Executive Office of Energy and Environmental Affairs
Massachusetts Office of Coastal Zone Management

REGIONAL SEDIMENT RESOURCE MANAGEMENT

Work Group Report
2014 Massachusetts Ocean Management Plan Update

March 5, 2014

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Workgroup Lead's Acknowledgement: *I would like to thank the entire workgroup for the effort that went into the preparation of this document. The work that they accomplished in updating the sediment and geological maps of the seafloor in and adjacent to state waters represents the most accurate data available. Without their input, the citizens of the Commonwealth would be deprived of easy access to this wealth of data. I would like to give special thanks to the team of GIS specialists at CZM, Dan Sampson and Emily Huntley, for their exceptional work in collating and analyzing the data and producing the maps presented here. The team at the USGS in Woods Hole has also been instrumental in providing data, sediment analysis, and guidance during the past four years. Also deserving recognition are Adrienne Pappal, Todd Callaghan, and the bevy of interns directed by Todd for the painstaking work they conducted in the analysis of over 10,000 seafloor images. Finally, I would like to express my appreciation to the members of the 2010, 2011, and 2012 oceanographic surveys aboard the USEPA Ocean Survey Vessel (OSV) "Bold" for their hard work during week-long surveys to ground truth the sediment data and collect benthic samples for analysis. The scientific parties were as follows;*

2010 Survey – Marcel Belaval, Dan Sampson, Alex Boeri, Chris Garby, Dave Janik, Emily Huntley, Robin Lacey, Kathryn Glenn, Kathryn Ford, Steve Voss, Mark Rousseau, Sarah Connors, Bob Boeri

2011 Survey – Marcel Belaval, Todd Callaghan, Kathryn Ford, Dave Turin, Kate Connors, Dan Sampson, Chris Garby, Dave Janik, Mary Garren, Bob Boeri, Emily Huntley, Alex Boeri, Kate Douglas, John Logan

2012 Survey – Marcel Belaval, Bob Boeri, Seth Ackerman, Dann Blackwood, Mike Bastoni, Steve Voss, Stephen Perkins, Emily Huntley, Lisa Engler, Julia Knisel, Tay Evans, Jim Sprague, Brendan Sprague, Alex Strysky, Marc Carullo, Marinna Martini, Katherine Yee, Regina Lyons, Chris Garby

Thanks to all.

SECTION TWO: Introduction and Mission

On May 28, 2008, Governor Deval Patrick signed the Massachusetts Oceans Act of 2008 (Act), which directed the Secretary of the Executive Office of Energy and Environmental Affairs to develop a comprehensive management plan to serve as the basis for the protection and sustainable use of the Commonwealth's ocean and coastal waters. As a result, the Massachusetts Ocean Management Plan (Plan) was promulgated on December 31, 2009. The Plan contained a list of 12 Special, Sensitive, or Unique (SSU) resource areas, including Hard/Complex Seafloor. These SSU areas were mapped as part of the 2009 Plan using the best available data existing at that time.

The preparation of the 2009 Hard/Complex Seafloor SSU and the Surficial Sediment Characterization maps were accomplished through the establishment of the Regional Sediment Resource Management (RSRM) Workgroup, whose mission was to identify existing, specific spatial data that characterize the physical and chemical properties of sediment in the planning area and/or that locate and quantify sediment types to be employed in RSRM. These data are used to assist with the siting and review of projects in the coastal zone that propose to remove and use sediment beneficially or whose location requires specific sediment types. These data are also used to prioritize sediment uses and needs, assisting resource managers and the public in evaluating sediment management activities.

Since 2009, over 30,000 additional data points have been added to the Massachusetts Office of Coastal Zone Management (CZM)/Massachusetts Division of Marine Fisheries (DMF) surficial sediment database. Additional high-resolution backscatter, bathymetry, and sub-bottom profiling data have also been collected through the continuation of the seafloor mapping cooperative between CZM and the U.S. Geological Survey (USGS). Analysis and groundtruthing of these data, along with the interpretation and inclusion of over 10,000 seafloor images, allowed for a significant improvement in the accuracy of the maps.

The Act requires that the Plan be reviewed and updated at least every five years. In 2013, the RSRM Workgroup was charged with updating the Hard/Complex Seafloor SSU map and to investigate the following:

- Identify any new data to add to or change the spatial extent of SSU resource areas from what was mapped in the 2009 Plan.
- Characterize notable trends in the condition of resources and uses covered in the Baseline Assessment (contained in Volume II of the 2009 Plan).
- Reveal any new science that might advance the characterization of the ocean planning area.
- Review the steps toward addressing the science and data priorities in the 2009 Plan and making recommendations for priority research and data acquisitions to be included in the 2014 Plan.

In this document, items listed under "*Near-term Actions for the 2014 Plan Update*" were incorporated into the updated maps presented. Those items listed under "*Long-term Actions for Future Ocean Plan Updates*" need further research prior to inclusion into subsequent Plan revisions.

SECTION THREE: Recommendations

Hard/Complex Seafloor

Hard/complex seafloor is seabed characterized singly or by any combination of hard seafloor, complex seafloor, artificial reefs, biogenic reefs, or wrecks and obstructions. Hard seafloor is seabed characterized by exposed bedrock or concentrations of boulder, cobble, or other similar hard bottom distinguished from surrounding unconsolidated sediments. Complex seafloor is a morphologically rugged seafloor characterized by high variability in bathymetric aspect and gradient. Biogenic reefs and man-made structures, such as artificial reefs, wrecks, or other functionally equivalent structures, may provide additional suitable substrate for the development of hard bottom biological communities.

CZM characterizes sediment using the Wentworth (1922) scale and the Barnhardt et al. (1998) classification scheme. The Wentworth scale is used to define the grain-size ranges for mud, sand, gravel, cobble, and boulder. Sediment data are then classified using the Barnhardt classification scheme (Figure 1), where the four corner classes (rock [R], gravel [G], sand [S], and mud [M]) have ≥90% of that particular sediment type. For the composite classes, the first letter is the majority grain-size component of the seafloor sediment and the second letter is the minority component. In the Barnhardt scheme, rock is characterized as cobble and larger (>64 mm) under the Wentworth scale. For the 2014 Plan, sediment data classified as rock (R), rock with gravel (Rg), rock with sand (Rs), or rock with mud (Rm) were mapped as hard seafloor. Therefore, when sediment is collected via a grab or other physical sampling devices, hard bottom is present when the dominant grain-size class (by volume) is >64 mm. When a sample is collected remotely via bottom photographs, hard bottom is present when sediment >64 mm is the spatially dominant sediment class in the field of view.

The workgroup recommended the following actions.

Near-term Actions for the 2014 Plan Update

- Incorporate the following new data:
    - Updated CZM/DMF sediment database
    - USGS interpreted sediment maps (published and unpublished data in review)
    - Seafloor photos from USGS and OSV *Bold* surveys
    - Rocky intertidal shores from 1:12,000 Massachusetts Department of Environmental Protection (DEP) wetlands data
    - Artificial reefs
    - Biogenic reefs (specifically *Crepidula* and worm reefs identified in seafloor photos) with 100-meter radius buffer around each reef location
    - Board of Underwater Archaeological Resources' recreational shipwreck sites designated as "exempted sites" (member sites of the National Oceanic and Atmospheric Administration [NOAA]/U.S. Department of the Interior [DOI] National System of Marine Protected Areas) with 100-meter radius buffer around each wreck
    - Automated Wreck and Obstruction Information System (AWOIS) with 100-meter radius buffer around each wreck and obstruction

- Eliminate 250-meter grid system of mapping and employ USGS interpretive sediment map (high confidence) and Thiessen polygons (lower confidence)
- Incorporate map confidence key for hard seafloor showing the spectrum of the greatest to lowest likelihood of being correct for any given location
- Consider the retention of “Complex” bottom in SSU (for protection of habitat as discussed below)

Long-term Actions for Future Ocean Plan Updates

- Investigate the importance of and develop shapefiles for additional biogenic reefs (e.g., mussels) and incorporate into Hard/Complex Seafloor map if appropriate
- Map *Crepidula* reefs using backscatter data and incorporate into Hard/Complex Seafloor map if appropriate
- Develop shapefiles for oyster restoration areas for possible inclusion in Hard/Complex Seafloor map as biogenic reef
- Continue collection and interpretation of bathymetry data, backscatter data, and sub-bottom profiling (areas presently mapped using high-resolution bathymetry and backscatter data are presented in Figure 2)
- Investigate purchase of higher resolution/more accurate wreck and obstruction data

Discussion

The 2009 Hard/Complex Seafloor map was created by combining three data sources. First, a statewide bathymetry dataset was created by combining the highest resolution bathymetric datasets available and then calculating rugosity, a measure of bathymetric heterogeneity. Highly rugose areas were then combined with seafloor delineated as hard bottom in USGS interpreted seafloor maps. Finally, the combination of these two datasets was added to points coded as hard bottom in the CZM/DMF sediment database. The resultant map was representative of hard/complex bottom, in that it was based upon the highest resolution data available. As listed above in the near-term actions, additional data sources have been identified and/or became available since 2009.

The Hard/Complex Seafloor map presented in the 2009 Plan covered a total of 904 km^2, or 16% of the planning area (Table 1). The updated map, including artificial and biogenic reefs, wrecks, and obstructions, covers a total area of 756 km^2, or 14% of the planning area. This is a 16% reduction in Hard/Complex Seafloor, the result of additional data points, increased accuracy, and refined mapping. Hard seafloor using updated data covers 578 km^2 and complex seafloor (including hard areas) covers 364 km^2, 10% and 7% of the planning area, respectively. The complex seafloor is further separated into complex hard bottom (192 km^2, 53% of complex seafloor) and complex soft bottom (171 km^2, 47% of complex seafloor). Complex seafloor [defined as areas of high rugosity, with rugosity calculated from 30x30-meter resolution bathymetry data using the ArcGIS Vector Ruggedness Measure tool, based on an algorithm developed by Sappington et al. (2007) with a 9x9-cell neighborhood size] contains diverse benthic communities in some places. An analysis of 8,911 bottom photographs taken within the planning area was conducted by CZM biologist Adrienne Pappal on select groups and taxa with the percentage of prevalence in the original and draft revised Hard/Complex Seafloor SSU areas. Percentages were calculated by dividing the number of photos with the group/taxa identified within the given hard/complex seafloor area by the number of photos with the group/taxa in the ocean planning area (Table 2). As an example, hard/complex areas contain approximately 78% of soft corals observed in the photos, while only 62% are covered by hard seafloor alone. Overall, there was an average of 9% more photos containing the select taxa when including hard and complex areas rather than just hard bottom. Separate maps identifying hard seafloor, complex seafloor, artificial and biogenic reefs, and wrecks and obstructions were prepared (Figures 3 thru 6), along with a combined Hard/Complex Seafloor SSU map (Figure 7). Examples of the structure provided by biogenic reefs, specifically *Crepidula* sp. and the tube-building polychaete *Ampharete* sp., are shown in photographs presented in Figure 8. Additionally, a map depicting the locations of areas identified as mussel reefs is presented in Figure 9 for discussion relating to their possible inclusion into the Hard/Complex Seafloor SSU.

Surficial Sediment

In addition to the Hard/Complex Seafloor maps, the workgroup also recommended the following updates to the Surficial Sediment map.

Near-term Actions for the 2014 Plan Update

- Incorporate the updated CZM/DMF sediment database with over 30,000 new data points obtained from:
    - 2010, 2011, and 2012 OSV *Bold* oceanographic surveys
    - CZM Dredge Material Management Plans
    - DEP Wetlands Sandy Beaches and Rocky Intertidal Shores Maps
    - DMF Northeast Consortium Study of MA Bay 2006 (analysis of bottom photographs)
    - Massachusetts Water Resources Authority (MWRA) Monitoring Reports (grain-size analysis 1991-2008, SPI photographs 2007)
    - U.S. Army Corps of Engineers (grain-size analysis Boston Harbor and Great Harbor 1998-2007)
    - NOAA nautical charts (sediment and "*" rocks)
    - usSEABED (DMF/CZM version)
- Eliminate 250-meter grid system of mapping and employ a combination of USGS interpretive sediment mapping and Thiessen polygons
- Incorporate map confidence key showing the spectrum of the greatest to lowest likelihood of being correct for any given location
- Incorporate available sediment data for areas adjacent to state waters

Long-term Actions for Future Ocean Plan Updates

- Develop regional sediment transport data
- Develop a comprehensive contaminated sediment database in the planning area
- Continue to research sediment data for areas adjacent to state waters for inclusion in future mapping efforts

Discussion

Figure 10 illustrates the sediment sample locations used to create the Surficial Sediment map. The Surficial Sediment map (Figure 11) contains a wealth of newly incorporated, high-resolution data, including new USGS interpreted seafloor sediment maps, DEP wetlands sandy beach and rocky shore delineations, older USGS interpreted sediment maps, and an updated version of the CZM/DMF sediment database used in the 2009 Ocean Plan. As part of the CZM-USGS Seafloor Mapping Cooperative, USGS is delineating areas of similar seafloor sediment texture for much of

Massachusetts marine waters by qualitatively analyzing acoustic backscatter (which can be used to estimate the seafloor hardness), bathymetry (which can be used to characterize rough and smooth topographies that are associated with rocky and finer sediments, respectively), surficial geologic and stratigraphic interpretations of seismic-reflection profiles, sediment samples, and bottom photographs.

In addition to the sediment map in the planning area, two maps were prepared that carry this mapping beyond state waters and into adjacent federal waters. Figure 12 incorporates the available data from the CZM/DMF sediment database out to a distance of 10 nautical miles. Using this source, the confidence in data beyond 10 nautical miles was low, and therefore not included. The map presented in Figure 13 employs data obtained from the USGS Continental Margin Mapping (CONMAP) Program. These data are useful during the siting and review of projects entering the state from federal waters and may also be useful for locating possible sand extraction sites outside of state waters.

The confidence key associated with the Surficial Sediment map was developed using four data confidence levels: low, medium, high, and very high.

- **Low** = low confidence Thiessen polygons and 1:1M scale USGS CONMAP[1]
- **Medium** = medium confidence Thiessen polygons
- **High** = high confidence Thiessen polygons and older USGS sediment interpretations[2]
- **Very High** = new USGS sediment interpretations[3] and DEP Wetlands[4]

[1] CONMAP data (Poppe et al. 2005) were used only outside the planning area
[2] Knebel and Circe 1995; Rendigs and Knebel 2002; Poppe et al. 2006; Poppe et al. 2007
[3] Pendleton et al. 2013 and unpublished data in review
[4] Mapped at 1:12,000, used to extract sandy beaches and rocky intertidal shores

Thiessen polygons were created from the CZM/DMF sediment database. The sediment data within contains a spectrum of quality, therefore CZM developed a "Data Quality Index" to quantify the variability in data confidence based on sample age, sampling device, and analytical technique.

Age Quality Values	**Sampling Device Quality Value**	**Analytical Technique Quality Value**
2000-present = 12	Grab = 4	Laboratory = 2
1985-1999 = 11	Photo = 4	Visual = 1
1960-1984 = 7	Core = 3	
Pre-1960 = 1	Dredge = 2	
	Lead Line = 1	

Data Quality Index (***I***) is:

$$I = ((A/12) + (S/4) + (N/2))$$ where,

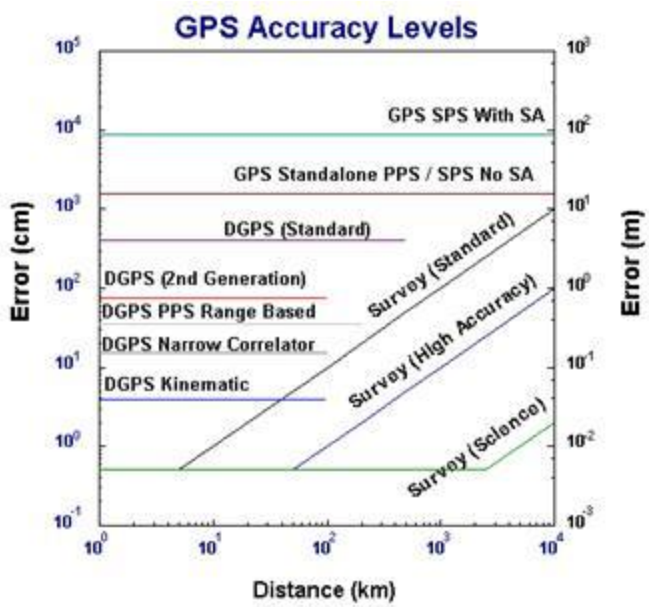
A is age of sample
S is sampling device
N is analytical technique

I values range from 0.83 to 3, the higher the number equating to a higher confidence in the data. The range was divided into quartiles yielding three confidence levels and attributed accordingly.

High > 2.46	(highest quartile)
Med 1.37 to 2.46	(middle two quartiles)
Low < 1.37	(lowest quartile)

The age quality value is based on the inferred technology used to locate the point.

Global Positioning System (GPS)
From the Naval Postgraduate School, http://www.oc.nps.edu/oc2902w/gps/gpsacc.html:



Per this table, the accuracy of:

GPS with Selective Availability (SA) is ±100 m
GPS after May 1, 2000 is ±12.6 m
Differential Global Positioning System (DGPS) is ±2 m

LORAN-C
"The distinction between absolute and repeatable accuracy is the most important one to understand. With the correct application of ASF's and within the **coverage area** defined for each chain, the absolute accuracy of the Loran system varies from between 0.1 and 0.25 nautical miles." [0.25 nm = 463 m] http://msi.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/APN/Chapt-12.pdf

Pre-LORAN
We presume a variety of different navigational techniques were used in the pre-LORAN era, hence we have no way to assign an approximate accuracy value. Some of the values are, however, reported as latitude-longitude pairs with two decimal places. Two decimal places can span up to 1.1 km (1,100 m).

Using the above information, CZM assigned the following Age Quality Values.

Year Range		Approx. accuracy	Age Quality Value
2000-present	DGPS	±2 m	12
1985-1999	GPS with SA	±100 m	11
1960-1984	LORAN-C	±463 m	7
Pre-1960	various	±1,100 m	1

Age Quality Values are derived from distances on the ground measured in 100 m intervals. When ranked each 100 m represents one ordinal number so that 2 m = 12, 100 m = 11 (12 - 1), 463 m = 7 (12 - 5 where 5 is 4.63 rounded), etc.

Potential Sand Extraction Areas

The workgroup recommended the preparation of the following maps and actions.

Near-term Actions for the 2014 Plan Update

- Develop map locating sites previously investigated for potential sand and gravel extraction
- Incorporate available core locations into the potential sand extraction map

Long-term Actions for Future Ocean Plan Updates

- Develop sub-bottom profile data in cooperation with USGS to identify sand deposits suitable for extraction
- Continue to research sediment data for state and federal waters, including the addition of core sample analysis for potential sand extraction sites
- Compile data attributes from existing core samples
- Incorporate sub-bottom profiling and coring data from studies conducted prior to CZM-USGS Seafloor Mapping Cooperative
- Overlay all sub-bottom data and sediment core data from available sources to identify additional deposits of beach compatible sand
- Develop a map of surficial sediments overlain by available coring information showing the depth of granular material
- Map existing nearshore disposal sites
- Map existing beach nourishment sites
- Conduct needs assessment for beach nourishment
- Develop screening criteria for potential extraction sites
- Develop screening criteria for potential nourishment sites

Discussion

When investigating the surficial and sub-bottom potential for sand extraction in the coastal and offshore waters of Massachusetts, it becomes readily apparent that the geology of this seabed is highly heterogeneous. An overview of the geology was conducted during a workshop with CZM and USGS in August 2013. As background for the discussion, the following is a summary of that overview.

In the north, the seafloor is dominantly sandy with few rocky areas, though more rock occurs closer to Cape Ann. Seismic-reflection surveys have identified areas of thick (up to 9 m) sand and mixed sand/gravel deposits. Many of these deposits are relatively close to shore, particularly in the Plum Island area. There is a need for more detailed subsurface sampling (coring) in this area in order to assess the resource potential of these deposits. Based on seismic data and existing cores, there is significantly less sand and more rocky areas in Massachusetts Bay and Western Cape Cod Bay. There are potential sand resources in western Massachusetts Bay that also need additional coring data to determine the texture and volume of the sediment deposits. This region is generally characterized by older glacial deposits (coarser sands). There also appear to be beach-compatible sand deposits close to shore near Hull and Duxbury. Buzzards Bay is a semi-enclosed basin with a fairly flat seafloor, with more rocky topography toward the mouth (southwest). Post-glacial drainage channels incised into Pleistocene outwash deposits are infilled with muddy estuarine fill and capped by Holocene fine-grained marine deposits. The central part of the basin is predominantly mud with margins that are sandy. Minimal existing cores reveal potential Pleistocene and Holocene sand resources. The post-glacial sediment may include Holocene sand, but could also include estuarine deposits (mixed benefit material) – e.g., the deposit could be 20 meters thick but contain only two to three meters of surficial sand. Holocene marine sand is likely to be well sorted; Pleistocene outwash is likely to contain some gravel mixed with sand and/or mud. An evaluation of sand thickness using isopach (sediment thickness) maps derived from seismic-reflection data as a guide to coring should be conducted in this area. There appears to be a significant sand deposit (approximately six meters thick) north of Cuttyhunk Island. In Vineyard Sound, most of the cores collected by Oldale and others did not penetrate through the sand layer. Some small wedges of sand are located near shorelines. There are several sand shoals in Vineyard Sound – sediment can reach 12 meters in thickness. These features are likely deposited on recessional moraines (Pleistocene in age). Vineyard Sound differs from Buzzards Bay in that the post-glacial drainage surface is exposed over much of the seabed. Waves and tidal flow have, and continue to rework these sediments, in places forming armored beds of winnowed gravel. Hedge Fence, Squash Meadow, Middle Ground, and L'Hommedieu shoals are relatively thick localized source of sand. There are also several thin, mobile barchan dunes northwest of the main shoal areas. These sources may be self maintaining (re-generate), allowing for the removal for nourishment purposes (depending on how much sand is removed, more analysis of sediment transport processes is needed). Sand waves in this area may migrate up to 10 meters per month (but not the underlying bank; the feature itself is stable). The tidal currents are very strong here and the stratigraphy is complex. In Vineyard Sound, swath bathymetry reveals several meters of relief. The backscatter data show large bodies of coarse grain material oriented in a north-south direction along the southwestern tip of the Vineyard. There are large boulders in the nearshore. Termed "sorted bedforms", these features are indicative of a highly mobile, high-energy environment. In Nantucket Sound, USGS recently collected data in a small area just north of the island. There are several areas of natural gas within five to 10 meters of the seafloor; likely related to the presence of buried estuarine or lacustrine sediment deposits. Based on backscatter data, it is not likely that any sand resources are located in the area just north of Nantucket.

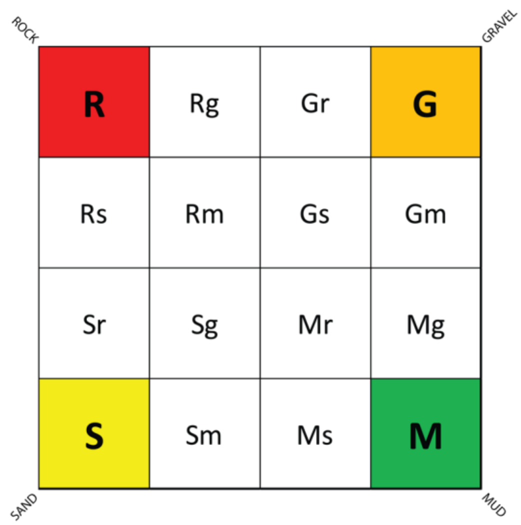
Several maps are presented. The first map, Figure 14, shows the locations of sites that were previously investigated for the possibility of sand and gravel extraction for use in beach nourishment projects. These potential sources of sand were identified using both the sub-bottom profiling results and sediment core analysis. It should be noted that the work conducted in the 1970s for the NOMES project was to be used for aggregate mining to support upland construction. Very little sand mining research has been conducted in state waters. Nearshore sediment disposal locations utilized by the USACE are presented in Figure 15. These sites, often used for the disposal of sand from channel dredging projects, may be sources of significant volumes of sand available for beach nourishment. Further investigation is required. Figure 16 marks the locations of sediment cores collected in and adjacent to the planning area. These data come from various sources and represent preliminary characterizations for those sites. To determine the extent of any possible sand resources for use in shoreline protection and beach nourishment needs, additional data collection and analysis must be performed, including subsurface cores, grain-size analysis, and sub-bottom profiling to determine the volume and type of sediment present and their compatibility with existing beach sediment. In addition, the environmental impacts of mining these potential sand sources would need to be assessed. Figure 17 represents the areas of seismic (sub-bottom) profiling data collected in and adjacent to state waters. Figures 18, 19 and 20 present maps showing the sediment thickness, in meters above bedrock, north of Cape Ann, in Massachusetts Bay, and in Boston Harbor. Total sediment includes Holocene, Pleistocene, and coastal plain deposits.

Bottom Type	2009 Plan Area (% of Planning Area)	2014 Update Area (% of Planning Area)	% Change (2009 vs. 2014)
Hard/Complex	904 km^2 (16%)	756 km^2 (14%)	-16%
Hard	308 km^2 (6%)	578 km^2 (10%)	88%
Complex	755 km^2 (14%)	364 km^2 (7%)	-52%
- Complex Hard	160 km^2 (3%)	192 km^2 (3%)	20%
- Complex Soft	596 km^2 (11%)	171 km^2 (3%)	-71%

Table 1. Area covered by Hard/Complex Seafloor SSU in the ocean management planning area.

Taxa/Group	**Number of Photos in Planning Area**	**Hard/ Complex Seafloor SSU (2009)**	**Hard Seafloor (1/2014)**	**Hard/ Complex Seafloor (1/2014)**
Alcyoniina (Soft Coral)	63	78%	62%	78%
Astrangia sp. (Stony Coral)	85	36%	38%	41%
Attached Fauna	680	58%	51%	61%
Attached Hydroids and Bryozoans	423	59%	47%	57%
Attached Mussels and Mussel Reefs	315	87%	86%	92%
Benthic Macroalgae	1,230	62%	66%	71%
Bivalvia (Clam Bed)	907	22%	6%	12%
Bivalvia and Soft Sediment Mussels	1,115	31%	14%	22%
Brachiopoda	371	77%	53%	76%
Canopy-Forming Algal Bed (Kelps)	96	79%	86%	90%
Diverse Colonizers	29	93%	100%	100%
Porifera (Sponge, Sponge Bed)	1,030	67%	53%	68%
Tube-Building Fauna	735	27%	7%	13%

Table 2. Select groups and taxa with percentage of prevalence in the original and draft revised Hard/Complex Seafloor SSU areas



Rock	Rock with gravel	Gravel with rock	Gravel
Rock with sand	Rock with mud	Gravel with sand	Gravel with mud
Sand with rock	Sand with gravel	Mud with rock	Mud with gravel
Sand	Sand with mud	Mud with sand	Mud

Figure 1. Barnhardt classification scheme (Barnhardt and others, 1998) used to classify sediments.

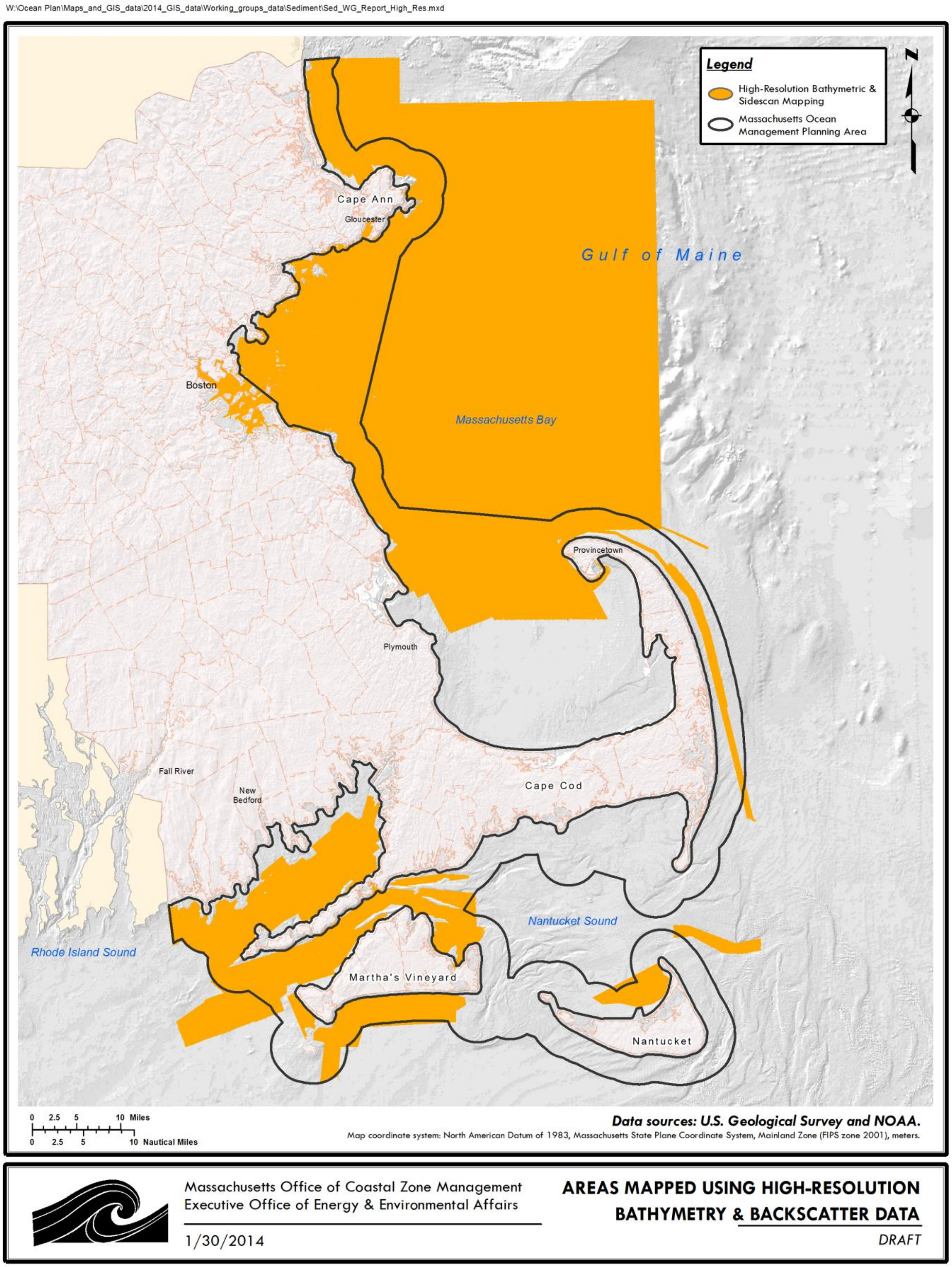


Figure 2. Seafloor mapped using high-resolution bathymetry and backscatter data.

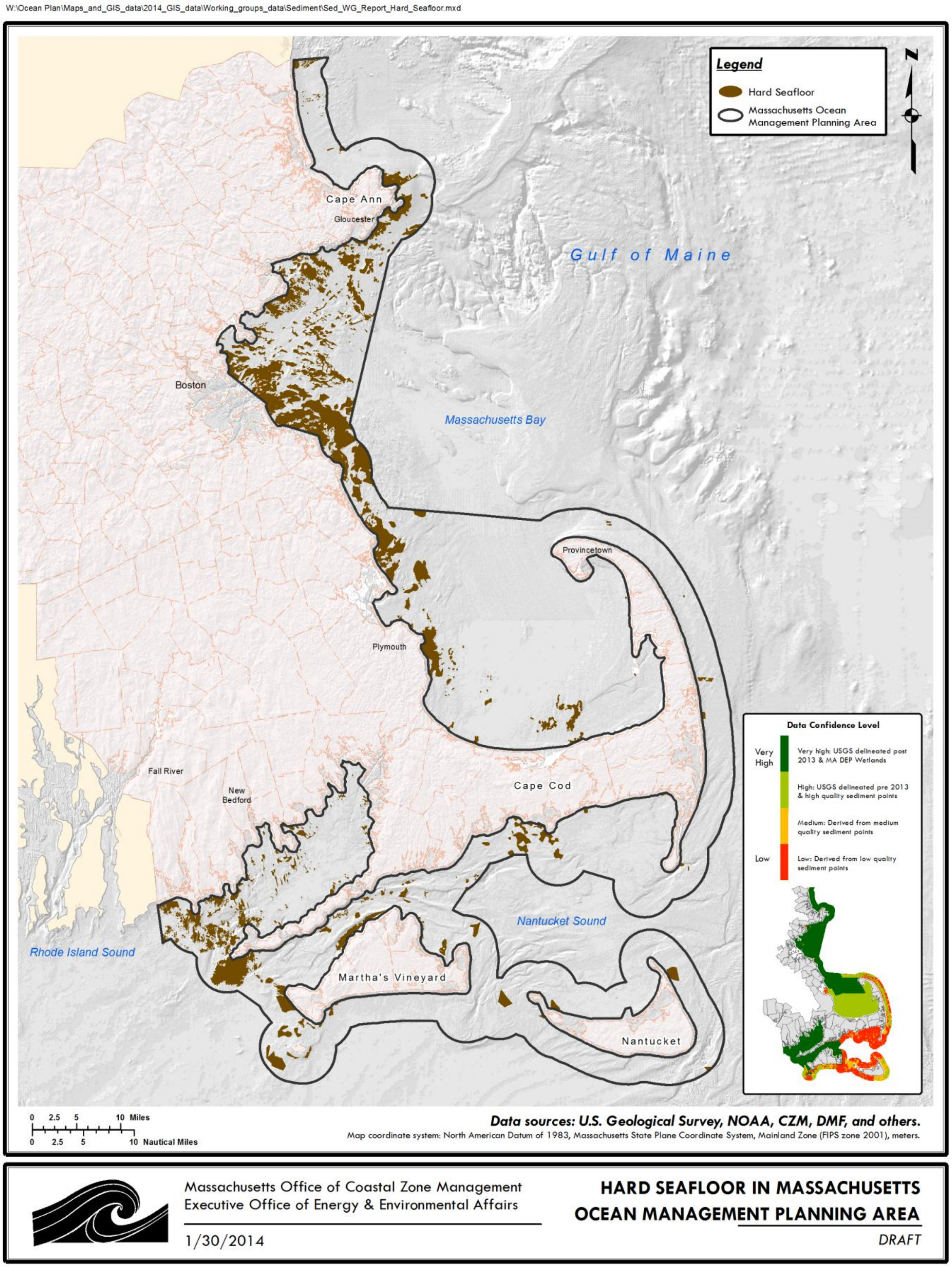


Figure 3. Hard seafloor in the ocean management planning area.

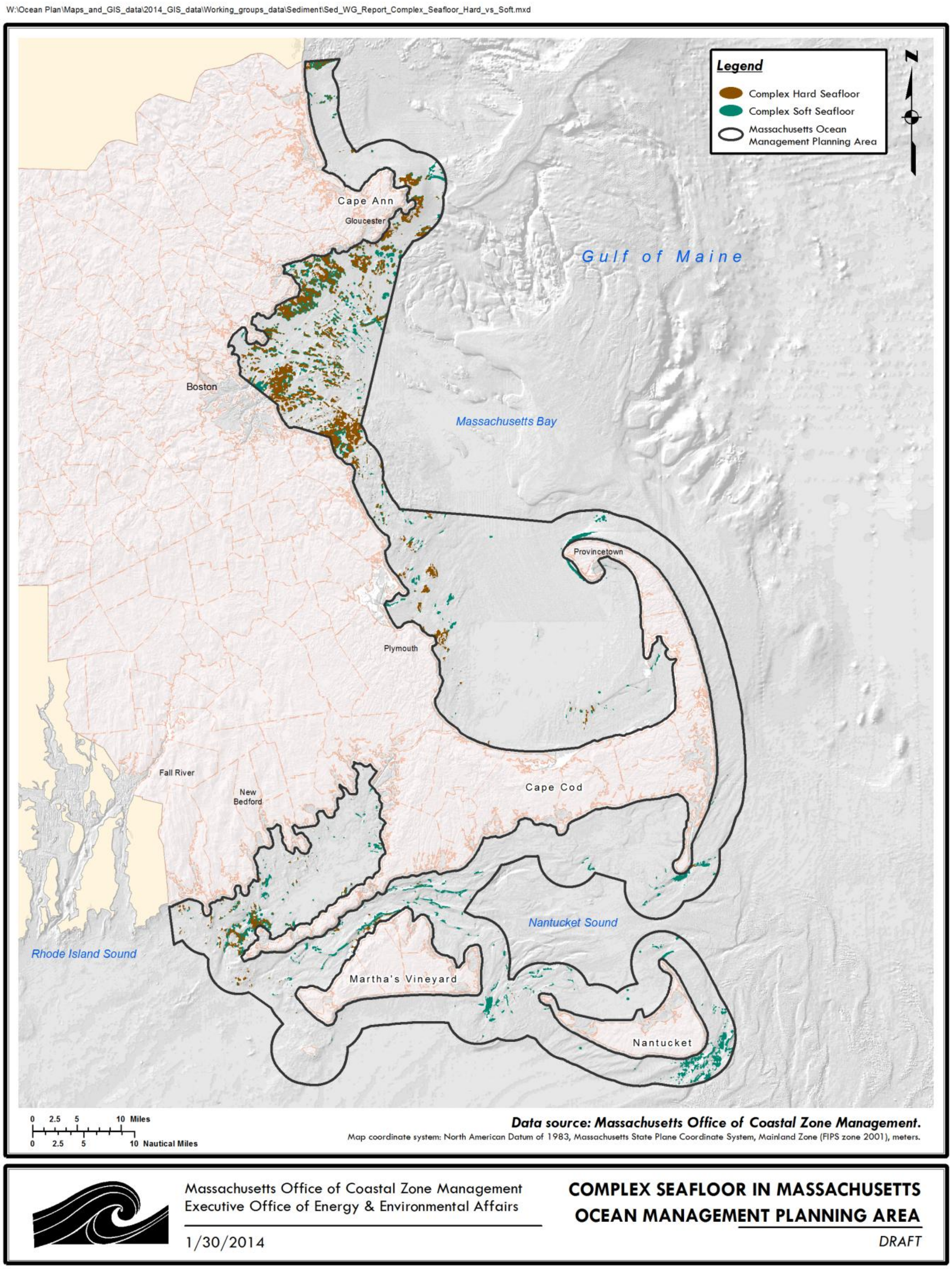


Figure 4. Complex seafloor in the ocean management planning area.

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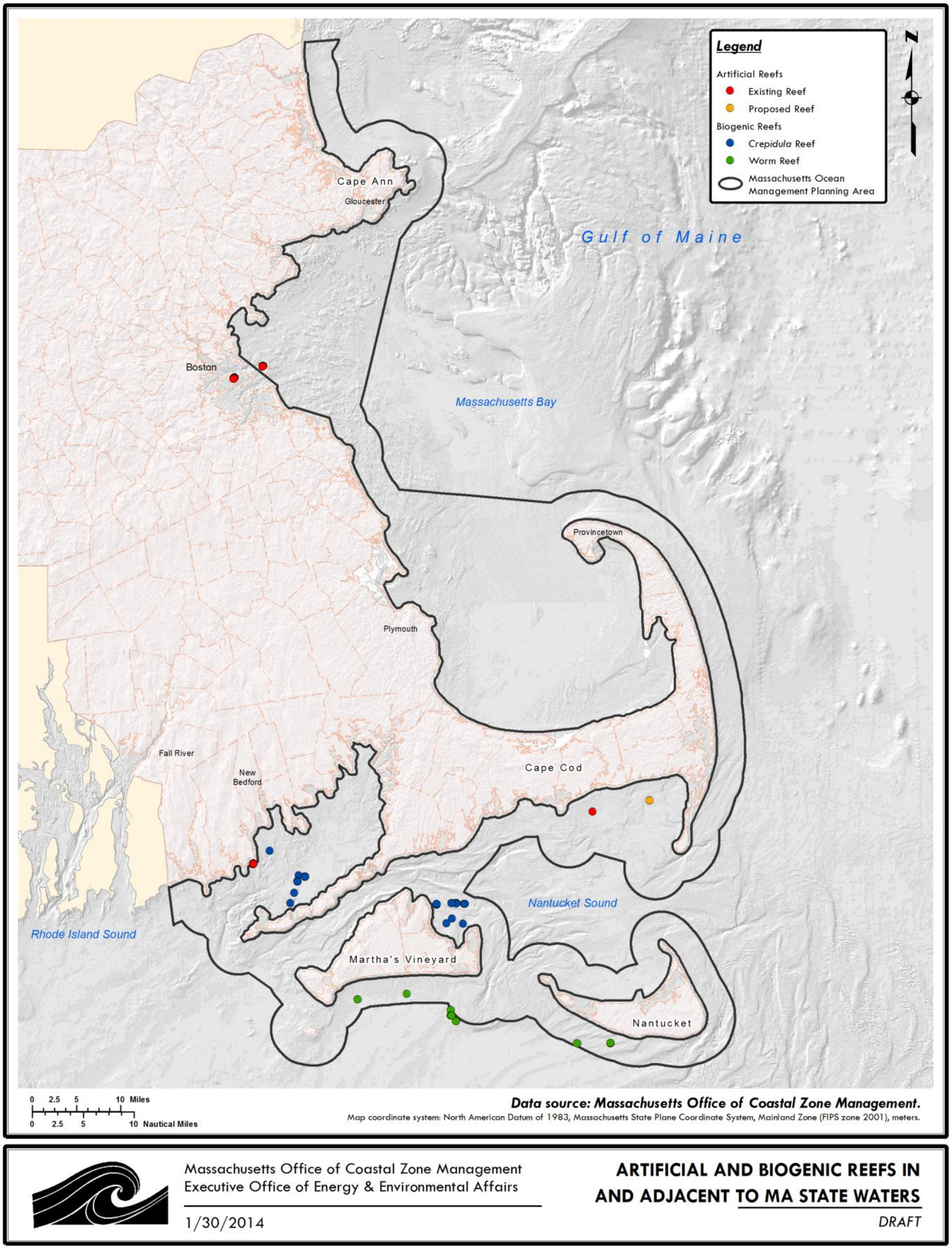


Figure 5. Artificial and biogenic reef sites in and adjacent to state waters.

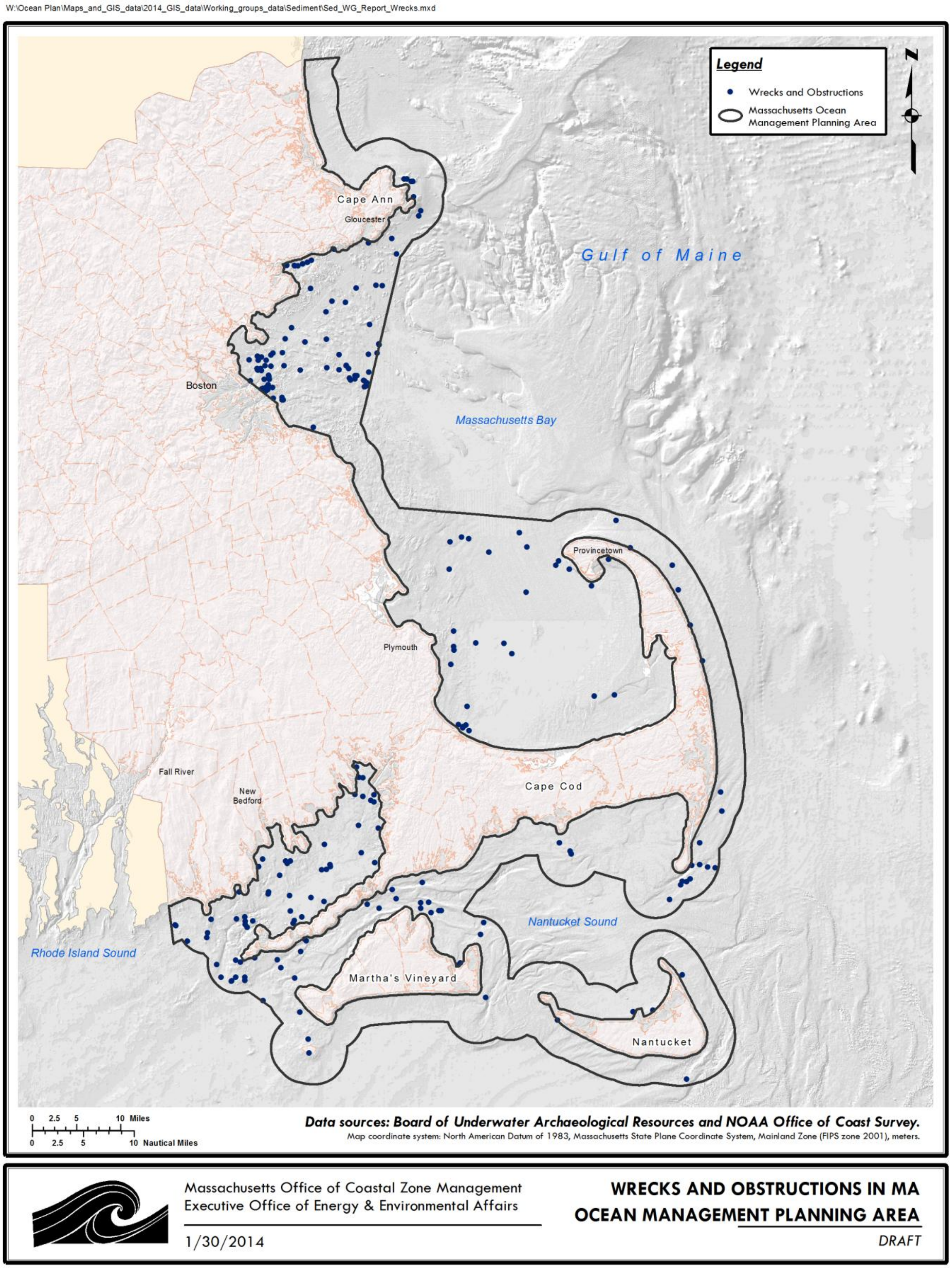


Figure 6. Wrecks and obstructions in the ocean management planning area.

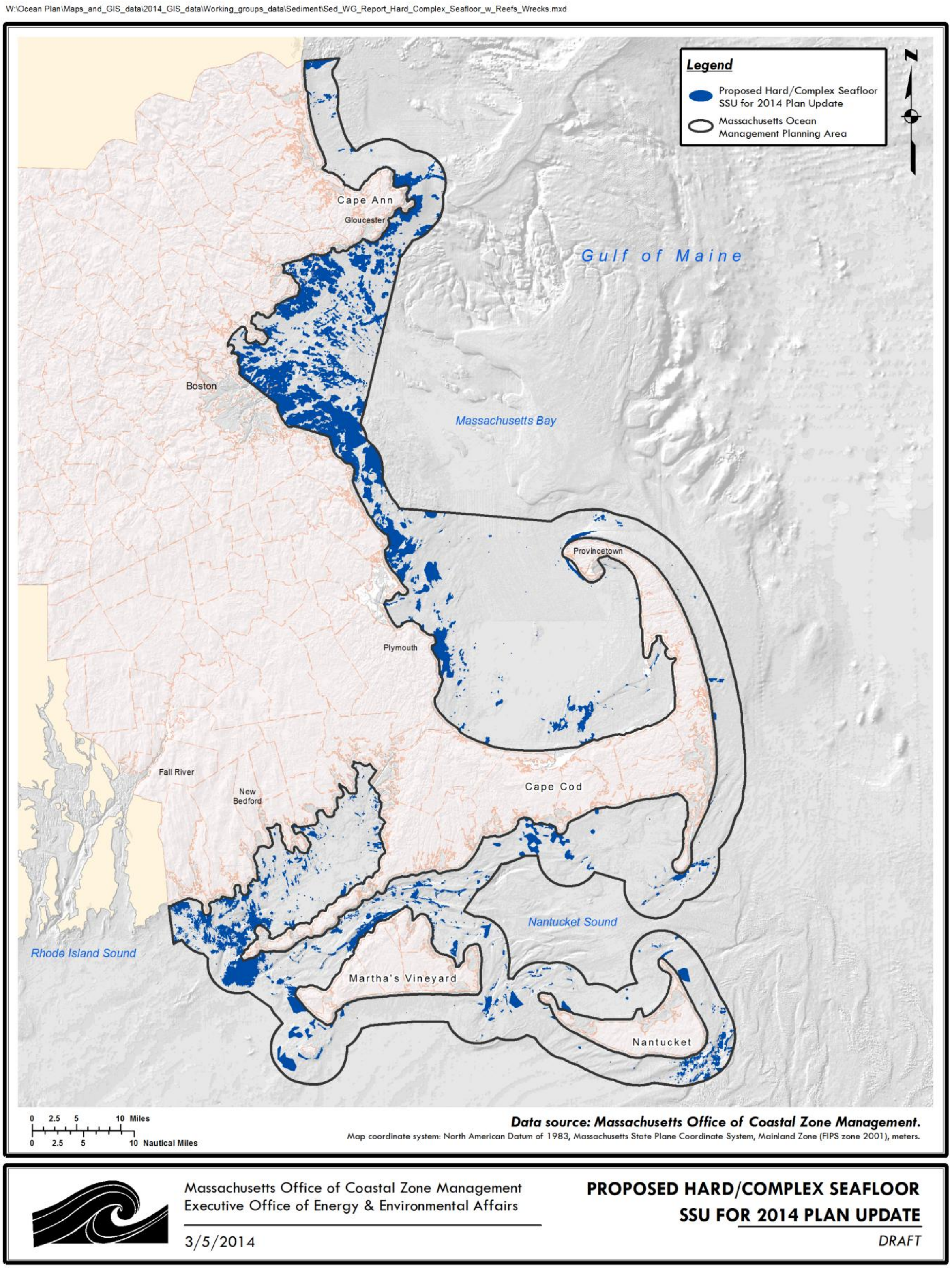


Figure 7. Hard/complex seafloor SSU in the ocean management planning area, including artificial reefs, biogenic reefs, wrecks, and obstructions.

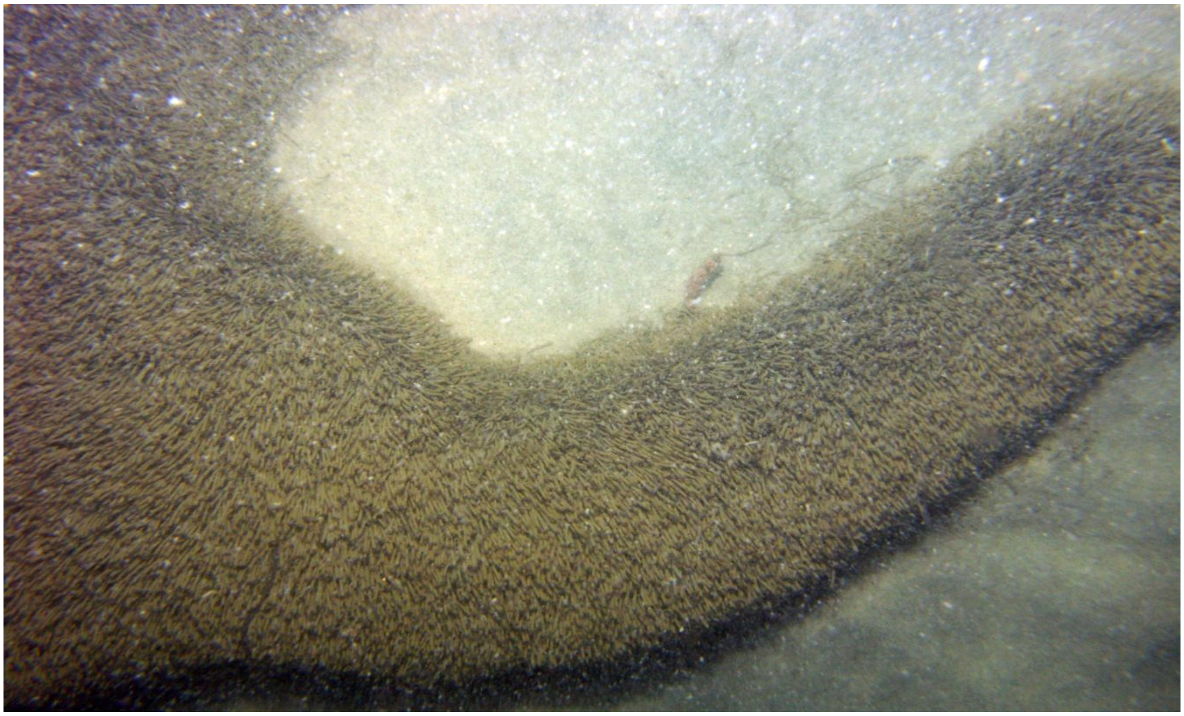


Figure 8. Biogenic reef structure formed by *Ampharete* sp. (top) and *Crepidula* sp. (bottom). Photos were obtained during surveys in state waters aboard the OSV *Bold*.

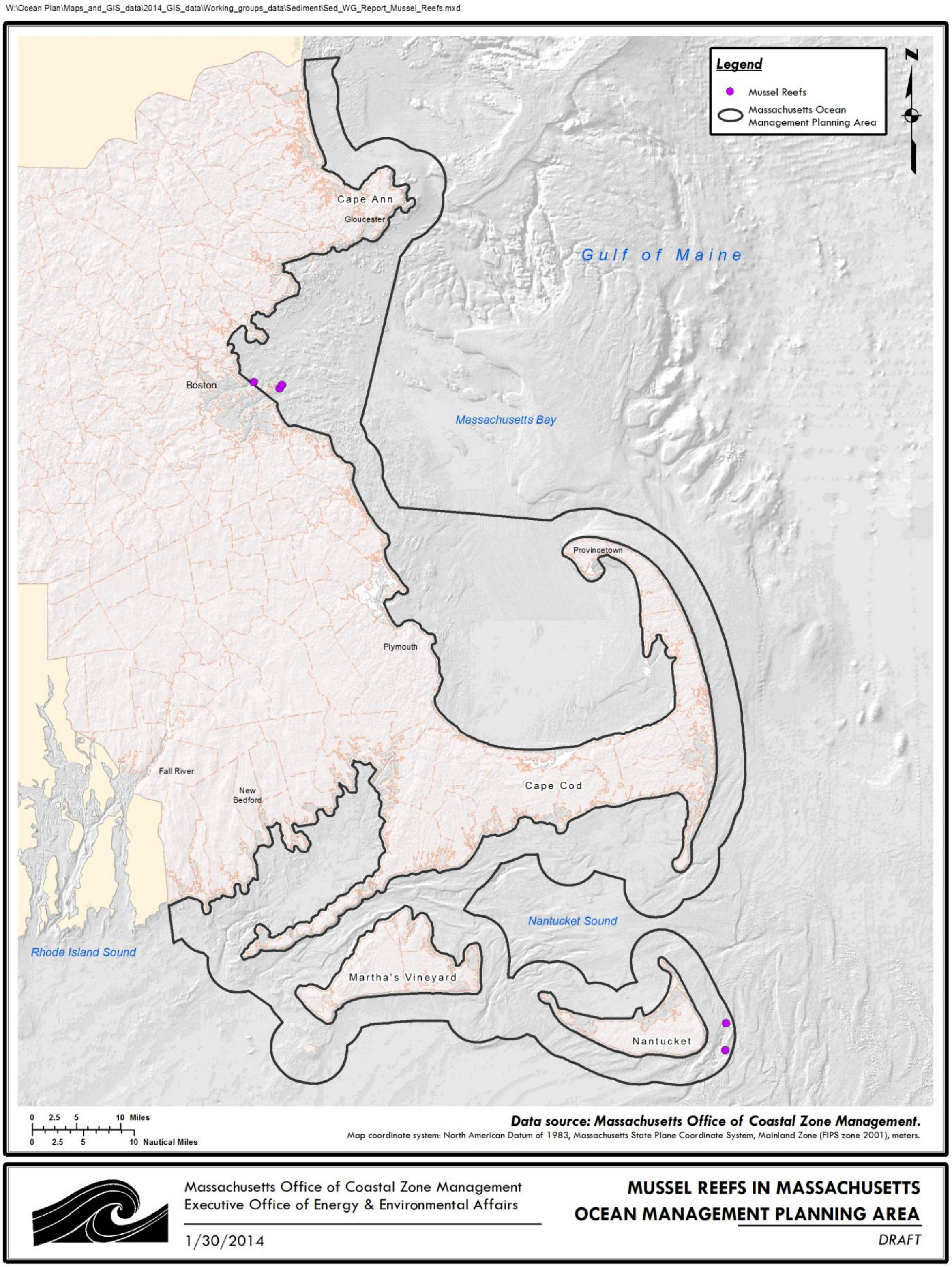
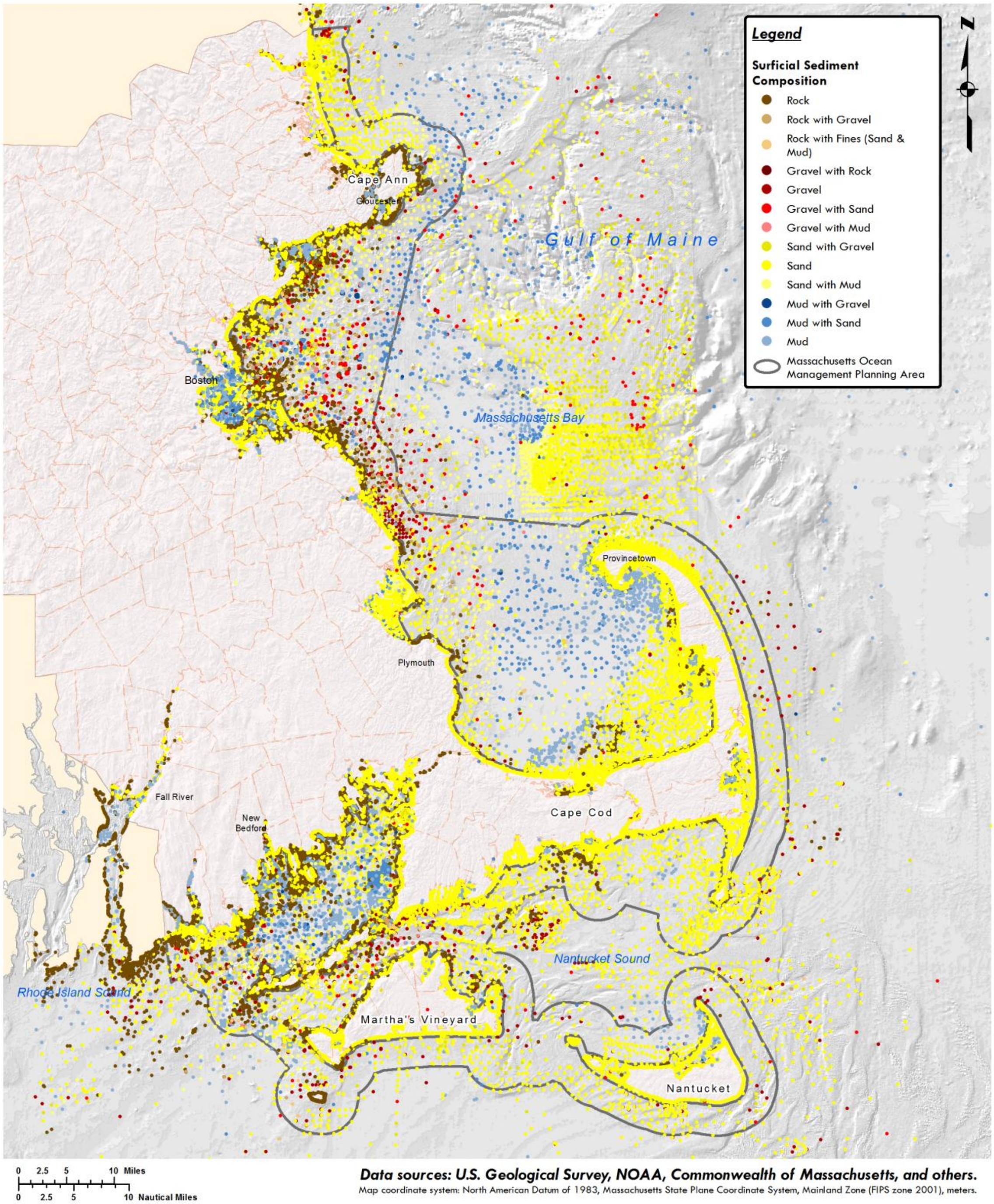


Figure 9. Mussel reefs in the ocean management planning area.

W:\Ocean Plan\Maps_and_GIS_data\2014_GIS_data\Working_groups_data\Sediment\Sed_WG_Report_Surficial_Sediment_Points.mxd



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SURFICIAL SEDIMENT SAMPLES AND CLASSIFICATION

DRAFT

Figure 10. Locations of surficial sediment samples in the CZM/DMF sediment database.

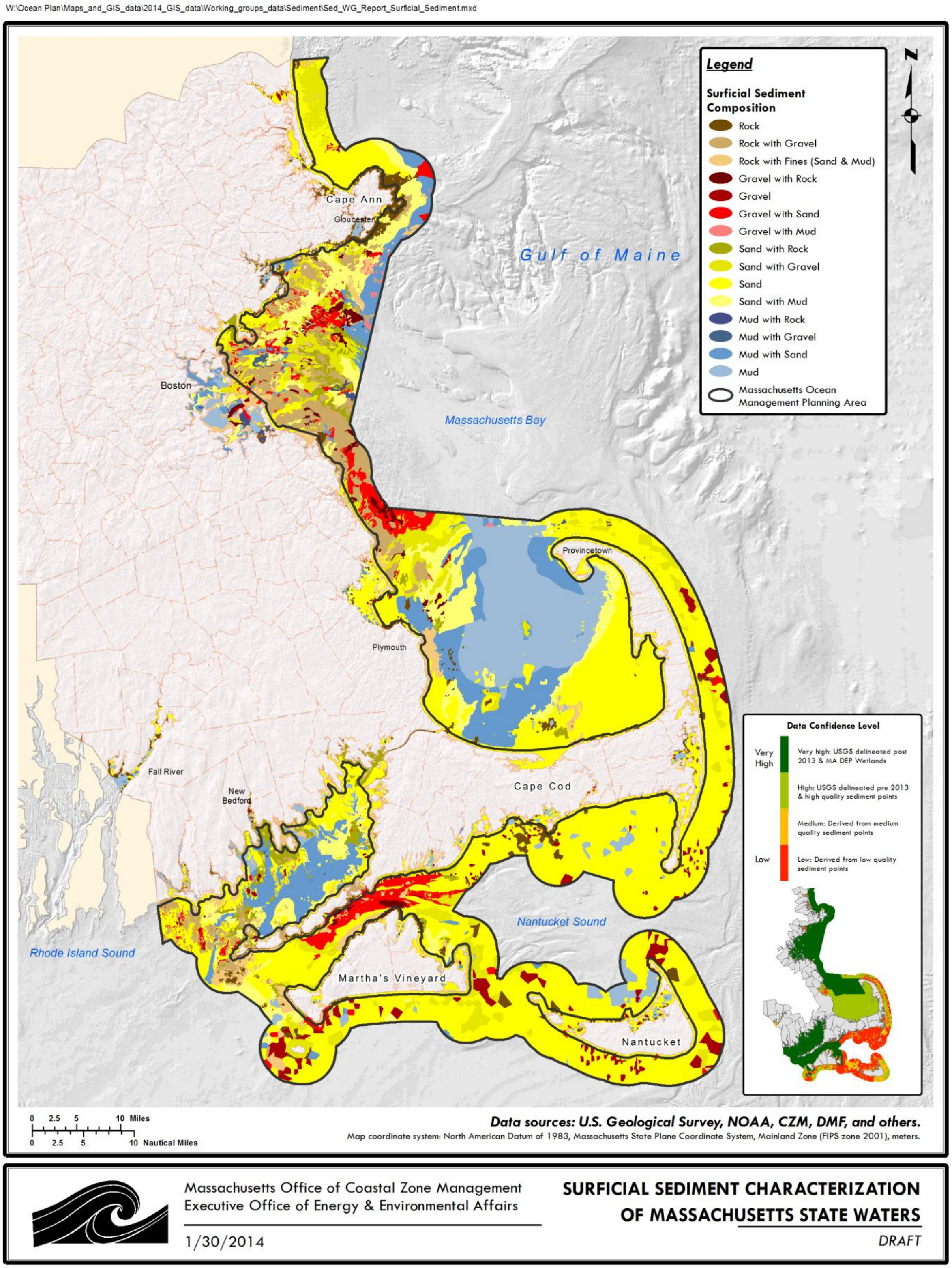


Figure 11. Surficial sediment in state waters.

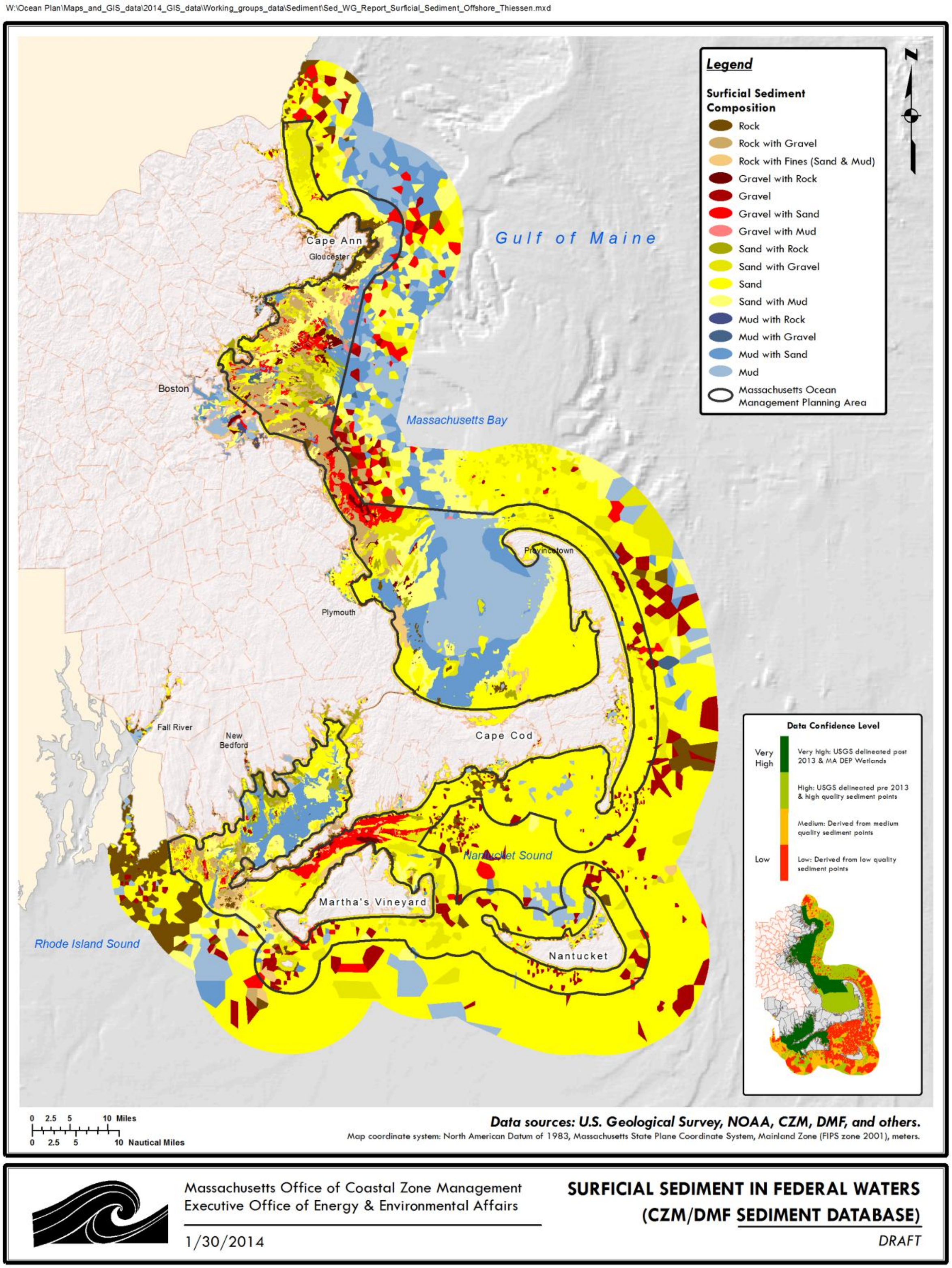


Figure 12. Surficial sediment out to 10 nautical miles using data derived from the CZM/DMF sediment database.

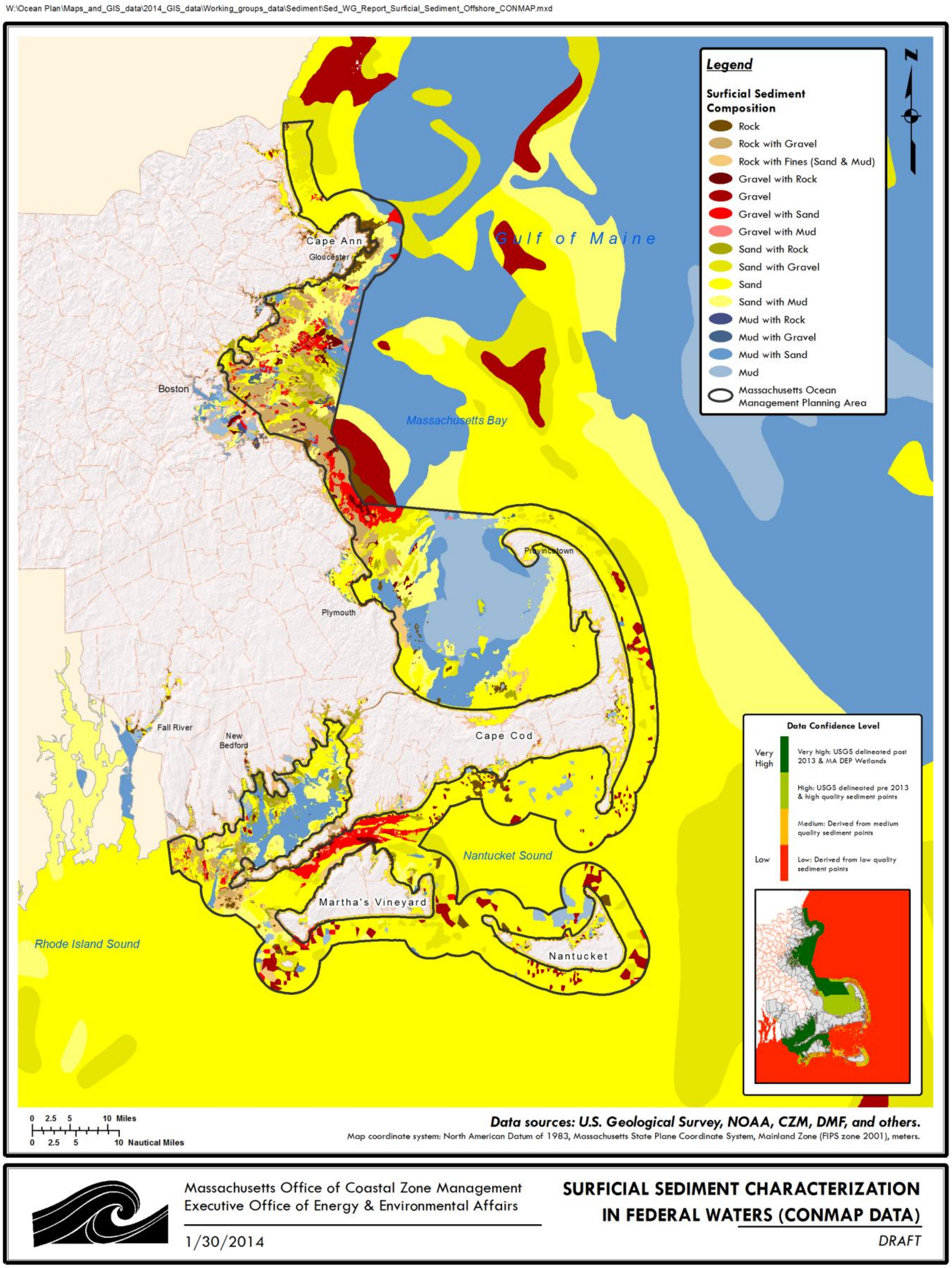


Figure 13. Surficial sediment beyond the ocean management planning area using data derived from the USGS Continental Margin Mapping (CONMAP) Program.

W:\Ocean Plan\Maps_and_GIS_data\2014_GIS_data\Working_groups_data\Sediment\Sed_WG_Report_Potential_Borrow_Sites.mxd

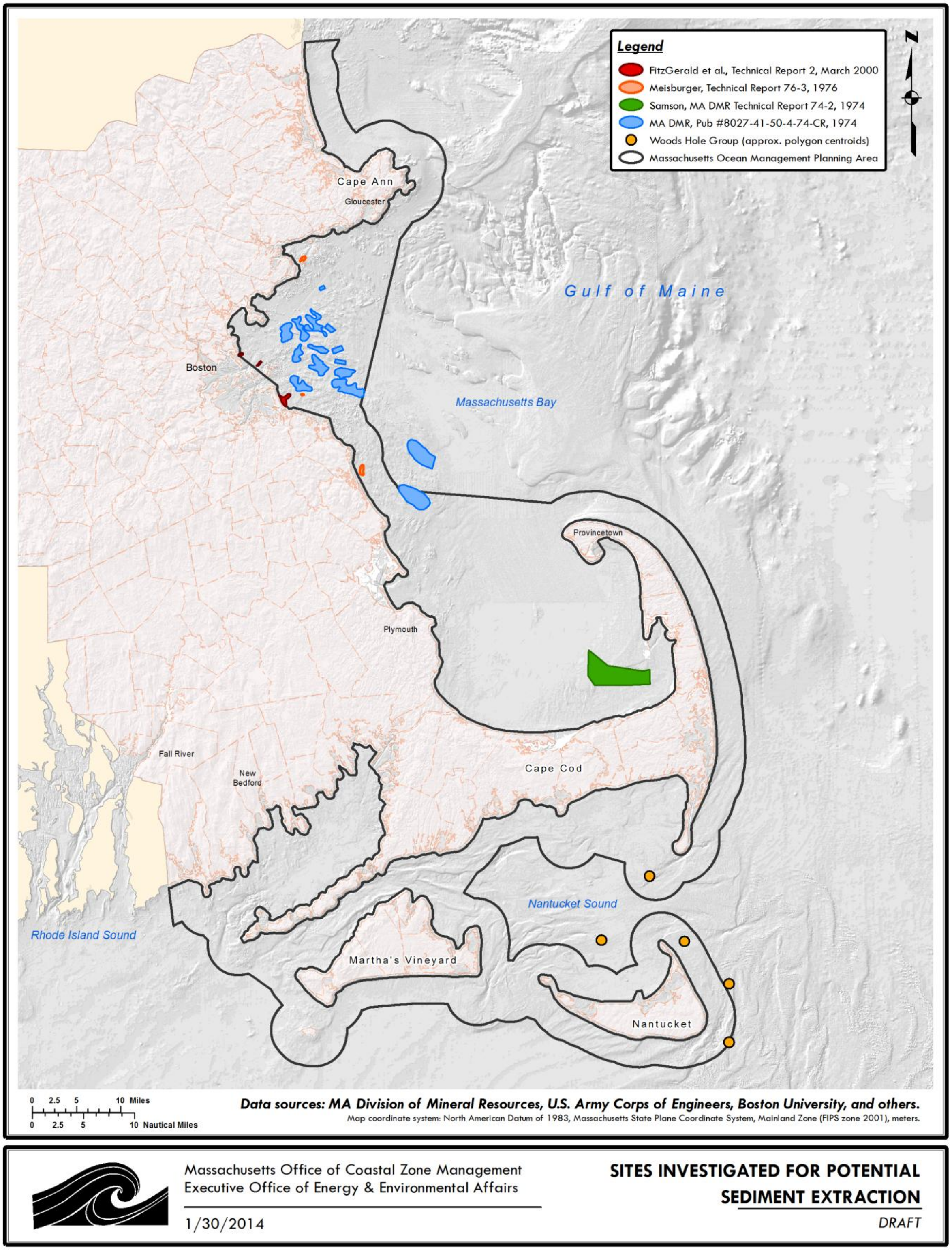


Figure 14. Sites investigated for potential sand and gravel extraction.

W:\Ocean Plan\Maps_and_GIS_data\2014_GIS_data\Working_groups_data\Sediment\Sed_WG_Report_Nearshore_Disposal_Sites.mxd

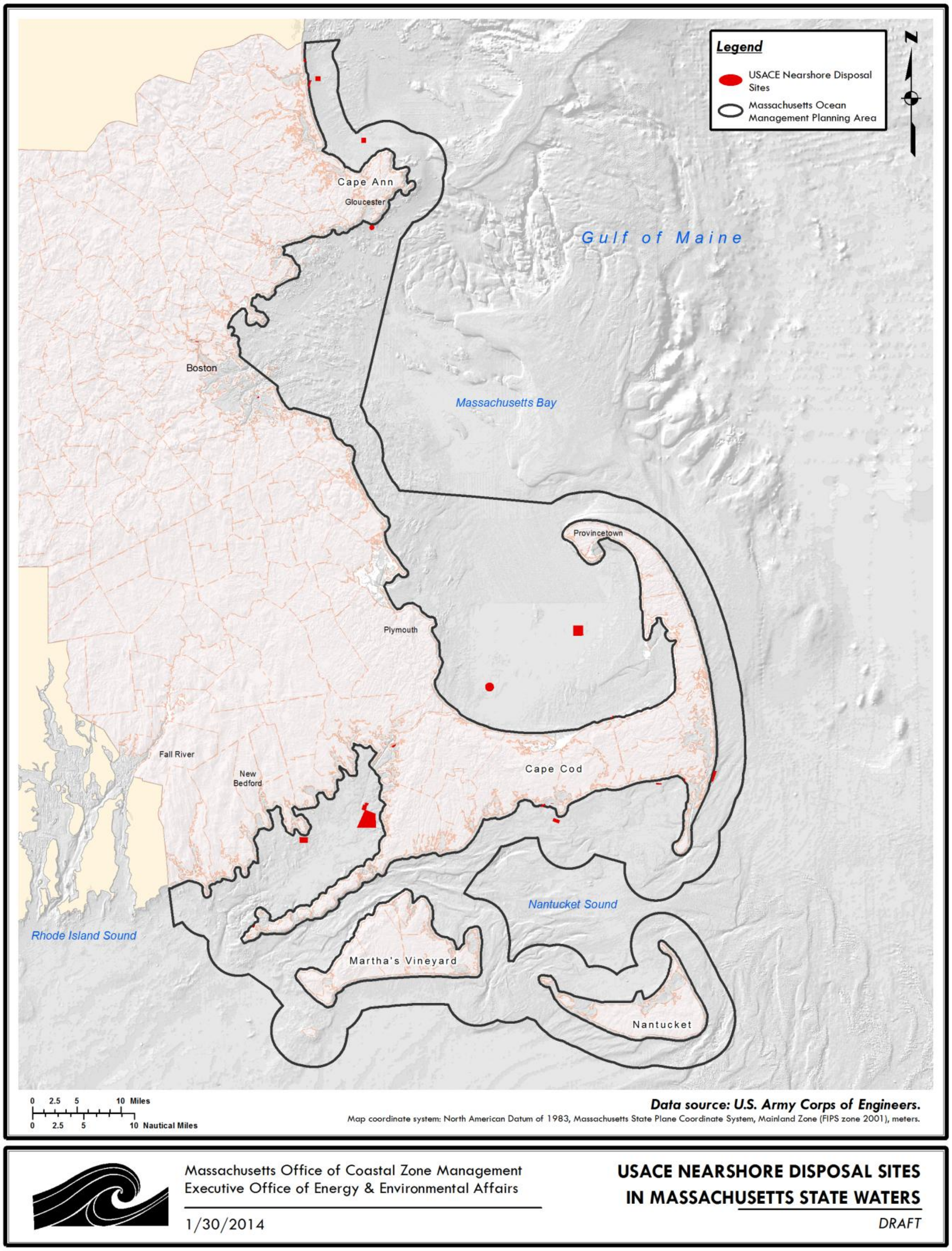


Figure 15. Nearshore disposal sites utilized by the U.S. Army Corps of Engineers.

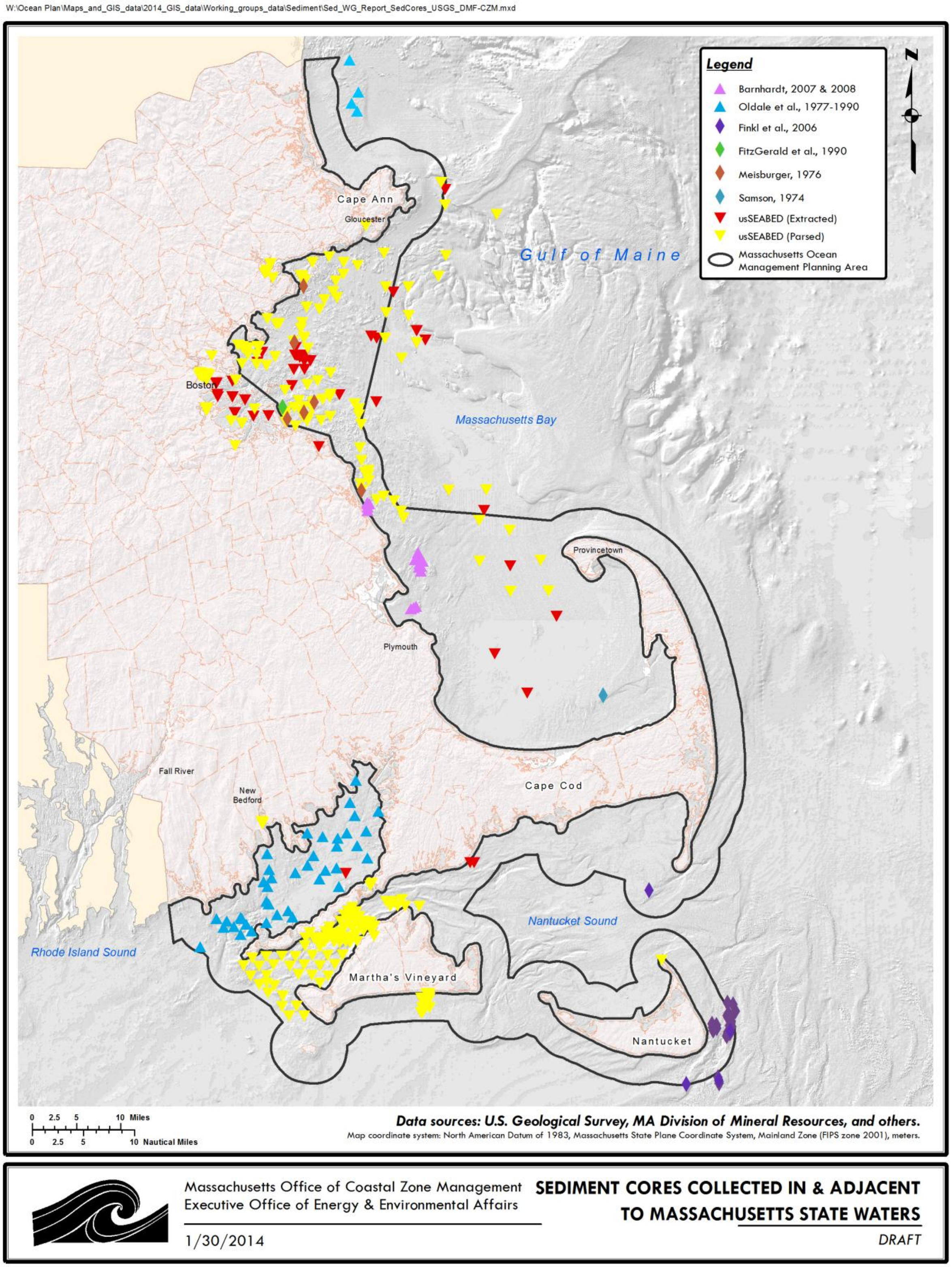


Figure 16. Sediment core locations in and adjacent to state waters.

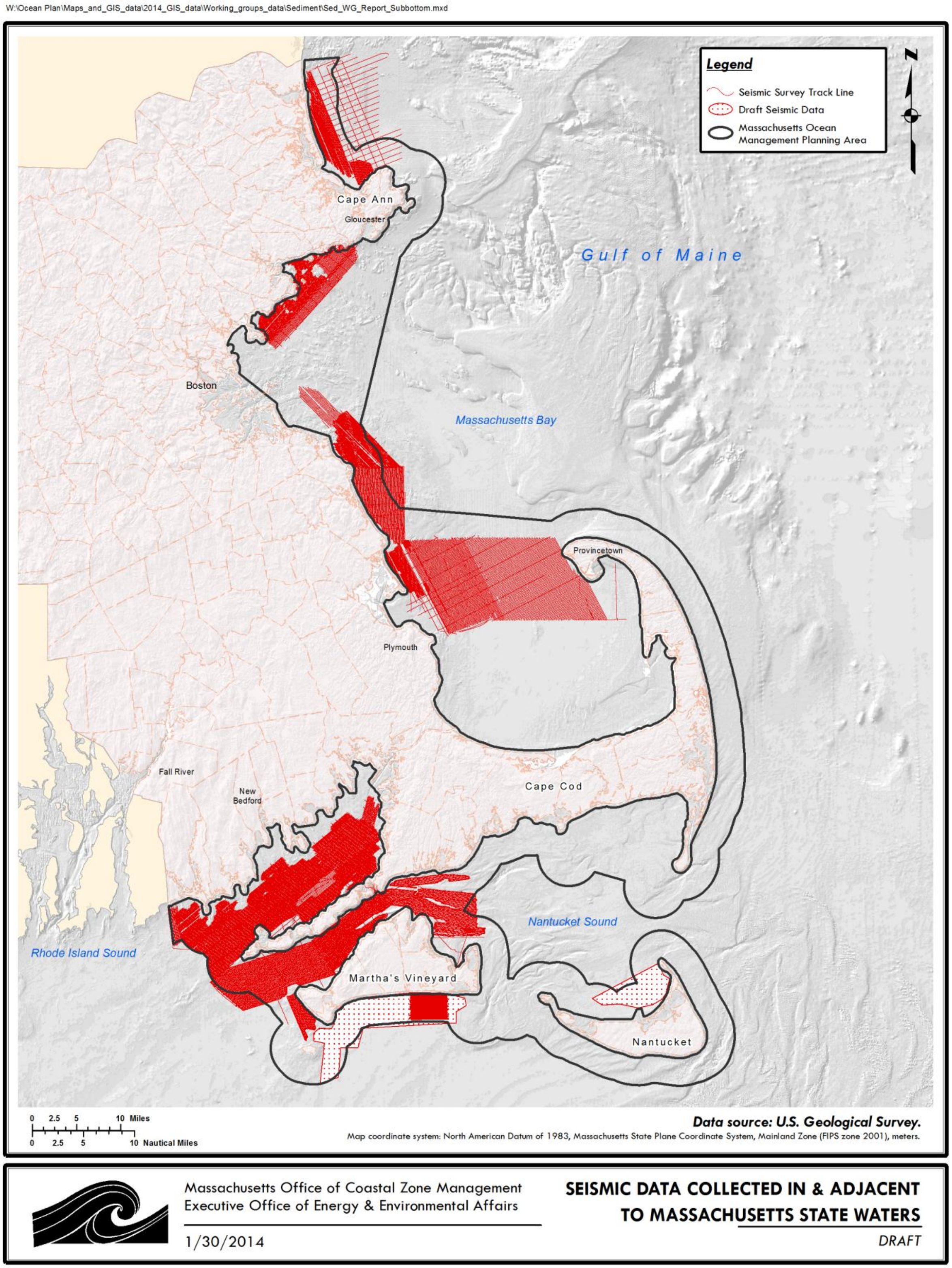
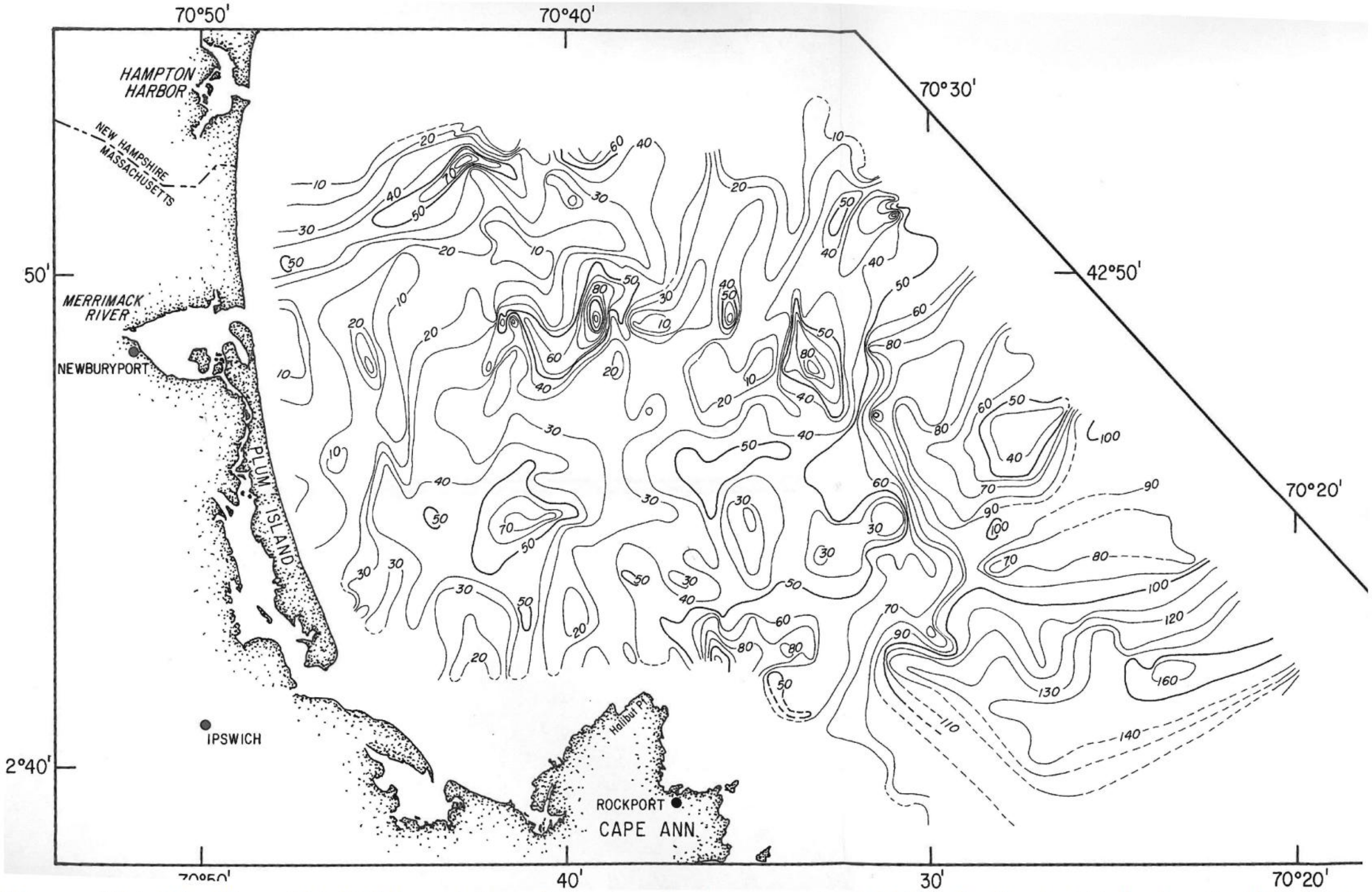


Figure 17. Areas of seismic (sub-bottom) profiling data collected in and adjacent to state waters.

W:\Ocean Plan\Maps_and_GIS_data\2014_GIS_data\Working_groups_data\Sediment\Sed_WG_Report_Sed_Thickness_N_of_Cape_Ann.mxd



Data source: Oldale, R.N, and Wommack, L.E., 1987, Maps and seismic profiles showing geology of the inner continental shelf, Cape Ann, Massachusetts to New Hampshire: U.S. Geological Survey Miscellaneous Field Studies Map MF–1892, 2 sheets.

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TOTAL SEDIMENT THICKNESS ABOVE BEDROCK IN WATERS NORTH OF CAPE ANN

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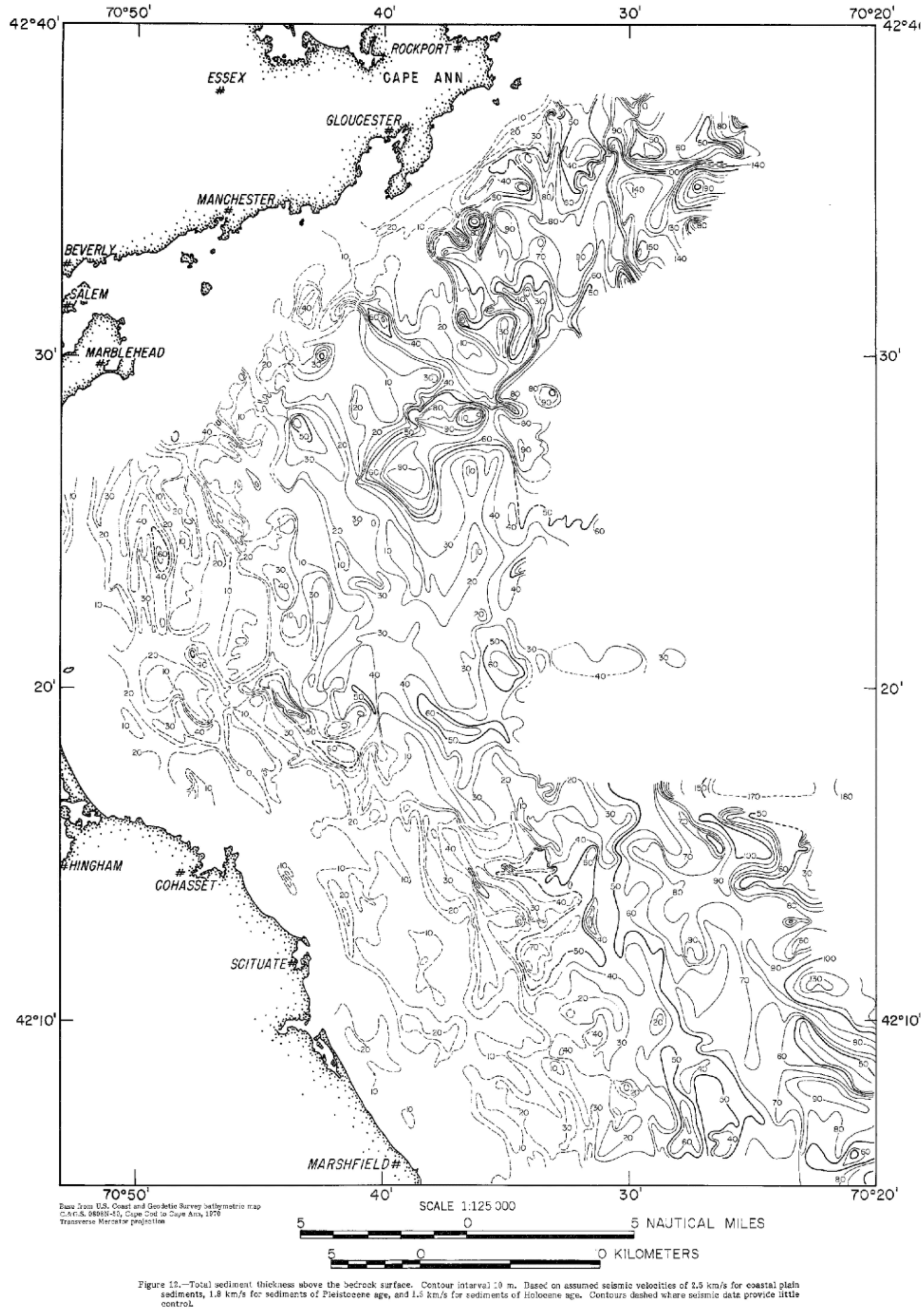
Figure 18. Total sediment thickness (in meters above bedrock) in waters north of Cape Ann.

W:\Ocean Plan\Maps_and_GIS_data\2014_GIS_data\Working_groups_data\Sediment\Sed_WG_Report_Sed_Thickness_in_Mass_Bay.mxd



Data source: Oldale, R.N, and Bick, Jennifer, 1987, Maps and seismic profiles showing geology of the inner continental shelf, Massachusetts Bay, Massachusetts: U.S. Geological Survey Miscellaneous Field Studies Map MF–1923, 4 sheets.

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TOTAL SEDIMENT THICKNESS ABOVE BEDROCK IN MASSACHUSETTS BAY

DRAFT

Figure 19. Total sediment thickness (in meters above bedrock) in Massachusetts Bay.

W:\Ocean Plan\Maps_and_GIS_data\2014_GIS_data\Working_groups_data\Sediment\Sed_WG_Report_Sed_Thickness_in_Bos_Harbor.mxd

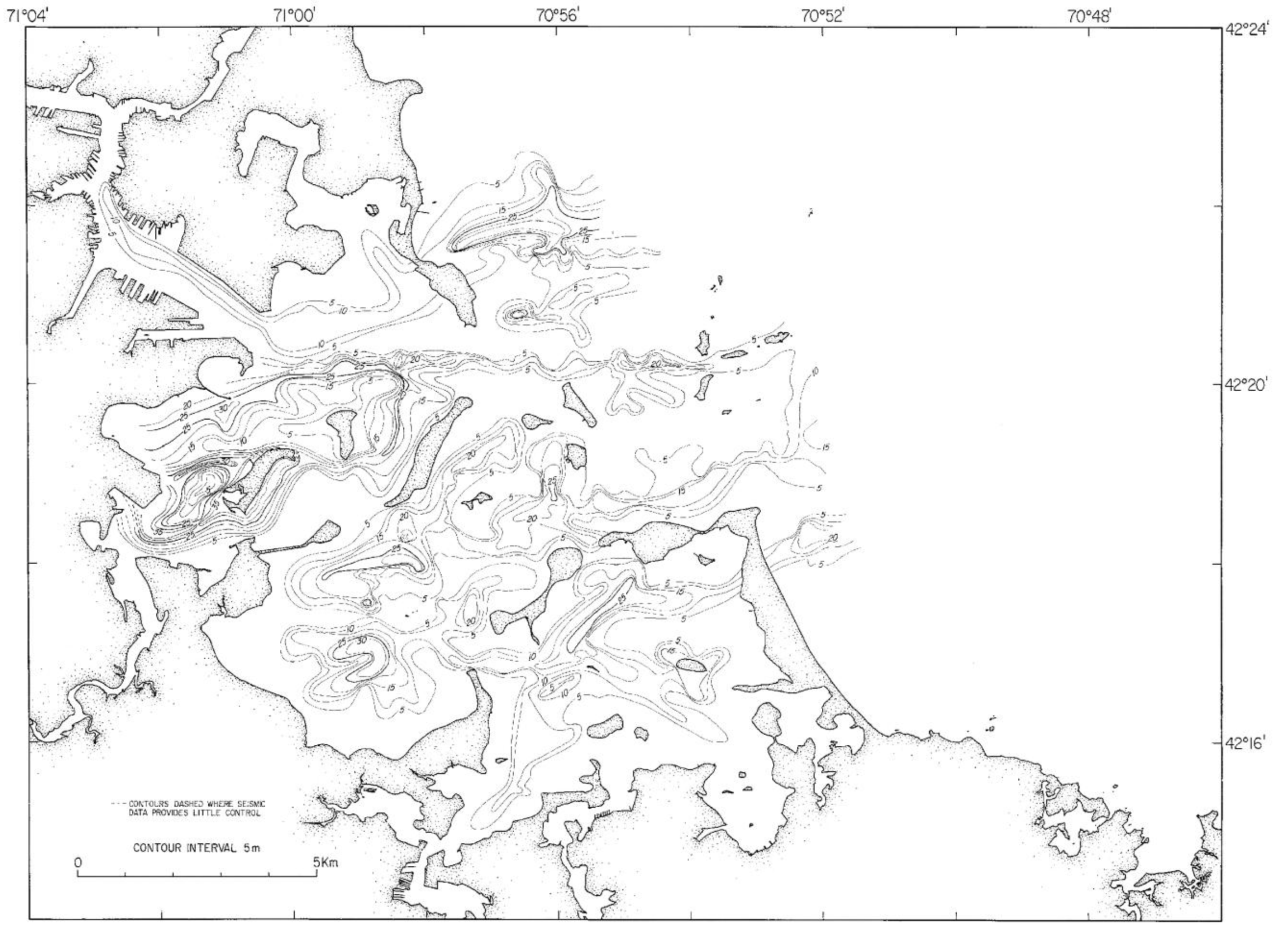

Figure 4.—Isopach map of the total thickness of Quaternary sediments overlying acoustic basement.

Data source: Rendigs, R.R., and Oldale, R.N., 1990. Maps showing the results of a subbottom acoustic survey of Boston Harbor, Massachusetts: U.S. Geological Survey Miscellaneous Field Studies Map MF–2124, 2 sheets.

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TOTAL SEDIMENT THICKNESS ABOVE BEDROCK IN BOSTON HARBOR

DRAFT

Figure 20. Total sediment thickness (in meters above bedrock) in Boston Harbor.

SECTION FOUR: Data Layer Descriptions and 2009/2014 Plan Comparisons

Table 3. Hard/complex seafloor: Comparison of 2009 Ocean Plan to Proposed 2014 Ocean Plan.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Source	***Hard seafloor:*** These data came from two data sources: 1) U.S. Geological Survey (USGS) interpreted physiographic zone and bottom type maps as published in Open-File Reports (OFR), and 2) a CZM/Massachusetts Division of Marine Fisheries (DMF) sediment database comprised of data from USGS usSEABED, CZM-USGS Seafloor Mapping Cooperative, DMF surveys, U.S. Environmental Protection Agency's National Coastal Assessment, and Massachusetts Water Resources Authority's monitoring program. ***Complex seafloor:*** These data were mapped using 30x30-meter resolution bathymetry data provided by USGS.	***Hard seafloor:*** These data were compiled from four sources: 1) new USGS interpreted seafloor sediment maps (Pendleton et al. 2013 and unpublished data in review), 2) Massachusetts Department of Environmental Protection (DEP) wetlands (1:12,000) rocky intertidal shore delineations, 3) older USGS interpreted sediment maps (Knebel and Circe 1995; Rendigs and Knebel 2002; Poppe et al. 2006; Poppe et al. 2007), and 4) an updated version of the CZM/DMF sediment database used in the 2009 Ocean Plan. ***Complex seafloor:*** The 2009 USGS bathymetry data have not been supplanted and were subsequently reused. ***Artificial reefs:*** Footprints of permitted and proposed artificial reefs were mapped by CZM using coordinates provided by DMF. ***Biogenic reefs:*** *Crepidula* reefs and worm reefs were mapped as biogenic reefs using information from analyzed seafloor photographs. Over 10,000 images of the seafloor have been obtained from the CZM-USGS Seafloor Mapping Cooperative and from surveys conducted by CZM and partners on the Ocean Survey Vessel *Bold*. CZM has classified the biological information in these photos according to a modified version of the Coastal and Marine Ecological Classification Standard, specifically the benthic biotic component (Federal Geographic Data Committee 2012). This dataset represents the locations of photos where the dominant biotic group was classified as a gastropod reef or a worm reef. ***Wrecks and obstructions:*** These data were mapped using the Board of Underwater Archaeological Resources' (BUAR) recreational shipwreck sites designated as "exempted sites" (member sites of the National Oceanic and Atmospheric Administration [NOAA]/U.S. Department of the Interior [DOI] National System of Marine Protected Areas) and NOAA's Automated Wreck and Obstruction Information System (AWOIS). AWOIS is a catalog of reported wrecks and obstructions that are considered navigational hazards in coastal U.S. waters. These data are not a comprehensive inventory of wrecks.

Table 3. Continued.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Description	Hard seafloor is seabed characterized by exposed bedrock or concentrations of boulder, cobble, or other similar hard bottom distinguished from surrounding unconsolidated sediments. Complex seafloor is a morphologically rugged seafloor characterized by high variability in bathymetric aspect and gradient. Hard/complex seafloor is the seabed characterized singly by hard seafloor or complex seafloor, or the overlap thereof.	Hard seafloor is seabed characterized by exposed bedrock or concentrations of boulder, cobble, or other similar hard bottom distinguished from surrounding unconsolidated sediments. Complex seafloor is a morphologically rugged seafloor characterized by high variability in bathymetric aspect and gradient. Biogenic reefs and man-made structures, such as artificial reefs, wrecks, or other functionally equivalent structures, may provide additional suitable substrate for the development of hard bottom biological communities. Hard/complex seafloor is seabed characterized singly or by any combination of hard seafloor, complex seafloor, artificial reefs, biogenic reefs, or wrecks and obstructions.
Data Extent	The Massachusetts ocean management planning area.	The Massachusetts ocean management planning area.
Data Adjustment and Pre-processing	***Hard seafloor:*** Hard seafloor data derived from the USGS usSEABED sediment point database were analyzed for consistency and replicate samples were removed whenever they could be clearly identified. ***Complex seafloor:*** None.	***Hard seafloor:*** None. ***Complex seafloor:*** None. ***Artificial reefs:*** None. ***Biogenic reefs:*** None. ***Wrecks and obstructions:*** Duplicate wrecks identified in both the BUAR and AWOIS datasets were removed from AWOIS.

Table 3. Continued.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Analysis	***Hard seafloor:*** Rocky zones were extracted from USGS interpreted maps published in the Cape Ann to Salisbury Beach OFR (Barnhardt et al. 2009), Nahant to Gloucester OFR (Barnhardt et al. 2006), and Boston Harbor and Approaches OFR (Ackerman et al. 2006). Hard bottom sediment data points were culled from the CZM/DMF database and buffered with a 125-meter radius. The rocky zones and buffered hard bottom points were merged and gridded to a 250x250-meter grid (i.e., where hard bottom intersected a grid cell, the grid cell was denoted as hard seafloor). ***Complex seafloor:*** Complex seafloor was calculated on bathymetry data using an algorithm developed by Sappington et al. (2007) that directly measures seafloor complexity. The unitless value can range from 0 (no seabed complexity) to 1 (complete seabed complexity). Complexity values were overlaid on a 250x250-meter grid.	***Hard seafloor:*** Hard seafloor was mapped by extracting areas characterized as rock, rock with gravel, rock with sand, or rock with mud from the *Surficial sediment in Massachusetts state waters* dataset (see Table 4 below). Surficial sediment was mapped by collating data sources such that high-quality data mask lower quality data in the following order, highest first: 1) new USGS interpreted seabed sediment (Pendleton et al. 2013 and unpublished data in review), 2) DEP wetlands, 3) older USGS sediment interpretations (Poppe et al. 2007; Poppe et al. 2006; Knebel and Circe 1995; Rendigs and Knebel 2002), and 4) interpolated Thiessen polygons derived from the CZM/DMF sediment database. (Thiessen polygons proportionally divide and distribute a point coverage into regions known as Thiessen or Voronoi polygons. Each Thiessen polygon defines an area of influence around its sample point, so that any location inside the polygon is closer to that point than any of the other sample points.) ***Complex seafloor:*** Complex seafloor was calculated as previously. ***Artificial reefs:*** None. ***Biogenic reefs:*** The locations of *Crepidula* reefs and worm reefs were buffered with a 100-meter radius to convert the point data to polygons. This radius was based on best professional judgment. ***Wrecks and obstructions:*** Wrecks and obstructions were buffered with a 100-meter radius to convert the point data to polygons. This radius was based on best professional judgment.

Table 3. Continued.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Classification	***Hard seafloor:*** Hard bottom data were classified using the Wentworth (1922) grain-size scale that defines hard bottom ("bedrock or concentrations of boulder, cobble, or other similar hard bottom") as sediment with a grain size of 64 mm or larger. ***Complex seafloor:*** Complex seafloor was classified from descriptive statistics calculated on the dataset as a whole. Seafloor complexity values greater than 3/8 standard deviation from the mean were classified as complex. This class break was based on a comparison between areas of known hard bottom (USGS delineated) and the complex dataset; complexity values coincident with hard bottom were noted at greater than or equal to 3/8 standard deviation.	***Hard seafloor:*** The 2013-present USGS interpreted surficial sediment data and the CZM/DMF sediment database were classified using the Barnhardt et al. (1998) scheme while all other data were crosswalked from their native sediment classification framework to Barnhardt. Barnhardt is based on four primary sediment units: rock (R), gravel (G), sand (S), and mud (M). Twelve additional two-part units represent combinations of the four primary units, where the majority texture is given an upper case letter and the next most common texture is given a lower case letter. Sediment grain sizes follow the Wentworth (1922) scale. Rock is characterized as cobble and larger (>64 mm), so R, Rg, Rs, and Rm are all classified as hard bottom. ***Complex seafloor:*** Complex seafloor was classified as previously. ***Artificial reefs:*** Not applicable. ***Biogenic reefs:*** Not applicable. ***Wrecks and obstructions:*** Not applicable.
Selection of SSU Area	All 250x250-meter grid cells classified as 1) hard seafloor, or 2) complex seafloor were selected for inclusion in the SSU.	All polygons classified as 1) hard seafloor, 2) complex seafloor, 3) artificial reefs, 4), biogenic reefs or 5) wrecks and obstructions were selected for inclusion in the SSU.

Table 4. Locations of surficial sediment samples in the CZM/DMF sediment database: Comparison of 2009 Ocean Plan to Proposed 2014 Ocean Plan.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Source	The CZM/Massachusetts Division of Marine Fisheries (DMF) sediment database used in the 2009 Plan was comprised of data from the following sources: 1) U.S. Geological Survey (USGS) usSEABED, 2) CZM-USGS Seafloor Mapping Cooperative, 3) DMF surveys, 4) U.S. Environmental Protection Agency's National Coastal Assessment, and 5) Massachusetts Water Resources Authority's (MWRA) monitoring program.	An updated version of the CZM/DMF sediment database was used in the 2014 Plan Update. Additional data were added to the 2009 sediment database from the following sources: 1) CZM/DMF/USGS Ocean Survey Vessel (OSV) *Bold* surveys, 2) USGS sediment lab, 3) National Oceanic and Atmospheric Administration (NOAA) National Ocean Survey nautical charts, 4) Massachusetts Department of Environmental Protection (DEP) wetlands data, 5) seafloor photos from the CZM-USGS Seafloor Mapping Cooperative and OSV *Bold* surveys, 6) CZM's Dredged Material Management Plan survey in Buzzards Bay, 7) DMF's 2006 Northeast Consortium study in Massachusetts Bay, 8) U.S. Army Corps of Engineers sediment data, and 9) new MWRA monitoring program data.
Data Description	The CZM/DMF sediment database contained the sediment composition of nearly 20,000 surficial sediment samples within a 10-kilometer buffer of Massachusetts state waters.	The updated CZM/DMF sediment database contains the sediment composition of over 50,000 surficial sediment samples within a 10-kilometer buffer of Massachusetts state waters.
Data Extent	The data extent encompassed Massachusetts state waters and extended 10 kilometers seaward of state waters.	The data extent encompasses Massachusetts state waters and extends 10 kilometers seaward of state waters and includes Stellwagen Bank.
Data Adjustment and Pre-processing	Sediment data derived from the USGS usSEABED database were analyzed for consistency and replicate samples were removed whenever they could be clearly identified.	Replicate samples were removed whenever they could be clearly identified.
Data Analysis	Not applicable.	Not applicable.

Table 4. Continued.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Classification	Sediment samples were described using the Wentworth (1922) grain-size scale and the Folk (1954, 1974) sediment classification scheme. The Wentworth scale was used to define the grain-size ranges for mud (<0.62 mm), sand (0.62–2 mm), gravel (2–64 mm), and hard bottom (>64 mm). The samples were then classified using the Folk scheme. The Folk sediment classes were combined to create maps of the following four generic sediment classes: 1) generally mud (Folk classes mud [M], sandy mud [sM], slightly gravelly mud [(g)M], slightly gravelly sandy mud [(g)sM], and gravelly mud [gM]), 2) generally sand (Folk classes muddy sand [mS], sand [S], slightly gravelly muddy sand [(g)mS], and slightly gravelly sand [(g)S]), 3) generally gravel (Folk classes gravelly muddy sand [gmS], gravelly sand [gS], muddy gravel [mG], muddy sandy gravel [msG], sandy gravel [sG], and gravel [G]), and 4) generally hard bottom.	Sediment samples were mapped using the Wentworth (1922) grain-size scale and the Barnhardt et al. (1998) sediment classification scheme. Barnhardt is based on four primary sediment units: rock (R), gravel (G), sand (S), and mud (M). Twelve additional two-part units represent combinations of the four primary units, where the majority texture is given an upper case letter and the next most common texture is given a lower case letter. Sediment grain sizes follow the Wentworth (1922) scale where mud is <0.62 mm, sand is 0.62–2 mm, gravel is 2–64 mm, and rock is >64 mm (cobble and larger).
Selection of SSU Area	Not applicable. These data are not mapped as SSU areas.	Not applicable. These data are not mapped as SSU areas.

Table 5. Surficial sediment mapping: Comparison of 2009 Ocean Plan to Proposed 2014 Ocean Plan.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Source	Surficial sediment data came from two data sources: 1) U.S. Geological Survey (USGS) interpreted physiographic zone maps as published in Open-File Reports, and 2) a CZM/Massachusetts Division of Marine Fisheries (DMF) sediment database comprised of data from USGS usSEABED, CZM-USGS Seafloor Mapping Cooperative, DMF surveys, U.S. Environmental Protection Agency's (EPA) National Coastal Assessment, and Massachusetts Water Resources Authority's (MWRA) monitoring program.	***Surficial sediment in Massachusetts state waters:*** These data came from four data sources: 1) new USGS interpreted seafloor sediment maps (Pendleton et al. 2013 and unpublished data in review), 2) Massachusetts Department of Environmental Protection (DEP) wetlands (1:12,000) sandy beach and rocky shore delineations, 3) older USGS interpreted sediment maps (Knebel and Circe 1995; Rendigs and Knebel 2002; Poppe et al. 2006; Poppe et al. 2007), and 4) an updated version of the CZM/DMF sediment database used in the 2009 Ocean Plan. ***Surficial sediment in federal waters derived from CZM/DMF sediment database:*** These data utilize the same four data sources as *Surficial sediment in Massachusetts state waters* (see above). ***Surficial sediment in federal waters derived from CONMAP:*** These data utilize the same four data sources as *Surficial sediment in Massachusetts state waters* (see above) with the addition of the USGS Continental Margin Mapping (CONMAP) sediments grain-size distribution for the U.S. East Coast Continental Margin (Poppe et al. 2005).
Data Description	The Massachusetts surficial sediment map characterized the seabed sediment as muddy, sandy, gravelly, or rocky.	***Surficial sediment in Massachusetts state waters:*** These data characterize the seabed with sixteen sediment types based on four primary sediment units: rock, gravel, sand, and mud. Twelve additional two-part units represent combinations of the four primary units. ***Surficial sediment in federal waters derived from CZM/DMF sediment database:*** These data extend mapping into federal waters using the CZM/DMF sediment database. As with *Surficial sediment in Massachusetts state waters,* the seabed is characterized with sixteen sediment types based on four primary sediment units: rock, gravel, sand, and mud. Twelve additional two-part units represent combinations of the four primary units. ***Surficial sediment in federal waters derived from CONMAP:*** These data extend surficial sediment mapping into federal waters using USGS CONMAP data (Poppe et al. 2005). As with *Surficial sediment in Massachusetts state waters,* the seabed is characterized with sixteen sediment types based on four primary sediment units: rock, gravel, sand, and mud. Twelve additional two-part units represent combinations of the four primary units.

Table 5. Continued.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Extent	The Massachusetts ocean management planning area.	***Surficial sediment in Massachusetts state waters*** includes state waters. ***Surficial sediment in federal waters derived from CZM/DMF sediment database*** encompasses state waters and extends seven nautical miles seaward of the ocean management planning area. ***Surficial sediment in federal waters derived from CONMAP data*** encompasses state waters and extends from the ocean management planning area to approximately 25 nautical miles offshore. (CONMAP data extend past this line seaward to the continental shelf).
Data Adjustment and Pre-processing	Sediment data derived from the USGS usSEABED sediment point database were analyzed for consistency and replicate samples were removed whenever they could be clearly identified.	None.
Data Analysis	Sediment data from the USGS publication, *usSEABED: Atlantic Coast Offshore Surficial Sediment Data Release* (Reid et al. 2005) were augmented by seafloor sediment data from DMF lobster surveys, DMF trawl surveys, EPA grab samples, MWRA grab samples and sediment-profile imaging (SPI) data, and USGS Open-File Reports (OFR). The data points were converted to Thiessen polygons to create a surficial sediment map.	***Surficial sediment in Massachusetts state waters*** and ***Surficial sediment in federal waters derived from CZM/DMF sediment database:*** These maps were created by collating data sources such that high-quality data mask lower quality data in the following order, highest first: 1) 2013-present USGS interpreted surficial sediment data (Pendleton et al. 2013 and unpublished data in review), 2) DEP wetlands, 3) older USGS sediment interpretations (Poppe et al. 2007; Poppe et al. 2006; Knebel and Circe 1995; Rendigs and Knebel 2002), and 4) interpolated Thiessen polygons derived from the CZM/DMF sediment database. ***Surficial sediment in federal waters derived from CONMAP data:*** This map was created in the same manner as above, however, all areas outside of Massachusetts state waters were mapped using USGS CONMAP data (Poppe et al. 2005).

Table 5. Continued.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Classification	Sediment was mapped using the Wentworth (1922) grain-size scale and the Folk (1954, 1974) sediment classification scheme. The resulting maps consisted of four generic sediment classes: generally mud (<0.62 mm), generally sand (0.62–2 mm), generally gravel (2–64 mm), and generally hard bottom (>64 mm).	The 2013-present USGS interpreted surficial sediment data and the CZM/DMF sediment database were classified using the Barnhardt et al. (1998) scheme while all other data were crosswalked from their native classification framework to Barnhardt. Barnhardt is based on four primary sediment units: rock (R), gravel (G), sand (S), and mud (M). Twelve additional two-part units represent combinations of the four primary units, where the majority texture is given an upper case letter and the next most common texture is given a lower case letter. Sediment grain sizes follow the Wentworth (1922) scale where mud is <0.62 mm, sand is 0.62–2 mm, gravel is 2–64 mm, and rock is >64 mm (cobble and larger). CZM used the following crosswalks for converting the DEP wetlands and older interpretive data from their native classification schemes to Barnhardt: • DEP wetlands: Rocky intertidal shores were extracted and classified as rock (R). Barrier beaches, barrier beaches-coastal beaches, barrier beaches-coastal dunes, barrier beach systems, coastal beaches, and coastal dunes were extracted and classified as sand (S). • Interpretive map of the surficial geology of Great Round Shoal Channel (Poppe et al. 2007): Barchanoid and transverse sand waves were extracted and classified as sand (S). • Interpretive map of the surficial sediment distributions off Eastern Cape Cod (Poppe et al. 2006) (Shepard [1954] name followed by Barnhardt name and code): gravelly sediment = sand with gravel (Sg), sand = sand (S), silty sand = sand with mud (Sm), clayey silt = mud (M), silty clay = mud (M). Areas classified as gravel under the Shepard scheme could be either gravel or rock under Barnhardt, so gravel areas were removed from the dataset. • Interpretive map of sedimentary environments in Boston Harbor-Massachusetts Bay (Knebel and Circe 1995) crosswalked by USGS at CZM's request: Each polygon was assigned a sediment type by interpreting the intersecting CZM/DMF sediment database points. For those polygons with no intersecting points, the following crosswalk was used (sedimentary environment/backscatter patterns followed by Barnhardt name and code): erosion or nondeposition/isolated reflection = rock (R), erosion or nondeposition/strong backscatter = gravel with sand (Gs), sediment reworking/strong to weak backscatter patches = sand (S), and deposition/weak backscatter = mud (M). • Interpretive map of surficial sediment in Cape Cod Bay (Rendigs and Knebel 2002) crosswalked by USGS using the CZM/DMF sediment database to assign sediment classes: sandy to clayey silt = mud (M), fine to very fine sand = mud with sand (Ms), very coarse to very fine sand = sand (S), sand with mud (Sm), or mud with sand (Ms). • CONMAP data (Poppe et al. 2005) crosswalked by USGS at CZM's request (Shepard [1954] name and code followed by Barnhardt name and code): bedrock (br) = rock (R), gravel (gr) = gravel (G), gravelly sand (gr-sd) = sand with gravel (Sg), sand (sd) = sand (S), clayey sand or silty sand (cl-st/sd) = sand with mud (Sm), sandy silt or clayey silt (sd-cl/st) = mud with sand (Ms), clay (cl) = mud (M), sandy clay or silty clay (sd-st/cl) = mud with sand (Ms), and sand, silt, clay (sd/st/cl) = mud with sand (Ms).

Table 5. Continued.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Selection of SSU Area	Not applicable. These data are not mapped as SSU areas.	Not applicable. These data are not mapped as SSU areas.

Table 6. High-resolution seafloor mapping data: Comparison of 2009 Ocean Plan to Proposed 2014 Ocean Plan.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Source	Not applicable.	High-resolution seafloor mapping data are from the following two sources: 1) CZM and U.S. Geological Survey (USGS) Seafloor Mapping Cooperative 2) USGS
Data Description	Not applicable.	In 2003, CZM and the USGS Woods Hole Science Center initiated a Seafloor Mapping Cooperative to jointly address the need for data and information characterizing seafloor resources. The goal of the cooperative is to comprehensively map the bathymetry and geology of the seafloor inside the three-nautical-mile limit of Massachusetts waters and in adjacent federal waters. As of 2012, the cooperative has mapped 2,200 square kilometers of Massachusetts marine waters and has published or is preparing to release these data as USGS Open-File Reports. Completed areas and dates of publication of USGS Open-File Reports are the following: 1) Nahant to Gloucester (2006), 2) Boston Harbor and Approaches (2006), 3) Cape Ann to Salisbury Beach (2009), 4) Duxbury to Hull (2010), 5) Northern Cape Cod Bay (2010), 6) Buzzards Bay (2013), and 7) Vineyard Sound (2013). Reports are in progress for the areas south of Martha's Vineyard and north of Nantucket. Additional mapping completed by USGS only in Massachusetts state waters include the following areas and dates of publication of USGS Open-File Reports: 1) Eastern Cape Cod (2006), 2) Quicks Hole (2007), 3) Great Round Shoal (2007), 4) Massachusetts Bay and Stellwagen Bank National Marine Sanctuary (2007), 5) Woods Hole (2008), 6) Edgartown (2009), 7) South Shore of Martha's Vineyard (2009), and 8) Eastern Rhode Island Sound (2011).
Data Extent	Not applicable.	In and adjacent to Massachusetts state waters.
Data Adjustment and Pre-processing	Not applicable.	None.
Data Analysis	Not applicable.	The coverage footprints of these surveys were merged by CZM to create a map depicting high-resolution acoustic mapping in and adjacent to Massachusetts state waters.
Data Classification	Not applicable.	Not applicable.
Selection of SSU Area	Not applicable.	Not applicable. These data are not mapped as SSU areas.

Table 7. Mussel reefs: Comparison of 2009 Ocean Plan to Proposed 2014 Ocean Plan.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Source	Not applicable.	The mussel reefs were mapped using information from analyzed seafloor photographs. Over 10,000 images of the seafloor have been obtained from the CZM and U.S. Geological Survey Seafloor Mapping Cooperative and from surveys conducted by CZM and partners on the Ocean Survey Vessel *Bold*. CZM has classified the biological information in these photos according to a modified version of the Coastal and Marine Ecological Classification Standard, specifically the benthic biotic component (Federal Geographic Data Committee 2012).
Data Description	Not applicable.	This dataset represents the locations of photos where the dominant biotic group was classified as a mussel reef.
Data Extent	Not applicable.	In and adjacent to Massachusetts state waters.
Data Adjustment and Pre-processing	Not applicable.	None.
Data Analysis	Not applicable.	None.
Data Classification	Not applicable.	Not applicable.
Selection of SSU Area	Not applicable.	Not applicable. These data are not mapped as SSU areas.

Table 8. Sites investigated for potential sand and gravel extraction: Comparison of 2009 Ocean Plan to Proposed 2014 Ocean Plan.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Source	Not applicable.	Sites investigated for potential sand and gravel extraction were compiled from reports by the U.S. Army Corps of Engineers, Boston University, Massachusetts Division of Mineral Resources, and others.
Data Description	Not applicable.	This dataset shows the locations of sites with potentially high-quality sand and gravel resources that were identified through general exploration as well as targeted projects. CZM mapped these sites using originator-supplied GIS data or digitizing older georeferenced paper maps.
Data Extent	Not applicable.	In and adjacent to Massachusetts state waters.
Data Adjustment and Pre-processing	Not applicable.	None.
Data Analysis	Not applicable.	None.
Data Classification	Not applicable.	Not applicable.
Selection of SSU Area	Not applicable.	Not applicable. These data are not mapped as SSU areas.

Table 9. Nearshore disposal sites utilized by the U.S. Army Corps of Engineers: Comparison of 2009 Ocean Plan to Proposed 2014 Ocean Plan.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Source	Not applicable.	The U.S. Army Corps of Engineers (USACE) provided a dataset of all of the nearshore disposal sites in Massachusetts state waters in their database.
Data Description	Not applicable.	This dataset shows the locations of nearshore disposal sites in Massachusetts state waters used by USACE.
Data Extent	Not applicable.	Massachusetts state waters.
Data Adjustment and Pre-processing	Not applicable.	None.
Data Analysis	Not applicable.	None.
Data Classification	Not applicable.	Not applicable.
Selection of SSU Area	Not applicable.	Not applicable. These data are not mapped as SSU areas.

Table 10. Sediment core locations: Comparison of 2009 Ocean Plan to Proposed 2014 Ocean Plan.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Source	Not applicable.	Sediment core locations were mapped by compiling data from the Massachusetts Division of Mineral Resources (now defunct), U.S. Geological Survey (published and unpublished), and various private sector consultants.
Data Description	Not applicable.	CZM mapped these data using published and unpublished data created by the originator. Older paper maps were georeferenced by CZM and pertinent data were digitized and attributed.
Data Extent	Not applicable.	In and adjacent to Massachusetts state waters.
Data Adjustment and Pre-processing	Not applicable.	None.
Data Analysis	Not applicable.	None.
Data Classification	Not applicable.	Not applicable.
Selection of SSU Area	Not applicable.	Not applicable. These data are not mapped as SSU areas.

Table 11. Areas of seismic (sub-bottom) profiling data: Comparison of 2009 Ocean Plan to Proposed 2014 Ocean Plan.

	2009 Ocean Plan	CZM Proposal for 2014 Ocean Plan
Data Source	Not applicable.	Seismic (sub-bottom) profiling data are from the following two sources: 1) CZM and U.S. Geological Survey (USGS) Seafloor Mapping Cooperative 2) USGS
Data Description	Not applicable.	In 2003, CZM and the USGS Woods Hole Science Center initiated a Seafloor Mapping Cooperative to jointly address the need for data and information characterizing seafloor resources. The goal of the cooperative is to comprehensively map the bathymetry and geology of the seafloor inside the three-nautical-mile limit of Massachusetts waters and in adjacent federal waters. As of 2012, the cooperative has mapped 2,200 square kilometers of Massachusetts marine waters and has published or is preparing to release these data as USGS Open-File Reports. Seismic-reflection profiles (pictures of sub-surface sediment layers) have been collected and published as USGS Open-File Reports in the following areas: 1) Nahant to Gloucester (2006), 2) Cape Ann to Salisbury Beach (2009), 3) Duxbury to Hull (2010), 4) Northern Cape Cod Bay (2010), 5) Buzzards Bay (2013), and 6) Vineyard Sound (2013). Reports are in progress for the areas south of Martha's Vineyard and north of Nantucket. Additional seismic-reflection profiles collected by USGS only in Massachusetts state waters include the following areas and dates of publication of USGS Open-File Reports: 1) Woods Hole (2008), 2) Edgartown (2009), and 3) South Shore of Martha's Vineyard (2009).
Data Extent	Not applicable.	In and adjacent to Massachusetts state waters.
Data Adjustment and Pre-processing	Not applicable.	None.
Data Analysis	Not applicable.	None.
Data Classification	Not applicable.	Not applicable.
Selection of SSU Area	Not applicable.	Not applicable. These data are not mapped as SSU areas.

Table 12. Total sediment thickness: Comparison of 2009 Ocean Plan to Proposed 2014 Ocean Plan.

	2009 Ocean Plan	**CZM Proposal for 2014 Ocean Plan**
Data Source	Not applicable.	The total sediment thickness maps were scanned and georeferenced by the U.S. Geological Survey (USGS). The sediment thickness in Boston Harbor was originally published in 1990 by USGS (Rendigs and Oldale). The sediment thickness on the inner continental shelf of Massachusetts Bay was originally published in 1987 by USGS (Oldale and Bick). The sediment thickness in waters north of Cape Ann was originally published in 1987 by USGS (Oldale and Wommack).
Data Description	Not applicable.	These figures were published by USGS and show total sediment thickness in meters above bedrock.
Data Extent	Not applicable.	Boston Harbor, Massachusetts Bay, and in waters north of Cape Ann.
Data Adjustment and Pre-processing	Not applicable.	None.
Data Analysis	Not applicable.	None.
Data Classification	Not applicable.	Not applicable.
Selection of SSU Area	Not applicable.	Not applicable. These data are not mapped as SSU areas.

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