Announcement M13AS00014: Hurricane Sandy Coastal Recovery and Resiliency - Resource Identification, Delineation and Management Practices

Agreement: M14AC00010: New Hampshire Cooperative Agreement;
University of New Hampshire and New Hampshire Geological Survey

Assessment of Offshore Sand and Gravel Resources for Beach Nourishment in New Hampshire

Summary Reports

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University of New Hampshire, Center for Coastal and Ocean Mapping

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Cooperative Agreement Outputs and Deliverables for the Northeastern U.S. Continental Shelf (Regional Studies):

Ward, L.G., Johnson, P., Bogonko, M., McAvoy, Z.S., and Morrison, R.C., 2021, Northeast Bathymetry and Backscatter Compilation: Western Gulf of Maine, Southern New England and Long Island Sound: BOEM/New Hampshire Cooperative Agreement (Contract M14ACOOO10) Technical Report.

High-resolution bathymetry is critical for mapping the surficial geology of the seafloor, identifying critical habitats, and assessing marine mineral resources such as sand and gravel. In 2016, a high-resolution bathymetry map was developed for the western Gulf of Maine (WGOM) utilizing all available multibeam echosounder (MBES) surveys, as well as several older extant surveys (Western Gulf of Maine Bathymetry and Backscatter Synthesis). As part of that effort, a backscatter mosaic also was developed for a subset of the MBES surveys. The backscatter synthesis did not include all of the MBES surveys due to low quality of some of the mosaics and limitations of combining MBES backscatter surveys (e.g., different frequencies).

To extend the high-resolution bathymetry coverage of the U.S. Northeast (NE), the WGOM Bathymetry and Backscatter Synthesis was substantially expanded. A careful review of all available high-resolution bathymetry and backscatter was conducted and the needed databases obtained. In addition, bathymetric lidar surveys were obtained, primarily in the WGOM. Unfortunately, the MBES coverage is relatively sparse over large areas of the NE region with few surveys available for mid and northern Maine, the area south of Cape Cod, and along the Atlantic coast of Long Island to New York Harbor. However, relatively good coverage exists for Long Island Sound. Similarly, high quality backscatter mosaics co-registered with the bathymetry is sparse. Nevertheless, the available bathymetry and backscatter does allow a significant expansion of the overall coverage and exposes areas where more information would be beneficial. Some low-resolution bathymetry data (e.g., single beam surveys that leave gaps between survey lines) were also obtained but were primarily used in a Regional Bathymetry Map.

The “Northeast Bathymetry and Backscatter Compilation: Western Gulf of Maine, Southern New England and Long Island Sound” expands the coverage of the high-resolution MBES to include southern New England and Long Island Sound. The bathymetry synthesis is gridded at 4m, 8m, and 16m (Figures 1, 2 and 3). Also included are MBES bathymetry surveys that provide more detail of regions where research projects have been conducted by the University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center (CCOM/JHC). The overall backscatter coverage for the WGOM inner continental shelf is relatively good. South of Cape Cod to New York Harbor including Long Island Sound the backscatter is limited and presented here as individual surveys.

The bathymetry and backscatter in the “Northeast Bathymetry and Backscatter Compilation: Western Gulf of Maine, Southern New England and Long Island Sound” is available through UNH CCOM/JHC at: (https://maps.ccom.unh.edu/portal/apps/webappviewer/index.html?id=5d314116ad094afebbd02ffc185164f6).

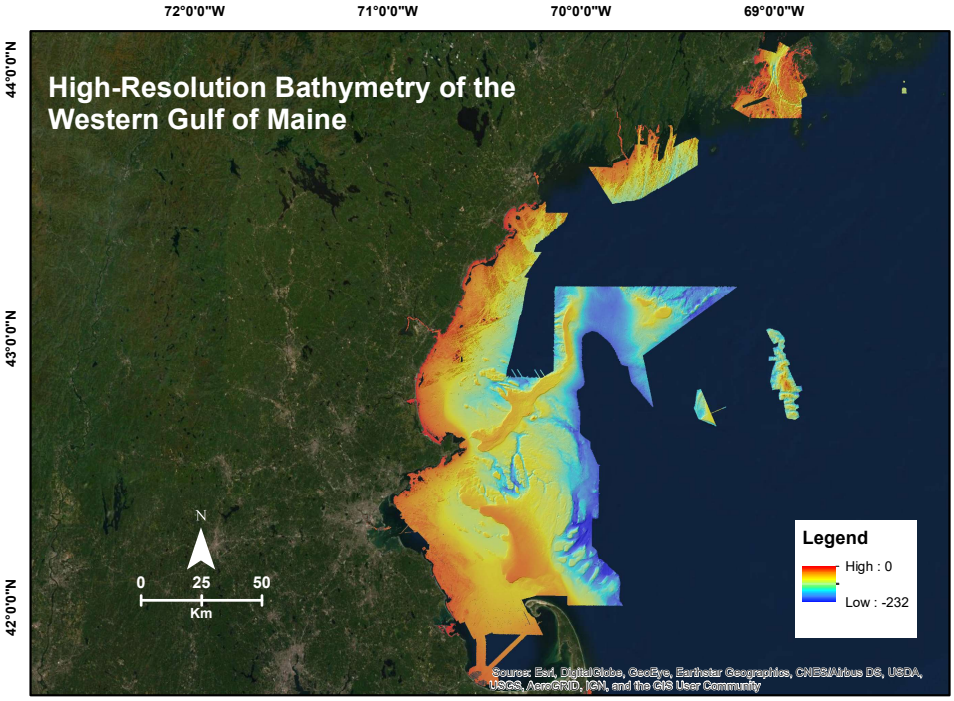

Figure 1. High-resolution bathymetry for the Western Gulf of Maine (top) gridded at 4m (bottom).

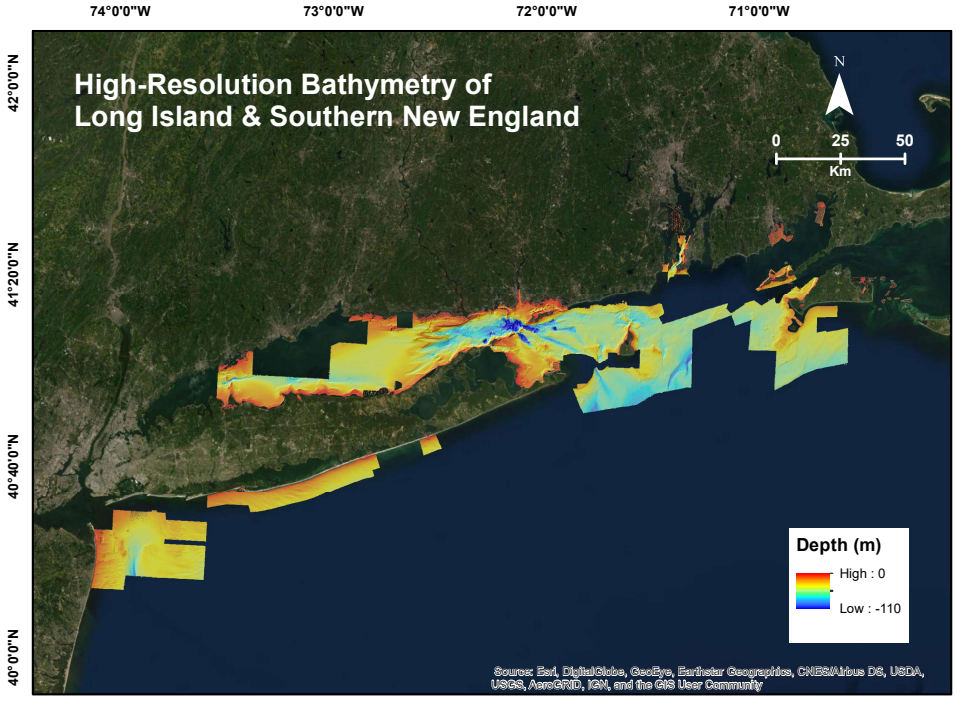

Figure 2. High-resolution bathymetry for Long Island and Southern New England gridded at 4m (bottom).

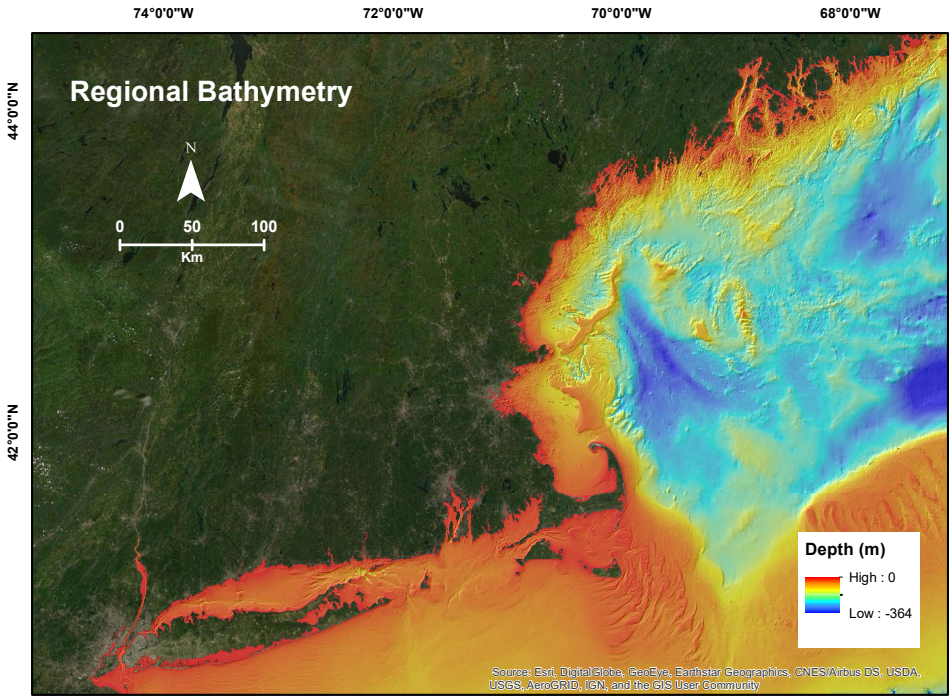

Figure 3. Regional bathymetry for the U.S. Northeast gridded at 16 m.

Ward, L.G., Johnson, P., Nagel, E., McAvoy, Z.S. and Vallee-Anziani, M., 2016, Western Gulf of Maine Bathymetry and Backscatter Synthesis: BOEM/New Hampshire Cooperative Agreement Technical Report.

Central to any effort to develop an understanding of seafloor geology, including surficial sediments, sand and gravel deposits, and morphologic features, is high-resolution bathymetry. Therefore, as an aid in mapping the New Hampshire continental shelf geology and potential marine mineral resources (sand and gravel), all available high-resolution multibeam echosounder (MBES) bathymetry for the Western Gulf of Maine (WGOM) was synthesized and presented as a composite in a GIS environment. The WGOM bathymetry synthesis is used as a base for the development of the surficial geology and sand body maps for the New Hampshire and vicinity continental shelf. In addition, the bathymetry is web-served as part of the WGOM Bathymetry and Backscatter Synthesis on the UNH CCOM/JHC website: (https://maps.ccom.unh.edu/portal/apps/webappviewer/index.html?id=be8b9f48f19b485b8fc75d584a05bfaf). The original surveys used in this compilation were gridded from 50 cm to 25 m. However, to produce more uniform composites, a synthesis of all the multibeam surveys was re-gridded to 4 m (Figure 4). A second composite that includes older surveys that are of a lower resolution (e.g., single beam echosounder survey gridded at 40 m) was re-gridded at 8 m. An extremely useful product from MBES surveys is the associated backscatter. Backscatter is the strength of the acoustic signal that returns to the transponder and is strongly affected by complex interactions with seafloor properties, such as sediment texture, roughness, or biota. In order to develop a composite of MBES backscatter in the WGOM, a subset of available MBES surveys was assembled that were available from NOS and UNH CCOM/JHC. The MBES backscatter was processed using QPS Fledermaus FMGT, then mosaicked in ArcGIS. Due to combining multiple backscatter surveys with varying frequencies, different systems, and dynamic ranges of relative backscatter intensity values, the range of pixel intensity values were normalized and standardized to create a seamless backscatter mosaic image. As a result of the poor quality of some of the original backscatter, the processing involved with the creation of the mosaic was

extremely time consuming. However, the final product is useful for assessing seafloor characteristics detected with MBES backscatter (Figure 5). The backscatter layer was gridded at 2m. This report is superseded by Northeast Bathymetry and Backscatter Compilation: Western Gulf of Maine, Southern New England and Long Island Sound (2021).

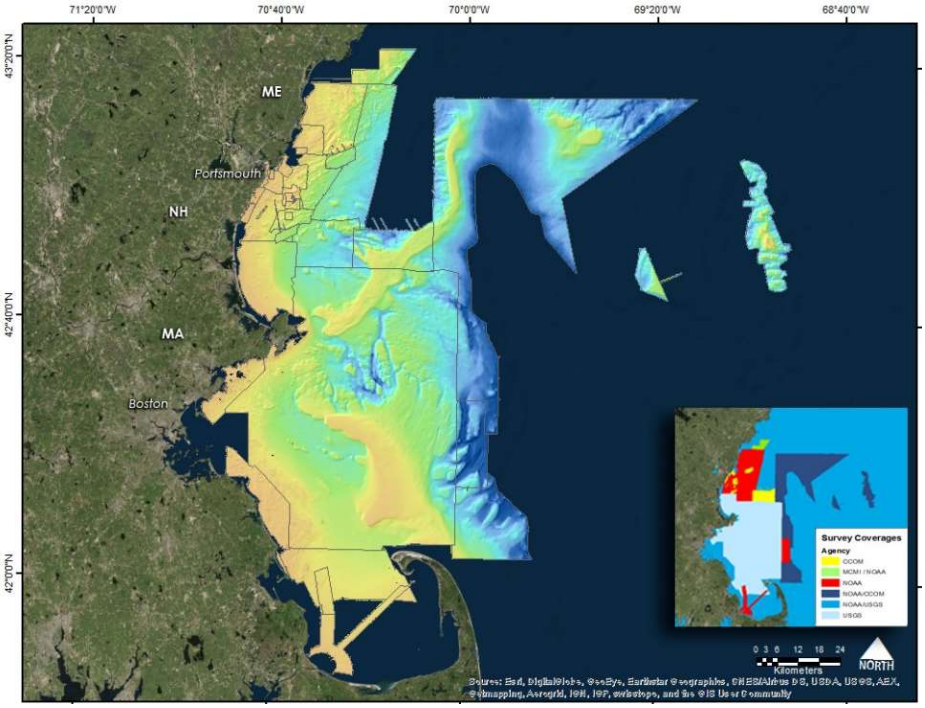

Figure 4. Western Gulf of Maine Bathymetry Synthesis.

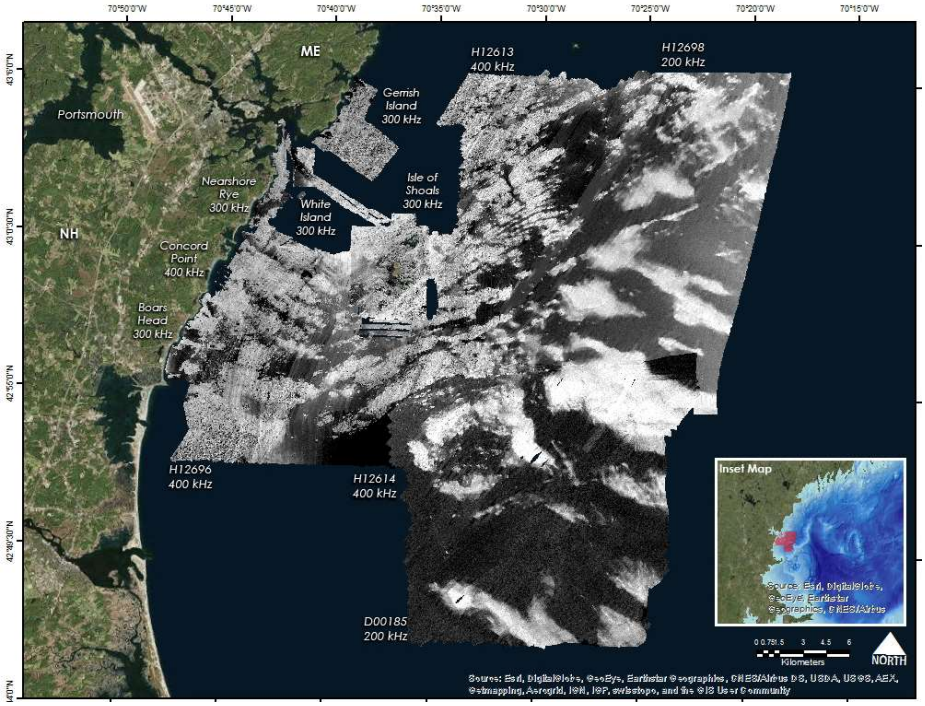

Figure 5 Western Gulf of Maine backscatter synthesis.

Cooperative Agreement Outputs and Deliverables for the Continental Shelf off New Hampshire (State Studies):

Ward, L.G., McAvoy, Z.S., Vallee-Anziani, M., and Morrison, R., 2021, Surficial Geology of the Continental Shelf off New Hampshire: Morphologic Features and Surficial Sediments: BOEM/New Hampshire Cooperative Agreement (Contract M14ACOOO10) Technical Report.

The continental shelf off New Hampshire (NH) in the Western Gulf of Maine (WGOM) is extremely complex and includes extensive bedrock outcrops, marine-modified glacial deposits, marine-formed shoals, seafloor plains, and associated features that are composed of a range of sediment types from mud to gravel. Furthermore, the physiography and composition of the seafloor frequently changes dramatically over relatively short distances (tens of meters). The complexity of the WGOM seafloor results from the interplay of glaciations, sea-level fluctuations, and marine processes (waves and currents). High-resolution multibeam echosounder (MBES) bathymetry and backscatter surveys, along with ground truth consisting of archived seismic reflection profiles, bottom sediment grain size data, vibracores, and video were used to develop surficial geology maps based on the Coastal and Marine Ecological Classification Standard (CMECS). The surficial geology maps cover ~3,250 km^2 and extend from the coast of NH seaward ~50 km to Jeffreys Ledge and depict major geoforms (physiographic features) and seafloor substrate (sediment size) classifications. CMECS provides a sound basis for classifying the texture of the seafloor; however, the geoform classifications need to be broadened for paraglacial environments in future studies.

The surficial geology maps presented are a major refinement of maps produced in 2016. The new maps reflect the results of a major field campaign conducted in 2016-2017 to obtain accurately located sediment samples and seafloor images to complement the original bottom sediment database. The new sites specifically targeted areas where high-resolution MBES bathymetry existed or where surficial features warranted further ground truth for evaluations. This work was designed to enhance the surficial geology mapping efforts and contribute to the development of new approaches for utilizing acoustics to remotely classify seafloor sediments and morphologic features (also supported by the University of New Hampshire Joint Hydrographic Center). The new surficial geology maps presented here depict the exposed bedrock, morphologic features, and sediment distribution on the continental shelf off NH, revealing features of the seafloor in exceptional detail that have not been previously described (Figures 6 and 7).

An important finding of this study was the extent and importance of marine-modified glacial features on the WGOM continental shelf. Extensive glacial deposits including drumlins, eskers, outwash, and moraines have been eroded and modified by wave and tidal currents as sea level fluctuated over the last 12,000 years. These features are potential sources of sand and gravel for future beach nourishment projects; however, more detailed subbottom seismic surveys and vibracores are needed for verification. Also, these potential resource areas are presently too far from shore and in too great a depth of water to be easily utilized. As the demand for sand and gravel becomes more acute and technologies advance, mineral resources farther offshore and in deeper water will likely become viable.

This report supersedes Ward, L.G., Vallee-Anziani, M. and McAvoy, Z.S., 2016, New Hampshire and Vicinity Continental Shelf: Morphologic Features and Surficial Sediments: BOEM/New Hampshire Cooperative Agreement Technical Report.

Associated Deliverables. This report and its associated databases, as well as additional sediment and seafloor photographs from the New Hampshire Continental Shelf 2016-2017 Field Campaign, are available digitally from the University of New Hampshire Scholars Repository (https://scholars.unh.edu/). Included are the following databases.

1. The *New Hampshire Continental Shelf Geophysical Database: 2016-2017 Field Campaign – Seafloor and Sample Photographs and Sediment Data* which includes photographs of the sediment samples, seafloor photographs of locations where samples were collected, and selected grain size statistics (Ward et al., 2021). (https://dx.doi.org/10.34051/d/2021.1)
2. The *New Hampshire Continental Shelf Geophysical Database: 2016-2017 Field Campaign - Stations and Sediment Data* which includes the station sampling history and sediment grain size data (Ward et al., 2021). (https://dx.doi.org/10.34051/d/2021.2)
3. The *New Hampshire Continental Shelf Geophysical Database: 2016-2017 Field Campaign - Seafloor Photographs* which includes 855 seafloor photographs from 155 stations on the inner continental shelf off NH (Ward et al., 2021). (https://dx.doi.org/10.34051/d/2021.5)
4. The *New Hampshire Continental Shelf Historical Geophysical Database: 1971 to 2015 - Sediment Data* which includes sediment grain size data from historical studies (Ward et al., 2021). (https://dx.doi.org/10.34051/d/2021.3)

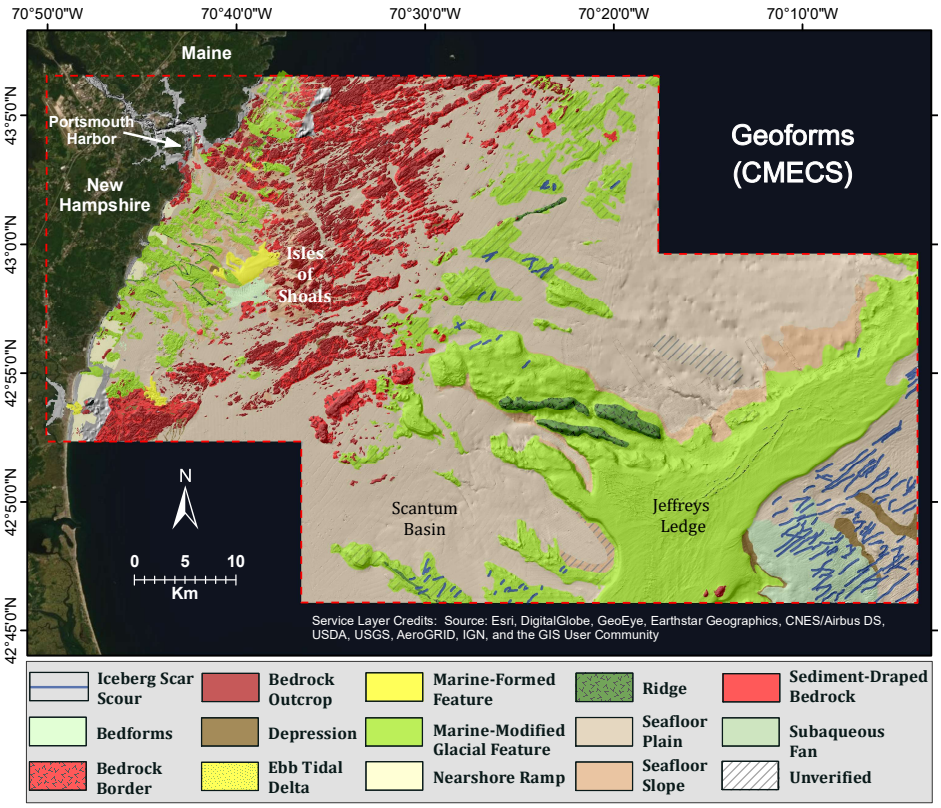

Figure 6. Surficial geology (Geoforms) map of the continental shelf off New Hampshire.

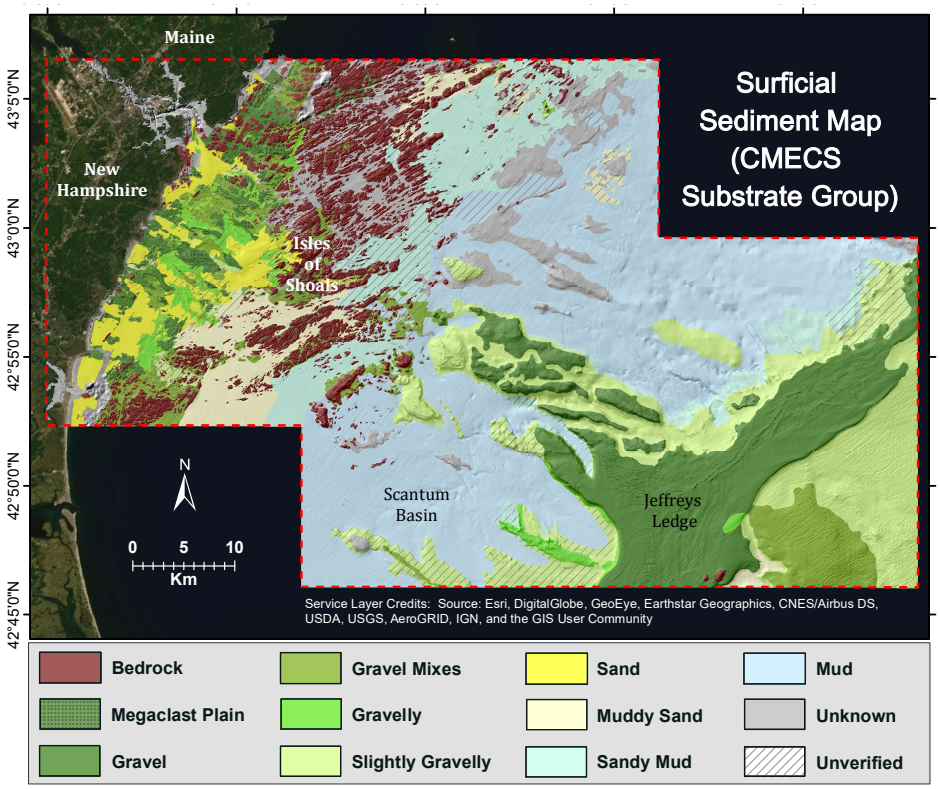

Figure 7. Surficial geology (Sediment) map of the continental shelf off New Hampshire.

Ward, L.G., Morrison, R.C., McAvoy, Z.S., and Vallee-Anziani, M., 2021, Analysis of Vibracores from the New Hampshire Continental Shelf from 1984 and 1988: BOEM/New Hampshire Cooperative Agreement (Contract M14AC00010) Technical Report.

The New Hampshire (NH) continental shelf is extremely heterogeneous and has been shaped by multiple glaciations, a complex sea-level history, fluvial inputs, and marine processes. The seafloor reflects this complex history and is composed of large bedrock outcrops, marine-modified or eroded glacial deposits (e.g., drumlins, eskers, marine deltas and outwash sediments) and Holocene marine deposits. Sediments range from mud to gravel and megaclast platforms, often changing dramatically over relatively short distances (tens of meters). Of major importance to the study presented here are several potential marine sand and gravel deposits on the NH shelf. The distribution and characteristics of the deposits were first described based on subbottom reflection profiling (Birch, 1984) and vibracores taken in 1984 (Birch, 1986b) and 1988 (Ward, 1989). These vibracores are the only direct source of information available to characterize the subsurface sediments on the NH shelf.

During this study, the twenty-three vibracores taken in 1984 and 1988 were reexamined, original descriptions verified and significantly expanded, and the cores sampled to provide complete grain size data (i.e. the original sediment grain size analyses were limited). The vibracores were grouped by location with respect to major physiographic features (geoforms) or surficial sediment type including Offshore Marine-Modified Glacial Features (Drumlins and Lodgement

Till Deposits), Northern Sand Body, Isles of Shoals, Nearshore Marine-Modified Glacial Features (Eskers and Drumlins), Nearshore Sheet Sand, and Offshore Seafloor Plain (Figure 8).

The Northern Sand Body (NSB), located near the Isles of Shoals ~10 km from shore, is relatively large measuring ~3.2km in length and ~1.3km in width, with a maximum relief of ~7m. Earlier studies estimated the NSB may contain as much as 17 million m^3 of sand and gravel, but this has not been verified. One of the vibracores taken at the northern end of the NSB has ~3.6m of medium to coarse sand with varying amounts of fine gravel overlying fine sand. Similarly, a vibracore from near the center of the NSB has ~3.1m of slightly granuley medium sand with shell fragments and scattered pebbles overlying fine sands. However, other vibracores taken at the NSB are largely fine to very fine sand of varying thickness. The NSB likely formed from deposits that were originally either a marine glacial delta, a subaqueous delta, or sandy outwash that was heavily modified by marine processes.

A vibracore taken on top of an offshore drumlin-like feature located ~24km from shore has ~4.7m of medium to coarse sand overlying fine sand and silty very fine sand to silt deposits. The upper sands likely represent a lag deposit formed by wave action during the last sea-level lowstand. However, it is not known if this lag deposit continues over the surface of the entire drumlin. Except for the NSB, and potentially the offshore drumlin, the other sand and gravel deposits examined are relatively small in aerial extent. However, several of the marine-modified glacial deposits have approximately three to five meters of sand and gravel. For example, a vibracore taken near an esker-like feature had ~5.75m of very coarse sand to gravelly sediments composing the matrix (the largest clasts were not measured due to limited sample size). The eskers were exposed during the last sea-level lowstand and were modified by shallow water waves and nearshore process during the Holocene transgression. The esker was likely eroded, the large gravel left as a lag deposit, and the finer sediment deposited as nearby shoals. The Nearshore Sheet Sand deposits located within a few kilometers of the coast are relatively thin (less than ~2.5m), flat-lying layers of sand and gravel unconformably overlying glacial marine sandy mud which were likely formed from reworked glacial marine sediment during the last transgression, especially wave-modified marine deltas or outwash. In addition, the deposits are likely part of the nearshore sand ramp extending from the beaches in southern NH.

High-resolution subbottom seismic reflection surveys and additional vibracores are needed to map and verify the potential sand and gravel resources on the NH continental shelf.

Associated Deliverables: This report and the sediment data from the vibracore samples and core logs are available from the University of New Hampshire Scholars Repository (https://scholars.unh.edu/). See:

Ward, L.G., Morrison, R.C., McAvoy, Z.S., and Vallee-Anziani, M., 2021, New Hampshire Continental Shelf Geophysical Database: Vibracore Logs and Sediment Data. University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center (CCOM/JHC), 24 Colovos Road, Durham, NH 03824. https://dx.doi.org/10.34051/d/2021.4

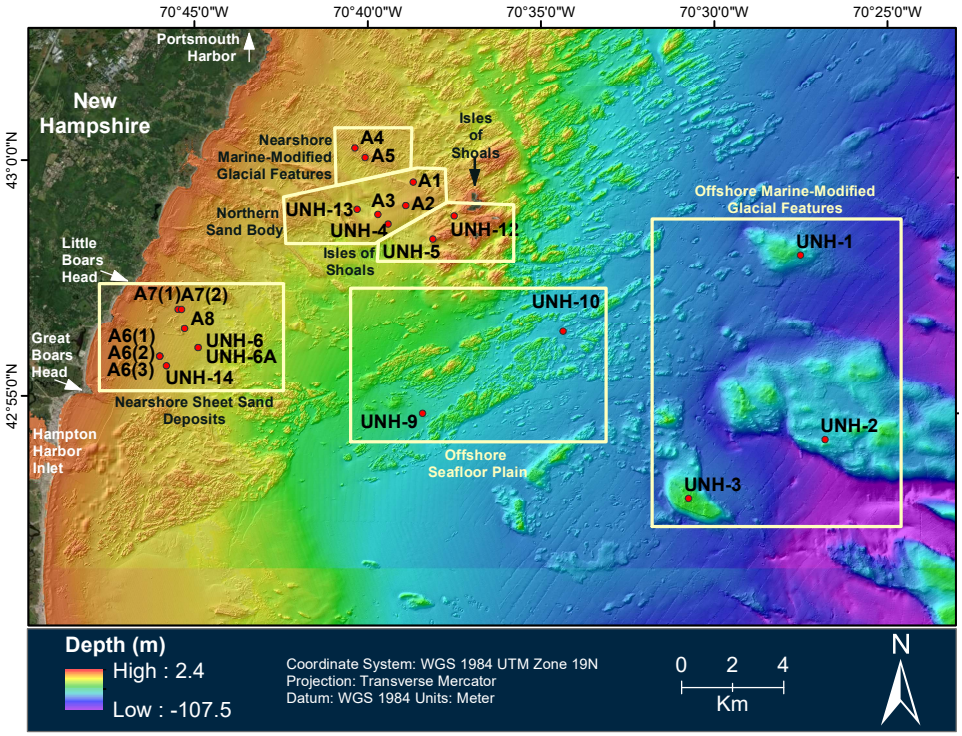

Figure 8. Location of vibracores taken on the New Hampshire continental shelf.

Ward, L.G., McAvoy, Z.S. and Vallee-Anziani, M., 2021, New Hampshire and Vicinity Continental Shelf: Sand and Gravel Resources: BOEM/New Hampshire Cooperative Agreement Technical Report.

The continental shelf off New Hampshire (NH) has extensive marine-modified glacial deposits and associated shoals. These features are potential targets for sand and gravel resources for beach nourishment and other efforts to build coastal resiliency. The distribution of sand and gravel deposits was evaluated based on the synthesis of relatively recent high-resolution bathymetry, new surficial sediment and geoform maps, and an extensive data archive that includes over ~1280 km of seismic profiles, ~750 grain size analyses, and 23 vibracores. This work heavily utilizes the results of previous research on mineral resources on the NH shelf by Birch (1984) and others. Unfortunately, much of the archived data was collected before the Global Navigation Satellite System (GNSS) was used routinely for navigation on research vessels. Consequently, much of the critical data from the archives has a large uncertainty associated with the positioning. Furthermore, the seismics are of variable quality. Nevertheless, the data archives coupled with recent high-resolution bathymetry and surficial sediment mapping, provided the basis to develop an initial or first order evaluation of the sand and gravel resources and identify areas where follow-up field campaigns are warranted. This report focuses on four sites where sand and fine gravel deposits may be suitable for extraction for beach nourishment. The most promising sites are referred to as the Northern Sand Body (NSB) (Figure 9) and the Southern Sand Deposits (SSD). Estimates of the volume of sand and fine gravel potentially available in the NSB and the SSD are on the order of 17.3 million m^3 and 16.4 million m^3, respectively. However, these values represent the total volume defined by subbottom seismics and include very fine sand and mud. Therefore, the volume of material that may be available for beach nourishment is likely considerably less. Both of these areas, as well as other potential

sites identified, need high-resolution seismic surveys and vibracores to fully evaluate the potential sand and fine gravel resources.

This report supersedes Ward, L.G., McAvoy, Z.S., and Vallee-Anziani, M., 2016, New Hampshire and Vicinity Continental Shelf: Sand and Gravel Resources: BOEM/New Hampshire Cooperative Agreement (Contract M14ACOOO10) Technical Report,

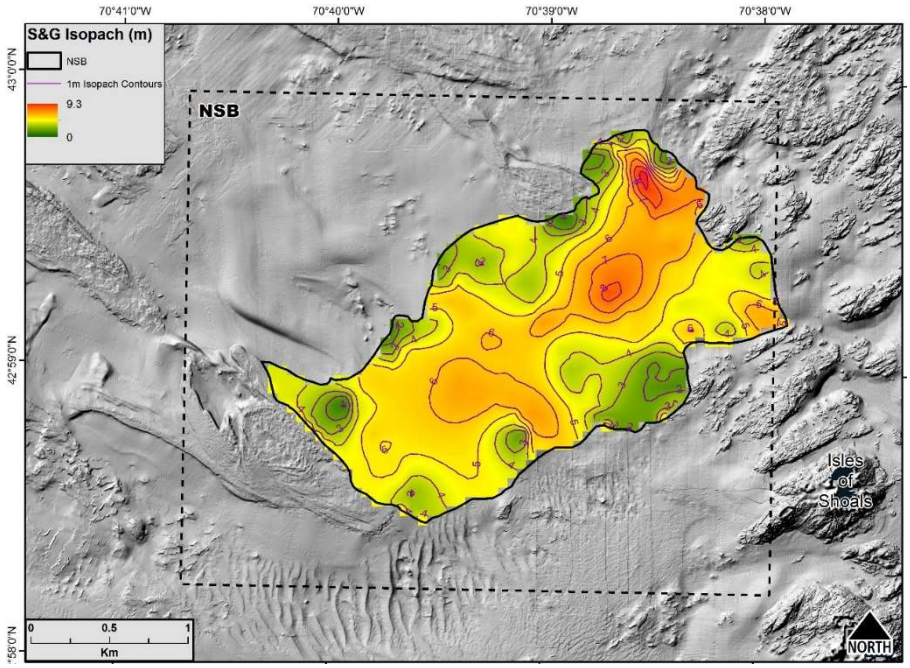

Figure 9. Preliminary isopach map of the Northern Sand Body located ~15 km off the NH coast. The contour interval is 1m.

Cooperative Agreement Outputs and Deliverables for NH Beaches (State Studies):

Ward, L.G., Corcoran, N.W., McAvoy, Z.S., and Morrison, R.C., 2021, Seasonal Changes in Sediment Grain Size of New Hampshire Atlantic Beaches: BOEM/New Hampshire Cooperative Agreement (Contract M14ACOOO10) Technical Report.

The beaches along the New Hampshire Atlantic coast are essential to the local and regional economy and are one of the major attractions of the seacoast (Figure 10). Beyond their economic importance, the beaches also have great aesthetic and ecological value that are vital to the character and history of New Hampshire. Unfortunately, climate change and an acceleration in sea-level rise, coupled with a major reduction in sediment supply and extensive development (including engineering structures along the coast), has led to loss of elevation and narrowing of many of the beaches. The forecast is that these trends will continue and likely become worse. It is also very likely that engineering solutions will be sought to reduce the impact of sea-level rise and coastal erosion in the near future as the loss of the beaches become more critical and coastal flooding becomes a more frequent threat. An option that will undoubtedly play an important role in efforts to mitigate the impacts of beach erosion, flooding and storm damage is beach nourishment. Essential to beach nourishment success is a thorough understanding of the natural sediments that compose the beach. This includes studying the grain size distribution under low energy conditions (typically summer) when the beaches tend to be accretional, and under higher energy conditions (typically winter and stormy periods), when the beaches erode and finer sediments are winnowed.

A preliminary inventory of the grain size of the natural sediment composing the major New Hampshire beaches was carried out by Ward et al. (2016). However, this study was conducted in summer 2015 after a prolonged period of accretional or stable conditions. In addition, samples were taken only in the upper ten centimeters of the sediment column. Here, a seasonal study (completed in 2017) of sediment grain size from seven major New Hampshire beaches is presented. A total of twenty-eight elevation profiles were measured and one hundred forty sediment samples collected at cross-shore transects in late winter – early spring following an extended period of beach erosion. In late summer twenty-two of the profiles were rerun and ninety-seven sediment samples collected following an extended period of accretion. Six stations were not rerun due to a late summer storm which eroded the beach. The samples were collected along shore-normal transects from the seawall or foredunes to the low tide swash. Large samples were typically collected (~1 kg to 24 kg) from the upper 20 to 30 cm of the sediment column.

Results of cross-shore elevation profiles at each beach verified that all locations sampled in late winter – early spring 2017 had been eroded by winter storms and often had sediment lag deposits. Conversely, all the beaches sampled following the summer accretional period had recovered and gained elevation. Along with the deposition of sediment there was a general fining of grain size, especially at bimodal beaches. This decrease in grain size by late summer was related to the deposition of fine to medium sand that migrated onshore, often in ridge and runnel systems. The bimodal beaches tended to show the largest change in grain size overall due to scattered pebbles or pebble lag deposits being buried by the sandy accretional wedge.

Associated Deliverables: The appendices from this report, as well as additional sediment and field photographs from the 2017 sampling period, are available from the University of New Hampshire Scholars Repository (https://scholars.unh.edu/). See:

Ward, L.G., Corcoran, N.W., McAvoy, Z.S., and Morrison, R.C., 2021, New Hampshire Atlantic Beaches: 2017 Field Campaign Database - Field and Sample Photographs and Sediment Data: University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center. UNH Scholars Repository. https://dx.doi.org/10.34051/d/2021.6

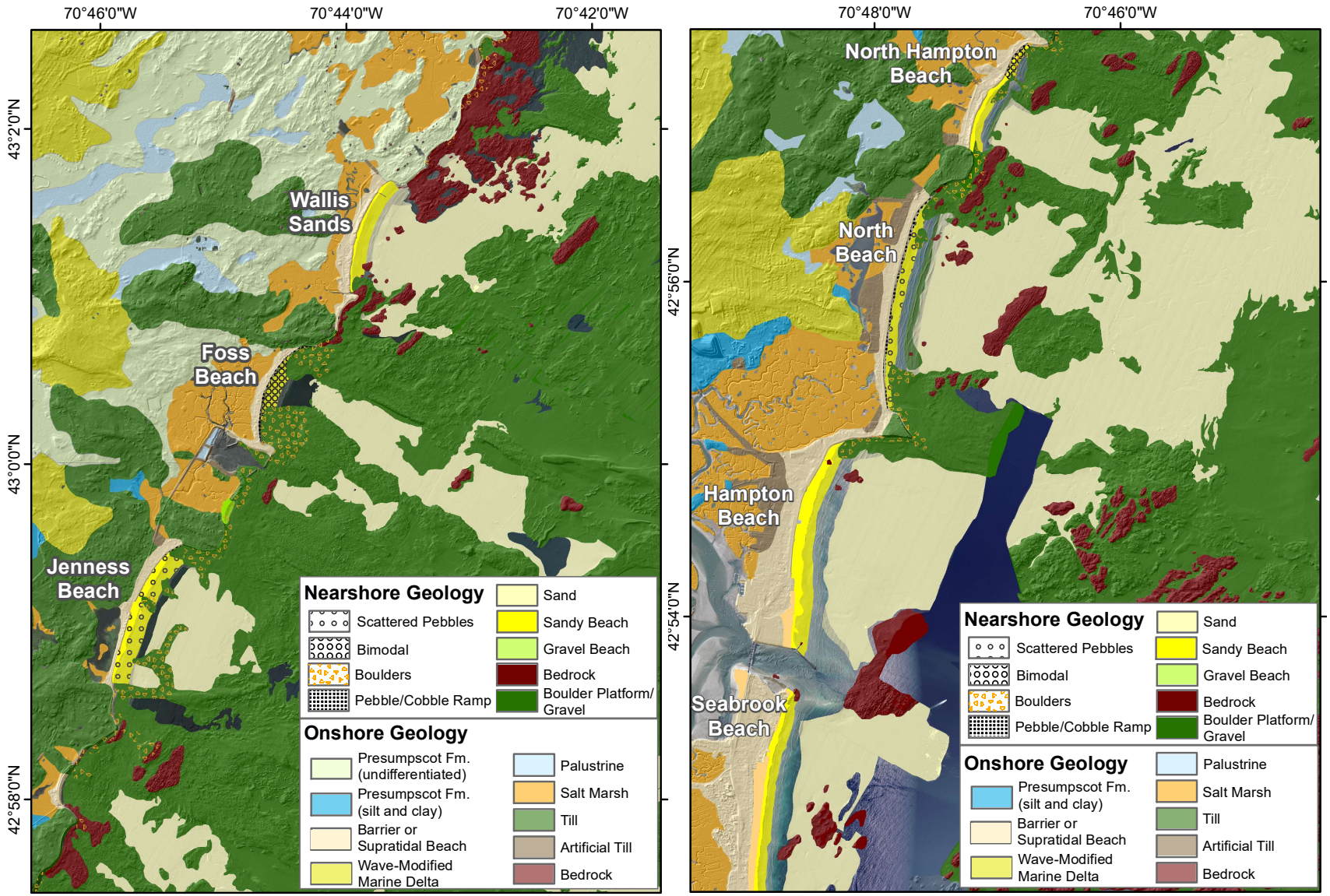

Figure 10. Surficial geology maps of the NH coastline (the northern half of the coast is on the left; the southern half is on the right). The upland is modified from the NH Geological Survey digital map series, the offshore is from Ward et al. (2021), and the beaches were mapped for this study.

Ward, L.G., McPherran, K.A., McAvoy Z.S. and Vallee-Anziani, M., 2016, New Hampshire Beaches: Sediment Characterization: BOEM/New Hampshire Cooperative Agreement Technical Report.

The grain size of the natural sediment on the major New Hampshire beaches under summer equilibrium conditions was determined in order to assess the sediment size that would be needed for beach nourishment. This information, in turn, provides criteria to determine the suitability of offshore sand and gravel deposits on the New Hampshire and vicinity continental shelf to be used for beach nourishment. In the summer of 2015, seven major beaches along the New Hampshire coast (Wallis Sands, Jenness Beach, Foss Beach, North Hampton Beach, North Beach, Hampton Beach, and Seabrook Beach) were sampled along three to five transects extending from either the dunes or engineering structures at their landward extent to the low water line at their seaward extent. At each transect, the beach was sampled at three to four locations. In addition, the transect cross-section was profiled and the location of the sediment samples on the profile were noted. Profiles were determined primarily using a GPS system on a rover (three-wheeled dolly). The sediment grain size data are archived and presented in a GIS environment.

Olson, N., Chormann, F. and Ward, L.G., 2016, New Hampshire Beaches: Shoreline Movement and Volumetric Change: BOEM/New Hampshire Cooperative Agreement Technical Report.

The stability (landward or seaward migration) of the New Hampshire coastline and volumetric changes of the beaches was determined over different time periods from lidar data, orthophotography and charts. Multiple vintages of airborne lidar spanning the last decade and a half were analyzed to detect volumetric changes between lidar surveys using a simple DEM of Difference (DoD) method. The entire New Hampshire coast was analyzed at a fine (1-2m) spatial resolution. All beaches showed variability in trends, but most beaches had a net loss of sediment (Figure 7). The two largest beaches in the state (Hampton Beach and Seabrook Beach; the two southernmost beaches) show similar variability to the other beaches, but with more gains than losses. Changes in shoreline positions over time were delineated from charts and orthophotography dating back to the mid-1800s using the Digital Shoreline Analysis System (DSAS). The large southernmost beaches show net seaward movement (accretion) and the smaller northern beaches show a net shoreward movement (erosion), similar to the pattern seen in the lidar data. By combining the two datasets, the long-term and short-term trends of sediment budgets in New Hampshire can be summarized. Such data can provide insights for coastal managers to help focus beach management strategies (e.g., nourishment).

Associated BOEM-NH Cooperative Agreement Outputs (Web Served Databases):

New Hampshire Shelf Surficial Geology

(https://maps.ccom.unh.edu/portal/apps/webappviewer/index.html?id=aecfde28e84340b49b45029e6418c02f)

The "New Hampshire Shelf Surficial Geology" web site displays high-resolution surficial geology maps, high-resolution bathymetry, sediment grain size data, and seafloor photographs of the continental shelf off New Hampshire. The web page was developed by the University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center.

Northeastern U.S. Bathymetry and Backscatter Compilation: Western Gulf of Maine, Southern New England and Long Island

https://maps.ccom.unh.edu/portal/apps/webappviewer/index.html?id=5d314116ad094afebbd02ffc185164f6

The "Compilation" brings together the MBES surveys for the U.S. Northeast, presenting a synthesis of all of the high-resolution bathymetry in a single gridded surface and presenting backscatter where available and of good quality. The high-resolution bathymetry synthesis primarily consists of MBES surveys gridded at 4 m. The regional bathymetry surface consists of single beam echosounder (SBES) and multi beam echosounder (MBES) surveys gridded at 16 m. The backscatter includes compilations for the inner shelf off New Hampshire (NH) by the University of New Hampshire (UNH) Center for Coastal and Ocean Mapping and Joint Hydrographic Center (CCOM/JHC). The "Compilation" is a major expansion of the "Western Gulf of Maine Bathymetry and Backscatter Synthesis" (below). More details of the "Northeast Bathymetry and Backscatter Compilation: Western Gulf of Maine, Southern New England and Long Island" can be found in Ward et al. (2021).

WGOM Bathymetry and Backscatter Synthesis

http://ccom.unh.edu/project/wgom-bathbackscatter

Synthesis of high-resolution bathymetry and backscatter for the regions of the Western Gulf of Maine. Web-served by the University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center. Active as of December 2015. Full description provided in Ward, L.G., Johnson, P., Nagel, E., McAvoy, Z.S. and Vallee Anziani, M., 2016, Western Gulf of Maine bathymetry and backscatter synthesis, BOEM/New Hampshire Cooperative Agreement Technical Report.

Associated BOEM-NH Cooperative Agreement Outputs (Presentations with Published Abstracts):

Ward, L.G., McAvoy, Z.S., Corcoran, N.W., Masetti, G., Johnson, P. and Morrison, R.C., 2019, High-resolution surficial geology mapping of the New Hampshire inner continental shelf and coastline: An important step towards coastal resiliency. Abstracts, Gulf of Maine 2050 International Symposium, Portland, ME, November 4-8.

https://www.gulfofmaine2050.org/wp-content/uploads/2019/11/Gulf-of-Maine-2050-Abstract-Booklet-Updated-November-5-2019.pdf

The combination of a reduction in sediment supply and an acceleration in sea-level rise has led to much of the NH coast being stressed by erosion and more frequent flooding. To help build coastal resiliency, high-resolution surficial geology maps of the NH shelf were developed depicting seafloor features (geoforms) and surficial sediment using the Coastal and Marine Ecological Classification Standard (CMECS). In addition, potential sources of sand and fine gravel were evaluated for beach nourishment. Presently, similar work is being done on the NH beaches: mapping major coastal features, determining beach sediment grain size under accretional and erosional conditions, and assessing beach stability. A goal of this work is to link the surficial geology of the mainland (published by the NH Geological Survey), the coast, and the inner shelf to better define the physiography, the sediment distribution (and sources), and the controlling processes.

Ward, L., McAvoy, Z., Masetti, G., and Morrison, R., 2019, High-resolution mapping of morphologic features and seafloor sediments of the New Hampshire and vicinity continental shelf, Western Gulf of Maine. Abstracts, Geological Society of America Annual Meeting, Northeastern Section, Portland, ME, March 17-19.
https://gsa.confex.com/gsa/2019NE/meetingapp.cgi/Paper/328549

Over the last decade, the geology (primarily morphology, depositional systems, and controlling processes) of the New Hampshire and vicinity continental shelf has been extensively studied based on archived databases (subbottom seismics, vibracores and surficial sediments), as well as more recently available high resolution multibeam echosounder (MBES) bathymetry and backscatter. In addition, field campaigns were conducted in 2016-2017 to obtain additional ground truth (bottom sediment samples and videography). From this database, high resolution seafloor maps were developed using various seafloor classifications, but primarily the Coastal and Marine Ecological Classification Standard (CMECS). Although much of the mapping effort ultimately relies on human interpretation or expert opinion, new approaches using acoustics are being evaluated such as BRESS (Bathymetry- and Reflectivity-Based Estimator for Seafloor Segmentation: see Masetti et al., 2018). The overall mapping effort is focusing on morphologic features (geoforms), classification of the grain size of surficial sediment, and description of selected sand and gravel deposits.

Corcoran, N., Ward, L., and McAvoy, Z., 2018, Temporal and spatial variability in sediment texture on northern, paraglacial beaches: New Hampshire. Abstracts, Geological Society of America (GSA) Annual Meeting, Northeastern Section, Burlington, Vermont, March 18-21.
https://gsa.confex.com/gsa/2018NE/meetingapp.cgi/Paper/311201

Typical of paraglacial environments, beaches along New Hampshire's (NH) ocean coast are strongly influenced by bedrock geology, previous glaciations and associated deposits, and a complex sea-level history. As a result, the morphology and sedimentology of the beaches are highly variable and exhibit

rapid spatial and temporal changes over the ~30 km-long coastline. The offshore bathymetry has a major influence on the morphology and sedimentology of the northern beaches. Recently mapped bathymetric highs extending from headlands likely interrupt longshore sediment transport, confining sediment movement to predominantly onshore-offshore. The barriers to the south (Hampton Beach and Salisbury Beach) exhibited rapid temporal change, accumulating finer-grained sediments during extended periods of accretion (typically summer) and significantly eroding during extended periods of erosion (typically winter). The coarser-grained, pebble rich beaches north of Great Boars Head tend to have lower volumetric change over time. However, finer sediments tend to accumulate during extended calm conditions, burying the coarser, more gravelly sediments. To quantify changes in grain size spatially and temporally on NH beaches, extensive sediment sampling was conducted during 2017 in spring/early summer and late summer/fall with support from the Bureau of Ocean and Energy Management (BOEM) and the University of New Hampshire.

Ward, L., McAvoy, Z., and Nagel, E., 2017, Mapping of the morphologic features and seafloor sediments of the New Hampshire continental shelf using the Coastal and Marine Ecologic Classification Standard (CMECS). Program and Abstracts, 2017 GeoHab Conference, Dartmouth, Nova Scotia, May 1-5, Geological Survey of Canada Open File 8295, p.119.

The New Hampshire continental shelf is extremely heterogeneous and includes extensive bedrock outcrops, sand and gravel deposits, and muddy basins. Some of the sand and gravel deposits may have potential use for beach nourishment and other efforts to build coastal resiliency. Relatively recent high resolution multibeam echosounder (MBES) bathymetric and backscatter surveys have revealed features of the New Hampshire shelf and vicinity seafloor in exceptional detail that has not been previously described. Synthesis of the MBES bathymetry and backscatter (along with bathymetric derivatives), coupled with an extensive archived database consisting of subbottom seismics, bottom sediment grain size data, and vibracores, were used to develop new surficial geology maps based on CMECS (supported by the Bureau of Ocean Energy Management). The new surficial geology maps of the New Hampshire shelf produced in ArcGIS represent a major improvement over previous mapping efforts and provide ground truth for testing automated classification approaches. Presently, the CMECS maps are being refined and the classification of the geoforms expanded for paraglacial environments. In addition, automated characterization and segmentation approaches using QPS Fledermaus Geocoder Toolbox Angle Range Analysis (ARA) and ESRI ArcGIS Spatial Analyst Tools are being evaluated.

Ward, L., McAvoy, Z., Olson, N., Vallee-Anziani, M., Chormann, F., McPherran, K., and Nifong, K., 2016, Integrated studies of the New Hampshire shoreline and continental shelf: an important step towards coastal resiliency. Abstracts, American Shore and Beach Protection Association Annual Meeting, Long Branch, NJ, October 25-28.

The coast of New Hampshire (NH) is extremely heterogeneous ranging from bedrock outcrops, beaches interrupted by rocky headlands or remnant glacial features (e.g., drumlins), and barrier islands. The composition of the beaches reflects this extreme variability ranging from fine sand to cobbles with bimodal sediment populations being common. Changes in the location of the NH shoreline was determined from charts and orthophotography dating back to the late 1800s and more recent lidar surveys using the Digital Shoreline Analysis System (DSAS). In general, the larger southern barrier beaches show a small net seaward movement (accretion), while the northern beaches show a small net shoreward movement (erosion). In contrast, the beaches have undergone larger vertical changes (volumetric) based on comparison of lidar surveys and seasonal beach profiling. Comparison of the lidar surveys from 2000 to 2014 showed large variability in trends, but most beaches appeared to have a net loss of sediment. However, the two largest beaches in the state (Hampton Beach and Seabrook Beach) show more gains than losses. Although coastal erosion issues in NH have not been overwhelming, the expected acceleration

in sea-level rise and the increase in storm severity will result in new challenges and requires building coastal resiliency. To address this expected need, offshore sources of suitable sand and gravel resources are being evaluated with significant support from the Bureau of Ocean Energy Management, the New Hampshire Geological Survey, and the University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center. As a result of the heterogeneity of the NH shelf, locating significant sand and gravel deposits is challenging. However, some of these modified glacial deposits and associated shoals, as well as some marine-formed shoals, represent significant sand and gravel deposits that have the potential for future use for beach nourishment and other efforts to build coastal resiliency.

Olson, N., Chormann, F. and Ward, L.G., 2016. Change analysis of New Hampshire's beaches from multiple airborne lidar collections, historical charts, and orthophotography: Abstracts, Geological Society of America (GSA) Annual Meeting, Northeastern Section, Albany, New York, March 21-23.

The stability of the New Hampshire coastline and volumetric changes of the beaches were analyzed using lidar data, charts, and orthophotography. Multiple airborne lidar surveys conducted over the last decade and a half were analyzed to detect changes in volume of sand and gravel beaches using a simple DEM of Difference (DoD) method. Changes in shoreline position were determined for shore-perpendicular transects using the Digital Shoreline Analysis System (DSAS) for the period from the mid-1800s to present.

McPherran, K. and Ward, L., 2016. Observations of seasonal changes and storm effects on a bedrock-influenced, paraglacial coastal system: New Hampshire: Abstracts, Geological Society of America (GSA) Annual Meeting, Northeastern Section, Albany, New York, March 21-23.

Monitoring stations were established along the New Hampshire coast to study beach morphology, volumetric changes, and sediments. Beach profiles were measured primarily utilizing a GPS rover system. The beach profiles and sediment samples were used to characterize the beach morphology and sediment grain size.

Ward, L.G., McAvoy, Z.S., Vallee-Anziani, M., Nagel, E. and Nifong, K., 2015, Depositional systems on the northern Massachusetts and New Hampshire inner continental shelf: Use of high resolution seafloor mapping to understand impacts of glaciation, marine processes and sea-level fluctuations: Abstracts, Geological Society of America Annual Meeting, Baltimore, Maryland, November 1-4, volume 47, number 7, p.264.

Depositional features on the continental shelf off northern Massachusetts and New Hampshire are dominated by remnant glacial features (e.g., drumlins, subaqueous deltas, moraines) that have been significantly modified by marine processes as sea level fluctuated following deglaciation. Apparent glacial deposits (e.g., drumlins) have been eroded leaving very coarse lag deposits while supplying sand to develop wave-formed features (shoals?). Of particular interest is a large sand body that is ~3.2 km in length, ~1.3 km in width, and has a maximum relief of ~7 m (in comparison to the surrounding seafloor). The sand body appears to extend between two eroded drumlins. The Quaternary geology of the New Hampshire and vicinity shelf exemplifies the interplay between glacial features, sea-level fluctuations, and modifications by marine processes.

Nifong, K. and Ward, L.G., 2015, Development of late Quaternary depositional history of Portsmouth Harbor, NH: Abstracts, Geological Society of America (GSA) Annual Meeting, Baltimore, Maryland, November 1-4, volume 47, number 3, p. 264.

The sedimentological and stratigraphic characteristics of Portsmouth Harbor, New Hampshire and the adjacent inner continental shelf were described using high-resolution multibeam echosounder (MBES) bathymetry and backscatter, side scan sonar (SSS), subbottom seismics, videography, and bottom

sediment samples in order to develop a depositional model and assess the late Quaternary geologic history. Several major depositional environments were identified within Portsmouth Harbor, including coarse channel lags, sand wave fields, and extensive bedrock outcrops that strongly influence the channel configuration. At the mouth of the harbor, an apron of low intensity backscatter, composed of fine sand, extends offshore onto the inner shelf. The inner shelf shows mixed high and low intensity backscatter reflecting bedrock outcrops interspersed with fine to coarse sand and gravel fields. Determination of the surficial geology based on the high-resolution bathymetry, SSS, and direct sampling, coupled with an assessment of the underlying seismic stratigraphy, enhances the development of a depositional model.

Ward, L.G., McAvoy, Z.S., Johnson, P. and Greenaway, S.F., 2015. Use of high-resolution bathymetry and backscatter for mapping depositional environments on the New Hampshire continental shelf: Abstracts, Geological Society of America (GSA) Annual Meeting, Northeastern Section, Bretton Woods, New Hampshire, March 23-25, volume 47, number 3, p. 85.

The New Hampshire continental shelf is extremely heterogeneous and includes extensive bedrock outcrops, sand and gravel deposits, and muddy basins. Many of the depositional features are glacial in origin and have been significantly modified by marine processes as sea level fluctuated since the end of the last major glaciation. Synthesis of the MBES bathymetry and backscatter, coupled with an extensive archived database consisting of subbottom seismics, bottom sediment grain size data and vibracores, is being used to develop new surficial geology maps and significantly improve our knowledge of the character and origin of the major depositional features of the New Hampshire shelf and vicinity (with support from the Bureau of Ocean Energy Management). Included are a number of large glacial features (e.g., drumlins) covering the bedrock that have been modified by marine processes (waves and currents).