

**Cooperative Agreement between the University of New Hampshire and the Minerals
Management Service**

**Assessment of Sand Resources and the Geologic Environment of the Continental
Shelf Offshore of New Hampshire**

Progress Report for Project Period from April 2004 to August 2006

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Summary

Despite the relatively large number of geologic studies conducted over the last several decades on the New Hampshire continental shelf, no systematic synthesis of the work has been done. Furthermore, most of the results of the research have not been brought into geospatial or geographic information systems. Consequently, the results of these earlier studies and the databases generated are not easily (if at all) available to the scientific community, federal and state regulators, and policy makers. One of the major goals of the cooperative agreement between the University of New Hampshire, the State of New Hampshire, and the Minerals Management Service is to locate, integrate and synthesize the results of the previous geologic studies conducted on the New Hampshire continental shelf. It is also our goal to make the results of this synthesis and the associated databases readily available to the scientific community, as well as the appropriate federal and state agencies.

Based on the review of the existing literature and databases for the New Hampshire continental shelf, this project is focusing on five major objectives:

- summarizing the general sedimentologic and stratigraphic characteristics of the New Hampshire continental shelf;
- conducting detailed analyses and syntheses of three previously identified sand and gravel deposits (Northern Sand Body, Southern Sand Body, and nearshore shoals);
- conducting a preliminary review of the seismic records and vibracores of offshore, eroded drumlins;
- conducting detailed analyses and synthesis of seismic and bottom sediment data from two sites (Portsmouth Harbor and south of the Isles of Shoals) that provide important information on shelf depositional environments and river-shelf interactions;
- and developing GIS based projects to depict the results of the study.

To meet these goals, our efforts during the first two years of the cooperative agreement with MMS have been directed at locating, recovering, re-analyzing where necessary, verifying where necessary, and synthesizing several key studies and databases. Presented here is a progress report on the objectives and tasks that have conducted to date for this project. Also included is a review of the deliverables expected at the end of the present funding cycle. However, since the cooperative agreement was set up as a five year agreement, adjustments in the deliverables have been made.

Introduction

Previous work on the New Hampshire continental shelf and adjacent areas (Figure 1) concerned with the sedimentology and shallow stratigraphy include a number of student theses done at the University of New Hampshire and research projects funded by federal and state agencies including the United States Geological Survey, National Science Foundation (NSF), and the Minerals Management Service (MMS). These studies provide

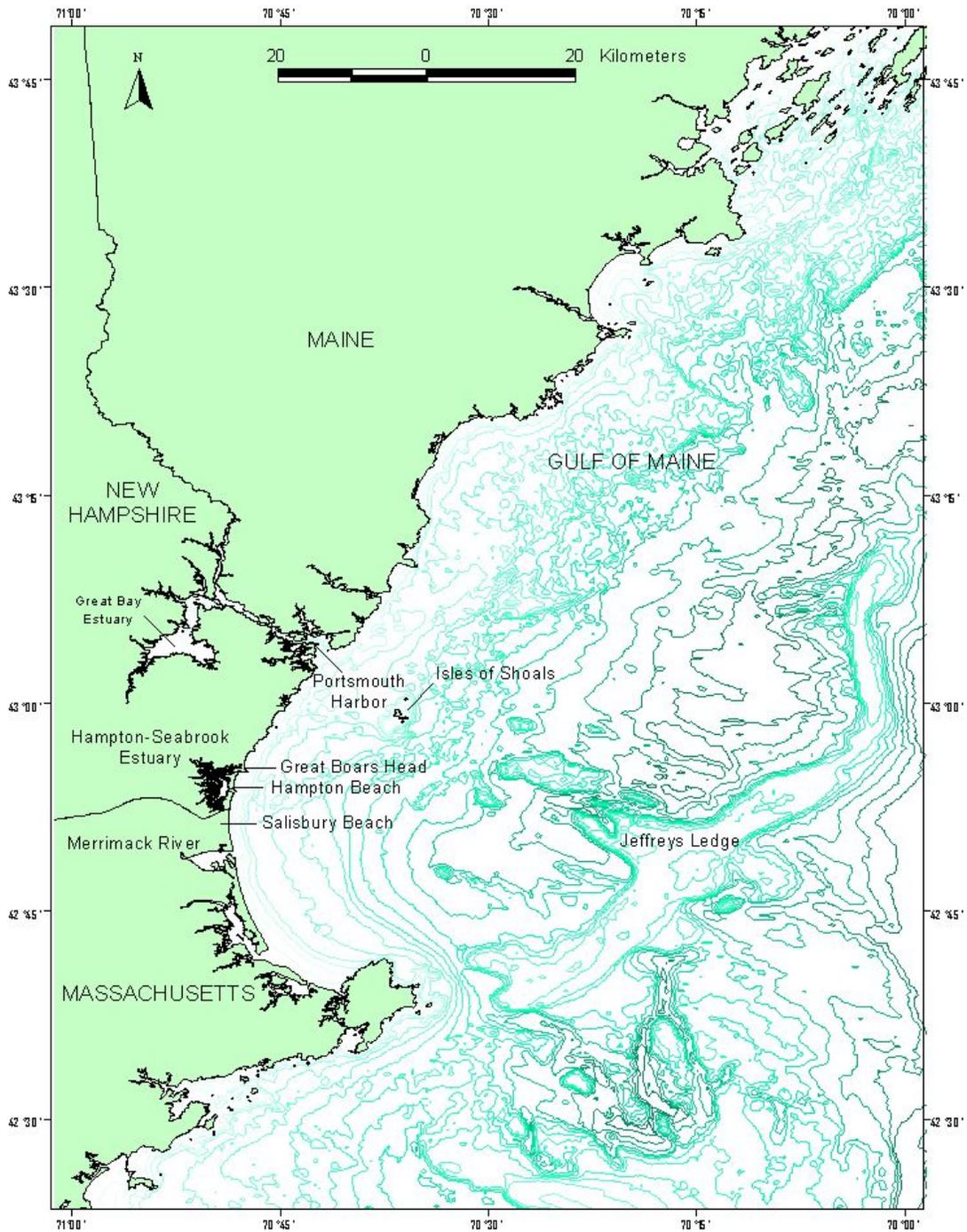


Figure 1. Location map of project area.

a general understanding of the geological environment of the region and identify several potentially important sand and gravel bodies. The results of these efforts have been reported in theses, numerous final reports, several journal publications, and a bottom sediment map. (Flight 1972; Mills 1977; Birch 1984a, 1984b, 1986a, 1986b; Anderson 1987; Birch 1988, 1989; Ward 1989, 1990; Ward and Anderson 1990; Ward and Birch 1993; Ward 1994; Ward and Birch 1996; Ward 2000).

Despite these efforts, the overall sedimentological and stratigraphic characteristics (and controlling processes) of the continental shelf offshore of New Hampshire have not been analyzed and synthesized in a comprehensive manner. Furthermore, the available information has not been assembled into a GIS format so that it can be easily retrieved and analyzed. The most detailed effort to date has been the aforementioned development of a surficial geology map by one of the principal investigators of this project (LGW) in conjunction with the University of Maine and the Maine Geological Survey. Although this map was based on the previous work, the actual database is rather sparse. Also, it does not include information on sand bodies (locations, thickness, and characteristics). Furthermore, exact locations and boundaries are vague.

Therefore, the results of the earlier work are not easily interpreted and integrated into the general understanding of the geologic evolution and resources of the New Hampshire continental shelf environment. Furthermore, there is a danger that much of the earlier mappings of sand bodies and other resources might be lost (due to the lack of most of the databases not being brought into modern geospatial information systems and similar software).

Methodology and Databases

Approach

In order to synthesize a relatively large number of studies undertaken over several decades by different investigators and enter the results into spatial data systems (i.e., GIS), the original databases had to be obtained and reviewed. The largest databases obtained for this study were the seismic records (Figure 2) and the bottom sediment grain size information (Figure 3). In total, ~1750 km of seismic records, ~850 bottom sediment samples, and 23 vibracores were recovered.

Unfortunately, the seismic records are of varying quality and are not digital (only analog records are available). Consequently, reviewing and analyzing the entire set of seismic records is not practical or warranted. However, earlier studies by Birch (1986b) and Ward and Birch (1999) describe several areas that are important as potential sand and gravel resources. In addition, several areas that have excellent seismic coverage and are important to the general understanding of the formation of sand and gravel deposits or the general characteristics of the New Hampshire shelf are identified. Therefore, our efforts to date have focused on six areas including three sites where major sand and gravel deposits occur (Northern Sand Body, Southern Sand Body and off Hampton-Seabrook Beach) and three sites that will provide important information about the sedimentology

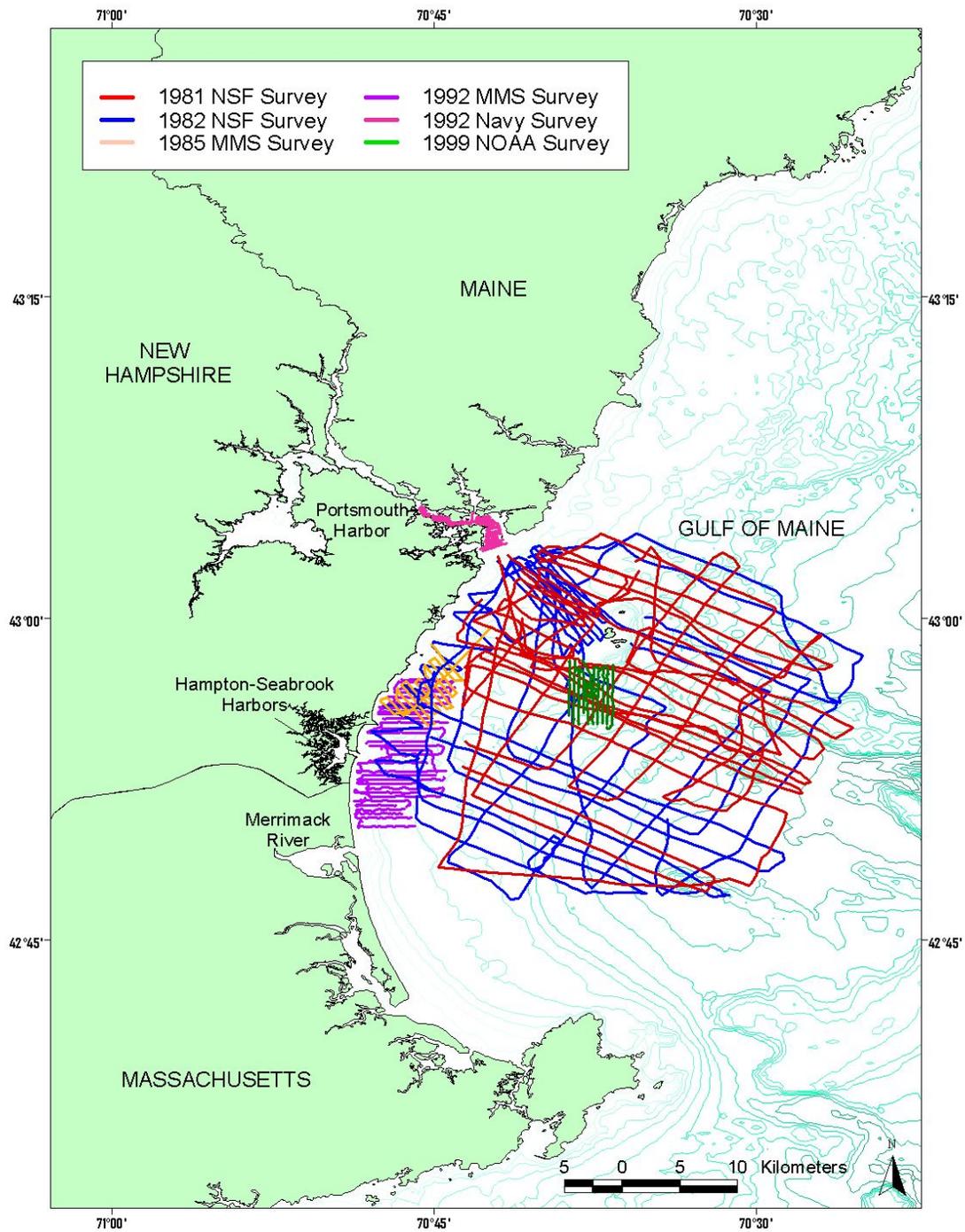


Figure 2. Seismic tracks from previous studies conducted by the University of New Hampshire.

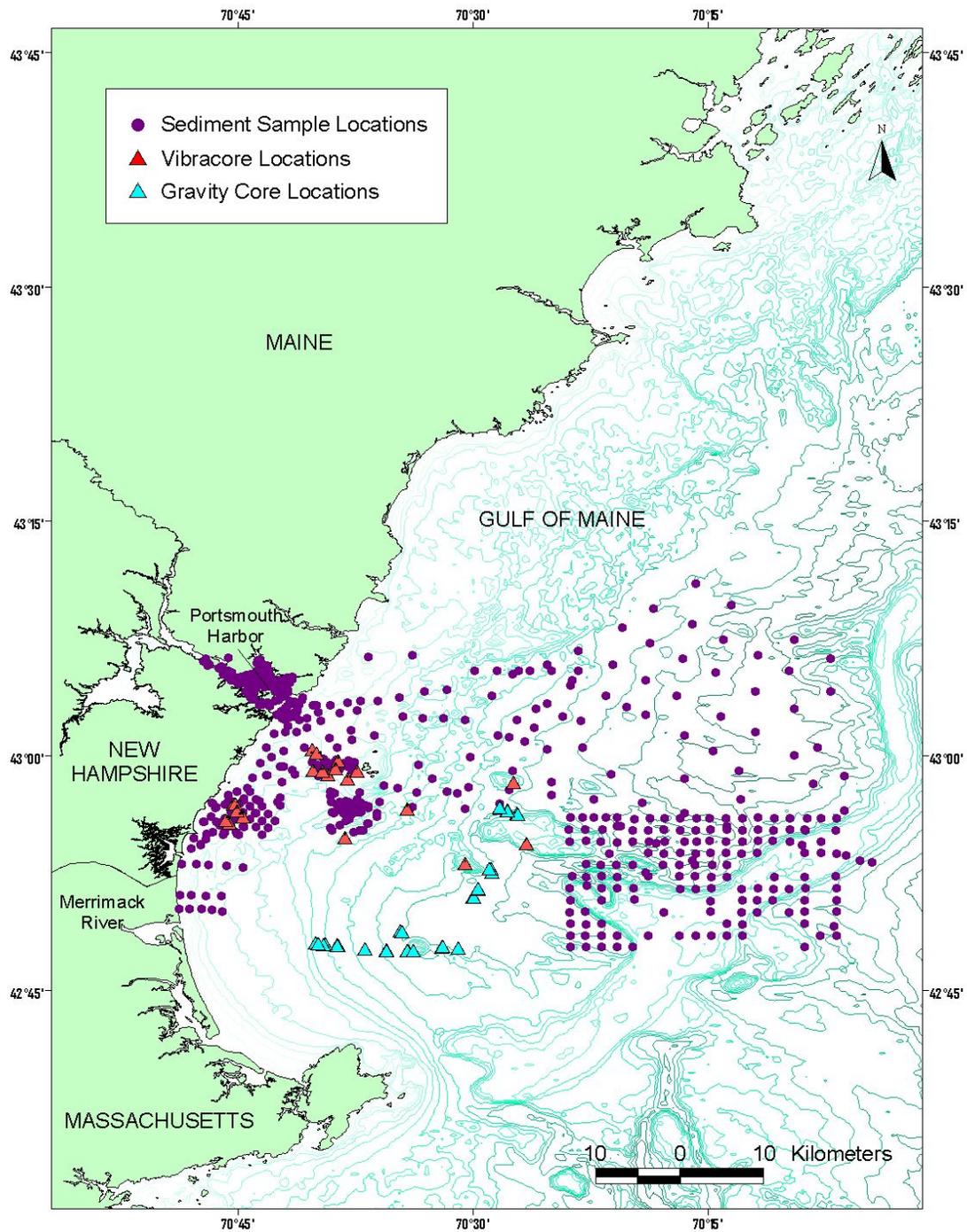


Figure 3. Location of stations included in the bottom sediment database.

and stratigraphy of the area (Portsmouth Harbor, an area south of the Isles of Shoals, and an area further offshore that appear to be eroded drumlins). These focus areas are shown in Figure 4.

Major Databases Being Used in This Project

1981-1982 Seismic Survey: The seismic survey includes ~1300 km of subbottom profiling from a relatively closely spaced grid extending from close to the coastline between Portsmouth Harbor and the Merrimack River and extended approximately 35 km seaward (Figures 1 and 2). The subbottom seismic profile unit consisted of a 300 joule E.G.&G. model 234 Uniboom system operated at a repetition rate of 0.5 s. Return echoes were picked up by towed hydrophones and recorded on dry paper with a EPA model 4100 recorder at a 0.25 s sweep rate. Location was determined by Loran C using a Northstar model 6000 system recorded by hand every 5 minutes. Only analog records of the seismics are available. The work was funded by the National Sciences Foundation (PI: Dr. Francis Birch, University of New Hampshire).

1985 Seismic Survey: The seismic survey includes ~250 kms of subbottom seismic lines run in a relatively closely spaced grid off an area north of Hampton-Seabrook Harbor and south of Portsmouth Harbor (Figures 1 and 2). The survey focused on potential nearshore sand bodies (e.g., Southern Sand Body) that could be used as borrow sites for beach nourishment. The subbottom seismic profiler and navigation system was basically the same as described above for the 1981-1982 seismic survey. Only analog records of the seismics are available. The work was funded by the Minerals Management Service (PI: Dr. Francis Birch, University of New Hampshire).

1992 Seismic Survey (Southern New Hampshire Nearshore): The seismic survey included ~150 kms of subbottom seismic profiles and side scan sonar records in a very closely spaced grid extending from the Merrimack River to north of Great Boars Head (Figures 1 and 2). The survey area focused on the nearshore area between the ~7 m to ~30 m isobaths. Subbottom seismic profiles were taken with a ORE model 140 unit broadcasting at a frequency of 3.5 kHz with variable power. The side scan sonar unit was a Klein dual-frequency towfish (model 422S-101HF) operating at 100 and 500 kHz simultaneously. The backscatter was recorded on a Klein digital recorder (model 595) on thermal paper. Precision navigation was provided by a UHF navigation system composed of a master transponder (Del Norte model 547) and three digital distance measuring units (Del Norte 547) with an accuracy of several meters. Although navigation was recorded in electronic files, only analog records of the subbottom seismic and side scan sonar records are available. The work was funded by the Minerals Management Service (PI: Dr. Larry Ward, University of New Hampshire).

1992 Seismic Survey (Portsmouth Harbor): Approximately 20 kms of subbottom seismic profiles and side scan sonar lines were run in a relatively closely spaced grid in Portsmouth Harbor (Figures 1 and 2). The subbottom seismic unit, side scan sonar unit and navigation system were basically the same as was used in the 1992 Southern New Hampshire Nearshore Seismic survey described above. Again, only hardcopies of the

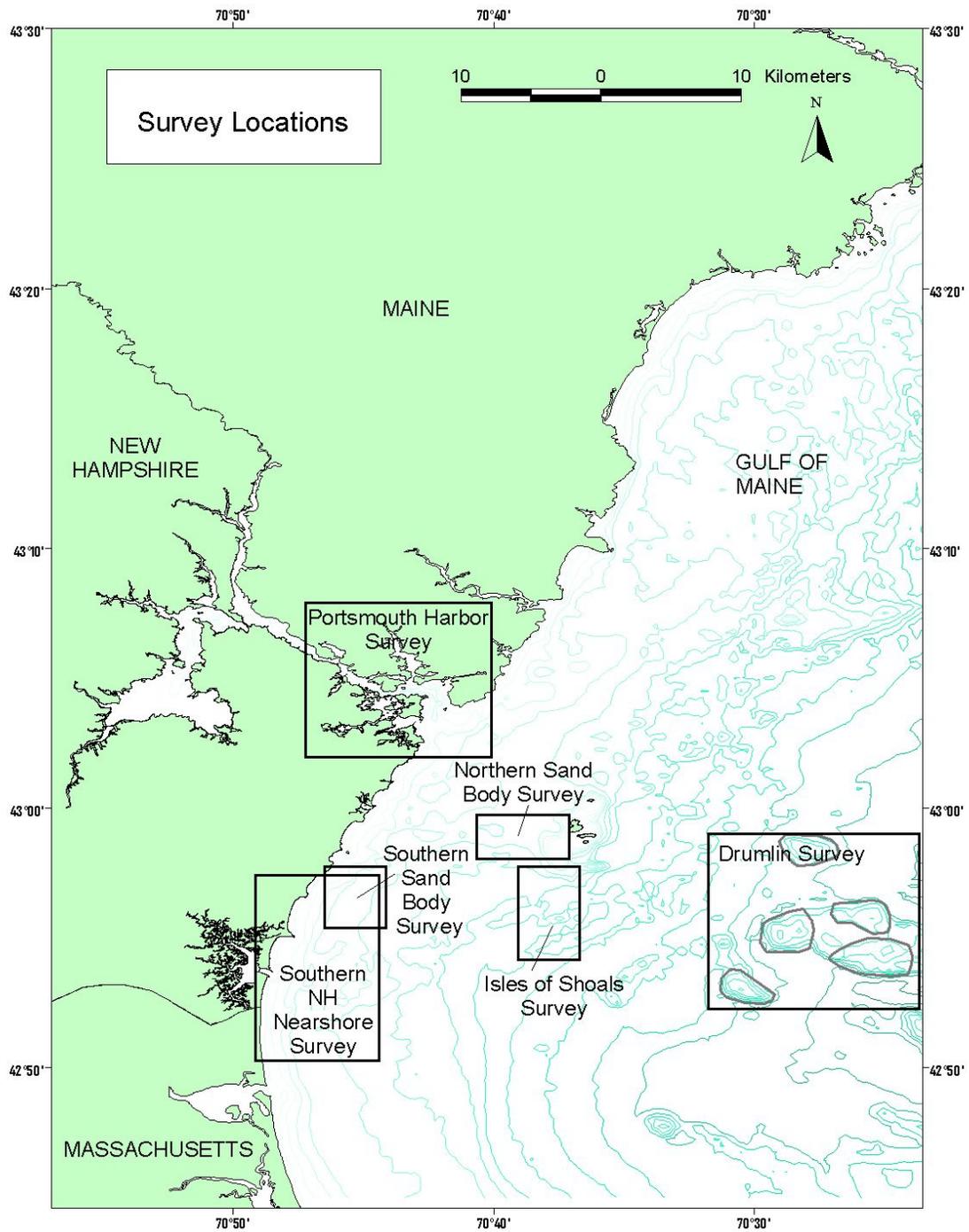


Figure 4. Location of areas offshore of New Hampshire that are the focus of the present project.

seismic records are available. The work was funded by the US Department of Defense (PI: Dr. Larry Ward, University of New Hampshire).

1999 Seismic Survey: Approximately 60 kms of subbottom seismic profiles and side scan sonar tracks were run in a tightly spaced grid ~two kms south of the Isles of Shoals (Figures 1 and 2). The subbottom seismic unit consisted of a Edgetech Xstar, the side scan sonar system was an Edgetech DF-1000, and the navigation and positioning system was a Northstar Differential GPS Navigation. Only analog records of the seismics are available. The work was funded by the NOAA through UNH CINEMar program (PI: Dr. Larry Ward, University of New Hampshire).

1984 and 1988 Vibracoring Projects: Twenty three vibracores were collected at key sites determined from the initial analyses of the 1981, 1982 and 1985 subbottom seismic profiles in order to verify interpretations of the acoustic records. Navigation was by Loran C with positions recorded by hand. The work was funded by the Minerals Management Service (PI: Dr. Francis Birch, University of New Hampshire). The vibracore locations are shown on Figure 3.

Surficial Bottom Sediment and Gravity Coring Projects: From 1971 to 2005 approximately seven different studies conducted at the University of New Hampshire collected and analyzed surficial and near-surface bottom sediments on the New Hampshire inner shelf and adjacent areas. The results of this work reside in several databases now maintained as part of this project. In total, grain size information is available for ~850 bottom sediments. Much of this data was previously provided to the U.S. Geological Survey at Woods Hole and was incorporated into the sediment data base for the Gulf of Maine (Poppe et al, 2003, USGS Open-File Report 03-001). The locations of the sediment samples are shown in Figure 3.

Results and Progress to Date

Northern Sand Body Survey

Based on several seismic surveys (1981, 1982 and 1985 seismic surveys), 5 vibracores and ~25 bottom samples, Birch (1984b) describe a sand deposit referred to as the Northern Sand Body (NSB). The NSB, which is located just west of the Isles of Shoals (Figure 4 and 5) has an estimated 25 million m³ of sand. Consequently, this area is of interest due to its potential as a sand source, as well as understanding the development of sand deposits on the New Hampshire shelf.

During the present study, a detailed surficial sediment map, an isopach map of the sand thickness, and a stratigraphic model of the NSB are being developed. The surficial sediment map will be based on the relatively closely spaced surficial sediment samples. The isopach map and the stratigraphic model will be based on re-evaluation and interpretation of the subbottom seismic records and five vibracores on and adjacent to the NSB. The results of each of these analyses will be synthesized in a GIS project. To date,

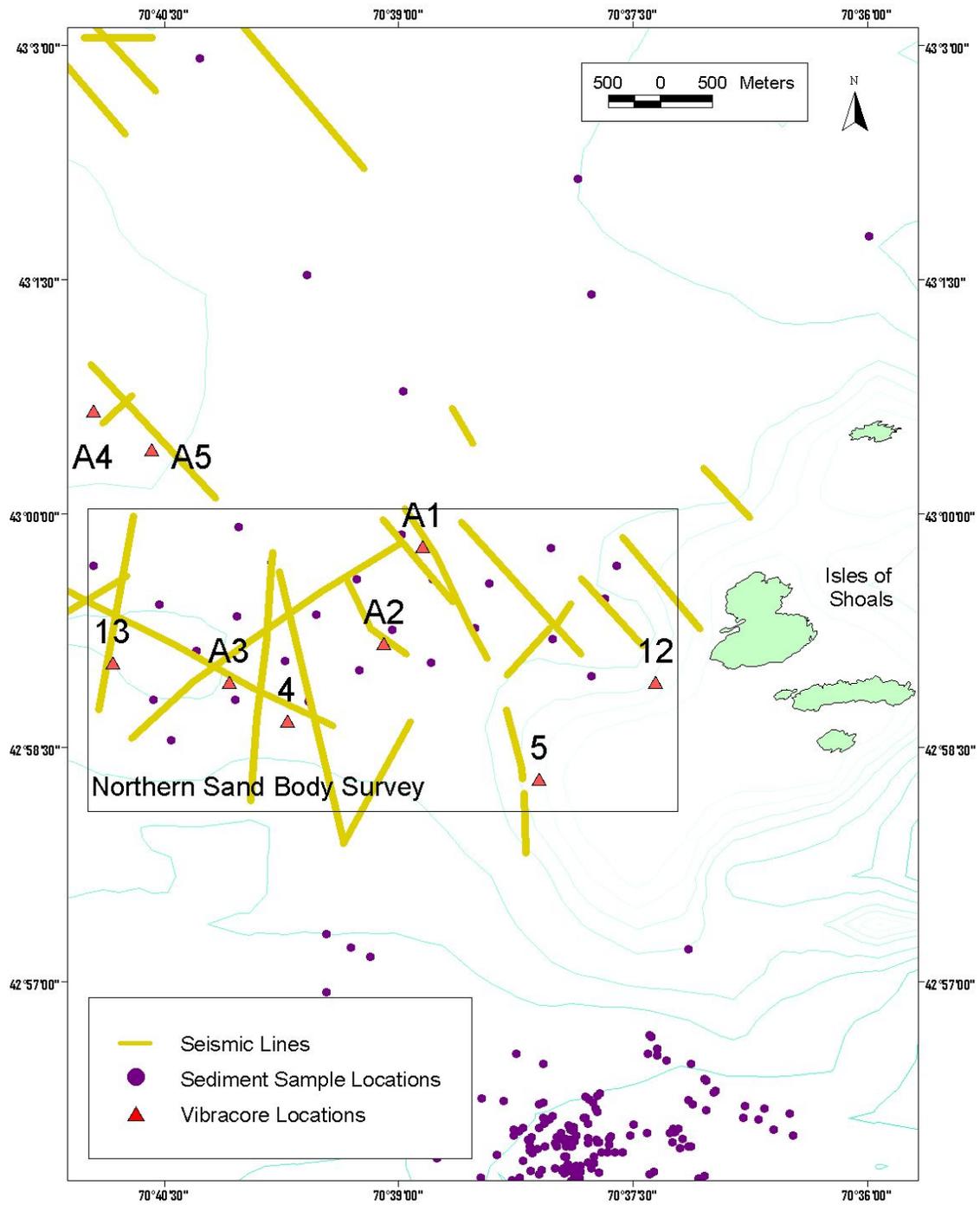


Figure 5. Location of seismic lines and sediment sampling stations in the Northern Sand Body.

the seismic records have been interpreted and the major reflectors identified. The vibracores have been described and logs created in Rockware (Figure 6). The isopach maps, stratigraphic model and GIS project remain as tasks.

Southern Sand Body Survey

Based on same surveys described above for the NSB, Birch (1984b) also described the Southern Sand Body (SSB). The SSB, which has an estimated 25 million m³ of sand, is located offshore about 10 kms north of Hampton-Seabrook Harbor (Figure 4 and 7). The SSB is of interest to this study as a potential borrow site for beach nourishment (due to its proximity to important New Hampshire beaches) and to help our understanding the formation of sand deposits or shoals on the inner New Hampshire shelf.

Similar to the NSB, a detailed surficial sediment map, an isopach map and a stratigraphic model are being developed from the seismic records, bottom sediment samples, and six vibracore for the SSB. All of this information will be depicted in a GIS project. To date, the vibracores have been logged and the sediment grain size data has been synthesized. Remaining tasks include analysis of the seismic lines, development of the isopach map, and development of the stratigraphic model. As this area is considered of lower priority due to the initial analyses of the seismic lines and a more detailed focus area (Southern New Hampshire Nearshore Survey) providing overlapping coverage, the SSB will be completed as time permits.

Southern New Hampshire Inner Shelf Survey

Based on a detailed subbottom seismic and side scan sonar survey and bottom sediment samples (Figures 4 and 7), Ward and Birch (1999) defined four sand bodies very close to shore that were interpreted as abandoned ebb tidal deltas. This area is of interest to this study due to the potential of these sand bodies as beach nourishment sources (close proximity to Hampton-Seabrook beaches). In addition, the results of the work in this area will further our understanding of coastal-inner shelf interactions and the impact of tidal inlets on inner shelf shoals through time.

Objectives for this area include bringing the surficial sediment and isopach maps into a GIS environment, completing the analyses of the subbottom seismic records, and developing, where possible, stratigraphic cross-sections from close to shore to the 30 m isobaths. This later objective is problematic due to the varying quality of the subbottom seismic records. To date, the sand thickness (Figure 8) and surface sediment data has been entered into a GIS project and the subbottom seismics have been interpreted. The remaining tasks include integrating the side scan sonar records with the subbottom seismic lines and merging this information with the sand thickness isopach map into a GIS project.

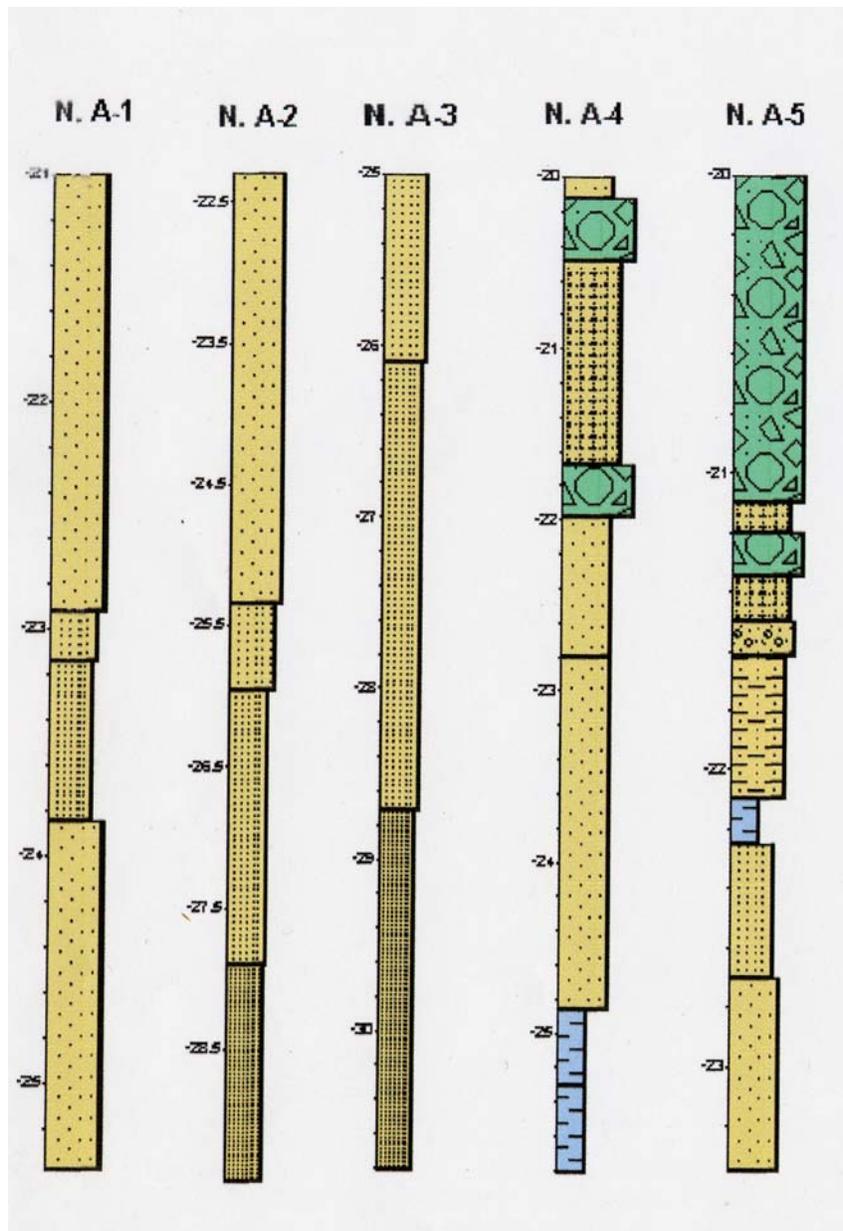


Figure 6. Logs of the vibracores from the Northern Sand Body. Green indicates gravel, yellow is sand, and blue are glacial marine sediments (primarily muds). The width of the core log indicates the relative grain size.

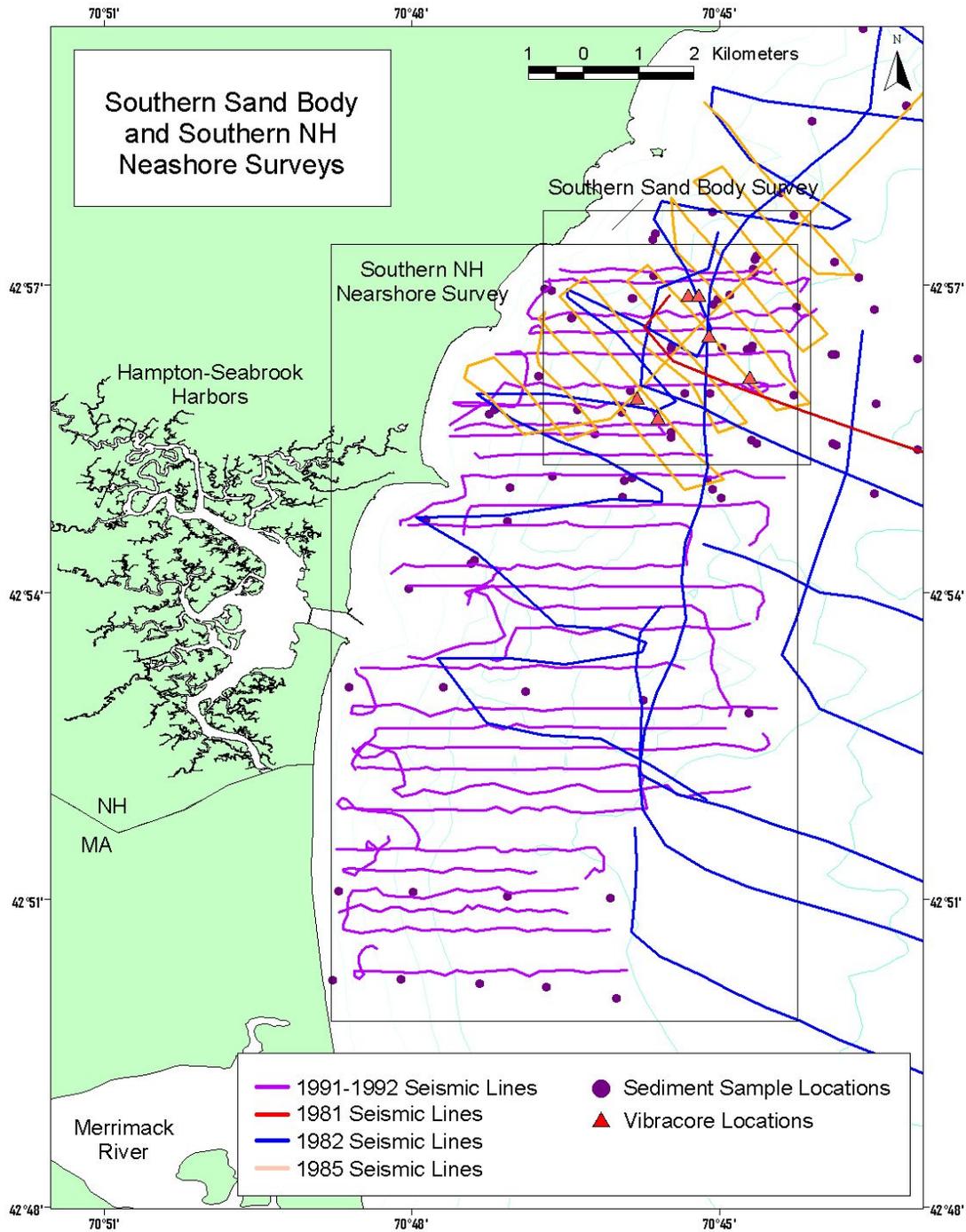


Figure 7. Location of seismic lines and sediment sampling stations in the Southern Sand Body and in the Southern New Hampshire Nearshore Survey focus areas.

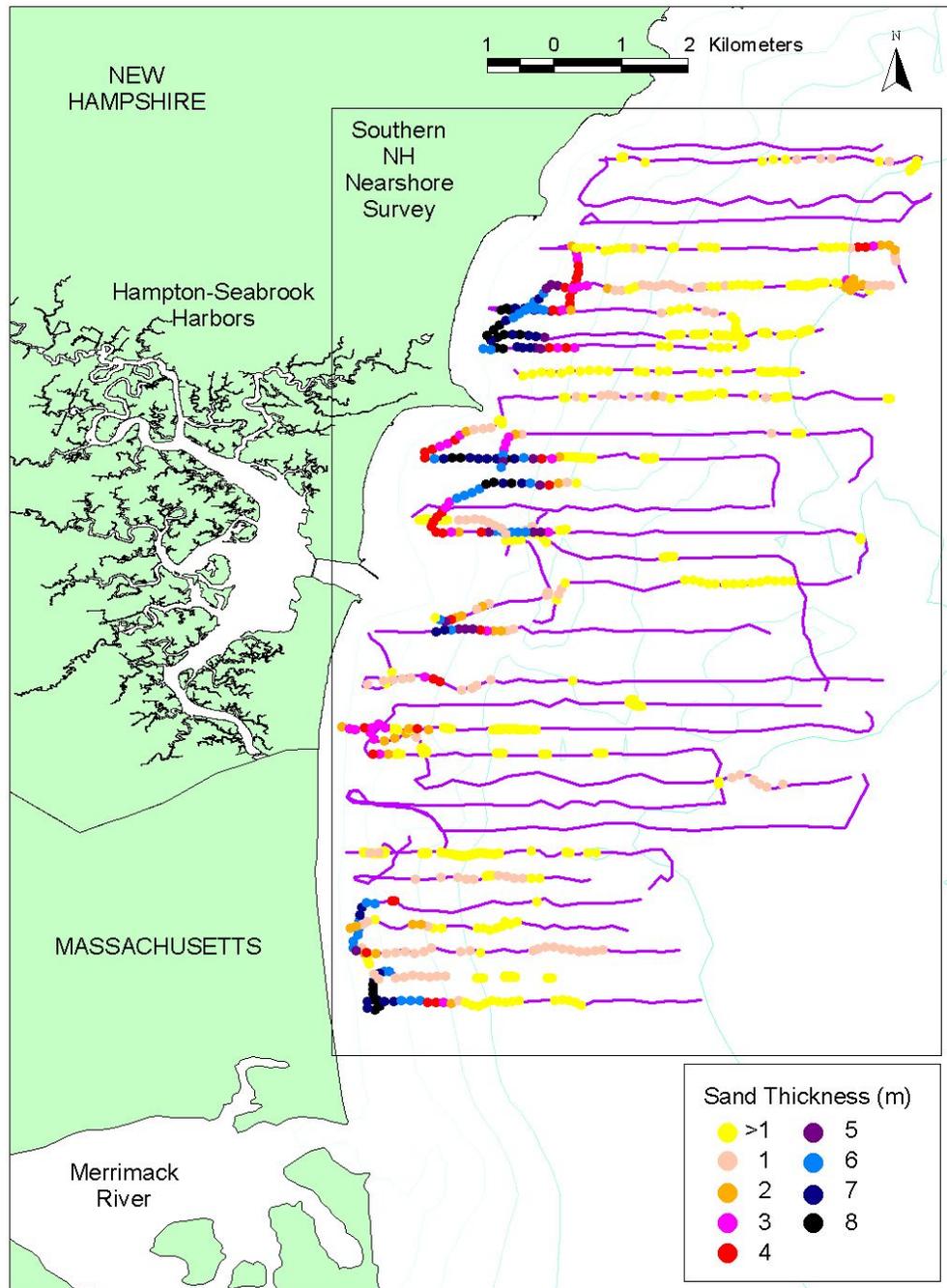


Figure 8. Thickness of sand deposits determined from the seismics in the Southern New Hampshire Nearshore Focus area. The sand thickness data will be used to develop an isopach map.

Offshore Drumlin Survey

The database for the offshore drumlins is limited to several seismic lines and two vibracores (Figures 2, 3 and 4). However, in order to better understand the sedimentologic and stratigraphic characteristics of the drumlin deposits, the seismic lines will be analyzed and combined with the vibracores descriptions. In addition, additional data sources will be reviewed. To date, only the vibracores have been examined and logged. The appropriate seismic lines have been identified and will be analyzed before the end of this project period to help define possible future studies. Examination of outside databases will occur as time permits.

Portsmouth Harbor Survey

Today, the major rivers in New Hampshire flow into the Great Bay Estuary (Figure 1) where most of their sediment loads are deposited (Ward and Bub 2005). However, at lower sea levels, these rivers flowed through what is now the Great Bay Estuary and Portsmouth Harbor and extended onto the continental shelf. Undoubtedly, at the time of the lower sea levels, the riverine sediments were introduced and deposited on the shelf. These deposits may be related to the sand deposits previously identified such as the NSB. Therefore, Portsmouth Harbor was chosen to study in detail in order to further our understanding of riverine-inner shelf interactions and the formation of the shelf sand bodies (Figure 4).

Fortunately, a substantial database exists for Portsmouth Harbor (Figure 9) including a closely spaced subbottom seismic and side scan sonar survey, several hundred bottom samples, and a number of gravity cores. This database will be used to develop a detailed bottom sediment map, a stratigraphic model, and an assessment of potential paleochannels. To date, the side scan sonar and subbottom seismic records have been re-analyzed to complete and verify earlier analyses. This information has been used to develop a more accurate bottom sediment map of the estuary (Figure 10). In addition, this information has been entered into a GIS, along with the grain size information from the bottom sediment stations. Therefore, the primary remaining task is to synthesize the results of the seismic analyses, develop the stratigraphic model, and enter the information into the GIS project. We expect this to be completed at the end of this contract period.

Isles of Shoals Survey

A second area helpful to understanding the sedimentology and stratigraphy of the New Hampshire shelf and where a substantial database exists is at the University of New Hampshire Open Ocean Aquaculture program field site located a little over 1 km south of the Isles of Shoals (Figures 1 and 2). At this location closely spaced subbottom seismic and side scan sonar records and over 100 bottom sediment samples provide a high resolution database of the sedimentologic and stratigraphic characteristics of this area (Figure 11). In order to better understand the influences of the extensive surface and subsurface bedrock on the major sedimentary units, this area was identified as a focus area.

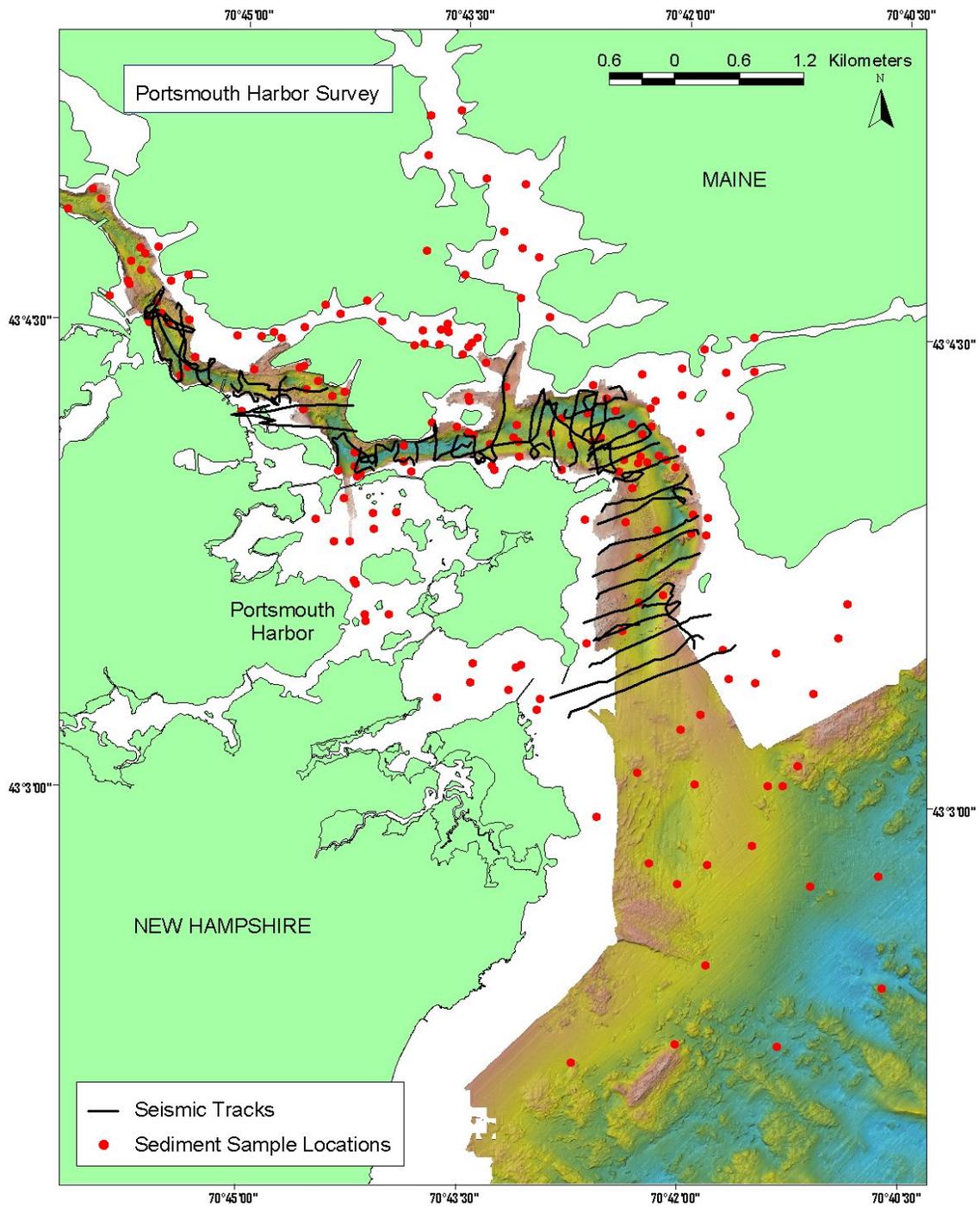


Figure 9. Location of seismic lines and sediment sampling stations in the Portsmouth Harbor area.

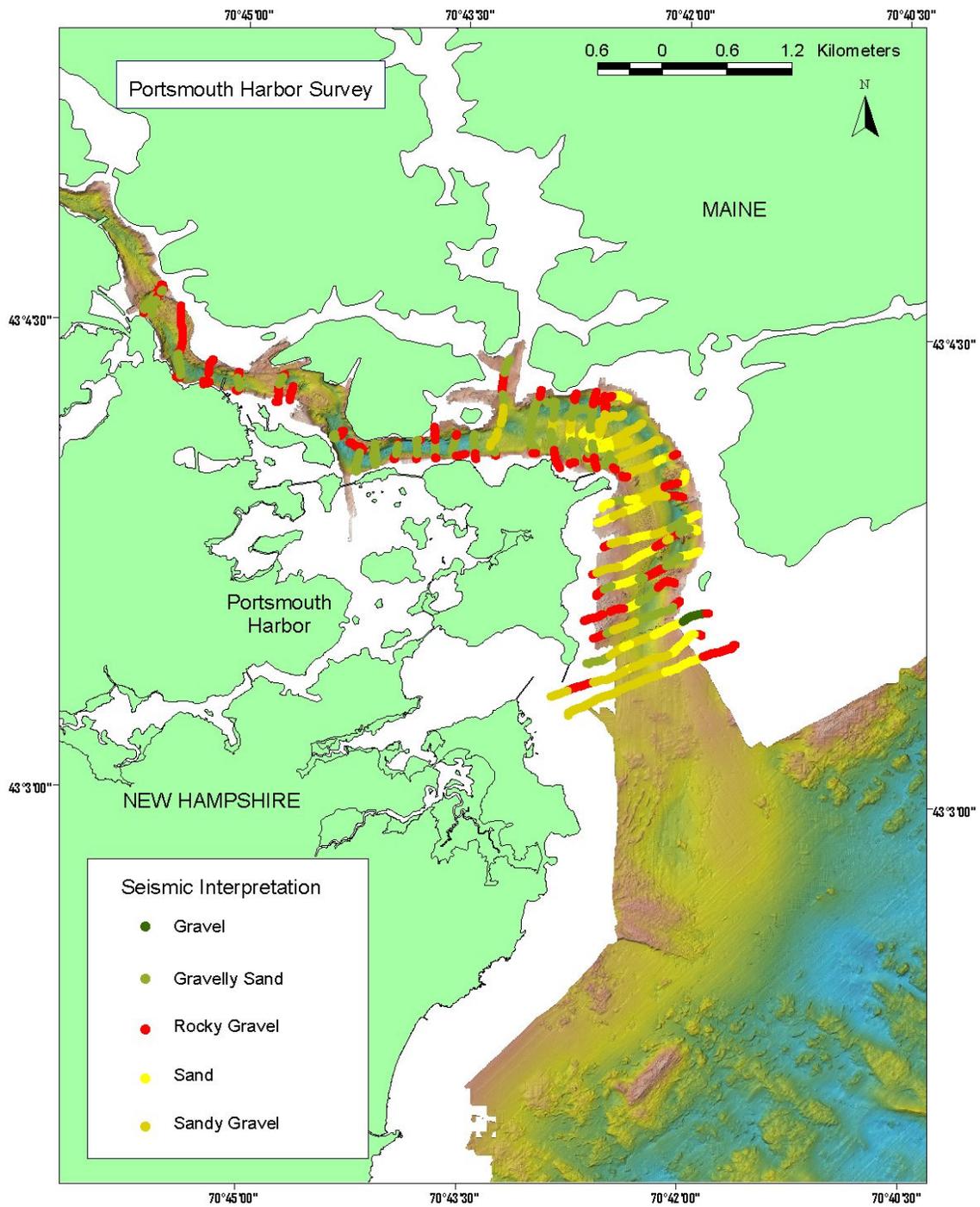


Figure 10. Distribution of the surficial sediments in Portsmouth Harbor based on the seismic survey and bottom sediment samples shown in Figure 9.

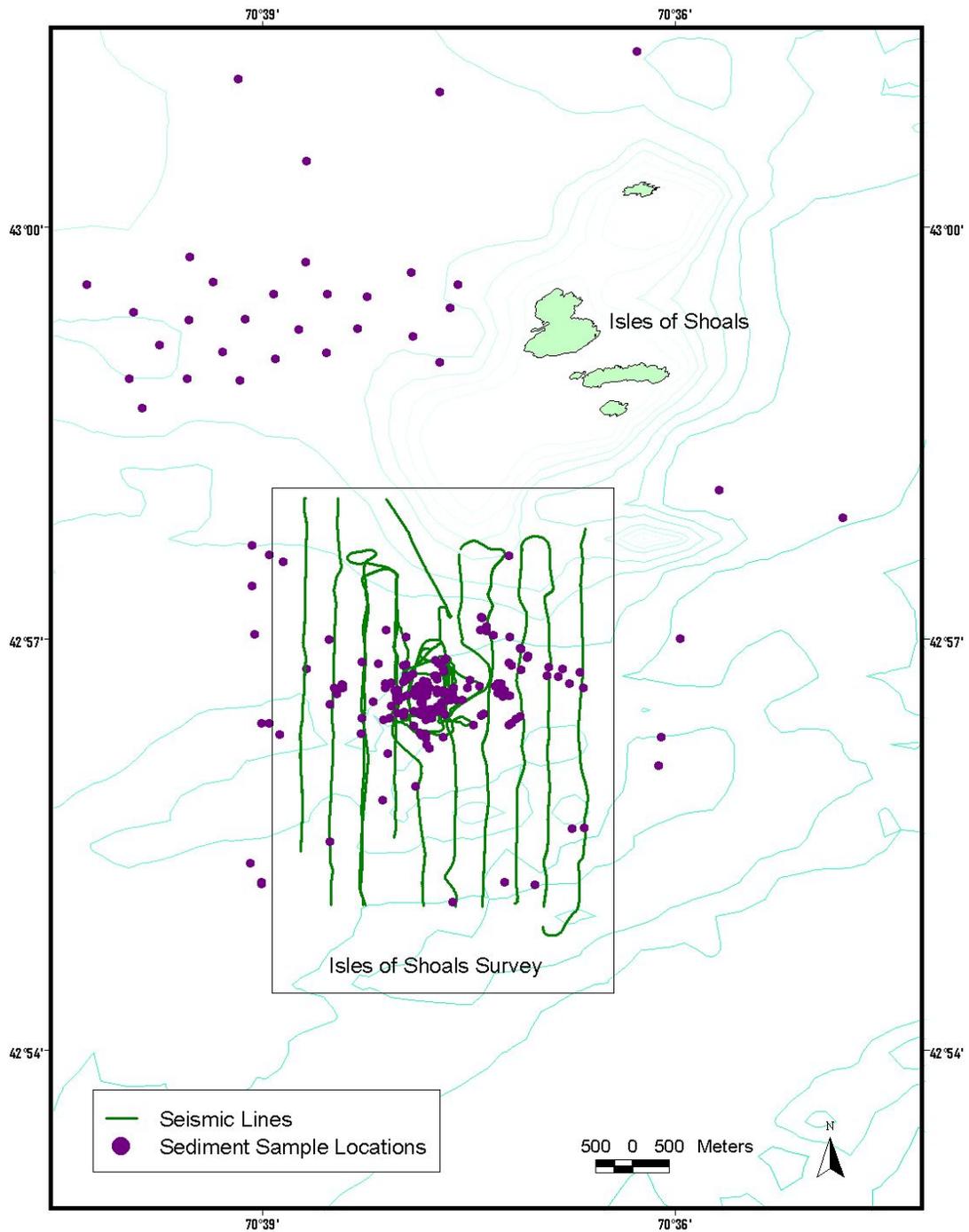


Figure 11. Location of seismic lines and bottom sediment samples in the Isles of Shoals focus area. The general location of the Northern Sand Body can also be seen from the cluster of sediment samples to the west of the Isles of Shoals.

To date, the side scan sonar records have been interpreted and the results merged into a bottom sediment map. However, the subbottom seismic records have not been analyzed and verified, which will take a major effort. Finally, the GIS project for this area must be built and the stratigraphic model developed. The work for this focus area will be done as a lower priority than the other focus areas and will be completed as time permits.

Summary

During the first two years of the cooperative agreement between the University of New Hampshire, the State of New Hampshire, and the Minerals Management Service, substantial progress has been made on the first phase of the project. A summary of the work being done, the progress to date, and the anticipated products are given below for the tasks outlined in the cooperative agreement proposal.

1. Update the present sedimentological database for the continental shelf offshore of New Hampshire. The bottom sediment database for the area offshore of New Hampshire that was developed by the principal investigator of this project (LGW) for inclusion in Gulf of Maine Sediment Database (produced by the U.S. Geological Survey) has been updated with the results of several additional studies. A substantial amount of new grain size data has been added to the original database providing good coverage of most of the inner shelf areas offshore of New Hampshire. However, several areas with limited coverage still remain.

2. Review existing seismic records and interpretations of the New Hampshire shelf by Birch (1984b, 1986a, 1988) and Ward and Birch (1993, 1996, 1999). As discussed in more detail above, subsets of the seismic records have been analyzed. Completed areas include the Southern New Hampshire Nearshore Survey (the 1992 Seismic Survey), the Portsmouth Harbor Survey (the 1992 Seismic Survey), and the Northern Sand Body Survey (portions of the 1981, 1982, and 1985 Seismic Surveys). At these locations, important reflectors, sediment thicknesses, and characteristics have been determined. Additional seismic analyses need to be done for the Southern Sand Body and the Offshore Drumlins.

3. Inventory and review existing records of vibracores from the continental shelf offshore of New Hampshire. The vibracores collected during earlier Minerals Management Service sponsored research have been re-analyzed to fill gaps in information and the core logs entered into Rockware. This work is complete.

4. Compile and synthesize the information from tasks one through three and update (modify) the surficial geology map of the continental shelf offshore of New Hampshire. The surficial sediment data, seismic records, core logs, previous reports and scientific publications will be summarized and used to update and enhance the present surficial geology map of the shelf of the New Hampshire shelf. At present, we do not anticipate being able to complete a new seafloor map unless the funding is continued for the

cooperative agreement. Rather, it is anticipated that a series of GIS projects of the focus areas will be developed and will accompany the seafloor map. All of these results will be available via the University of New Hampshire Jackson Estuarine Laboratory Coastal Geology Web Site.

5. Initiate work to create maps of the New Hampshire coastal environment that will depict shore types, coastal sediment types, and potential sand and gravel sources to the beaches. This work will not be initiated until the funding for the cooperative agreement is resumed.

6. Identify information gaps and design new field and laboratory studies. An evaluation of the information gaps in the mapping and characterization of sand and gravel deposits offshore of New Hampshire will be included in the final report for years one and two of the cooperative agreement. This will then be used to develop the workplan and studies for the final three years of our cooperative agreement.

7. After review, transfer the GIS projects, databases, and other relevant information to the New Hampshire Geological Survey (NHGS) archives. In addition, prepare a CD-ROM, web site and report depicting project results. The final report for the first two years of the project (which will include a CD-ROM with the report and databases included) will be completed at the end of the present funding cycle and submitted to MMS. Appropriate results of the project will also be available via the University of New Hampshire Jackson Estuarine Laboratory Coastal Geology Web Site. All reports and databases will be provided to the NHGS.

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