ENC_7_20190823

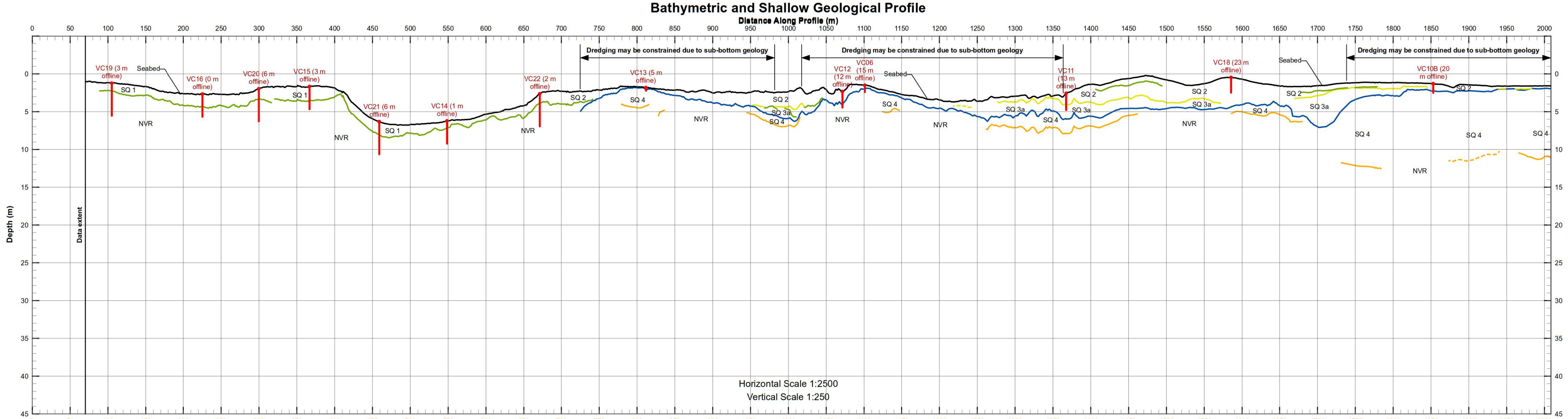
Bathymetry



Surficial Geology



Bathymetric and Shallow Geological Profile



KEY MAP

BATHYMETRY LEGEND

- Proposed pipeline route
- Bathymetric contour (1 m intervals)
- Bathymetric contour extent
- Adjacent map sheet
- KP Location
- Vibracore location
- Grab sample location
- Abercrombie Wildlife Management Area

SURFICIAL GEOLOGY LEGEND

- Proposed pipeline route
- Ice scour
- Adjacent map sheet
- Vibracore location
- Grab sample location
- Magnetic anomaly location
- Anthropogenic contact
- Point source reflector (probable boulder > 1m dia.)
- KP Location
- Abercrombie Wildlife Management Area

Surficial Geology

- Cobble / Gravel
- Sand and Gravel
- Sand
- Silty Sand
- Sandy Silt
- Silt
- Clayey Silt
- Sediment transport features

PROFILE LEGEND

Sub-bottom Reflectors

- R1 -Top of proglacial sediments (SQ 3a)
- R2 -Top of proglacial sediments (SQ 3b)
- R3 -Top of glacial till (SQ 4)
- Top of clay (SQ 3a)
- Bottom of clay (SQ 3a)
- AB - Acoustic basement
- Top of shallow gas

Sub-bottom Sequences

- Sequence 1 = SQ 1
- Sequence 2 = SQ 2
- Sequence 3a = SQ 3a
- Sequence 3b = SQ 3b
- Sequence 4 = SQ 4
- NVR = No Visible Reflector

Note: Solid line indicates data 0 to 20 m from proposed route. Dashed line indicates data 20 to 35 m from proposed route. See report for detailed information on sub-bottom reflectors and geological sequences.

NOTES

FIELD SURVEY

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SURVEY EQUIPMENT

Vessel:	SeaQuest / Nova Endeavor
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Sonar Acquisition System:	SonarPro

BASEMAP

Horizontal Datum:	NAD83 CSRS
Projection:	Universal Transverse Mercator (Zone 20N)
Vertical Datum:	Chart Datum (LLWLT)
Horizontal Scale:	1:2500
Units:	Metres

BACKGROUND

The shoreline was digitized from CHS charts 443701, 448301 and 448302 and is considered approximate.

The Abercrombie Wildlife Management Area outline was obtained online at https://geonova.novascotia.ca.

PREPARED FOR

NORTHERN PULP
NOVA SCOTIA CORPORATION
A PAPER EXCELLENCE COMPANY

CSR GeoSurveys Ltd.
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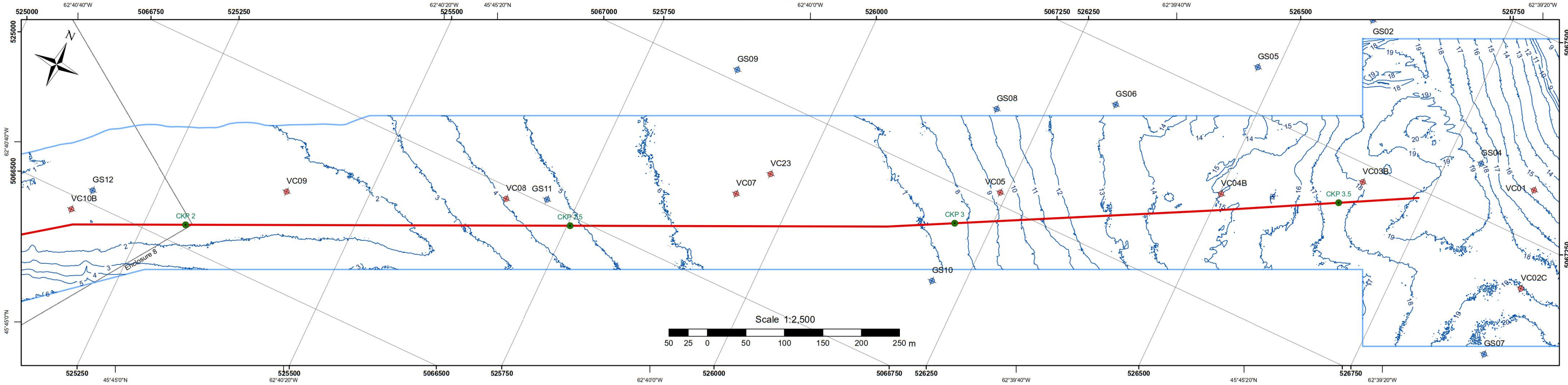
ENGINEERING AND ENVIRONMENTAL GEOPHYSICS

2019 Geophysical and Geotechnical Survey
Caribou Harbour Nearshore
Alignment Sheet 2
Enclosure 8

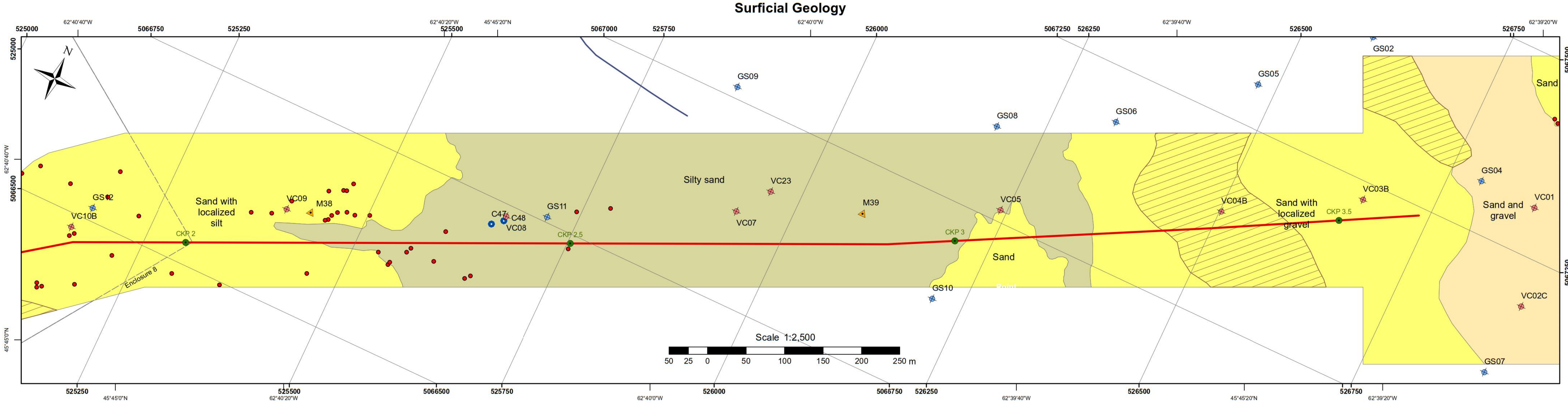
REV	DATE	REMARK	INTERPRETED BY	COMPILED BY	CHECKED BY
0	Aug. 14, 2019	Draft	AD MS LM CT	MW	PC
1	Aug 23, 2019	Final	AD MS LM CT	MW	PC

SCALE: 1:2500	PROJECTION: UTM 20
CSR PROJECT # : 1806	FILE: CSR1806_Align_ENC_8_20190823

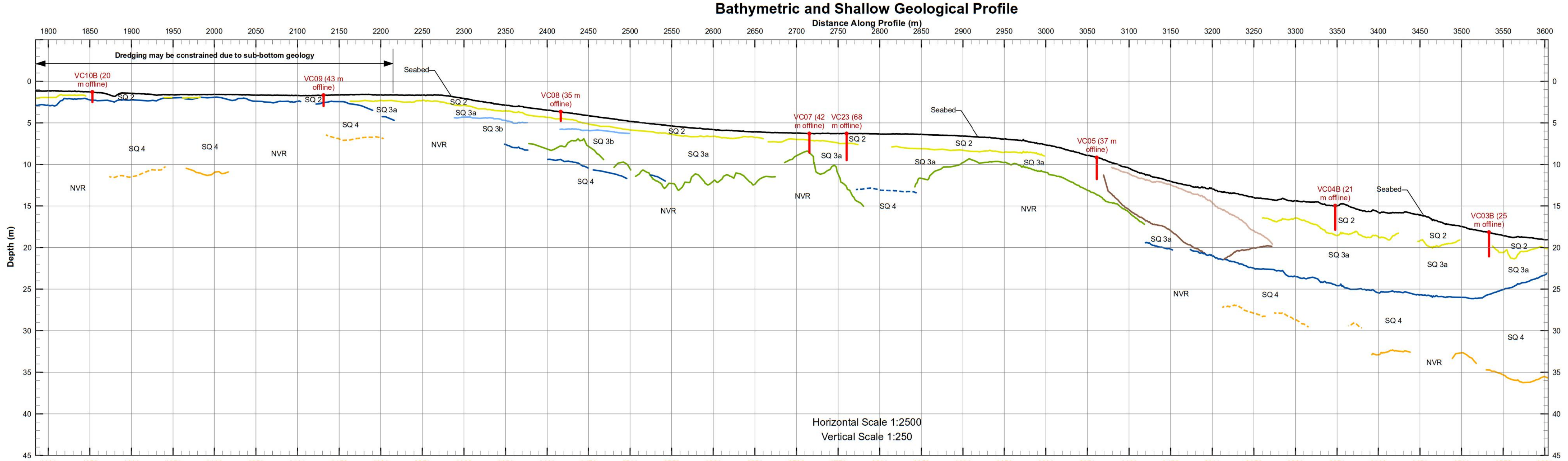
Bathymetry



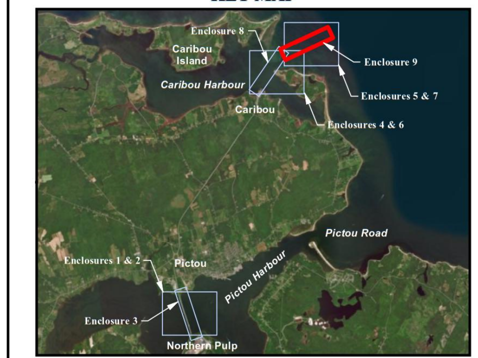
Surficial Geology



Bathymetric and Shallow Geological Profile



KEY MAP



BATHYMETRY LEGEND

- Proposed pipeline route
- Bathymetric contour (1 m intervals)
- Bathymetric contour extent
- Adjacent map sheet
- KP Location
- Vibracore location
- Grab sample location
- Abercrombie Wildlife Management Area

SURFICIAL GEOLOGY LEGEND

- Proposed pipeline route
- Ice scour
- Adjacent map sheet
- Vibracore location
- Grab sample location
- Magnetic anomaly location
- Anthropogenic contact
- Point source reflector (probable boulder > 1m dia.)
- KP Location
- Abercrombie Wildlife Management Area

Surficial Geology

- Cobble / Gravel
- Sand and Gravel
- Sand
- Silty Sand
- Sandy Silt
- Silt
- Clayey Silt
- Sediment transport features

PROFILE LEGEND

Sub-bottom Reflectors

- R1 -Top of proglacial sediments (SQ 3a)
- R2 -Top of proglacial sediments (SQ 3b)
- R3 -Top of glacial till (SQ 4)
- Top of clay (SQ 3a)
- Bottom of clay (SQ 3a)
- AB - Acoustic basement
- Top of shallow gas

Sub-bottom Sequences

- Sequence 1 = SQ 1
- Sequence 2 = SQ 2
- Sequence 3a = SQ 3a
- Sequence 3b = SQ 3b
- Sequence 4 = SQ 4
- NVR = No Visible Reflector

Note: Solid line indicates data 0 to 20 m from proposed route. Dashed line indicates data 20 to 35 m from proposed route. See report for detailed information on sub-bottom reflectors and geological sequences.

NOTES

FIELD SURVEY

CSR GeoSurveys Ltd. conducted geophysical and geotechnical surveys during April and May, 2019.

SURVEY EQUIPMENT

Vessel:	SeaQuest / Nova Endeavor
Positioning System:	Trimble 5700/5800, Hemisphere R110 DGPS
Positioning/Heading System:	Hemisphere VS-330 GNSS SBG Ekinox D
Multibeam Echosounder:	Teledyne-RESON T-20P (200-400 kHz)
Motion Sensor:	SBG Ekinox D
Sound Velocity:	Teledyne-RESON Odom Digibar
Tide Gauge:	RTK Tides - CAN NET
Sidescan Sonar System:	Klein 3000 (100 kHz and 500 kHz)
Sub-bottom Systems:	Klein 3310 Chirp (2-8 kHz) EG&G 240 Boomer System
Seismic Refraction:	Pro-Seismic 24 channel marine cable with Geometrics Geode Seismic Recorder
Grab Sampler:	Van Veen Petite Ponar
Vibracore System:	Rossfelder P-3C Vibracorer
Survey Navigation System:	Hypack
Multibeam Acquisition System:	Hysweep & Teledyne-RESON Seabat UI
Sonar Acquisition System:	SonarPro

BASEMAP

Horizontal Datum:	NAD83 CSRS
Projection:	Universal Transverse Mercator (Zone 20N)
Vertical Datum:	Chart Datum (LLWLT)
Horizontal Scale:	1:2500
Units:	Metres

BACKGROUND

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ENGINEERING AND ENVIRONMENTAL GEOPHYSICS

2019 Geophysical and Geotechnical Survey
Caribou Harbour Offshore
Alignment Sheet 3
Enclosure 9

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