Lake Manitoba & Lake St. Martin Outlet Channels Project

Aquatic Environment Monitoring, 2021 - Aquatic Habitat

REPORT

Prepared for Manitoba Transportation and Infrastructure
By North/South Consultants Inc. • 83 Scurfield Blvd. • Winnipeg, MB

Lake Manitoba & Lake St. Martin Outlet Channels Project

Aquatic Environment Monitoring 2021

Aquatic Habitat in Birch Bay and The Narrows of Lake St. Martin

A Report Prepared for

Manitoba Transportation and Infrastructure

By:

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EXECUTIVE SUMMARY

North/South Consultants Inc. (NSC) was retained by Manitoba Transportation and Infrastructure (MTI) to collect supplemental data with respect to the aquatic environment in support of the Lake Manitoba and Lake St. Martin Outlet Channel Project (the Project). A draft Aquatic Effects Monitoring Program (AEMP) was developed in 2020 and revised in late 2021 to provide a plan for monitoring the effects of the Project on the aquatic environment, focusing on key issues identified during the environmental assessment. To support specific monitoring studies presented within the AEMP, targeted studies to collect data to supplement existing information are required.

This report presents the results of aquatic habitat studies that were conducted during September 25-28, 2021, to provide more detailed pre-construction habitat data for selected sites in the Birch Bay and The Narrows areas in Lake St. Martin. Sites were selected to represent key habitats that might be altered due to Project effects, including sediment deposition (Birch Bay) and scouring (The Narrows). Surveys were conducted using a suite of methods including single beam, multi-beam and side scan sonar technologies, underwater videography and collection of substrate samples. Substrate composition was interpreted from sonar data, qualitative assessment of substrate grab samples, underwater videography, laboratory analysis of substrate samples from selected locations, and examination of satellite imagery. Shoreline observations of substrate conditions recorded in The Narrows on June 10, 2021 were also used.

Water level on Lake St. Martin was low during 2021, approximately equalling the 7th percentile water level condition observed during 1966-2017. The low water level restricted navigation by boat and use of sonar equipment within The Narrows and, consequently, limited the ability to collect habitat data from areas peripheral to the central channel. The survey included substrate sample collection and visual observations of substrate composition at 16 locations in The Narrows and collection of single beam and multi-beam sidescan acoustic data along a single 7 km long transect between sampling sites. The information collected supplements previously collected data and provides a better understanding of substrate and overall habitat conditions within The Narrows. However, low water level restricted access to much of the area, and survey coverage was not sufficient to produce aquatic habitat maps accurate enough to allow for quantitative spatial assessment. Additional baseline habitat data will need to be collected prior to commissioning of the Permanent Outlet Channels (POCs) to provide a basis for comparison to future conditions in The Narrows.

Single-beam echosounder (SBES), multibeam echosounder (MBES), and side scan sonar (SSS) acoustic data characterizing aquatic habitat characteristics (water depth, substrate classification, and occurrence of aquatic vegetation) were collected at eight habitat monitoring areas in Birch Bay. Acoustic sampling resolution (i.e., spacing between transects) was such that SSS imagery covered 90% or more of each of the habitat survey areas. The high level of survey coverage combined with substrate validation sampling and laboratory analysis of sediment samples provides a highly detailed description of substrates, as well as water depth and the presence/distribution of aquatic vegetation, within the survey areas.

Future habitat monitoring activities in Birch Bay related to POC construction and operation will include repeated surveys replicating the methods and survey areas used in this study. Data collected here will be integral towards determining shifts in substrate that may be related to POC commissioning and operation.

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ACRONYMS

AEMP	Aquatic Effects Monitoring Program
EIS	Environmental Impact Statement
FRWCS	Fairford Water Control Structure
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
LMOC	Lake Manitoba Outlet Channel
LSMOC	Lake St. Martin Outlet Channel
MBES	Multibeam Echosounder
MTI	Manitoba Transportation and Infrastructure
NSC	North/South Consultants Inc.
PSA	Particle Size Analysis
QA/QC	Quality Assurance/Quality Control
SBES	Single Beam Echosounder
SSS	Sidescan Sonar

1.0 INTRODUCTION

North/South Consultants Inc. (NSC) was retained by Manitoba Transportation and Infrastructure (MTI) to collect supplemental data with respect to the aquatic environment in support of the Lake Manitoba and Lake St. Martin Outlet Channel Project (the Project). The proposed Project is designed to manage flood waters on Lake Manitoba and Lake St. Martin by providing constructed channels (the Permanent Outlet Channels or POCs) by which flood waters can be conveyed, in addition to the natural outflow via the Fairford and Dauphin rivers (Figure 1). The Project consists of two outlet channels that are intended to work together:

- The 24 km Lake Manitoba Outlet Channel (LMOC) will work in tandem with the existing water control structure on the Fairford River (the Fairford Water Control Structure or FRWCS) to help regulate water levels and mitigate flooding on Lake Manitoba; and
- The 24 km Lake St. Martin Outlet Channel (LSMOC) will restore a more natural water regime to Lake St. Martin and will also provide flood protection by mitigating increased inflows from operation of the FRWCS, as well as additional inflows from the LMOC.

A draft Aquatic Effects Monitoring Program (AEMP) was developed in 2020 and subsequently revised to provide a plan for monitoring the effects of the Project on the aquatic environment, focusing on key issues identified during the environmental assessment. The specific objectives of the AEMP were to:

- Verify the predicted effects to surface water quality and fish and fish habitat identified during the environmental assessment;
- Determine the effectiveness of mitigation measures;
- Assess the need for additional mitigation measures if initial measures are not adequate;
- Determine the effectiveness of any additional/adapted measure(s); and
- Confirm compliance with regulatory requirements relevant to surface water quality and fish and fish habitat set out in the Project approvals (e.g., Manitoba Environment Act License; *Fisheries Act* Authorization).

To support specific monitoring studies presented within the AEMP, targeted studies to collect data to supplement existing information are required

Recent hydrological modelling has illustrated the spatial extent over which sediments will be deposited during channel operations. Further, modelling has indicated an increase in water velocity through The Narrows between the north and south basins of Lake St. Martin during channel operations, which may increase substrate erosion in the area. Additional detailed information describing existing substrate conditions in areas of anticipated sediment deposition and in areas of potential erosion is required to monitor potential substrate changes and understand what potential substrate changes may mean to fish using those areas. For example, it is known that The Narrows provides spawning habitat for Lake Whitefish (*Coregonus clupeaformis*) and it will be important to know whether substrate changes occur due to POC operation, and what those changes may mean to spawning whitefish.

This report provides results of surveys to collect supplemental detailed habitat data from selected areas near the LMOC inflow to Lake St. Martin and in The Narrows between the north and south basins of Lake St. Martin (Figure 1). Additional high detail habitat data will be collected from near the LSMOC inflow to Sturgeon Bay during summer 2022; if water levels permit, habitat mapping will also be conducted at The Narrows to supplement data collected along a single transect in 2021. Survey results presented herein and the upcoming survey in Sturgeon Bay will better define pre-operation conditions and provide the basis for comparison with post-commissioning and post-operation conditions.

2.0 METHODS

Existing aquatic habitat data collected in Lake St. Martin and Sturgeon Bay and presented in the EIS was collected using a single beam echosounder (SBES) sonar system. Single beam systems collect data directly along the survey transect and map products are produced by interpolating between survey transects. The level of detail or resolution provided by a single beam system is therefore dependant upon the spacing between survey transects. Previous data collections in Lake St. Martin and Sturgeon Bay used pre-determined survey grids with spacing of 0.5-2.0 km between survey transects. The grid spacing used in those surveys was appropriate to provide an overall description of aquatic habitat, given the large area to be sampled. However, more detailed mapping is required to support aquatic habitat monitoring in areas potentially affected by the Project to confirm and document current assessment predictions of no significant effects.

Habitat mapping methods used in this study provide increased habitat detail in selected areas using a multibeam echosounder (MBES) sonar system. The multi-beam system collects continuous data across broad swaths on either side of the survey transect. By allowing overlap between swaths of adjacent transects, continuous and complete coverage of the survey area is achieved.

2.1 SITE SELECTION

Site selection for detailed habitat mapping was based on:

- The presence of substrates that are suitable for spawning in the existing environment;
- Substrates that could be altered by Project effects, either due to the deposition of fine sediments over gravel and cobble shoals in Birch Bay or by the scouring of gravel and cobble shoals in The Narrows due to increased water velocity; and
- A range of different locations, in case Project effects differ within the local area (e.g., sediments could be deposited in different locations near the outlet of the LMOC depending on prevailing winds at the time of operation).

Low water level in Lake St. Martin during 2021 precluded the use of the multi-beam sonar system in The Narrows. A shallow draft jon boat was used to navigate The Narrows area and sample sites were selected at regularly spaced intervals in accessible areas and where areas of interest were noted in satellite imagery. Single beam sonar data were collected when transiting between sample sites.

Multi-beam surveys were conducted at eight discrete sites in Birch Bay. Existing habitat data (depth and substrate), hydrological modelling results (e.g., modelled sediment plumes), and high-resolution satellite imagery were considered when selecting representative survey areas. These areas included the following (also see Figure 2):

- South Shoal Area: a small shoal in the southeastern portion of Birch Bay that was identified from satellite imagery collected under low water conditions. This site was selected because of its proximity to the LMOC outlet and its potential to support spawning fish;
- Outlet Area: the area in the immediate vicinity of the LMOC outlet. This area was selected because it will be directly affected by LMOC construction and operation;
- West Shore Area: a nearshore area of course substrates located along the west shore of Birch Bay to the north of the LMOC outlet. This area was identified during previous habitat mapping and was re-surveyed as part of this study to confirm the presence of coarse substrates at that location and because of its potential to support spawning fish;
- Deepwater Reference Area: a deep water (3.5 to 4 m) area in the middle of Birch Bay selected to represent a soft/fine substrate reference area;
- Shoal areas in the northern part of Birch Bay: Four survey areas were selected from a large area of a glacial till (cobble, gravel, and boulder) shoal complex that extends off the northeast shoreline of Birch Bay and continues towards Dillabough's Point. This area provides an abundance of potential spawning habitat for fish. Representative areas that were surveyed include:
    a. South Dillabough Shoal Area;
    b. North Dillabough Shoal Area;
    c. South East Shore Shoal Area; and
    d. North East Shore Shoal Area.

2.2 DATA COLLECTION

2.2.1 Water Level

Hourly water level data for Lake St. Martin (Station 05LM005) during 2021 were provided by the Water Survey of Canada (WSC 2022a). Historic data (1966-2017) were also acquired to calculate percentile water level conditions for the lake (WSC 2022b).

2.2.2 Acoustic Surveys

Two types of sonar were used to collect acoustic data during habitat surveys. The first, a consumer grade single beam Lowrance® Elite7 FS sonar/GPS echosounder, was used to collect depth and bottom composition data as well as sidescan sonar (SSS) imagery in The Narrows and Birch Bay. The system included a TotalScan™ transducer (83/200 kHz traditional sonar beams, as well as 455/800 kHz sidescan/downscan beams) which was fixed to the transom of the survey vessel in line with the keel. A 50 m sidescan range (100 m swath) was set for data collection on the sonar. Georeferenced digital sidescan image data and single beam sounding data were recorded by the sonar unit. Geographic positioning was

recorded using the internal geographic positioning system (GPS) Lowrance unit. Realtime sidescan digital imagery and depth information displayed on the control unit were used to assist in interpreting bottom types and rocky structure during surveys.

The second system used was a Ping DSP Inc. 3DSS-IDX-450 combined SSS and MBES. This system collects simultaneous high-resolution 3D sidescan amplitude data and swath bathymetric data (Figures 3 and 4). The useable range of sidescan imaging for this system is 10-20 times the depth below the transducer. The useable range of swath bathymetric data for this system is typically limited to 10-12 times the depth below the transducer. The system was set to collect both sidescan amplitude data and swath bathymetric data at a 50 m range (100m swath) for this study. Acoustic swath bathymetric, backscatter, and sidescan data were recorded simultaneously by navigating along transects oriented parallel to shore and spaced approximately 50 m apart.

The Ping DSP echosounder was mounted to the back port-side of the survey vessel using a custom-built mount. The transducer was positioned to sit 0.2 m below the keel of the survey vessel and was coupled to a Septentrio dual antenna GNSS receiver to provide precise positions and heading information. An integrated SBG GNSS aided inertial navigation sensor and an AML Micro-X sound velocity sensor provided additional important corrections for vessel/transducer movement and sound velocity variations. Positions of all sensors and antennae relative to each other were measured and entered into the control software so that subsequent surveys would be able to replicate the 2021 surveys. Position and navigation data were logged to separate binary files for future post-processing analyses that will allow for the direct comparison of future habitat monitoring survey data sets. The Ping DSP Inc. 3DSS-IDX-450 sonar uses proprietary software stored on a laptop computer to control the sonar, record data, and view data in real-time to ensure complete data coverage.

2.2.3 Substrate Validation

Bottom validation was conducted by collecting substrate grab samples and qualitatively assessing substrate composition, through laboratory analysis of selected grab samples and using underwater videography. The real-time side scan display from the single beam echosounder was also used to assist in the confirmation of rocky substrate and provide accurate depths at validation sites. Shoreline habitat observations taken near the downstream end of The Narrows on June 10, 2021 were used to augment substrate observations made as part of this study. The shoreline observations are summarized in Appendix 1.

Substrate grab samples were collected using a petite ponar (0.023 m^2 surface area) dredge. Photos of successful grab samples were taken using a digital camera. A handheld Garmin GPSMAP 78 was used to mark coordinates at each sampling site. Primary, secondary, and tertiary substrate types were identified at each validation site and classified according to a modified Wentworth sediment size classification (Table 1; Wentworth 1922). It should be noted that field classification of sediments smaller than sand is difficult and, although attempts were made to qualitatively determine the proportion of silts and clays present at a given site, sediment classes smaller than sand are referred to as mud (Table 1). The presence of aquatic vegetation was also noted.

At a number of sites where fine sediments were encountered, the grab samples were preserved in a Ziploc bag and refrigerated until submission to ALS Laboratories in Winnipeg, MB (a Canadian Association for Laboratory Accreditations, Inc. accredited laboratory) for sediment particle size analysis (PSA), texture classification, and organic content analysis.

A Marcum Quest HD fixed underwater drop camera was used to collect video at select substrate validation sites in the study areas. The camera was lowered over the side of the boat and location was recorded using a hand held GPS. The camera was lowered down to the lake bed, video recordings were taken and initial observations from the real-time display were recorded. Post-survey, all digital still images, videos, and coordinates were compiled into an inventory table. Each video was reviewed and further notes were recorded, with digital frames extracted and presented as report figures.

2.2.4 Satellite Imagery

Multi-spectral Sentinel-2 satellite imagery (10 m pixel resolution) representative of the low water conditions encountered in 2021 was obtained from the European Space Agency's (ESA) Copernicus Open Hub. Image data for the study area acquired on August 8 and November 9, 2021 were used to assist in habitat assessment and the production of mapping components for this report.

2.3 DATA PROCESSING AND ANALYSIS

2.3.1 Water Level

Mean daily water level was plotted for Lake St. Martin. The daily 5th, 25th, 50th,75th and 95th percentile water levels were calculated based on 1966-2017 data and used to provide historical context for water levels occurring during the aquatic habitat mapping in 2021.

2.3.2 Acoustic Data Processing

Acoustic data collected with the SBES and the 455 kHz transducer were processed with Reefmaster® software. The single beam data allows for general characterization of depth, bottom hardness, and roughness, and derivation of lakebed slope. The bottom depth picked during data collection was reviewed for completeness, false picks due to noise and any other acoustic anomalies that may have occurred during data acquisition. Data were corrected for transducer to GPS receiver offset and transducer to water level offset. Data were exported to a .csv data format for further spatial analyses using GIS software. High-resolution Reefmaster® screen images were exported for display.

The MBES data recorded in the field in 3DSS format was converted to an XTF 2D sidescan and multibeam bathymetric format to import the data into the acoustic post-processing software, SonarWiz® 7. For the purposes of this study, the multibeam bathymetric data were reviewed but not analyzed or presented in detail.

Sidescan sonar image data have been shown to be effective in mapping the substrate classes of benthic environments (Lucieer 2008; Kaeser et al. 2013; Fakiris et al. 2019). Sidescan image data from the MBES

was reviewed for completeness and a georeferenced image mosaic that merges successive lines of overlapping data into one image was produced for each survey area. The image mosaics were then exported to .png georeferenced (UTM Zone 14N, WGS84) digital image format for additional mapping and display using GIS software. Additional high-resolution sidescan 'waterfall' images, or non-georeferenced images, were exported from SonarWiz® 7 for display in the report.

The Seabed Classification tool in SonarWiz® 7 was used to delineate image texture classes as vector polygons in acoustic imagery from the sidescan sonar data. The SonarWiz Seabed Characterization function works with sidescan imagery and acoustic backscatter data inputs from swath mapping sonars. The characterization tool is used to analyze 'waterfall' sidescan images to generate a user supplied number of classes of similar texture in the acoustic imagery. After a review of validation data, the side scan image mosaics, and existing substrate maps, six texture classes were selected in order to provide a basis for mapping substrate classes.

The texture analysis used three basic image texture analysis parameters (standard deviation, entropy, and intensity) and three Grey Level Co-Occurrence Matrix (GLCM) texture parameters (contrast, asimilarity, and homogeneity; Haralick [1979]). The acoustic image classification, represented by classes of similar texture, was then exported to a georeferenced vector polygon layer for import into a GIS for additional processing, class labeling, and habitat mapping.

2.3.3 Habitat Mapping

ESRI ArcGIS 10.8 and ArcGIS Pro 2.8 software was used to complete additional processing, assessment and interpretation to produce habitat maps. All spatial data sets including bottom validation, single-beam depth data, and the sidescan image mosaics and acoustic bottom characterization classification produced in SonarWiz® 7 were imported into the GIS.

The satellite imagery from August 8, 2021 was used to derive an estimated 242.7 m shoreline by digitizing the boundary between land and water in Birch Bay. The vector shoreline was used to provide a boundary condition in bathymetric models that had survey areas closer to shore.

The single-beam depth data were used to produce general bathymetric maps for each of the survey areas in Birch Bay. A 'Topo to Raster' interpolation technique was used to produce continuous 1 metre resolution depth grids of each of the survey areas using the single-beam acoustic depth data. The individual depth surface grids were merged into a single file. Vector depth contours at a 0.25 m interval were generated for additional mapping display. A zonal statistics routine produced a summary of key depth statistics (min, max, mean, volume) for each of the survey areas. The bathymetric maps were symbolized with colour gradients and the 0.25 m vector contours and presented using the November 9, 2021 Sentinel 2 satellite imagery as a base map representative of low-water conditions.

The vector lakebed classification polygons were displayed over the sidescan image mosaics for each of the eight survey areas. The classifications were then labeled according to the six substrate mapping classes determined above (Table 2). The bottom validation data were used to assist in the labeling of these classes. In some cases where image artifacts such as shadow or blur distortion misrepresented the

substrate class, manual edits were made by interpreting the class boundary. In general, the acoustic image classification showed excellent agreement with the visible boundaries between fine and coarse shoal substrates. Some class confusion resulted between boulder/cobble and cobble/gravel/boulder, but in general boulders were associated with darker areas (acoustic shadow) in the sidescan image mosaics. Areas for each mapped substrate class were tabulated and presented. Classes were symbolized and final detailed maps were produced.

3.0 RESULTS

3.1 WATER LEVEL

Water level on Lake St. Martin was very low during fall 2021. Mean daily water levels recorded by Water Survey of Canada (Station 05LM005) ranged from 242.70-242.74 mASL between September 25-28, 2021, lower than median water level conditions recorded for the same period during 1966-2017 (243.33-243.40 mASL). Average water levels observed during the 2021 sampling period were approximately equal to the 7th percentile water level observed on the same dates during 1966–2017.

3.2 THE NARROWS

3.2.1 Sampling Effort

A boat-based habitat survey was conducted in The Narrows on September 25, 2021 (Figure 5). The survey included petite ponar dredge sampling and visual observations of substrate composition at 16 locations (Table 3; Figures 5-7). Underwater camera sampling (Table 4; Figure 7) and laboratory analysis of sediment grabs from selected sites (Table 5) provided additional substrate information. Single beam and sidescan acoustic data were collected along a 7 km transect while traversing between substrate sampling sites. Acoustic sampling was restricted to the use of a SBES due to shallow depths throughout much of The Narrows; the SBES transducer sits level with the keel of the boat, whereas the MBES transducer requires approximately 30 cm of clearance beneath the keel of the boat. In most areas, water depth was insufficient to use the MBES without risk of damage to the transducer. Observations of shoreline habitat conditions collected on June 10, 2021 were used to augment habitat information collected as part of this study.

3.2.2 Site Descriptions

Site LSM-N-001 was in the south basin of Lake St. Martin upstream of The Narrows, and near the downstream end of dense perennial submerged aquatic vegetation beds. The aquatic vegetation is clearly visible as a darkly toned area in the satellite image captured on November 9, 2021 when water column conditions were relatively clear (Figure 5). Sediment obtained from a petite ponar grab was described as softly compacted fines (mud) and plant material was present (Figure 6). Laboratory analysis of the preserved sediment sample indicated a high fraction of silt (84.7%), with smaller proportions of clay and sand. Total carbon content in the sample was highest among all samples (14.7%), 7% of which was attributed to organic carbon.

Site LSM-N-002, the deepest sampling site in The Narrows at 2.5 m, was located 300 m downstream of LSM-N-001 in the relatively deep, narrow channel between Snake Island and Red Willow Point. The ponar grab sample taken at this site contained moderately compacted coarse sand and gravel sediment (Figure 6). Sidescan imaging indicated the presence of cobble, gravel, and intermittent boulder in the area immediately downstream of the sampling site (Figure 8). The thalweg of the channel between LSM-N-002 and LSM-N-003 remained relatively deep with a mean depth of approximately 1.5 m. Large boulders were

present along the shoreline of the island south of Snake Island (Figure 9). Sidescan imaging along the centre of the channel indicated the presence of predominantly coarse cobble and gravel substrate with intermittent boulder. A large patch visible in the sidescan imagery just upstream of LSM-N-003 was assumed to be aquatic vegetation or a combination of aquatic vegetation and woody debris (Figure 10). The ponar grab sample taken at LSM-N-003 was classed as coarse sand with small gravel. Plant material was not present in the sample. A rocky shoal extending off the north end of Red Willow Point is visible in the satellite image in Figure 5.

LSM-N-004, located north of Snake Island and south of the shoreline of the south basin of Lake St. Martin, was under approximately 0.3 m of water at the time of survey. The entire area was flat with compact cobble, gravel and boulder. Large boulders were scattered throughout the area (Figure 11). Sand was present in interstitial spaces of the rocky substrate and on the leeward side of some larger rocks. Sparse aquatic vegetation was also found on the leeward side of some larger boulders (Figure 12). Larger clams and clam shells were noted at this site.

Sampling at LSM-N-005a indicated the presence of finer silty sand substrates and aquatic vegetation, which was confirmed with underwater video data. Another grab taken at LSM-N-005b, located towards the centre of the channel and slightly deeper (1.77m), was similar but had slightly more gravel content. Laboratory analysis of the sediment from this site indicated 96% sand with only trace silt and clay fractions; organic carbon content was 2.9% (Table 5). Sidescan imaging indicated large hummocky features and tufts of dense vegetation (Figure 13). These large vegetation patches are also visible in the satellite imagery from November 9, 2021 (Figure 5).

LSM-N-006, located 600m downstream of LSM-N-005b towards the south shoreline, was comprised of predominantly of small algae covered gravel. Dense aquatic vegetation was visible in the sidescan imagery along the shore just downstream of the sampling site. Further downstream between LSM-N-006 and LSM-N-007, dense aquatic vegetation beds are visible in an embayment along the south shore in the satellite imagery, as is a large cobble and boulder shoal complex extending off the north shore (Figure 5). Cobble and large boulder were visible on the southern periphery of this shoal complex in the sidescan imagery. The sediment grab sample at LSM-N-007, 850 m downstream of LSM-N-006 in an area where The Narrows begins to widen, revealed a mixture of fine sediments and gravels. Laboratory analysis indicated the sediment to be predominantly sand (96%) with silt (4%). Organic carbon comprised 2% of the sample.

Denser aquatic vegetation was present through the middle of the channel beginning approximately 350 m downstream of LSM-N-007 (Figure 14). Dense plant beds are visible in the satellite imagery in the off-channel bays to the north and south of LSM-N-008, and as patchy areas across the middle of the channel (Figure 5). The grab sample taken at LSM-N-008, located 830 m downstream of LSM-N-007, contained predominantly fine substrates. Laboratory analysis of the sediment sample revealed an increase in silt fraction (22%), and a decrease in sand fraction (76%) relative to LSM-N-007. Organic carbon content was 4.7%, and the sediment texture class was loamy sand.

LSM-N-009, 730m downstream of LSM-N-008, was comprised of fine substrates and small gravel; the laboratory sample had a higher sand fraction than LSM-N-008 at 89%. Aquatic vegetation was less

prevalent in the sidescan imagery in the reach between LSM-N-008 and LSM-N-009 than in the previous reach.

The sediment grab at LSM-N-010a, 450 m downstream of LSM-N-009, contained predominantly gravel and sand with traces of silt; small plants were sparsely present in the grab sample. Underwater video taken at this site showed cobble in conjunction with the gravel and sand and small sparse aquatic vegetation. An additional site was sampled here (LSM-N-010b): laboratory analysis indicated 87% sand and 2.6% total organic carbon. Plants were not observed in sidescan imagery. Satellite imagery shows a narrow rocky shoal to the north and a broader shoal to the south (Figure 5).

Substrate at LSM-N-011, located 1900 m downstream of LSM-N-010 and off the main channel closer to the north shore, was predominantly comprised of fine sediments and was classed as silt/clay with sand and small gravels in the field. Moderately abundant, small (10-15 cm) aquatic vegetation was present in the grab sample and visible in the underwater video. Reedy emergent vegetation was also observed in the area. Laboratory analysis indicated a 29% silt fraction in the sediment sample, and the sediment was classed as sandy loam/loamy sand. The sample contained 4.2% total organic carbon.

Sampling site LSM-N-012 was located 1300 m across the channel, closer to the south shore of The Narrows. The grab sample at this site was classed as soft silty sand in the field and plants were visible in both the sidescan imagery and in the satellite imagery (Figure 5). Silt comprised 34% of the sediment fraction and the texture was classed as sandy loam. The sample contained 3.7% organic carbon.

LSM-N-013 was located just upstream of an area of The Narrows where the flow channels again become constricted by large rocky shoals. Sampling at this site revealed soft silty sand sediments with small sparse plants also evident in underwater camera video. Embedded cobble and gravel were also evident in the video. Laboratory analysis revealed sand to be the predominant fine sediment while silt comprised 12% of the fraction, and total organic carbon was 3.8%.

LSM-N-014, located 1100 m downstream of LSM-N-013, was in the downstream constricted area of The Narrows where large boulder and cobble shoals are much more evident (Figure 15). The sediment grab sample at this site was predominantly gravel with trace amounts of sand. Coarse rocky substrates were again evident in the sidescan imagery. Boulder and cobble shoals are evident in the satellite imagery, appearing as bright and textured (Figure 5).

The sediment sample collected at LSM-N-015, located 1000 m downstream of LSM-N-014, was predominantly comprised of sand with small sparse plants and clam shells. Laboratory analysis indicated a 93% sand fraction in the fine sediments. Sidescan data indicated coarse substrates and intermittent large boulder. Plants were visible in sidescan and satellite imagery immediately downstream of the site.

LSM-N-016 was located 1200 m downstream of LSM-N-015 in an area where The Narrows widens again into the very shallow north basin of Lake St. Martin. The sediment grab at this site had higher silt content (12%) than the previous site upstream. Plants were sparse but present, and decaying plant material was also present. Underwater video showed small, sparse aquatic vegetation amongst fines.

Substrate conditions were recorded at several exposed shoreline and shoal sites on June 10, 2021 (Figure 5; Appendix 1). These sites are in the downstream constriction of The Narrows, adjacent to site LSM-N-015 and downstream of LSM-N-016. In general, the observations confirmed the presence of coarse beach substrates of cobble, gravel, and boulder, and exposed lakebed substrate of gravels and sand over finer sediment with intermittent large boulders. Sites downstream of LSM-N-016 confirm the presence of exposed rocky shoal habitat into the north basin of Lake St. Martin.

3.2.3 Summary

The Narrows are a reach of water approximately 7 km long that connects the south and north basins of Lake St. Martin. Flow moves from the south basin through The Narrows to the north basin and exits the north basin via the Dauphin River (Figure 1). During low water level conditions observed during 2021, water flow to The Narrows was primarily through a narrow (< 100 m) and relatively deep (2.5 m) channel to the east and north of Snake Island (see Figure 5). During higher water conditions, Snake Island can be submerged. On September 25, 2021, substrate and water depth information was collected from 16 sites and a 7 km long transect through The Narrows was surveyed using single beam sonar. Soft fine sediments with relatively high organic carbon content and large, dense beds of aquatic vegetation occur upstream on either side of the entrance channel into The Narrows. Substrates within the entrance channel are coarse gravel and sand and water depth was 2.5 m or greater, making this the deepest area within The Narrows. Large boulders and cobble material occur along the shorelines. Downstream of the entrance channel, The Narrows widens, finer sediments occur, and aquatic vegetation becomes more evident in off-channel areas. Approximately 4 km downstream of the entrance channel, The Narrows widens and the thalweg becomes indeterminant. Through this area, numerous exposed cobble, gravel, and boulder shoals are interspersed in a matrix of sand and silt substrates. A second constriction occurs within the Narrows prior to entrance into the north basin. Large intermittent boulders and exposed shoals occur throughout this area and water depth was less than 0.5 m. Substrates consist of sand and gravel interspersed with large boulders and shoals of gravel and cobble. Where the second constriction widens and enters the north basin of Lake St. Martin, lakebed sediments again become finer.

3.3 BIRCH BAY

3.3.1 Sampling Effort

SMES and MBES acoustic data characterizing water depth and substrate classification were collected at selected habitat monitoring areas in Birch Bay (Figure 16) on September 26 and 27, 2021. Substrate validation activities were conducted on September 28 and included petite ponar dredge sampling and visual observations of substrate composition (Table 6; Figure 17), underwater camera sampling (Table 7; Figure 18), and laboratory analysis of select sediment grabs (Table 8). Acoustic sampling resolution (i.e., spacing between transects) was such that SSS imagery covered 90% or more of each of the habitat survey areas.

3.3.2 Site Descriptions

This section describes habitat conditions occurring at each of the selected monitoring areas in Birch Bay.

3.3.2.1 South Shoal Area

A total of 62,181 m^2 of shoal habitat was mapped. This shoal was the shallowest of all areas surveyed, ranging from 0.53-2.25 m in depth and having a mean depth of 1.46 m (Table 9; Figure 19). Due to the shallow water at this site, acoustic sampling was limited to data recorded with the Lowrance Elite FS echosounder. Acoustic tracking and sidescan imaging data were used to delineate the large boulder material in the middle of the study area, and fine substrates and aquatic vegetation to the north and northeast of the shoal (Figures 20 and 21). Fine substrates were sampled at LSM-BB-001, and plants were observed in underwater camera video footage. Laboratory analysis of sediment indicated predominantly sand (86%) with a lesser amount of silt (13%). Total organic carbon content of the sample was 3.8%. Underwater video camera bottom validation sampling at LSM-BB-002 and LSM-BB-003 revealed cobble, boulder, and gravel substrates, with mixed fines. Large boulders were evident at the water surface; some boulders in the area extended 10-20 cm out of the water at the time of survey (Figure 22).

Substrate mapping derived from analysis of sidescan image data indicated rocky boulder and cobble along the central axis of the shoal, which covered an approximate 300 m x 50 m area, comprising 27% of the total area (Table 10; Figures 20 and 23). The peripheral areas of the shoal had smaller cobble, gravel, and intermittent boulder substrate, which represented 45% of the survey area. Fine substrates contributed to 23% of the area.

3.3.2.2 Outlet Area

A 915,675 m^2 area was mapped near the LMOC outlet. Water depth ranged from 0-2.87 m, with a mean depth of 2.15 m (Table 9; Figure 19). The shoreline at the approximate location of the LMOC centreline at site LSM-BB-004 was comprised of compact gravel, and cobble with sand in the interstitial spaces (Figure 24). Acoustic sampling began approximately 100 m offshore. Habitat within 100 m of shore was flat, very shallow and low-sloped, which precluded a boat-based survey. Bottom validation sampling began 130 m offshore with underwater camera footage and ponar grabs. Video footage taken at the first offshore site, LSM-BB-005, indicated that the coarse shoreline substrate had transitioned to fines with some gravel and aquatic vegetation. A sediment grab taken at LSM-BB-005 indicated silty sand with gravel substrate. Laboratory analysis of the grab sample indicated a high sand fraction (98%) and organic carbon content was 1.69%. Large ripple or dune-like bedform features were noted in the sidescan imagery in the nearshore survey zone shallower than 1.75 m. Beginning below the 1.75 m depth contour, dense aquatic vegetation was visible in the sidescan imagery amongst homogenously distributed fine substrates (Figure 25). This cover of large, dense patches of aquatic vegetation continued throughout the entire study area, as viewed in the sidescan imagery, with slightly higher densities appearing to occur towards the southern end of the survey area (Figure 26). In general, the plants were noted as growing to a height of approximately half the water column in the densest areas. Bottom validation at site LSM-BB-006, located 270m offshore, indicated fine substrates, with sand still comprising the predominant fraction of sediment at 88%, but with a notable increase in the silt fraction at 12%. Organic carbon content at this site was

2.65%. Sites LSM-BB-007 to LSM-BB-010 all had similar characteristics with higher fractions of silt relative to the sites closer to shore. Organic carbon content at these sites ranged from 3.30 to 5.92%. At the far northeast end of the survey area, LSM-BB-011 had a higher sand fraction (86%) than that observed at adjacent validation sites.

Substrate mapping derived from analysis of sidescan image data indicated the area is dominated by a large homogenous area of fine substrates that contributed 83% to the total area (Table 10; Figures 20 and 26). A shallow low-sloped area close to the shoreline was left unclassified, accounting for 5% of the survey area. Sand bedforms in the nearshore area accounted for 10% of the total survey area. Patches of gravel and sand substrate were also mapped in the nearshore area (2%). Rocky substrate was mapped at the south end of the east side of the survey area, only accounting for <1 % of the total area mapped.

3.3.2.3 West Shore Area

A 228,386 m^2 area was mapped at this site. Depth in this area 130 m off the western shore of Birch Bay ranged from 1.29 to 2.99 m with a mean depth of 2.17 m (Table 9; Figure 19). The shoreline here is rocky, with large boulders. The nearshore area is relatively flat and low-sloped. Underwater video footage at three sampling sites, LSM-BB-018 to LSM-BB-020, indicated predominantly cobble and gravel substrates with sand in the interstitial space. This substrate, along with intermittent boulder, extended to approximately 2.5 m depth. The transition to predominantly fine substrates towards the east side of the survey area was visually apparent in the sidescan imagery (Figures 27 and 28). Submerged aquatic vegetation appeared in patches throughout the areas of fine substrates.

Substrate mapping derived from analysis of sidescan image data indicated the area to be dominated by a coarse gravel, cobble, and intermittent boulder substrate which covered 72% of the total area (Table 10; Figures 20 and 29). Smaller pockets of sand and gravel substrates (3%) were found throughout the survey area and comprised the transition from rocky to fine substrates. Fine substrates comprised the southeast portion of the survey area and constitute 25% of the survey area.

3.3.2.4 Deepwater Reference Area

A small 138,989 m^2 area in the deepest part of Birch Bay was surveyed and mapped. Depth in this area had a narrow range of 3.57 to 3.93 m and mean depth was 3.79 m (Table 9; Figure 19). This area of Birch Bay has a silty mud bottom. Sediment grabs at three sites (LSM-BB-12 to LSM-BB-014) were characterized as silty sand or silt and clay substrates with sand, with an obvious upper layer of depositional silt overlying silty sand. Plant material was not present in any of the sediment samples. Underwater video at LSM-BB-012a showed fine sediments with sporadic, small (5-10 cm) aquatic vegetation. Sparse, sporadic vegetation was observed in the sidescan imagery. Overall, the sidescan imagery showed a homogenous muddy, pockmarked bottom (Figure 30). A few larger (approximately 2 m diameter), crater-like depressions were also observed in this area (Figure 30). Laboratory analysis of the sediment grabs at these three sites indicated the highest fractions of silt amongst all Birch Bay samples. Organic carbon content at these sites was also slightly higher than other sites.

Substrate mapping revealed this area to be 100% fine substrate (Table 10; Figures 20 and 31).

3.3.2.5 South Dillabough Shoal Area

A 178,226 m^2 relatively deep shoal area was surveyed and mapped offshore in the middle of Birch Bay adjacent to Dillabough's Point. Depth in this area ranged from 2.59 to 3.37 m and mean depth was 3.08 m (Table 9; Figure 19). Three benthic validation sites were sampled within this survey area, which is part of the larger connected shoal complex that extends northwest towards Dillabough's Point from the eastern shoreline of Birch Bay.. Substrate at LSM-BB-015, on the west side of the survey area, was classed as sand and gravel. Underwater video showed predominantly finer sediment amongst embedded gravel and cobble and small sparsely distributed plants. The sample at LSM-BB-016 in the middle of the survey area also revealed sand and gravel substrate. Underwater video again showed gravel and cobble substrates embedded in finer sediments. Underwater video at site LSM-BB-017 showed cobble and gravel along with sandy sediment. Plants were not visible in video at LSM-BB-016 or LSM-BB-017. Sidescan imaging clearly showed the presence of large patchy aquatic vegetation amongst fine substrate in low sloped deeper depressions adjacent to the predominantly cobble and gravel and intermittent boulder substrate of the shoal structure (Figures 32 and 33).

Substrate mapping derived from analysis of sidescan image data indicated that coarse gravel, cobble, and intermittent boulder substrate covered 41% of the total area (Table 10; Figures 20 and 34). Large boulder and cobble (20%) piles occurred mostly in the shallowest portions of the survey area. Smaller pockets of sand and gravel substrates (4%) were detected throughout the survey area, and at the transition from rocky to fine substrates. Sand, silt, and clay with intermittent gravel comprised 31% of the survey area, mostly in the eastern and northeastern portion of the survey area, and in pockets in narrow low-sloped depressions to the north and south. A few smaller areas were left unclassified (4%) due to limited data coverage.

3.3.2.6 North Dillabough Shoal Area

A relatively large (524,125 m^2) and long (1.3 km) offshore shoal area in the middle of Birch Bay adjacent to Dillabough's Point was surveyed and mapped . Depth in this area ranged from 1.26 to 3.27 m and mean depth was 2.55 m (Table 9; Figure 19). This survey area is part of the larger connected shoal complex that extends northwest towards Dillabough's Point from the eastern shoreline of Birch Bay and is likely connected to the South Dillabough Shoal Area. Sidescan imaging was used to validate the bottom types here, as habitat characteristics were like the South Dillabough Shoal Area. Large boulder and cobble were found throughout this area and was evident in sidescan imaging (Figure 35). Cobble, gravel, and intermittent boulder substrate made up most of the shoal structure, as indicated in the imagery. Sand, silt, clay and intermittent gravel with large patches of aquatic vegetation adjacent to the rocky shoal material were also apparent in the sidescan imaging (Figure 36).

Substrate mapping derived from analysis of sidescan image data indicated the area was dominated by a coarse gravel, cobble, and intermittent boulder substrate (56% of the total area) (Table 10; Figures 20 and 37). Large boulder and cobble (17%) occurred mostly in the shallowest portions through the middle of the survey area. Smaller pockets of sand and gravel (8%) were mapped throughout the survey area, and within the transition from rocky to fine substrates. Sand, silt, clay with intermittent gravel substrates were observed within deeper low-sloped areas towards the four corners of the survey area, comprising 15% of

the survey area. A swath was left unclassified (4%) as the survey transects were too wide for complete sidescan data coverage.

3.3.2.7 South East Shore Shoal Area

A relatively large (915,675 m^2) nearshore shoal area was surveyed and mapped along the east shore of Birch Bay. Depth in this area ranged from 0.97 to 3.15 m and mean depth was 2.24 m (Table 9; Figure 19). This survey area is also thought to be part of the larger connected shoal complex that extends northwest towards Dillabough's Point from the eastern shoreline of Birch Bay. Large boulder substrate was observed just below the surface throughout the survey area and was evident in the sidescan image data (Figure 38 and 39). Fine sediments were visible towards the north and south periphery of the survey area in deeper lower-sloped areas and depressions.

Substrate mapping derived from analysis of sidescan image data indicated the area to be dominated by large boulder and cobble substrate (63% of the total area) (Table 10; Figures 20 and 40). Rocky gravel, cobble, and intermittent boulder sized substrate comprised 15% of the survey area. Smaller pockets of sand and gravel substrates (4%) were mapped throughout the survey area, and within the transition from rocky to fine substrates. Fine sediments with intermittent gravel substrates at the north and south ends of the survey area represented 18% of the survey area.

3.3.2.8 North East Shore Shoal Area

A 524,125 m^2 nearshore shoal area was surveyed and mapped along the east shore of Birch Bay near the mouth of Beardy Creek. Depth in this area ranged from 0.63 to 3.15 m and mean depth was 2.20 m (Table 9; Figure 19). This survey area is also thought to be part of the larger connected shoal complex that extends northwest towards Dillabough's Point from the eastern shoreline of Birch Bay. Similar to the survey area to the south, large boulder substrate extended off the shoreline and was observed just below the surface throughout the survey area (Figure 41). Large boulder material was evident in the sidescan image data (Figure 42). Fine sediments were visible in the imagery collected along deeper lower-sloped areas and long finger-like depressions towards the north end of the survey area.

Substrate mapping derived from analysis of sidescan image data indicated the area to be dominated by rocky cobble, gravel and intermittent boulder sized substrate, which covered 53% to the total area (Table 10; Figures 20 and 43). Large boulder and cobble (33%) occurred mostly in the shallowest areas towards the south end of the survey area. Smaller pockets with sand and gravel substrates (8%) were mapped throughout the survey area, and within the transition from rocky to fine substrates. Fine sediments with intermittent gravel substrates occurred towards the north end of the survey area, within deeper low-sloped relatively narrow areas, comprising 5% of the survey area.

3.3.3 Summary

A total of eight non-contiguous areas were surveyed in Birch Bay at the south end of Lake St. Martin September 26-28, 2021. A long, 300m x 50m, predominantly boulder and cobble shoal was identified and mapped at the south end of Birch Bay adjacent to the LMOC Outlet Area. At the LMOC Outlet, nearshore

substrate included sand/gravel and sand bedforms. The LMOC Outlet survey area, located farther offshore, was dominated by fine soft sand and silt and contained a moderately dense cover of aquatic vegetation throughout. A survey along the western shoreline north of the LMOC Outlet Area indicated the presence of rocky gravel, cobble, and intermittent boulder habitat extending 0.5 km offshore to a depth of 2.5 m. A deep-water substrate area in the centre of Birch Bay was also mapped, confirming the presence of depositional silt at water depths greater than 3 m. Four areas, thought to be part of a large glacial till shoal complex extending off the eastern shore towards Dillabough's Point, were mapped to confirm the presence of rocky shoal habitat. Mapping confirmed the presence of this habitat in all four areas, with varying degrees of material size. The offshore shoal areas adjacent to Dillabough's Point were predominantly cobble and gravel with intermittent boulder, while the nearshore shoal areas along the eastern shoreline near Beardy Creek contained higher proportions of boulders. In all four cases, areas of fine substrates in deeper low-sloped areas were clearly distinguishable in high resolution sidescan imaging.

4.0 SUMMARY

Detailed aquatic habitat mapping surveys were conducted in The Narrows and Birch Bay area of Lake St. Martin during September 25-28, 2021. Surveys were conducted using a suite of methods including SBES, MBES and SSS technologies, underwater videography and interpretation of satellite imagery. Substrate composition was interpreted from sonar data, qualitative assessment of substrate grab samples, underwater videography, laboratory analysis of substrate samples from selected locations, and shoreline observations of substrate conditions conducted on June 10, 2021.

Water level on Lake St. Martin was low during 2021, approximately equalling the 7th percentile water level condition observed during 1966-2017. The low water level restricted movements and use of sonar equipment within The Narrows and, consequently, limited the ability to collect habitat data from peripheral areas. The survey included substrate sample collection and visual observations of substrate composition at 16 locations in The Narrows and collection of single beam and sidescan acoustic data along a single 7 km long transect between sampling sites. The information collected supplements previously collected data and provides a better understanding of substrate and overall habitat conditions within The Narrows. However, low water level restricted access to much of the area, and survey coverage was not sufficient to produce aquatic habitat maps accurate enough to allow for a quantitative spatial assessment. Additional baseline habitat data will need to be collected prior to commissioning of the POCs to support future habitat monitoring activities in The Narrows.

SMES and MBES acoustic surveys were conducted to characterize aquatic habitat (water depth, substrate classification, and occurrence of aquatic vegetation) at eight habitat monitoring areas in Birch Bay. Acoustic sampling resolution (i.e., spacing between transects) was such that SSS imagery covered 90% or more of each habitat survey area. The high level of survey coverage combined with substrate validation sampling and laboratory analysis of sediment samples provided a detailed description of substrates, as well as water depth and the presence/distribution of aquatic vegetation, within the survey areas. Future habitat monitoring activities in Birch Bay related to POC construction and operation will include replicating the aquatic habitat surveys conducted in this study. Data collected here will be integral towards determining whether there are changes in substrate type that may be related to POC commissioning and operation.

5.0 REFERENCES

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Table 1. Modified Wentworth scale of material size used to classify substrate *in situ* (after Wentworth 1922).

Size Range	Wentworth Class	General Class	Basic Class
-	-	Bedrock	Rock
>256 mm	Boulder	Boulder	
64–256 mm	Cobble	Cobble	
32–64 mm	Very coarse gravel	Gravel	
16–32 mm	Coarse gravel		
8–16 mm	Medium gravel		
4–8 mm	Fine gravel		
2–4 mm	Very fine gravel		
1–2 mm	Very coarse sand	Sand	Sand
0.5–1 mm	Coarse sand		
0.25–0.5 mm	Medium sand		
125–250 µm	Fine sand		
62.5–125 µm	Very fine sand		
3.9–62.5 µm	Silt	Silt	Mud
0.98–3.9 µm	Clay	Clay	
-	-	Organic	Organic

Table 2. Substrate mapping classes and their descriptions used in this study.

Basic Class	Class	Description
Rock	Boulder/Cobble	Large rocky material ranging from large cobble to very large boulder (> 1 m)
	Cobble/Gravel/ Boulder	Hard, coarse substrates, predominantly cobble and gravel sized material with intermittent boulder
Sand	Sand/Gravel	Sand and gravel substrates
	Sand Bedforms	Compacted nearshore sand substrate ripples and dune bedforms
Mud	Silt/Sand/Gravel/Clay	Loose or unconsolidated mixed fines often containing shells and small gravel.
	Silt/Clay	Softly compacted silt and clay substrates
	Clay	Moderately compacted cohesive substrate
-	Unclassified	Areas of the study area that were not classified or mapped

Table 3. Results of substrate validation sampling and characterization in The Narrows, September 25, 2021.

Site ID	Method	Location [1]		Time	Plants Present	Water Depth (m)	Compaction	Estimated Grab Sample Composition						Substrate Class
		Easting	Northing					Substrate [1]	%	Substrate [2]	%	Substrate [3]	%	
LSM-N-001	ponar	541634	5732181	11:01	yes	0.8	soft	Silt	70	clay	30	-	-	silt/clay
LSM-N-002	ponar	541509	5732477	11:33	no	2.5	moderate	sand	60	gravel	40	-	-	sand/gravel
LSM-N-003	ponar	541493	5733032	11:56	no	1.62	moderate	sand (coarse)	40	small gravel	30	fine sand	20	sand/gravel
LSM-N-004	visual	541120	5733020	12:12	no	0.35	hard	gravel	60	cobble	20	boulder	20	gravel/cobble/boulder
LSM-N-005a	ponar	541798	5733492	12:37	yes	1.1	soft	sand	70	silt	30	-	-	silty sand
LSM-N-005b	ponar	541832	5733427	12:49	no	1.77	moderate	sand	70	silt	25	gravel	5	silty sand
LSM-N-006	ponar	542422	5733376	12:58	no	1.4	hard	gravel	100	-	-	-	-	gravel
LSM-N-007	ponar	543289	5733257	13:07	no	1.46	moderate	silt	50	sand	40	gravel	5	silty sand
LSM-N-008	ponar	544060	5733575	13:38	yes	1.72	soft	silt	70	clay	20	sand	10	silty sand
LSM-N-009	ponar	544547	5734105	13:52	no	1.44	moderate	silt	50	sand	30	gravel	20	silty sand/gravel
LSM-N-010a	ponar	544939	5734309	14:07	yes	1.14	moderate	sand	40	gravel	40	silt	20	silty sand/gravel
LSM-N-010b	ponar	544939	5734309	14:07	no	1.14	moderate	gravel	50	sand	30	silt	20	silty gravel/sand
LSM-N-011	ponar	546741	5734685	14:32	yes	1.46	soft	silt	50	clay	30	sand	10	silt/clay
LSM-N-012	ponar	545992	5733545	14:53	yes	1.79	soft	silt	60	sand	30	clay	10	silty sand
LSM-N-013	ponar	547647	5732877	15:13	no	0.89	soft	silt	70	sand	20	clay	10	silty sand
LSM-N-014	ponar	548547	5733508	15:33	no	0.5	moderate	gravel	80	sand	20	-	-	gravel
LSM-N-015	ponar	548313	5734414	15:57	yes	1.16	soft	sand	80	silt	20	-	-	sand
LSM-N-016	ponar	547950	5735573	16:14	yes	1.26	soft	sand	50	silt	30	clay	20	silty sand

1 - UTM coordinates: NAD83, Zone 14U

2 - Primary substrate

3 - Secondary substrate

4 - Tertiary substrate

Table 4. Results of underwater video camera observations in The Narrows, September 25, 2021.

Site ID	Location [1]		Time	Video File	Plants	Water Depth (m)	Compaction	Estimated Composition						Substrate Class
	Easting	Northing						Substrate [2]	%	Substrate [3]	%	Substrate [4]	%	
LSM-N-005a	541798	5733492	12:37	n/a	yes	1.1	soft	sand	70	silt	30	-	-	silty sand
LSM-N-010a	544939	5734309	14:07	20210925_141211	yes	1.14	moderate	gravel	40	cobble	40	sand	20	gravel/cobble with sand
LSM-N-011	546741	5734685	14:32	20210925_143842	yes	1.46	soft	silt	50	clay	30	sand	10	silt/clay
LSM-N-013	547647	5732877	15:13	20210925_151841	no	0.89	soft	silt	70	sand	20	clay	10	silty sand
LSM-N-016	547950	5735573	16:14	20210925_162047	yes	1.26	soft	sand	50	silt	30	clay	20	silty sand

1 - UTM coordinates: NAD83, Zone 14U

2 - Primary substrate

3 - Secondary substrate

4 - Tertiary substrate

Table 5. Laboratory results of particle size assessment, texture class assessment, and organic content analysis of select sediment grabs taken in The Narrows, September 25, 2021.

Site	Sand (%2.0mm - 0.05mm)	Silt (%0.05mm - 2um)	Clay (% <2um)	Texture	$CaCO^3$ Equivalent (%)	Total Carbon by Combustion (%)	Inorganic Carbon (%)	Total Organic Carbon (%)
LSM-N-001	6.5	84.5	9.0	Silt	64.0	14.7	7.68	7.0
LSM-N-005	96.3	3.6	<1.0	Sand	19.8	5.22	2.37	2.9
LSM-N-007	95.8	4.1	<1.0	Sand	21.5	4.70	2.58	2.12
LSM-N-008	75.9	21.5	2.5	Loamy sand	36.5	9.08	4.38	4.7
LSM-N-009	88.9	11.0	<1.0	Sand	23.7	7.18	2.84	4.3
LSM-N-010	87.4	9.6	3.0	Sand	17.9	4.72	2.15	2.57
LSM-N-011	70.3	29.4	<1.0	Sandy loam / Loamy sand	21.7	6.80	2.60	4.2
LSM-N-012	64.6	33.7	1.7	Sandy loam	28.8	7.14	3.46	3.7
LSM-N-013	87.7	12.1	<1.0	Sand	22.4	6.45	2.69	3.8
LSM-N-015	93.2	2.3	4.5	Sand	23.2	5.43	2.78	2.7
LSM-N-016	87.6	12.3	<1.0	Sand	19.9	5.22	2.39	2.8

Table 6. Results of substrate validation sampling and characterization in Birch Bay, September 28, 2021.

Site ID	Method	Location [1]		Time	Plants Present	Water Depth (m)	Compaction	Estimated Grab Sample Composition						Substrate Class	ALS Sample
		Easting	Northing					Substrate [2]	%	Substrate [3]	%	Substrate [4]	%		
LSM-BB-001	ponar	534735	5703927	14:45	yes	1.84	soft	silt	50	clay	40	sand	10	silt/clay with sand	yes
LSM-BB-004	visual	534047	5704114	15:08	no	0.00	hard	gravel	80	cobble	20	-	-	gravel/cobble	no
LSM-BB-005	ponar	534168	5704231	15:16	yes	1.67	soft	silt	50	clay	40	sand	10	silt/clay with sand	yes
LSM-BB-006	ponar	534239	5704303	15:22	no	2.23	moderate	silt	50	sand	30	clay	20	silt/clay with sand	yes
LSM-BB-007	ponar	534296	5704398	15:30	no	2.41	moderate	silt	40	clay	40	sand	20	silt/clay with sand	yes
LSM-BB-008	ponar	534363	5704519	15:36	no	2.51	moderate	silt	40	clay	30	sand	30	silt/clay with sand	yes
LSM-BB-009	ponar	534476	5704638	15:45	no	2.59	moderate	silt	50	clay	30	sand	20	silt/clay with sand	yes
LSM-BB-010	ponar	534557	5704888	15:52	no	2.74	soft	silt	60	clay	30	sand	10	silt/clay with sand	yes
LSM-BB-011	ponar	534644	5705010	16:00	no	2.80	soft	silt	50	clay	50	-	-	silt/clay	yes
LSM-BB-012	ponar	533807	5706743	16:14	no	3.92	moderate	silt	40	sand	40	clay	20	silty sand	yes
LSM-BB-013	ponar	533657	5706659	16:25	no	3.72	moderate	silt	50	clay	30	sand	20	silt/clay with sand	yes
LSM-BB-014	ponar	533529	5706819	16:32	no	3.64	moderate	silt	40	clay	40	sand	20	silt/clay with sand	yes
LSM-BB-015	ponar	533677	5707970	16:40	no	3.31	moderate	sand	50	gravel	50	-	-	sand/gravel	no
LSM-BB-016	ponar	533798	5708009	16:49	no	2.90	moderate	sand	50	gravel	50	-	-	sand/gravel	no

1 - UTM coordinates: NAD83, Zone 14U

2 - Primary substrate

3 - Secondary substrate

4 - Tertiary substrate

Table 7. Results of underwater video camera observations in Birch Bay, September 28, 2021.

Site ID	Location [1]		Time	Video File	Plants	Water Depth (m)	Compaction	Estimated Composition						Substrate Class
	Easting	Northing						Substrate [2]	%	Substrate [3]	%	Substrate [4]	%	
LSM-BB-001	534701	5703820	14:42	20210928_144759	yes	1.14	moderate	silt	50	clay	30	gravel	20	Silt/Clay with gravel
LSM-BB-002	534660	5703857	14:55	20210928_150034	yes	1.38	hard	cobble	60	boulder	20	gravel	20	cobble/boulder with gravel and fines
LSM-BB-003	534600	5703911	14:59	20210928_150432	no	1.58	hard	cobble	70	boulder	20	gravel	10	cobble/boulder with gravel
LSM-BB-005	534145	5704204	15:14	20210928_151859	yes	1.43	moderate	silt	50	clay	40	gravel	10	silt/clay with gravel
LSM-BB-006	534220	5704316	15:19	20210928_152445	yes	2.16	soft	silt	50	clay	40	sand	10	silt/clay with sand
LSM-BB-007	534295	5704399	15:28	20210928_152558	yes	2.41	soft	silt	50	clay	40	sand	20	silt/clay with sand
LSM-BB-008	534363	5704519	15:36	20210928_153303	yes	2.51	soft	silt	50	clay	40	sand	20	silt/clay with sand
LSM-BB-009	534476	5704638	15:45	20210928_154134	yes	2.59	soft	silt	50	clay	40	sand	20	silt/clay with sand
LSM-BB-010	534557	5704888	15:52	20210928_154952	yes	2.74	soft	silt	50	clay	40	sand	20	silt/clay with sand
LSM-BB-011	534644	5705010	16:00	20210928_155739	yes	2.80	soft	silt	50	clay	40	sand	20	silt/clay with sand
LSM-BB-012	533807	5706743	16:14	20210928_160544	yes	3.92	soft	silt	50	clay	40	sand	20	silt/clay with sand
LSM-BB-015	533677	5707970	16:40	20210928_164600	yes	3.31	soft	silt	50	clay	40	sand	20	silt/clay with sand
LSM-BB-016	533798	5708009	16:51	20210928_165441	no	2.90	soft	silt	50	cobble	30	gravel	20	silty gravel/cobble
LSM-BB-017	533958	5708000	16:54	20210928_165954	no	3.26	moderate	cobble	50	gravel	30	sand	20	cobble/gravel with sand
LSM-BB-018	533275	5706227	17:02	20210928_170756	no	2.65	hard	cobble	50	gravel	30	sand	20	cobble/gravel with sand
LSM-BB-019	533389	5705913	17:05	20210928_171033	no	1.91	hard	cobble	50	gravel	30	sand	20	cobble/gravel with sand
LSM-BB-020	533359	5705887	14:30	20210928_143601	no	1.77	hard	cobble	50	gravel	30	sand	20	cobble/gravel

1 - UTM coordinates: NAD83, Zone 14U

2 - Primary substrate

3 - Secondary substrate

4 - Tertiary substrate

Table 8. Laboratory results of particle size assessment, texture class assessment, and organic content analysis of select sediment grabs taken in the Birch Bay study area, September 28, 2021.

Site	Sand (%2.0mm - 0.05mm)	Silt (%0.05mm - 2um)	Clay (% <2um)	Texture	$CaCO^3$ Equivalent (%)	Total Carbon by Combustion (%)	Inorganic Carbon (%)	Total Organic Carbon (%)
LSM-BB-001	86.1	13	<1.0	Sand	19.7	6.19	2.36	3.8
LSM-BB-005	97.6	1.6	<1.0	Sand	10.7	2.97	1.28	1.69
LSM-BB-006	87.7	12.1	<1.0	Sand	12.3	4.13	1.48	2.65
LSM-BB-007	76.2	20.3	3.5	Loamy sand	16.5	6.07	1.98	4.09
LSM-BB-008	65.5	33.5	<1.0	Sandy loam	19	7.45	2.29	5.16
LSM-BB-009	81.4	18.3	<1.0	Loamy sand	15.9	5.83	1.91	3.92
LSM-BB-010	80.7	19.1	<1.0	Loamy sand	15.1	5.12	1.81	3.3
LSM-BB-011	86.4	13.1	<1.0	Sand	16.4	5.82	1.97	3.9
LSM-BB-012	58.1	36.3	5.6	Sandy loam	33.3	9.79	3.99	5.8
LSM-BB-013	48.4	46.2	5.4	Sandy loam	25	8.79	3	5.8
LSM-BB-014	55.3	43.3	1.4	Sandy loam	24.1	8.23	2.89	5.3

Table 9. Summary of modelled bathymetric mapping data for each monitoring area derived from single-beam sonar data collected during September 2021 habitat surveys.

Area Name	Area ID	Cell Count	Modelled Depth [1]					Volume (m^3)
			Min (m)	Max (m)	Range (m)	Mean (m)	SD [2]	
West Shore Area	1	228,227	1.29	2.99	1.70	2.17	0.46	494,237
Outlet Area	2	915,134	0.00	2.87	2.86	2.15	0.66	1,964,082
South East Shore Shoal Area	3	421,839	0.97	3.15	2.18	2.24	0.49	944,622
North East Shore Shoal Area	4	257,833	0.63	3.15	2.51	2.20	0.50	566,863
North Dillabough Shoal Area	5	524,122	1.26	3.27	2.00	2.55	0.35	1,337,401
Deepwater Reference Area	6	138,983	3.57	3.93	0.36	3.79	0.07	526,440
South Shoal Area	7	61,957	0.53	2.25	1.72	1.46	0.41	90,642
South Dillabough Shoal Area	8	178,169	2.59	3.37	0.78	3.08	0.17	548,209

1 - Relative to 242.7 m ASL

2 - standard deviation

Table 10. Summary of substrate mapping data derived from sidescan sonar data collected during September 2021 habitat surveys.

Area Name	Area ID	Substrate Class														Total Area (m^2)
		Boulder/Cobble		Cobble/Gravel/ Boulder		Sand/Gravel		Sand bedforms		Silt/Sand/Gravel/ Clay		Silt/Clay		Unclassified		
		Area (m^2)	% of Area	Area (m^2)	% of Area	Area (m^2)	% of Area	Area (m2)	% of Area	Area (m^2)	% of Area	Area (m^2)	% of Area	Area (m^2)	% of Area	
West Shore Area	1	0	0	165,073	72	7,269	3	0	0	56,044	25	0	0	0	0	228,386
Outlet Area	2	0	0	1,487	0	18,730	2	87,284	10	763,258	83	0	0	44,915	5	915,675
South East Shore Shoal Area	3	267,556	63	61,641	15	17,280	4	0	0	75,629	18	0	0	164	0	422,270
North East Shore Shoal Area	4	85,261	33	137,728	53	20,649	8	0	0	11,996	5	0	0	2,247	1	257,881
North Dillabough Shoal Area	5	89,986	17	294,465	56	39,522	8	0	0	80,860	15	0	0	19,293	4	524,125
Deepwater Reference Area	6	0	0	0	0	0	0	0	0	0	0	138,989	100	0	0	138,989
South Shoal Area	7	16,670	27	28,086	45	2,928	5	0	0	14,497	23	0	0	0	0	62,181
South Dillabough Shoal Area	8	35,512	20	72,418	41	8,365	5	0	0	55,133	31	0	0	6,797	4	178,226
	Total	494,986	18	760,898	28	114,742	4	87,284	3	1,057,418	39	138,989	5	73,417	3	2,727,734

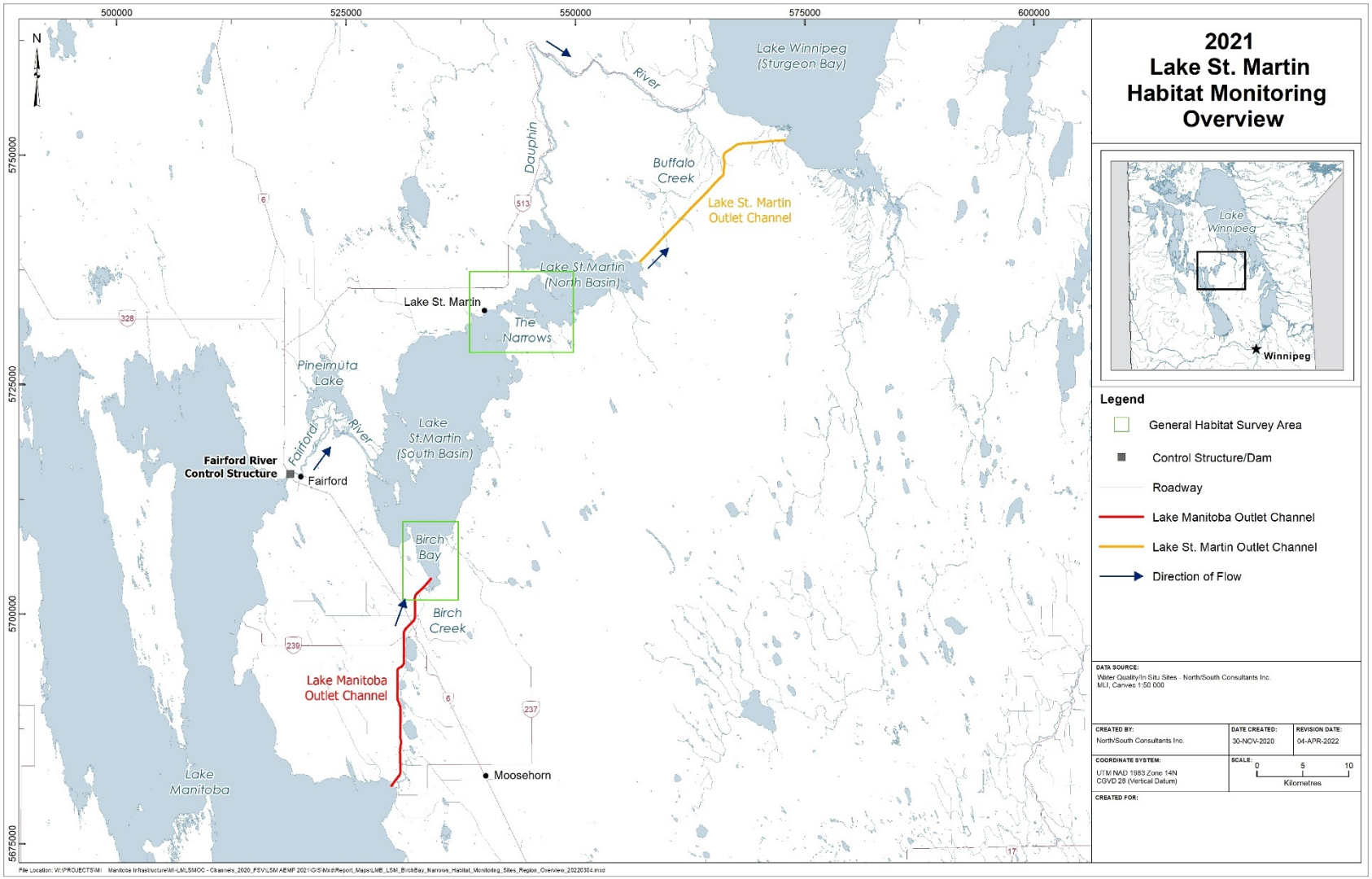

Figure 1. Location of Lake Manitoba and Lake St. Martin Outlet Channels in central Manitoba, including an overview of 2021 habitat survey areas at the Lake St. Martin Narrows and Birch Bay.

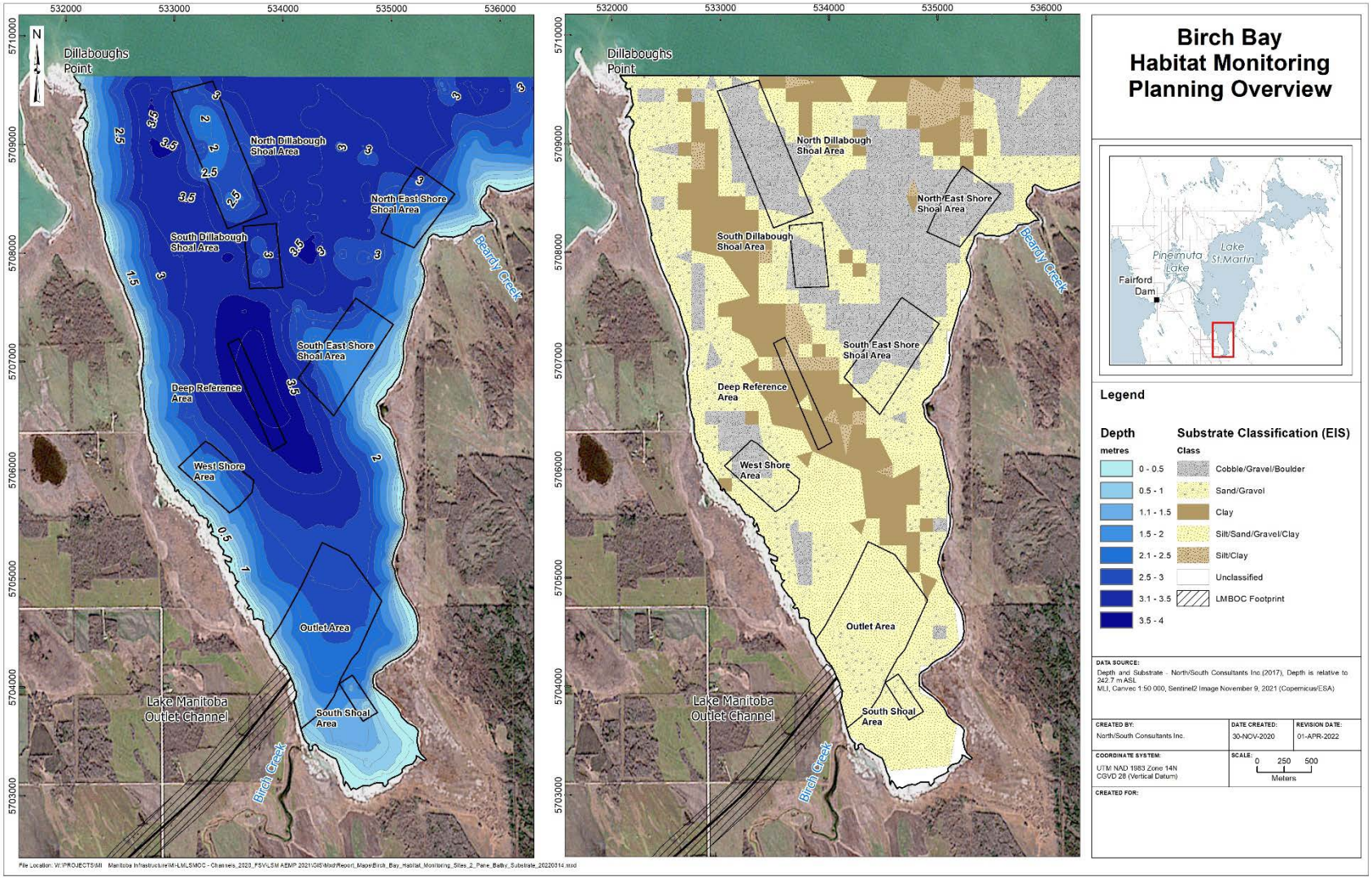

Figure 2. Selected habitat monitoring areas in Birch Bay overlying EIS baseline habitat (depth and substrate) mapping.

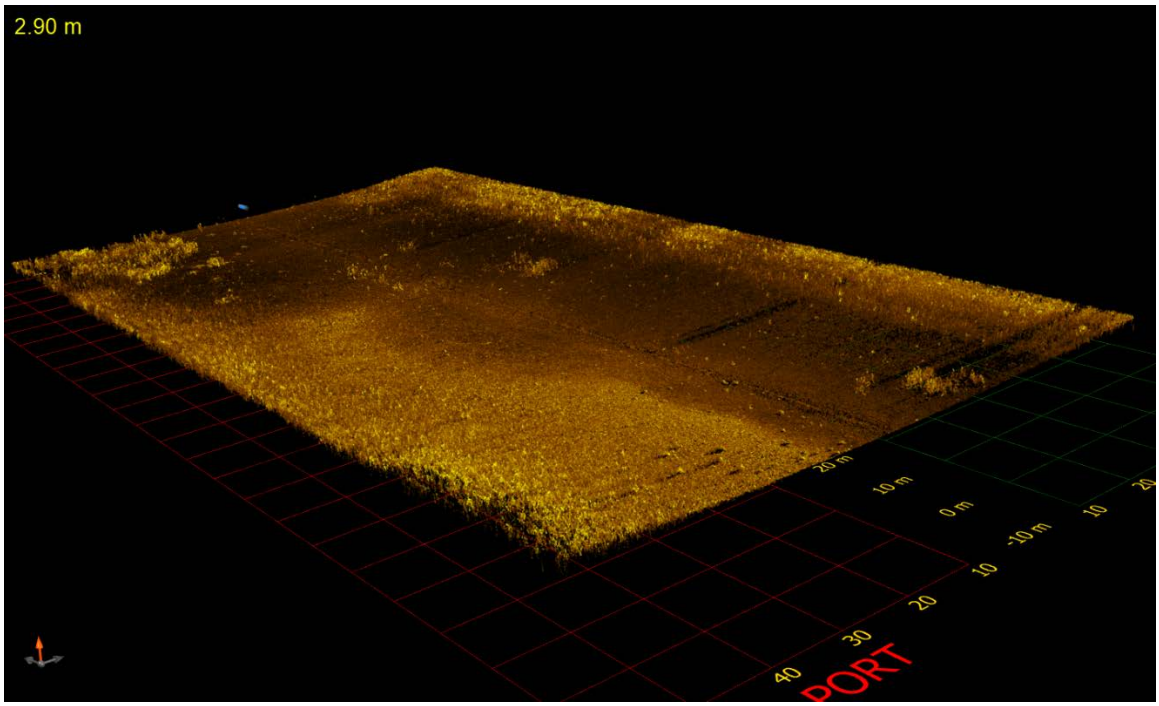

Figure 3. Ping DSP 3DSS-IDX-450 sidescan amplitude data (100 m swath) in the southeast corner of the South Dillabough Shoal Survey Area.

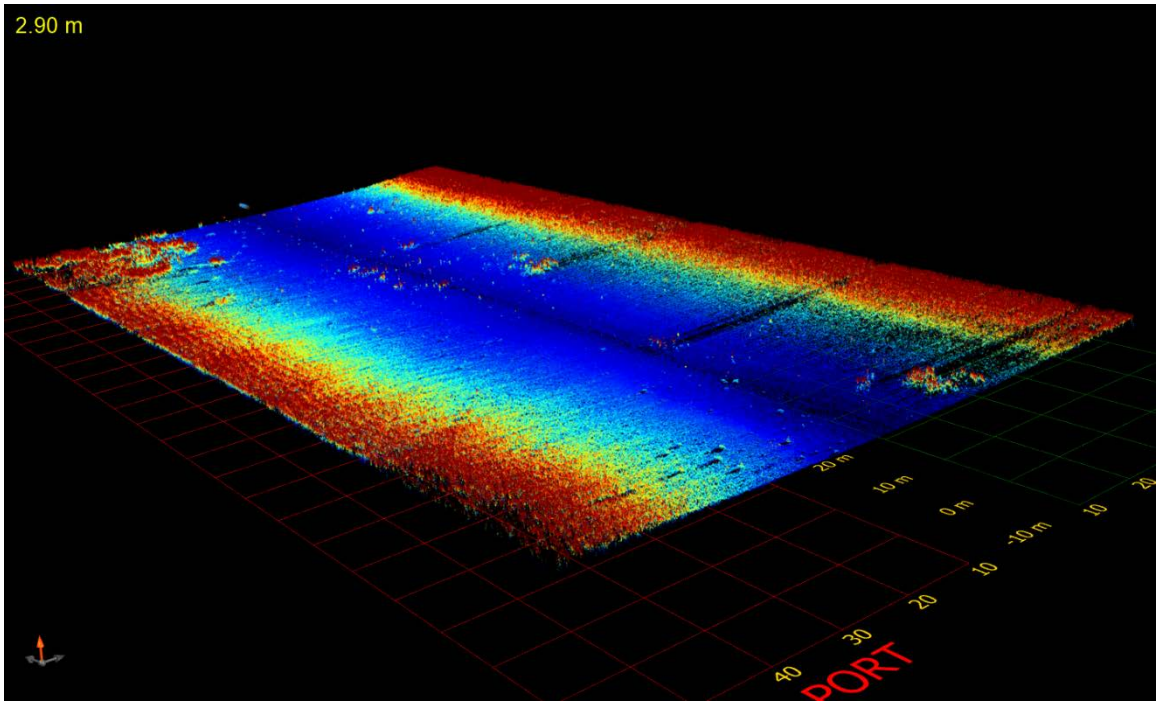

Figure 4. Ping DSP 3DSS-IDX-450 swath bathymetric data in the southeast corner of the South Dillabough Shoal Survey Area.

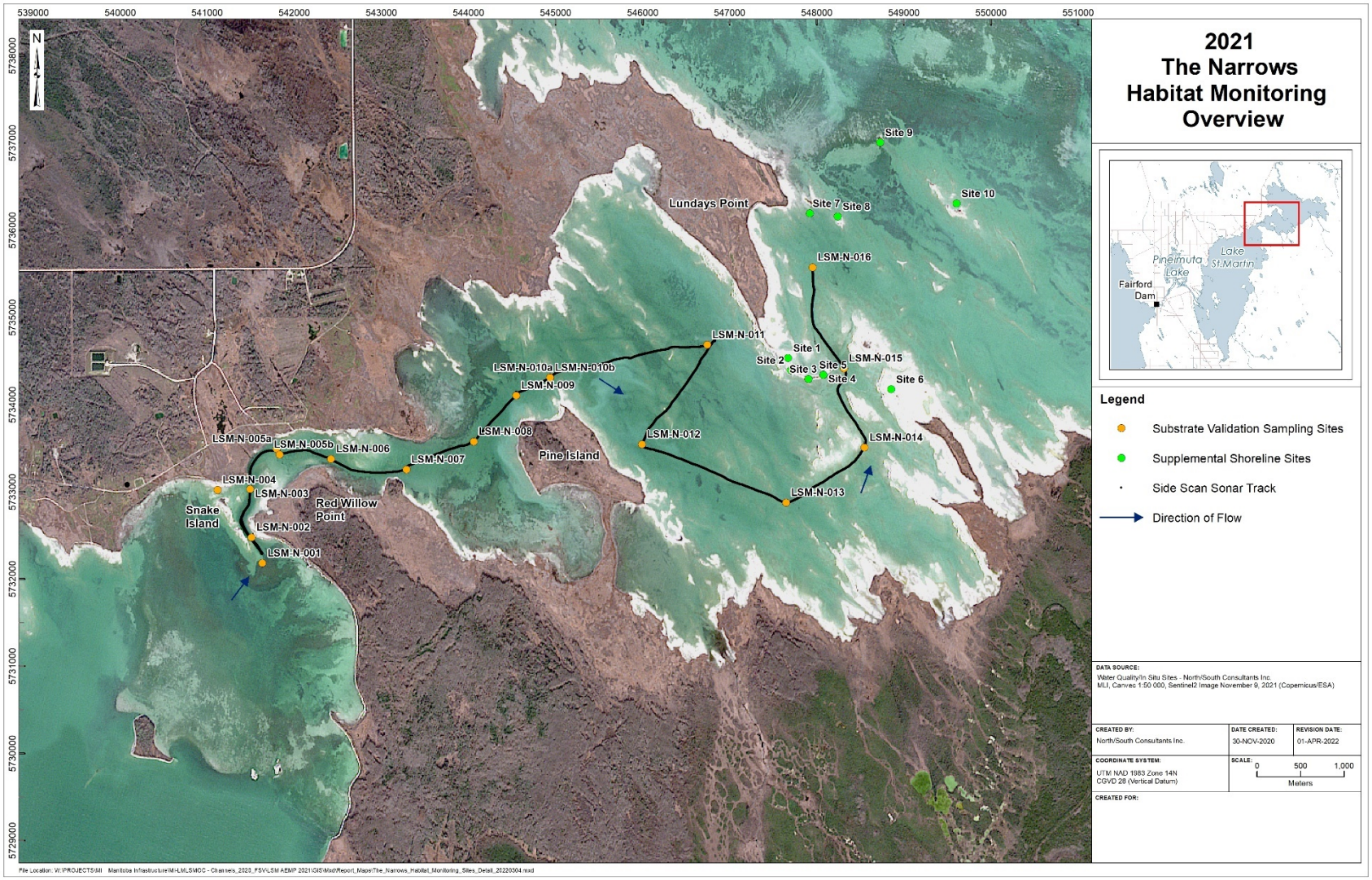

Figure 5. Habitat sampling sites and side scan sonar track from habitat surveys in The Narrows, September 25, 2021.


LSM-N-001


LSM-N-002


LSM-N-003


LSM-N-004


LSM-N-005a


LSM-N-012

Figure 6. Selected photographs of substrate samples collected in The Narrows, September 25, 2021.

LSM-N-013

LSM-N-014

LSM-N-015

LSM-N-016

Figure 6. (continued).

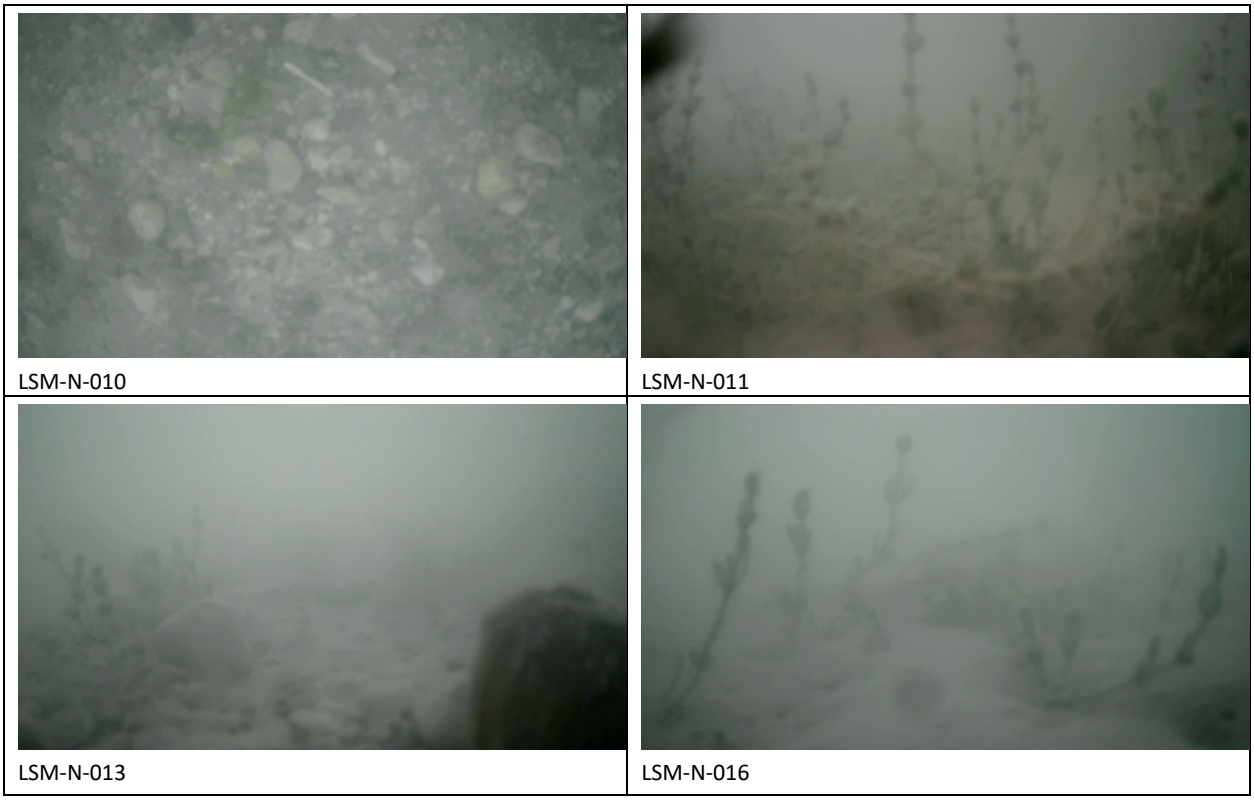

Figure 7. Selected screen captures of the underwater video camera survey showing benthic environment and substrates at sampling sites in The Narrows, September 25, 2021.

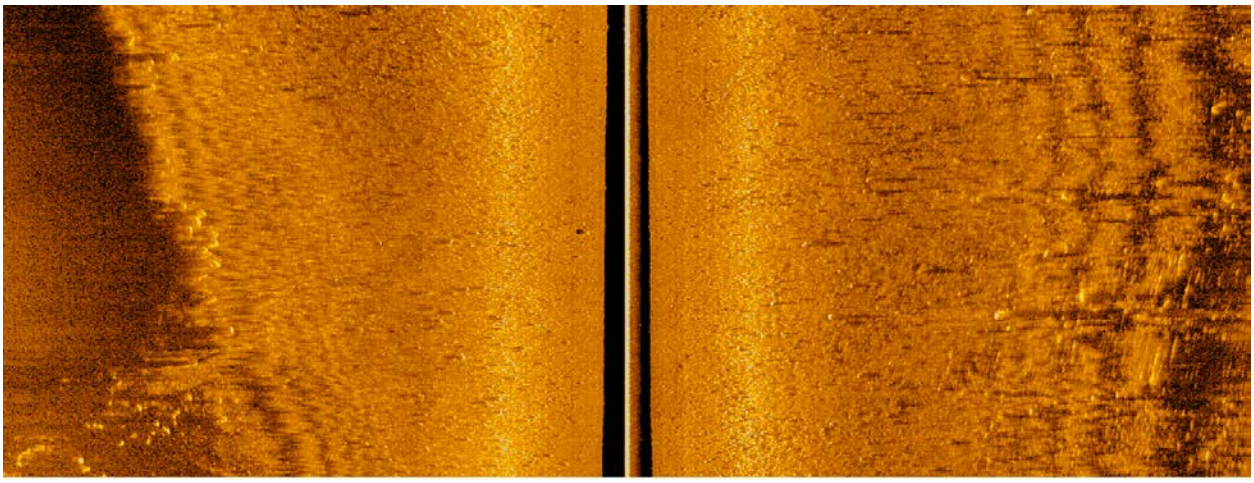

Figure 8. A sidescan sonar 'waterfall' image just downstream of LSM-N-002 at the inlet to The Narrows. Coarse substrate including gravel, cobble and intermittent boulder are apparent.

Figure 9. Photograph of exposed boulders along the shore at the entrance to The Narrows, September 25, 2021.

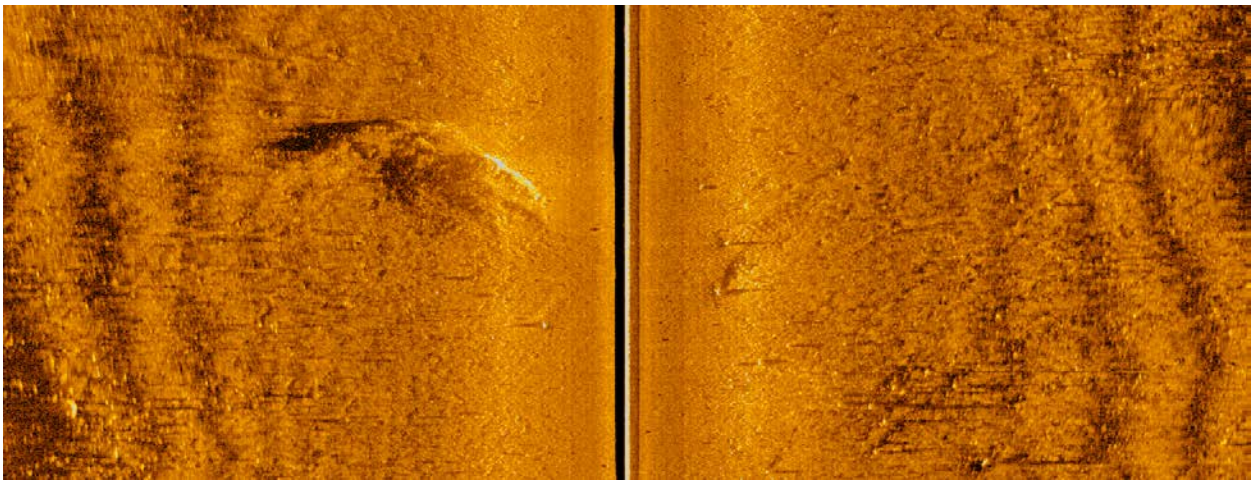

Figure 10. A sidescan sonar 'waterfall' image taken just upstream of LSM-N-003 in The Narrows. Coarse substrates including gravel, cobble and intermittent boulders are apparent.

Figure 11. Photograph of large exposed boulders amongst predominantly cobble and large gravel substrate at site LSM-N-004, September 25, 2021. Note the watermark stain on the boulder in the foreground.

Figure 12. Photograph of aquatic vegetation growing in the interstitial space of compact cobble and gravel substrate on the leeward side of large boulder substrate near site LSM-N-004.

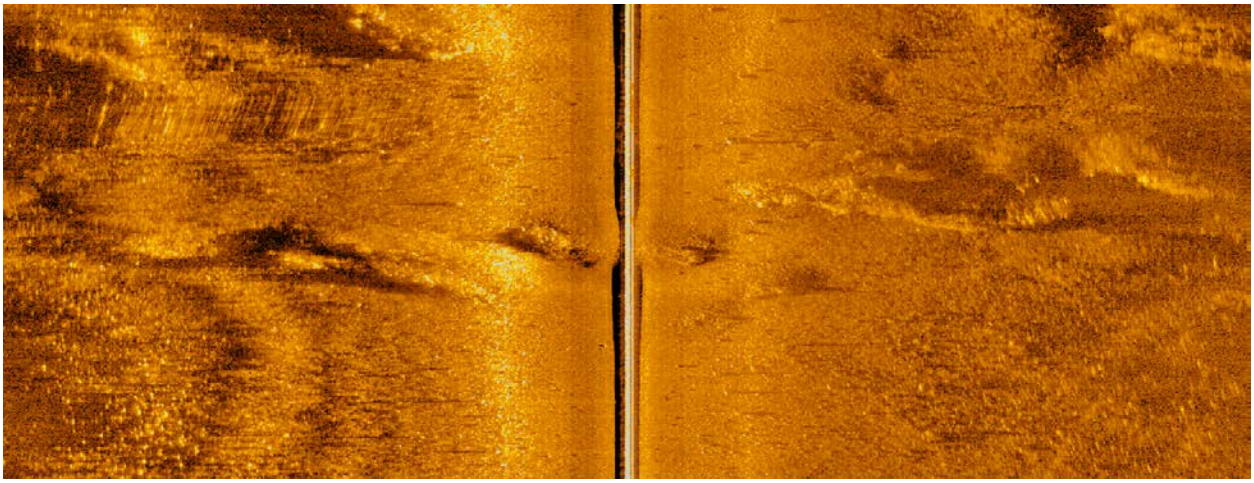

Figure 13. A sidescan sonar 'waterfall' image downstream of LSM-N-005 in The Narrows. Coarse substrates including gravel, cobble and intermittent boulder are apparent. Several tufts of aquatic vegetation are also visible.

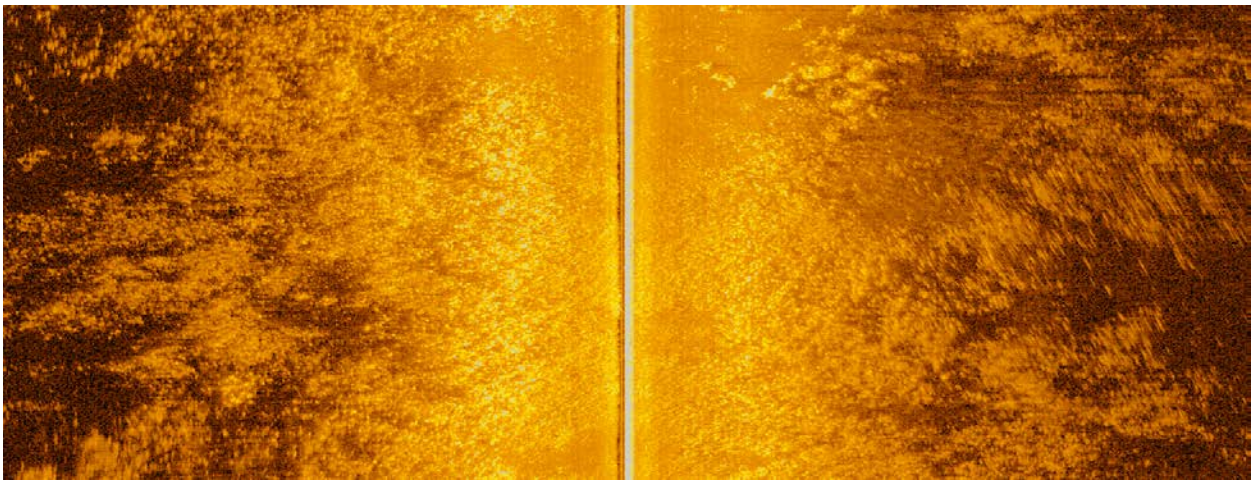

Figure 14. A sidescan sonar 'waterfall' image upstream of LSM-N-008 illustrating dense aquatic vegetation through the middle of the channel.

Figure 15. Photograph of flat boulder and cobble shoal area between LSM-N-013 and LSM-N-014 at the downstream constriction of The Narrows.

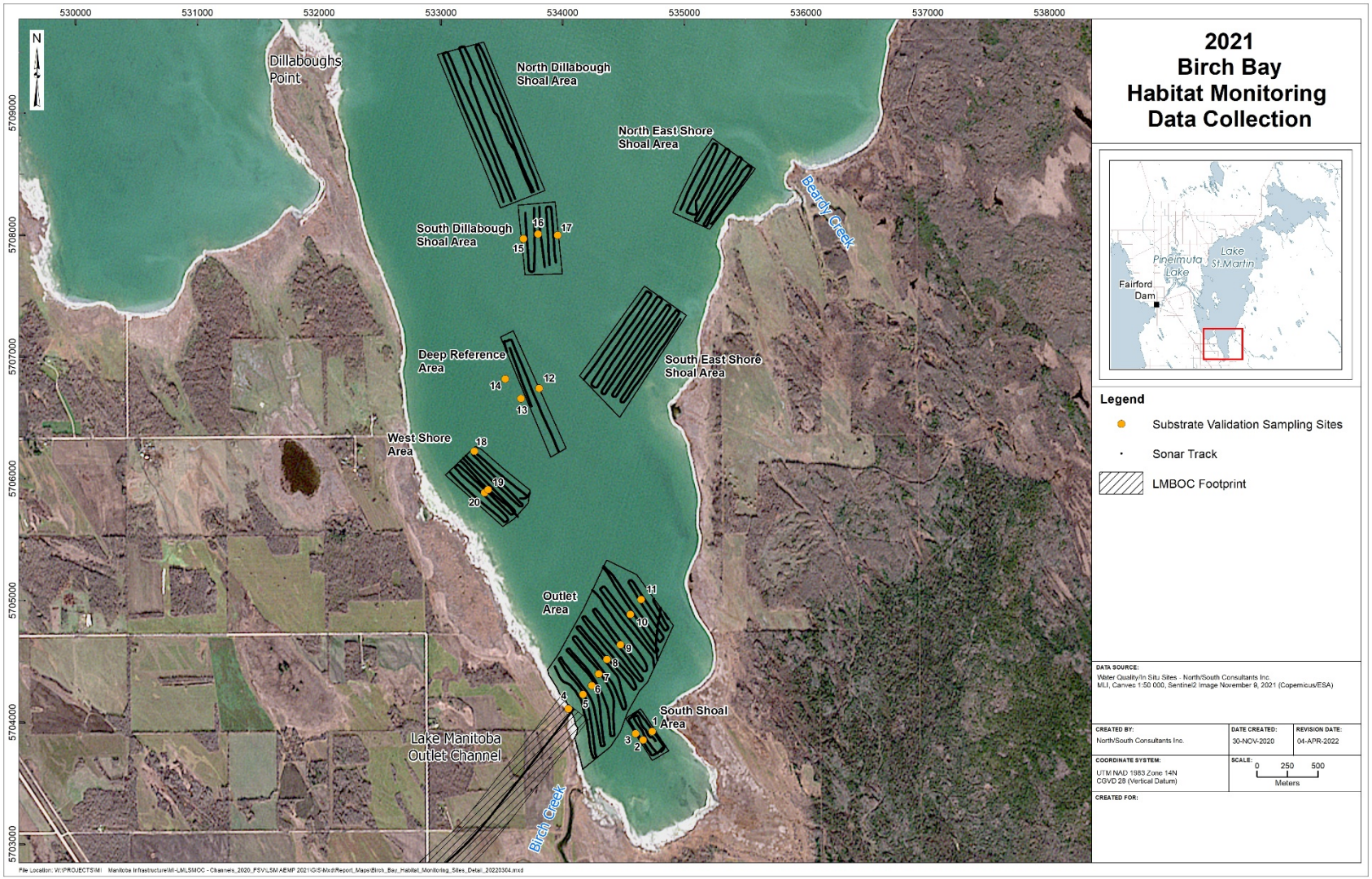

Figure 16. Map of bottom validation sites and sonar tracking from habitat surveys in Birch Bay, September 2021.


LSM-BB-001


LSM-BB-006


LSM-BB-007


LSM-BB-009


LSM-BB-010


LSM-BB-013

Figure 17. Selected photographs of substrate samples collected in Birch Bay, September 28, 2021.

LSM-BB-015

LSM-BB-016

Figure 17. (continued).

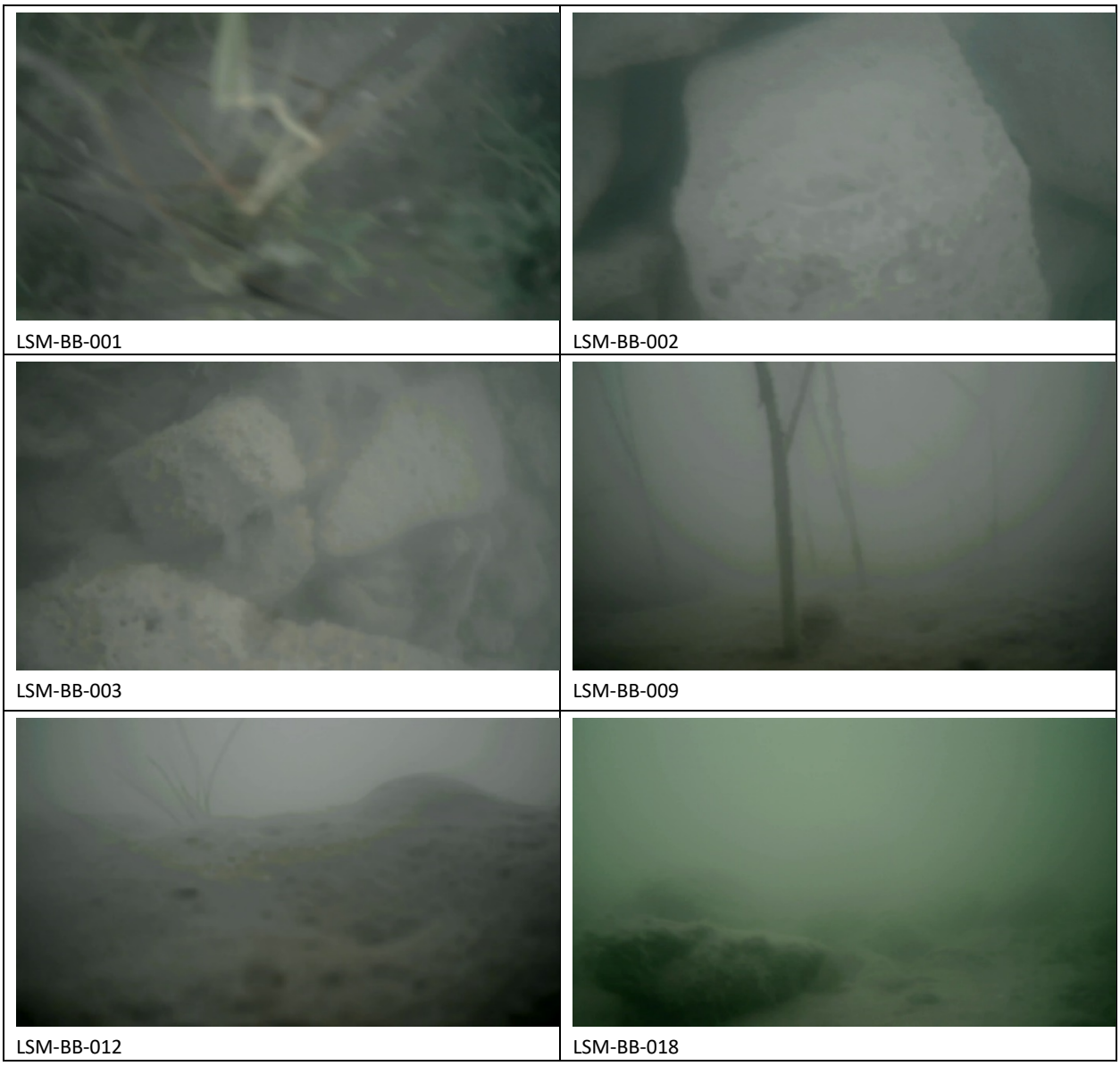

Figure 18. Selected screen captures of the underwater video camera survey showing benthic environment and substrates at sampling sites in Birch Bay (also see Table 7).

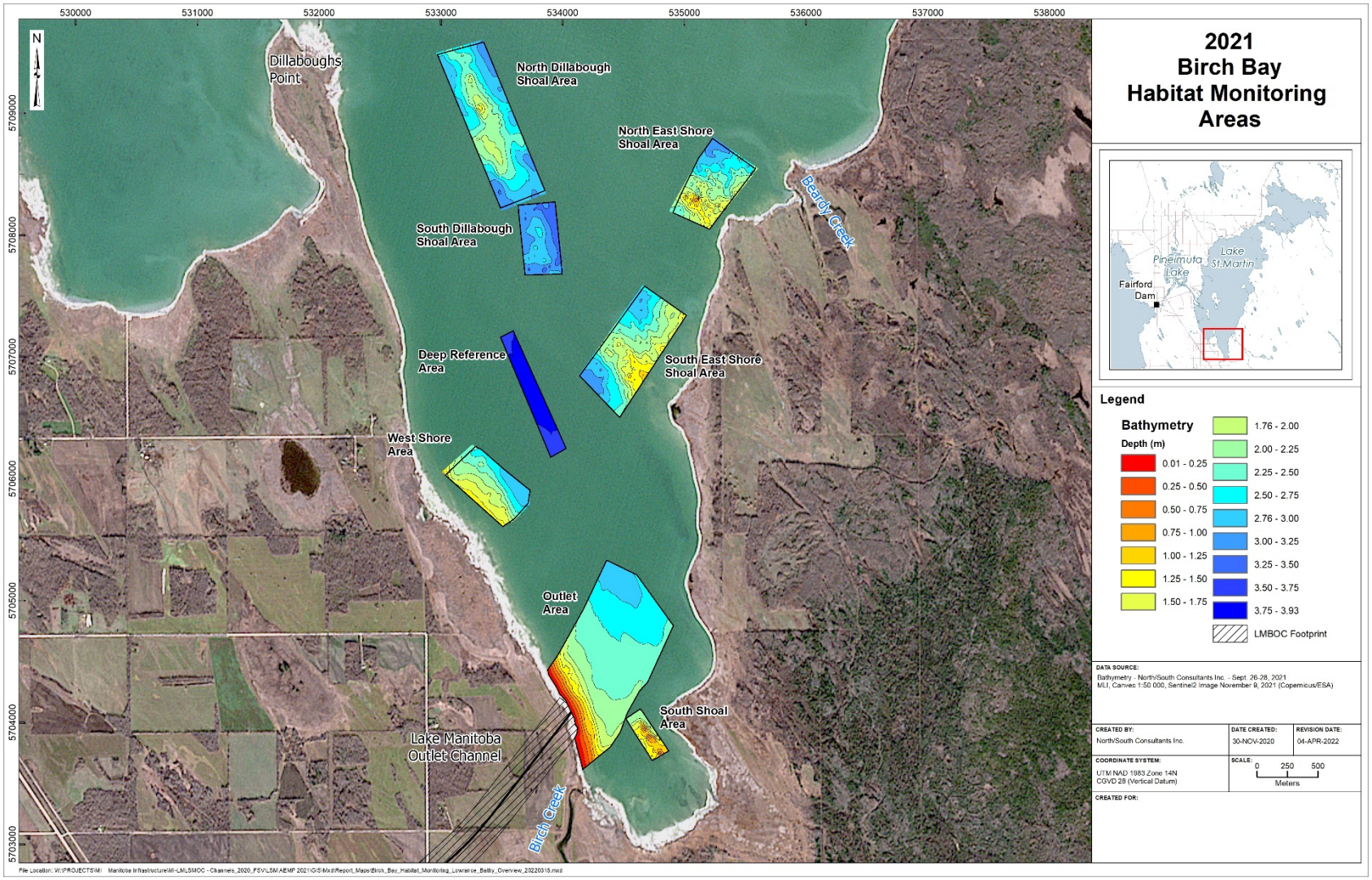

Figure 19. Overview of bathymetric mapping derived from single-beam sonar data collected during habitat surveys in Birch Bay, September 2021.

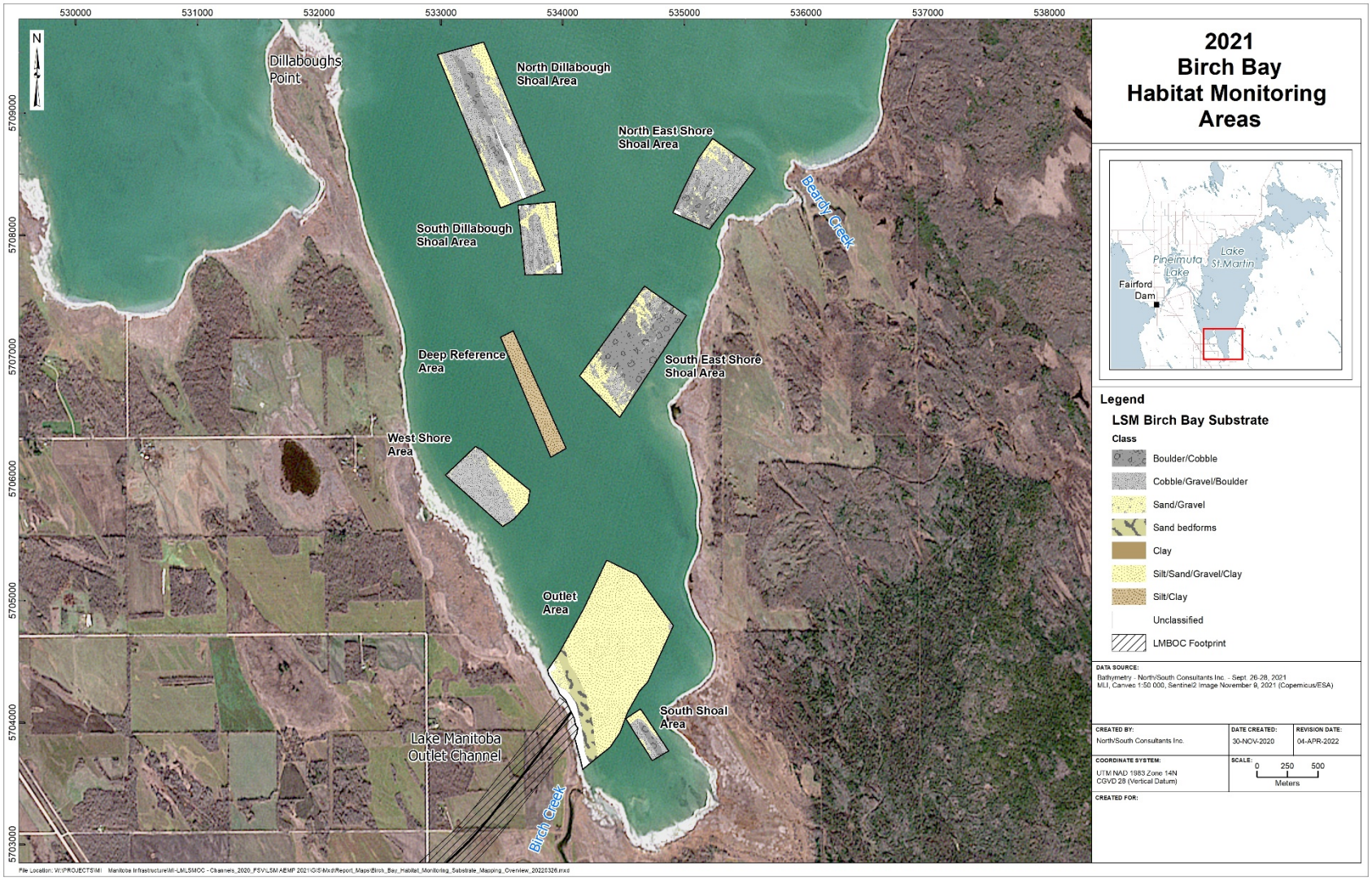

Figure 20. Overview of substrate mapping derived from side scan sonar data collected during habitat surveys in Birch Bay, September 2021.

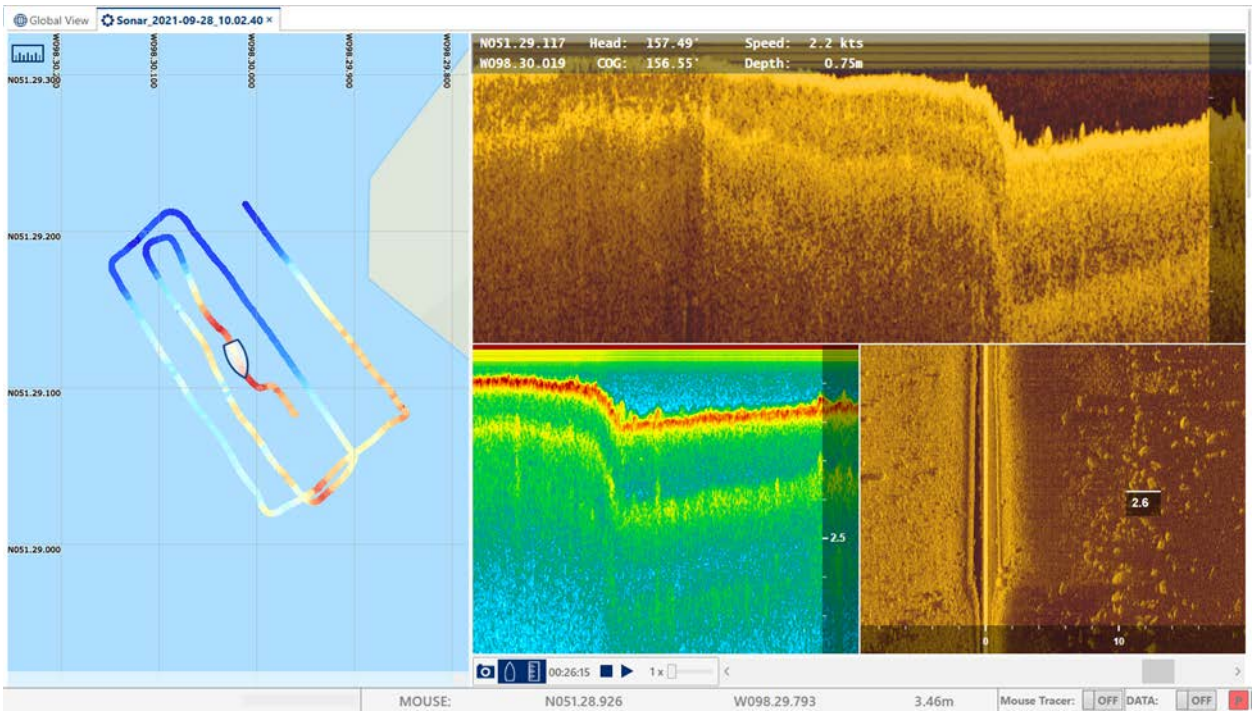

Figure 21. Lowrance Elite FS single beam acoustic tracking showing relative depth (left) and 455 kHz downscan (top right) and sidescan data of the South Shoal Area of Birch Bay. Large boulders are visible in the side scan 'waterfall' image in the bottom left panel.

Figure 22. Photograph of large boulders breaking the surface in the middle of the South Shoal Area of Birch Bay.

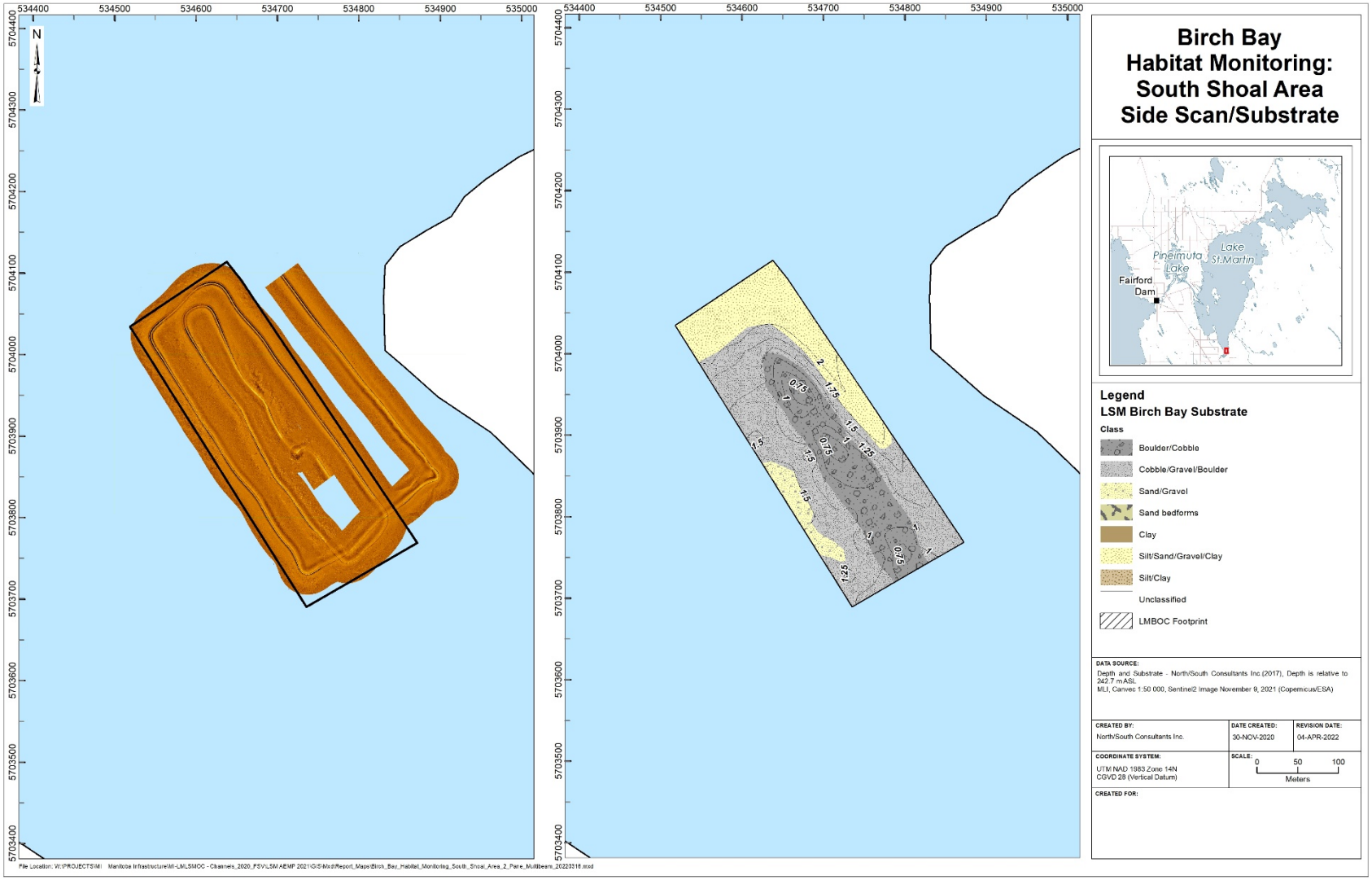

Figure 23. Map of the processed sidescan image mosaic, showing a small data gap where largest boulders occurred (left), and classified substrate with 0.25m depth contours (right) in the South Shoal Area of Birch Bay.

Figure 24. Photograph of exposed compact gravel and cobble shoreline at the LMOC Outlet Area of Birch Bay.

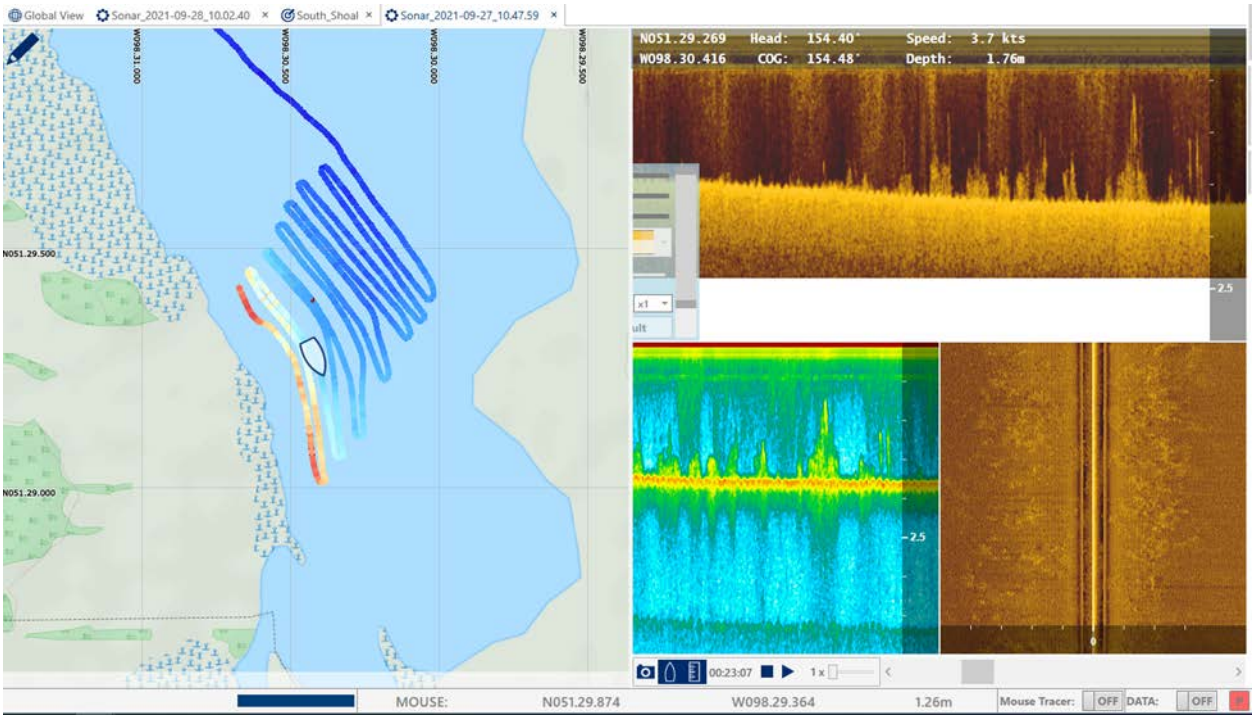

Figure 25. Lowrance Elite FS single beam acoustic tracking showing relative depth (left) and 455 kHz downscan (top right) and sidescan data of the Outlet Area of Birch Bay. Moderately dense patches of aquatic vegetation occur throughout the area beginning 150 m offshore, visible in the side scan and downscan imagery (top right and bottom right).

Figure 26. Map of the processed sidescan image mosaic showing patches of dense aquatic vegetation throughout (left), and classified substrate with 0.25m depth contours (right) in the Outlet Area of Birch Bay.

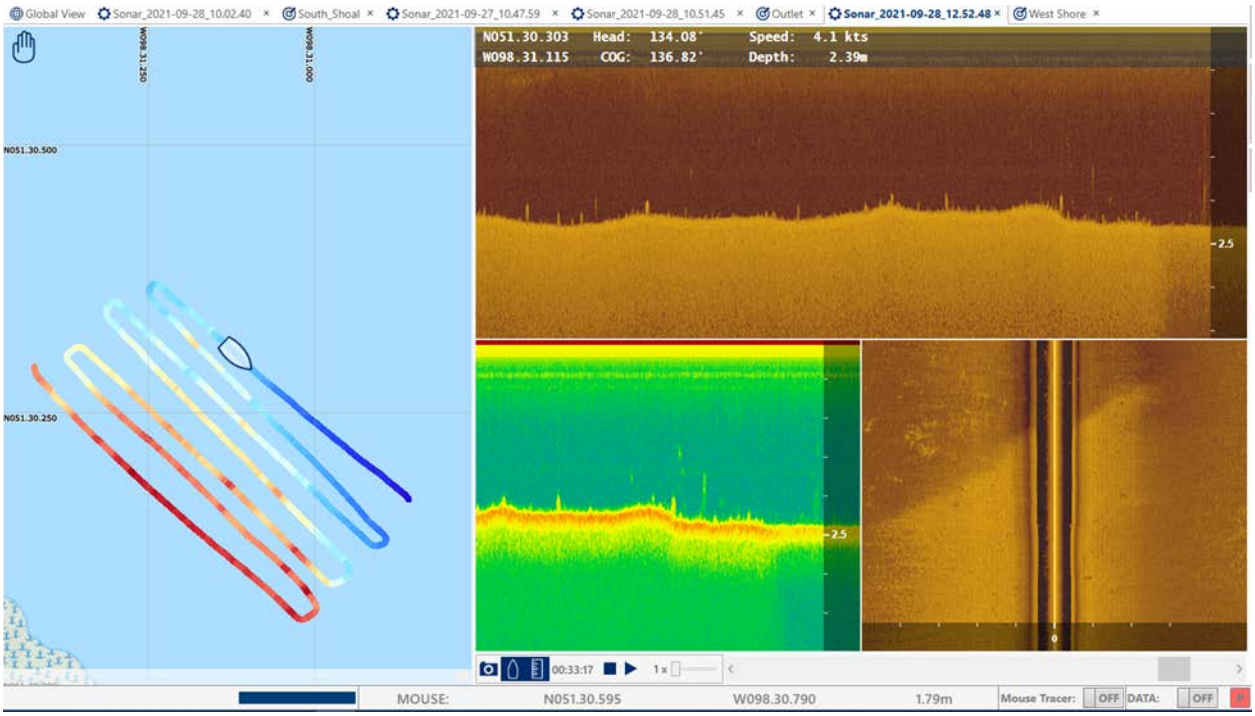

Figure 27. Lowrance Elite FS single beam acoustic tracking showing relative depth (left) and 455 kHz downscan (top right) and sidescan data of the West Shore Area of Birch Bay. The transition from cobble, gravel, and intermittent boulder to sand, silt, clay substrates is shown in the northeast corner of the survey area.

Figure 28. A high-resolution Ping 3DSS-IDX-450 sidescan 'waterfall' image of the transition from cobble, gravel, and boulder substrate to finer sand, silt, clay and mixed gravels in the northeast corner of the West Shore Area. Note the intermittent patches of aquatic vegetation against the dark toned fine substrates.

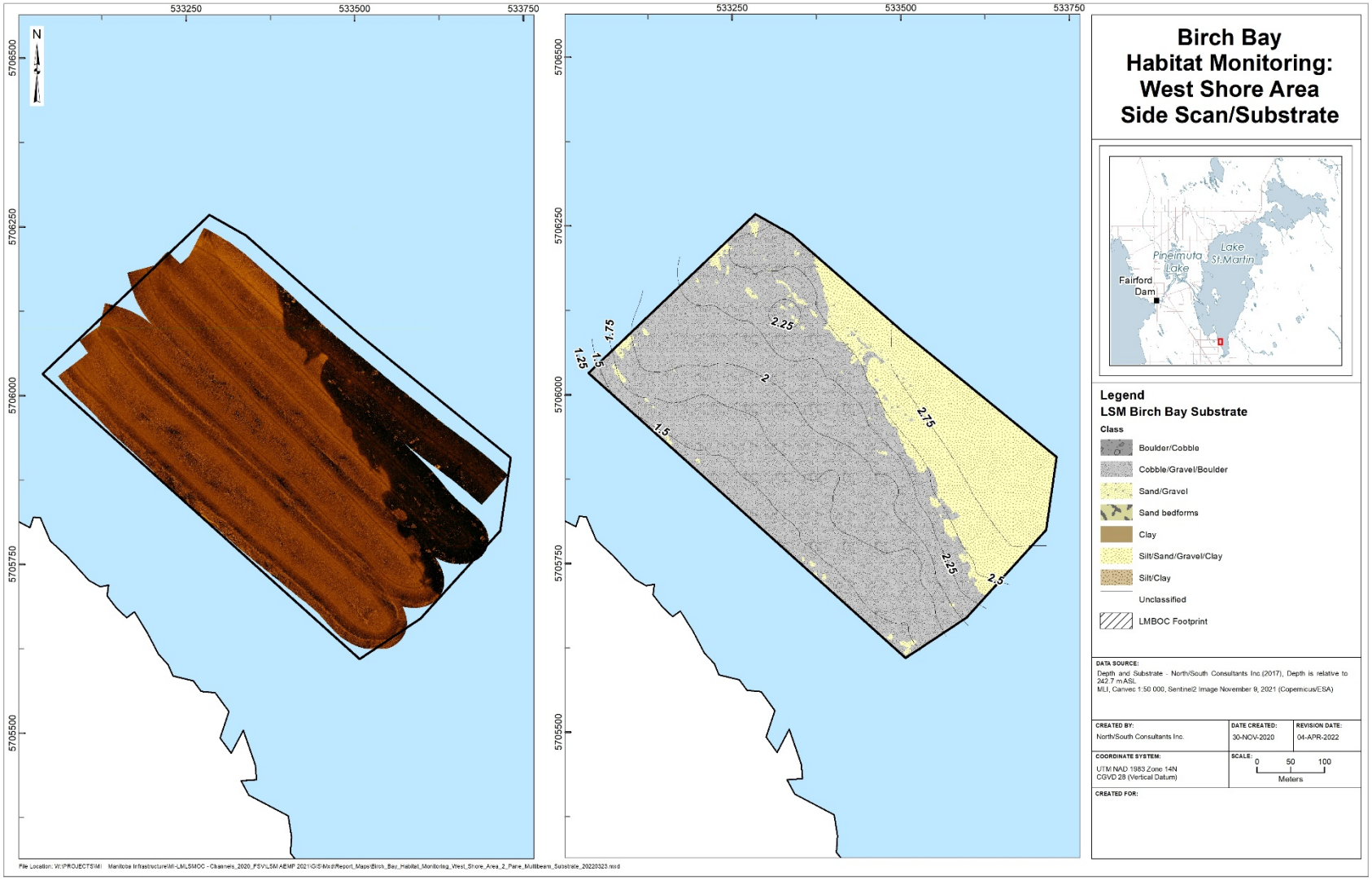

Figure 29. Map of the processed sidescan image mosaic (left), and classified substrate with 0.25m depth contours (right) in the West Shore Area of Birch Bay.

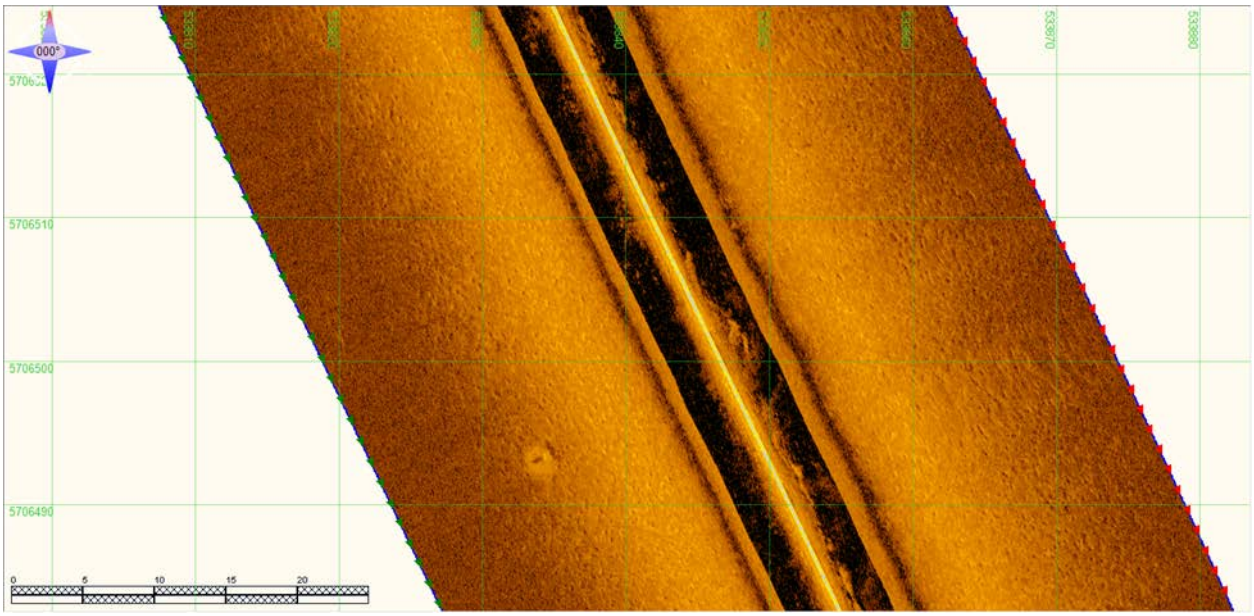

Figure 30. Zoomed in map of the processed sidescan image mosaic in the offshore Deepwater Reference Area of Birch Bay. Pockmarked fine silt, sand, and clay sediments are distributed homogenously throughout the area. A large 2 m wide crater like depression was noted in the area.

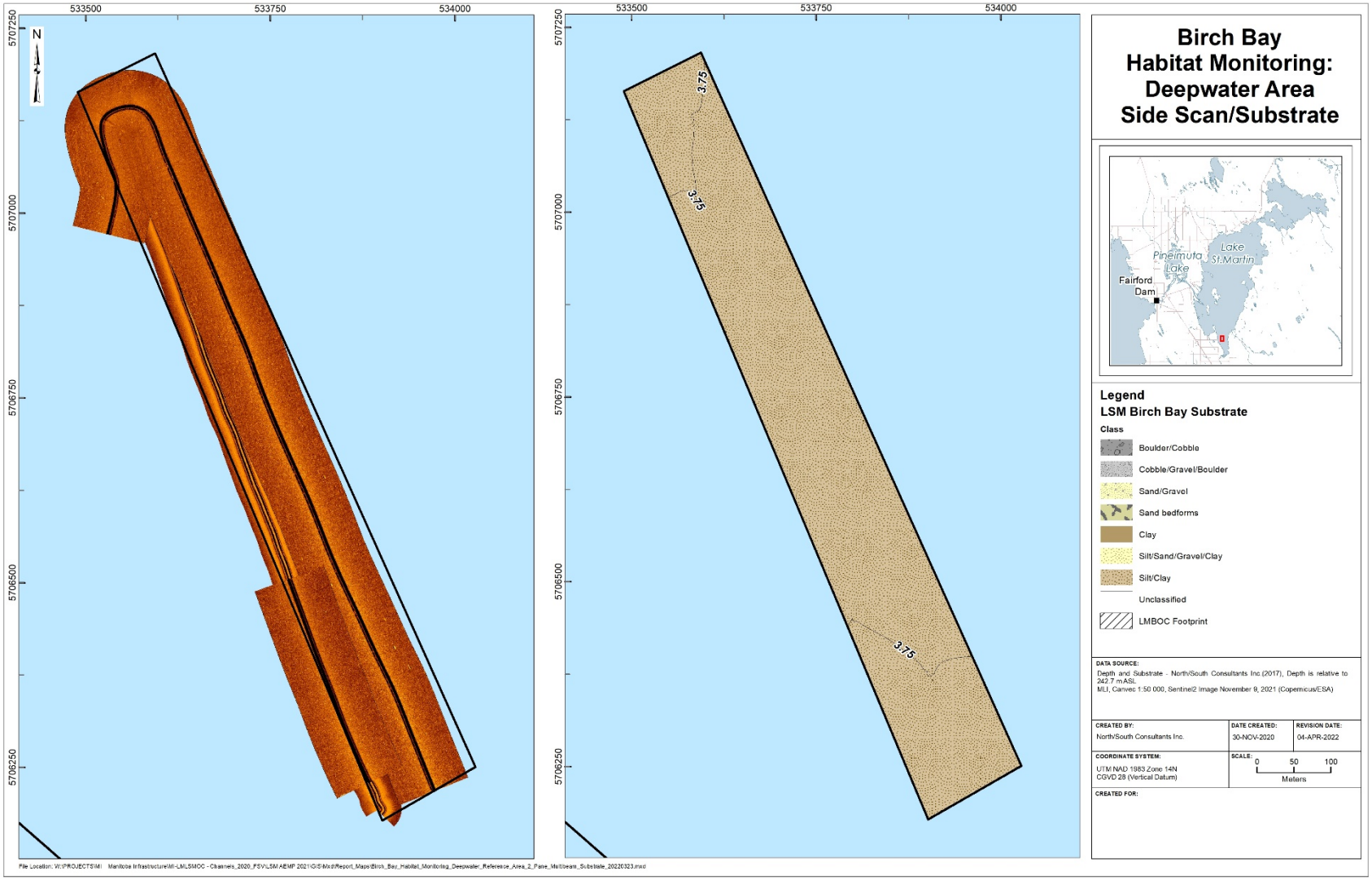

Figure 31. Map of the processed sidescan image mosaic (left), and classified substrate with 0.25m depth contours (right) in the Deepwater Reference Area of Birch Bay.

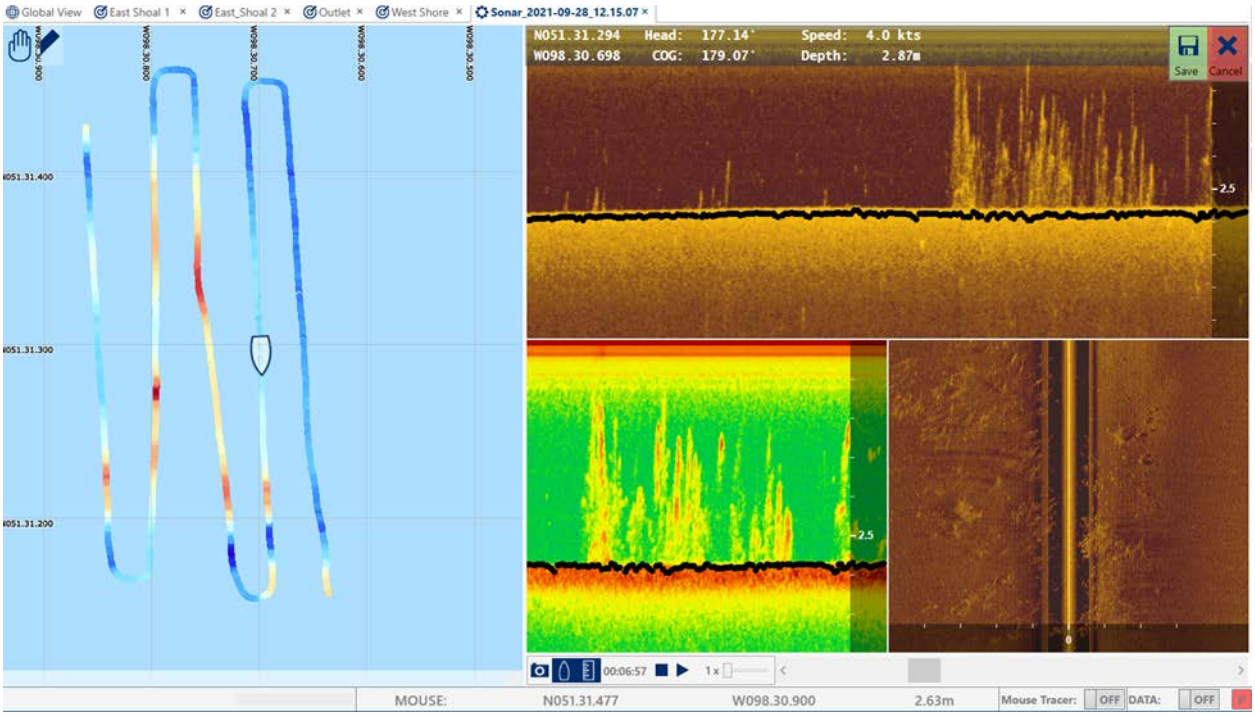

Figure 32. Lowrance Elite FS single beam acoustic tracking showing relative depth (left) and 455 kHz downscan (top right) and sidescan data of the South Dillabough Shoal Area of Birch Bay as viewed in Reefmaster software. Low lying fine sediment area with aquatic vegetation visible (right).

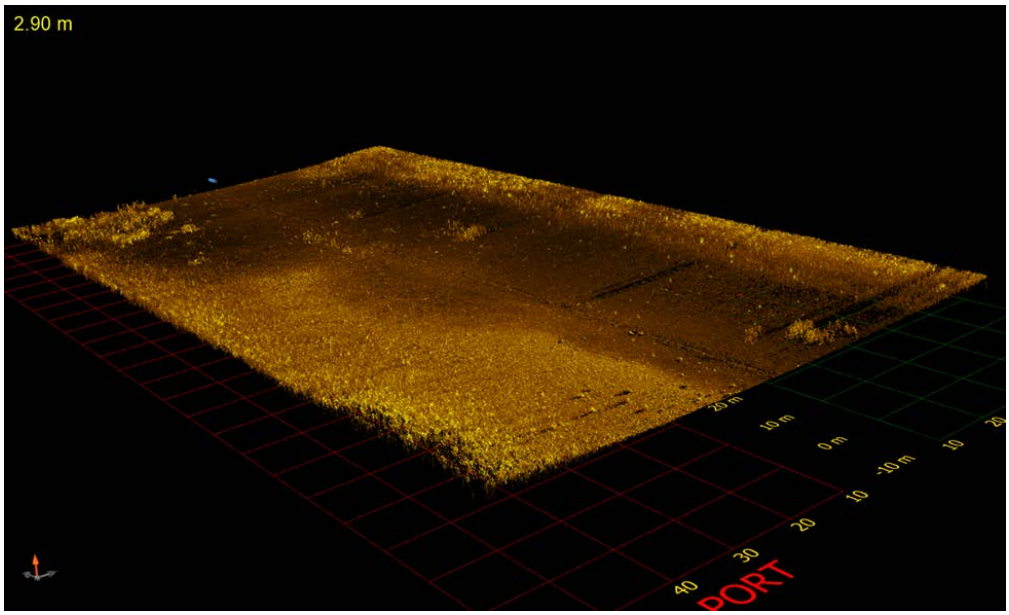

Figure 33. High resolution Ping 3DSS-IDX-450 sidescan amplitude data displayed in 3D perspective showing fine substrates, and patches of vegetation adjacent to coarse shoal substrates in the South Dillabough Shoal Area.

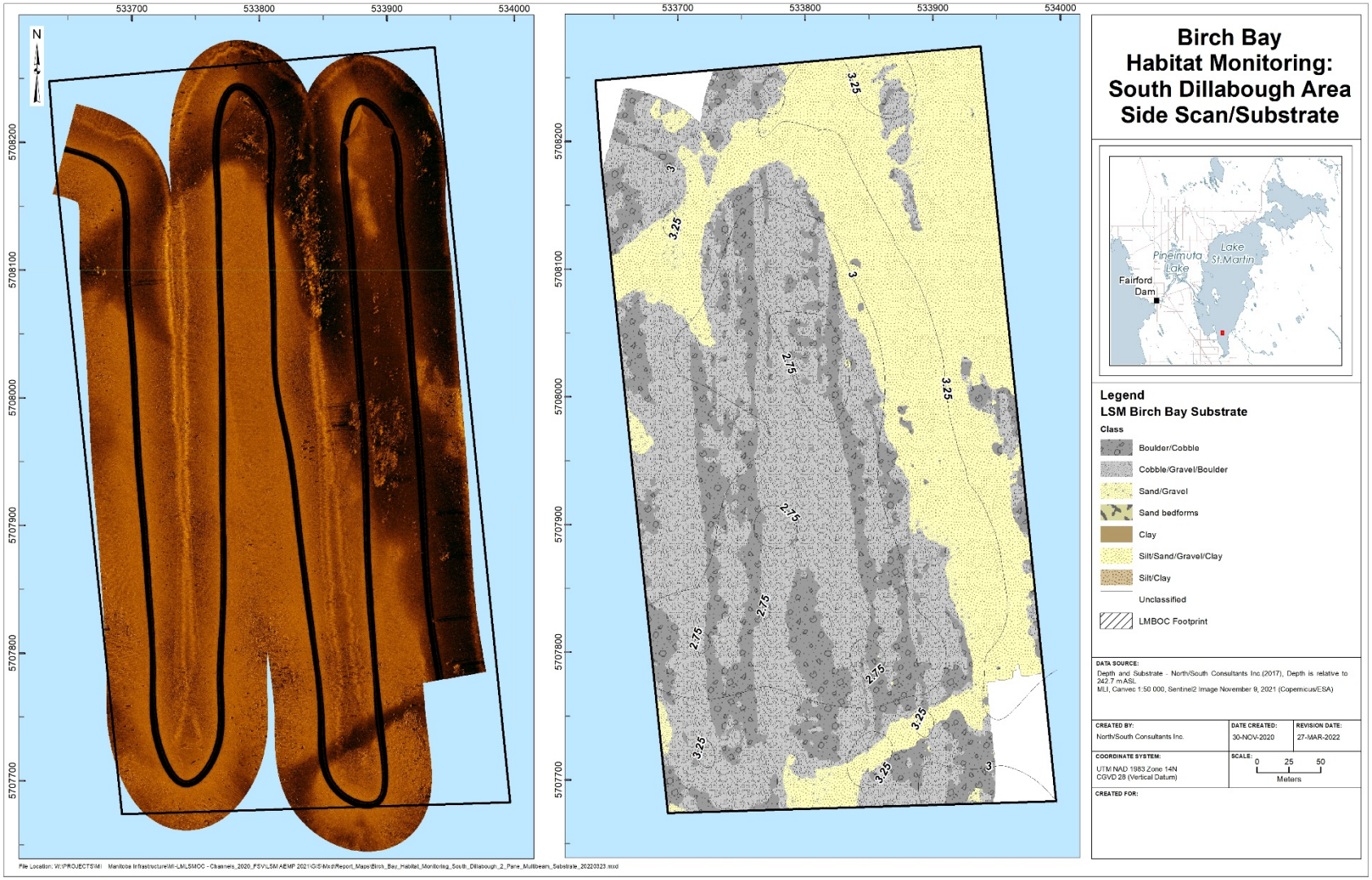

Figure 34. Map of the processed sidescan image mosaic (left), and classified substrate with 0.25m depth contours (right) in the South Dillabough Shoal Area of Birch Bay.

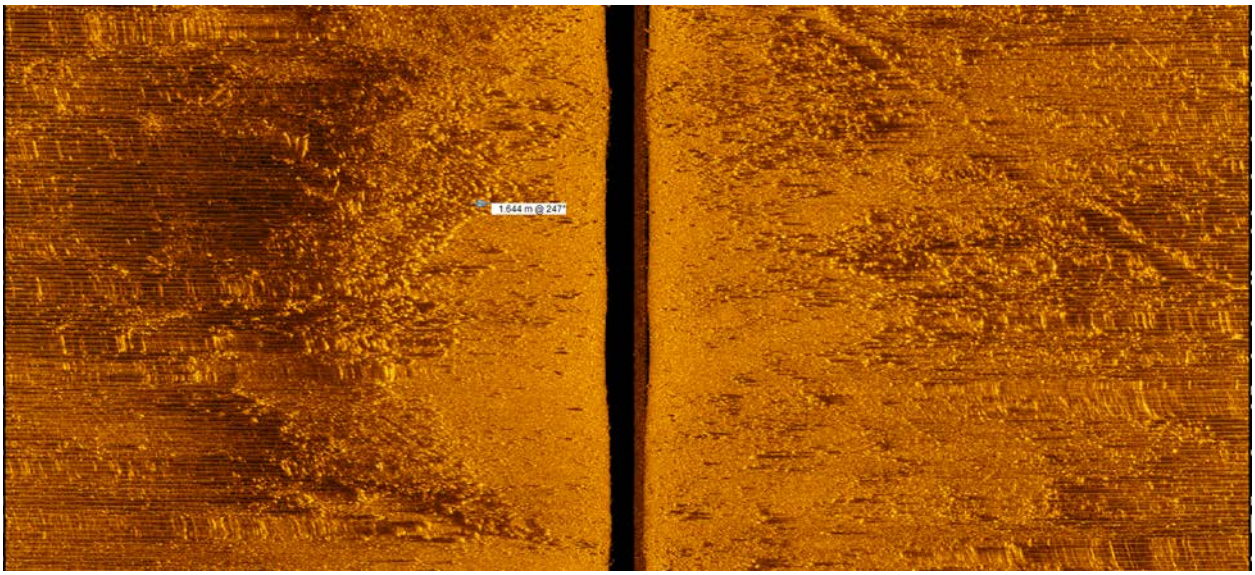

Figure 35. A high-resolution Ping 3DSS-IDX-450 sidescan 'waterfall' image of clusters of large boulders amongst cobble gravel and intermittent boulder in the North Dillabough Shoal Area.

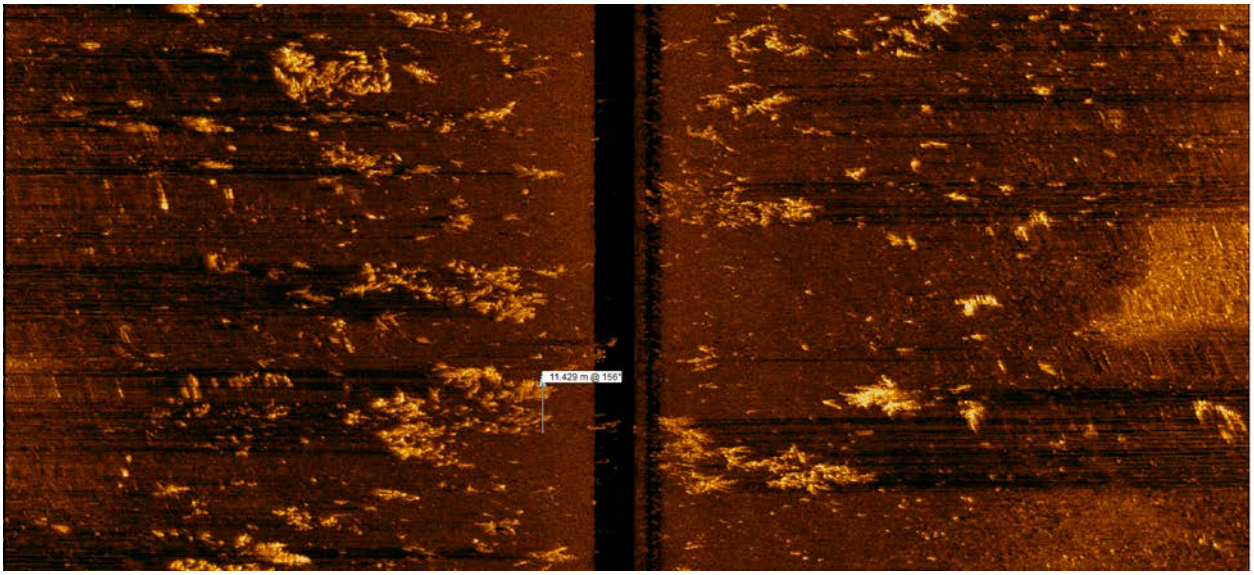

Figure 36. A high-resolution Ping DSP 3DSS-IDX-450 sidescan 'waterfall' image of finer sand, silt, clay and mixed gravels in the northeast corner of the North Dillabough Shoal Area. Note the large patches of aquatic vegetation against the dark toned fine substrates.

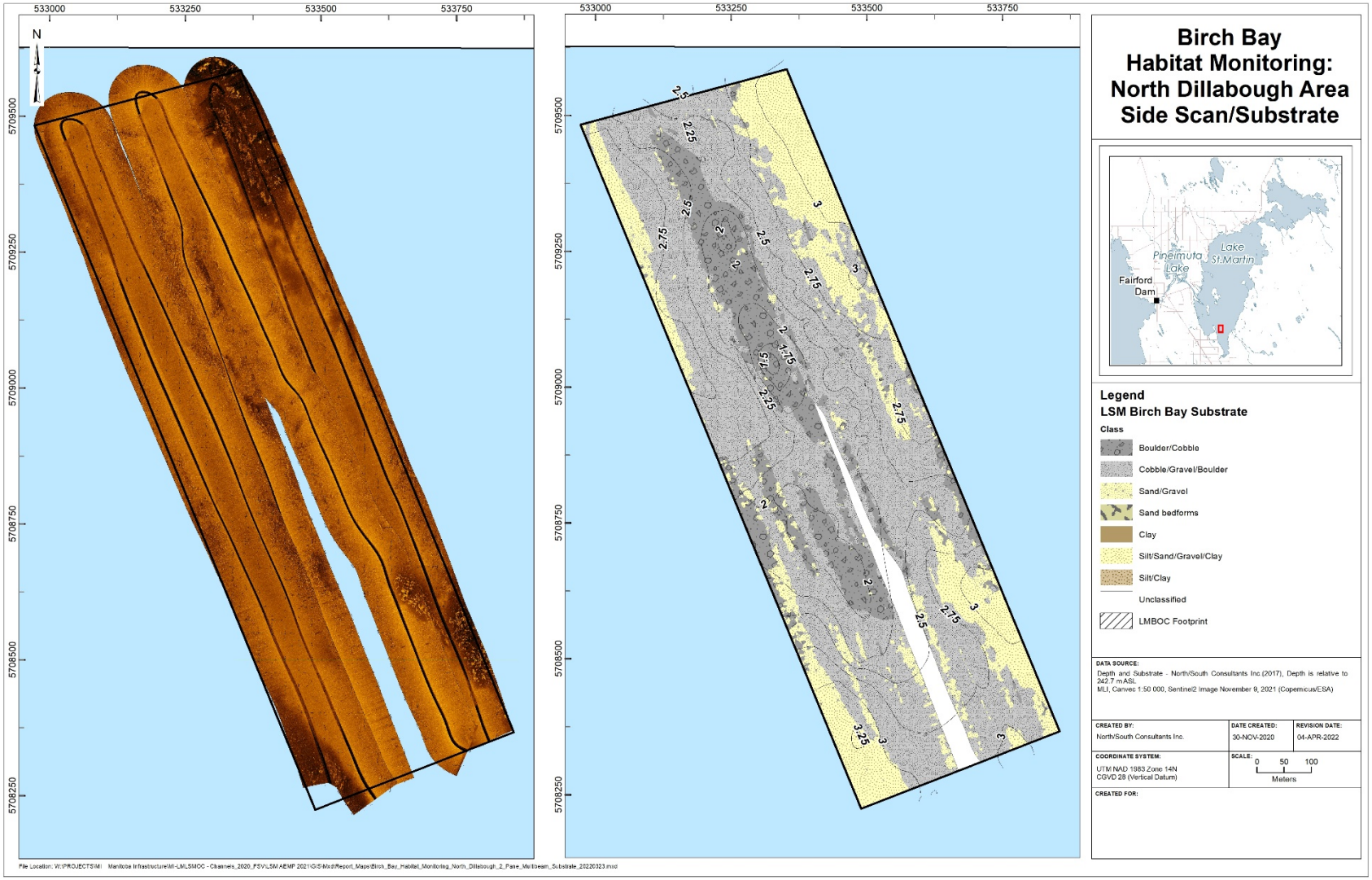

Figure 37. Map of the processed sidescan image mosaic (left), and classified substrate with 0.25m depth contours (right) in the North Dillabough Shoal Area of Birch Bay.

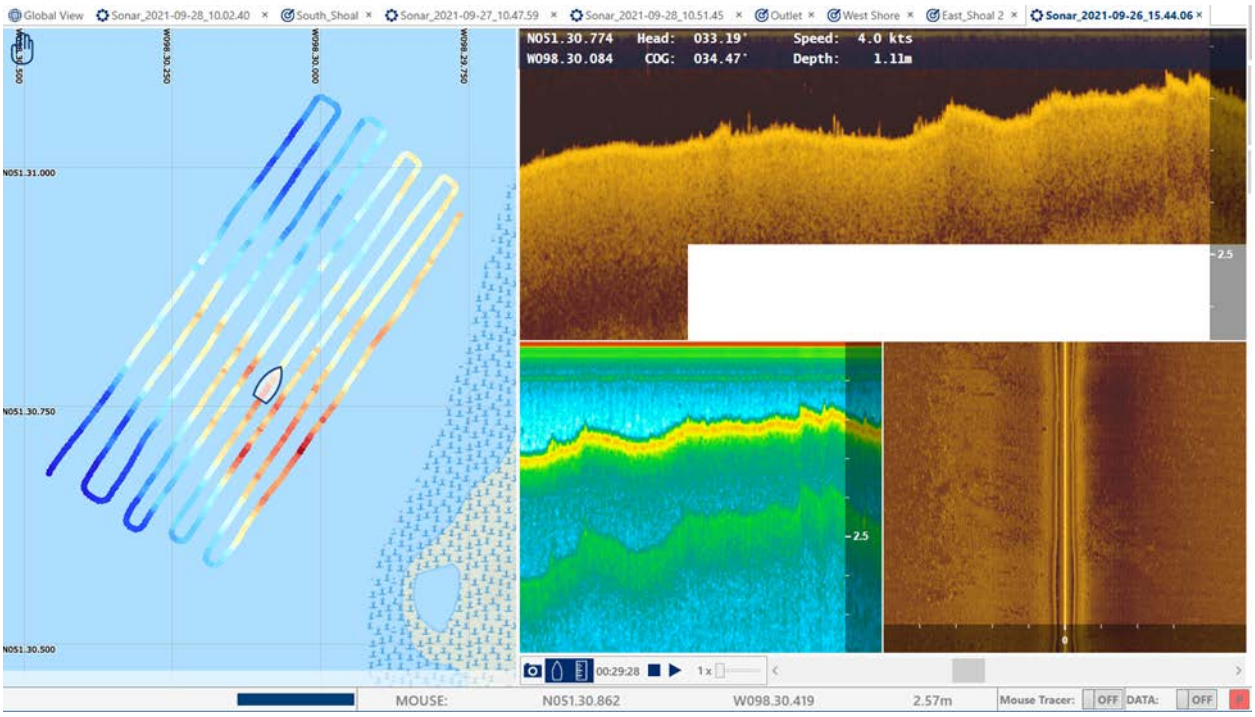

Figure 38. Lowrance Elite FS single beam acoustic tracking showing relative depth (left) and 455 kHz downscan (top right) and sidescan data of the South East Shore Shoal Area of Birch Bay as viewed in Reefmaster software. Shoal substrates are predominantly boulder, cobble, and cobble, gravel, and intermittent boulder.

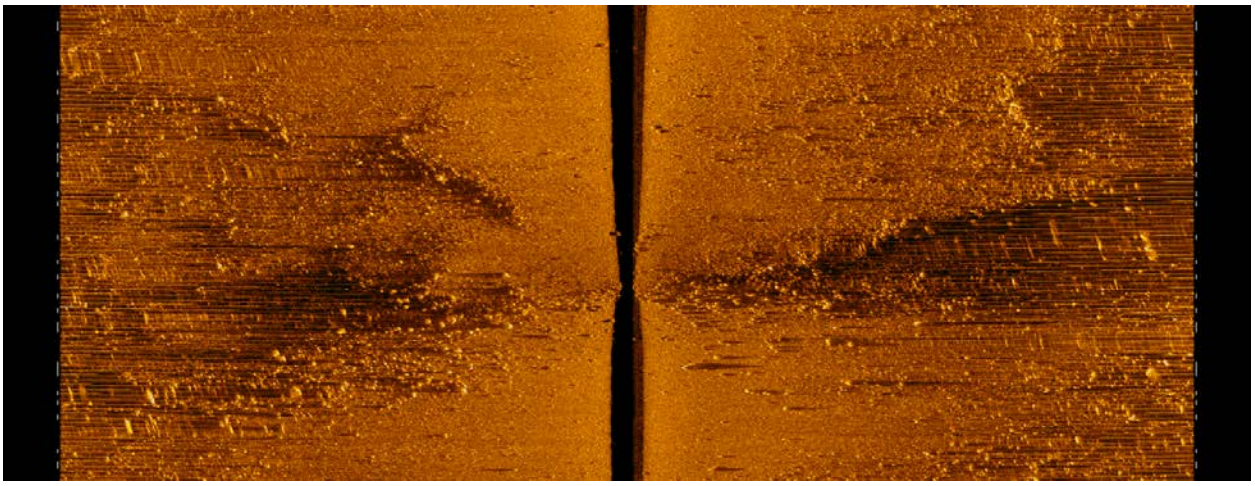

Figure 39. A high-resolution Ping 3DSS-IDX-450 sidescan 'waterfall' image of rocky shoal substrates in the South East Shore Shoal Area of Birch Bay. Note the piles of large boulder surrounded by cobble, gravel, and intermittent boulder.

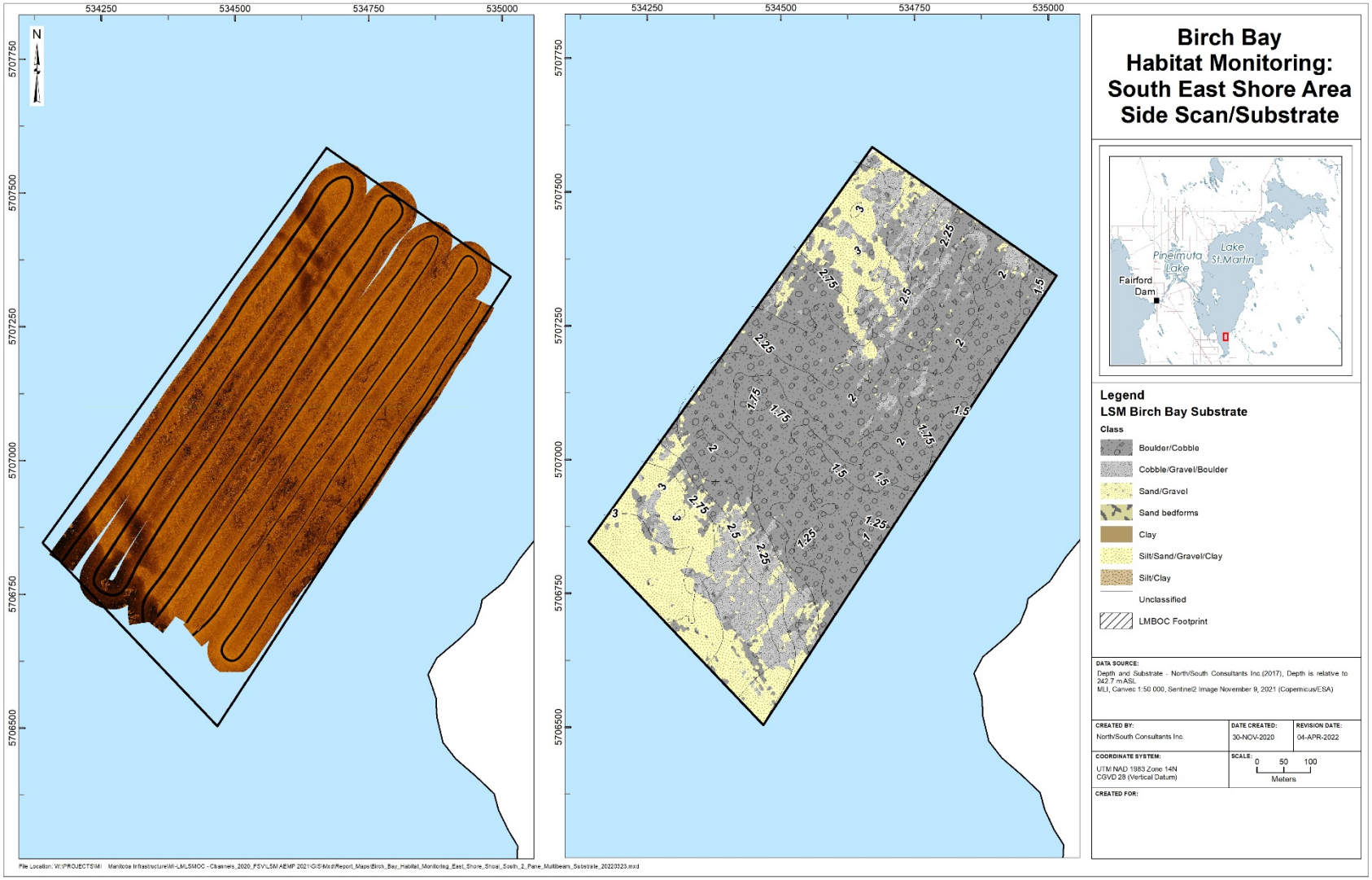

Figure 40. Map of the processed sidescan image mosaic (left), and classified substrate with 0.25m depth contours (right) in the South East Shore Shoal Area of Birch Bay.

Figure 41. Photograph looking southeast towards the rocky shoreline of the North East Shore Shoal Area of Birch Bay.

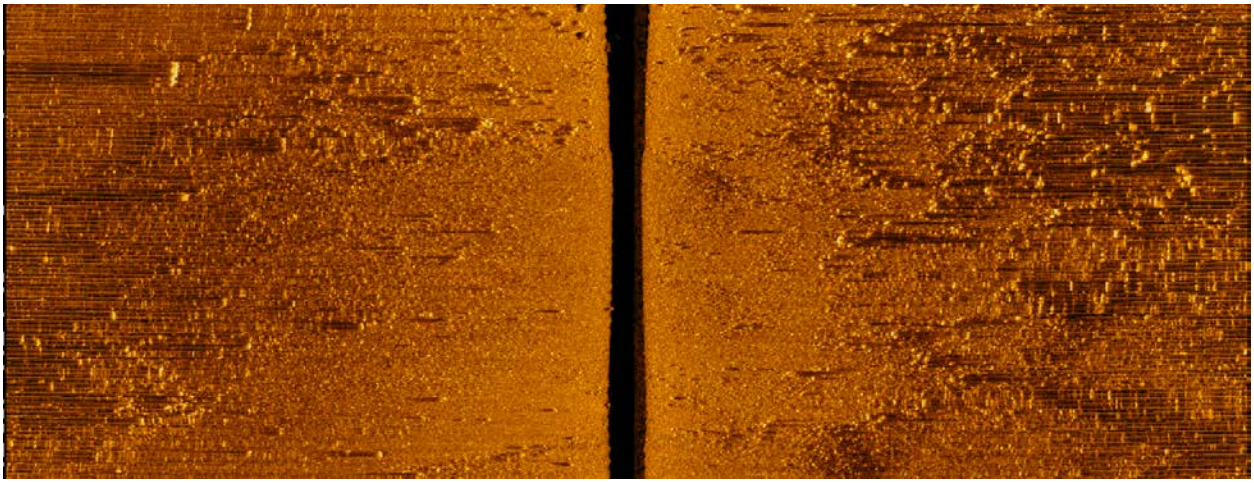

Figure 42. A high-resolution Ping 3DSS-IDX-450 sidescan 'waterfall' image of rocky shoal substrates at the North East Shore Shoal Area. Note the large boulder surrounded by cobble, gravel, and intermittent boulder substrate.

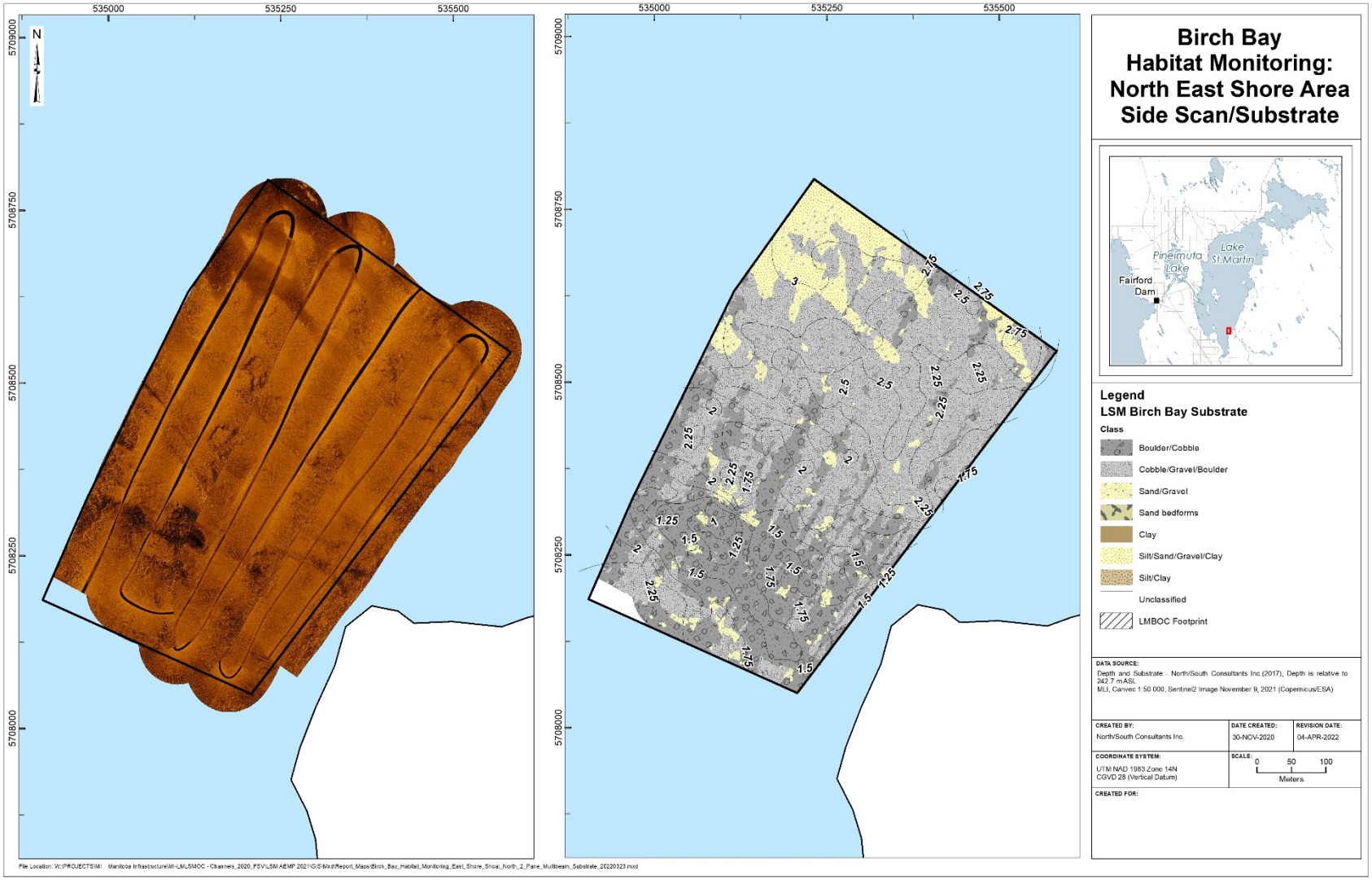

Figure 43. Map of the processed sidescan image mosaic (left), and classified substrate with 0.25m depth contours (right) in the North East Shore Shoal Area of Birch Bay.

APPENDIX 1. SHORELINE OBSERVATIONS IN THE NARROWS OF LAKE ST. MARTIN, JUNE 10, 2021

Table A1-1. Summary of habitat observations recorded on June 10, 2021.

Site	Location [1]		Substrate Classification Conditions					General Description
	Easting	Northing	Mud	Sand	Gravel	Cobble	Boulder	
Site 1	547671	5734535	20%	40%	20%	10%	10%	Beach ridge west - boulders, interspersed with gravel and cobble. South beach - sands, some clay and gravel with medium compaction. Nearshore - sand/gravel (small) on top of clay, soft compaction, lots of clam shells. Beach ridge approximately 20 m wide, 50 cm high without boulders. Flats on north side.
Site 2	547701	5734396	25%	45%	15%	10%	5%	South nearshore substrate - sand and small gravel over clay. Some larger gravel deposits. Soft medium compaction. Beach ridge 30-40 m wide and 1.0-1.2 m high. Sand, gravel and cobble to north, boulders in middle. Flats to north, with sand and small gravel over clay, interspersed with cobble and boulders, medium compaction nearshore.
Site 3	547905	5734294	0%	15%	45%	30%	10%	Less sand, more gravel and cobble than sites 1 and 2, boulders to shore. Deeper offshore. Nearshore substrate - sand and small gravel, medium compaction. Ridge height 1.2-1.5 m, ridge width 60-70 m. North side of ridge - sands/small gravel interspersed with cobble and boulder overlay.
Site 4	548074	5734342	0%	45%	50%	0%	5%	Spit - small gravel and sand, few boulders. Larger gravel near shore. Sand on west side of spit and some small gravel.
Site 5	548435	5734082	30%	45%	15%	5%	5%	Sand and small gravel over clay, some cobble and boulder.
Site 6	548854	5734178	0%	40%	45%	10%	5%	Substrate - sand and gravel over fines, interspersed with cobble and boulder
Site 7	547920	5736194	0%	30%	30%	20%	20%	Exposed boulder cobble and gravel shoal
Site 8	548238	5736157	0%	20%	20%	30%	30%	Exposed boulder, cobble, and gravel/sand shoal
Site 9	548726	5737007	0%	20%	20%	20%	30%	Exposed boulder, cobble, and gravel shoal
Site 10	549604	5736308	0%	15%	15%	20%	50%	Exposed boulder and cobble shoal

1 - sites illustrated on Figure 5; UTM coordinates; Datum NAD83, 14U

Photograph A1-1. Looking west along the top of a boulder pile at Site 1.

Photograph A1-2. Compact cobble and gravel beach at Site 1.

Photograph A1-3. Exposed sand and gravel substrate with intermittent boulder at Site 1.

Photograph A1-4. Exposed gravel, sand, and cobble/boulder substrate at Site 2.

Photograph A1-5. Close up of sand ripples, gravel and clam shell at Site 2.

Photograph A1-6. Boulder and exposed gravel and cobble at Site 3.

Photograph A1-7. Compact gravel substrate at Site 3.

Photograph A1-8. Intermittent boulder and exposed gravel and sand substrate at Site 5.

Photograph A1-9. Exposed gravel, cobble and intermittent boulder at Site 6

Photograph A1-10. Compact gravel and cobble substrate at Site 6.

Photograph A1-11. Exposed boulder and cobble shoal at Site 7.

Photograph A1-12. Exposed cobble and gravel shoal at Site 8.

Photograph A1-13. Exposed boulder and cobble shoal at Site 9.

Photograph A1-14. Exposed boulder and cobble shoal at Site 10.