Multibeam Mapping in Long Island Coastal Waters

Roger D. Flood

Marine Sciences Research Center

State University of New York

Stony Brook, NY 11794-5000

ABSTRACT

The coastal sea floor is a complex and dynamic, but poorly imaged, environment. Traditional mapping techniques such bathymetric survey generally provide low-resolution data that is insufficient to resolve important details. Newer approaches such as side-scan sonar can provide a high resolution image of the sea bed based on acoustic backscatter, but the resulting images are sometimes difficult to interpret because backscatter depends on both topography and sediment character. An important new technology for imaging the coastal sea bed is swath bathymetry designed for shallow-water use which collects both bathymetric and imaging data at high resolution.

INTRODUCTION

Multibeam (swath) bathymetry techniques have been used in deep sea research since the introduction of SeaBeam to the academic community in the early 1980s. These early systems operated at 12 kHz, and were ineffective at water depths less than about 1000 m. Multibeam systems operating at higher frequencies (about 100 kHz) were introduced in the early 1990s and are effective on the continental shelf and in coastal waters (e.g., Gardner et al., 1998; Clarke et al., 1996). Multibeam technology has now been transported to the coastal zone with systems that operate at higher frequencies (e.g., 300 kHz) and at water depths from 0.5 m to about 100 m. MSRC at SUNY Stony Brook has recently acquired a shallow-water multibeam system (Simrad EM 3000, a research-grade multibeam system) under a grant from the Office of Naval Research in order to bring swath technology to researchers in the coastal zone. The MSRC EM 3000 was the first such system acquired by a US academic institution, and we are applying this new technology to a range of topics in shallow-water coastal environments. Our EM 3000 has so far been operated only on the MSRC Research Vessel ONRUST, but the system is portable and can be moved to other vessels for use in local waters.

TECHNIQUES

A multibeam system operates by transmitting a sound beam perpendicular to the ship track, and then processing the returned sonar data to determine a number of depths across the ship track (Fig. 1). For example, our EM 3000 forms 127 echosounder beams (each nominally spaced 0.9 degrees apart) in a swath width four times the water depth. In 10 m of water, beams have a width of 0.25 m under the ship, and beam width increases slightly towards the outer beams. The system pings up to 20 pings per second, resulting in a dense coverage of depth and backscatter (the strength of each of the received beams) from a swath along the ship track. The system also collects a side-scan sonar record at 300 kHz which is very similar to a traditional side-scan sonar system, although the sound beams are directed down more than sideways. The specified accuracy of each depth measurement is 0.05 m. Many additional pieces of equipment (all available for the MSRC system) are required to obtain high-quality multibeam data. These pieces include a POS/MV attitude sensor that corrects the sonar record for heading, roll, pitch and heave; a differential GPS system (supplemented by inertial navigation; also part of the POS/MV system) which determines position to within 1 meter; a separate display to guide the boat along precise survey lines; a CTD for determining the sound velocity profile; a tide gauge for determining local sea-level changes during a survey; Sun and SGI computers (with 36" wide and page-size printers) for logging, storing, processing and displaying the data, and multibeam processing software. Near-final survey products can be generated within a short time after the survey is completed, and our products generally meet hydrographic mapping standards.

The depth data is gridded at an appropriate interval (usually 0.25 m to 1 m) to create a digital terrain map (DTM). This DTM is contoured as needed (typically at 0.5 to 1 m) to show regional bathymetric patterns. A sun-illuminated image is routinely created by shining a synthetic sun across the DTM. This step provides a remarkable image of the sea bed, and small bathymetric features difficult to resolve on contoured bathymetry, are clearly visible. The side-scan sonar data is also gridded to provide an image of the backscatter, an acoustical property linked to bottom roughness and distinct from topography. Areas with higher backscatter include coarser materials (sand and shell) as well as rocky regions, but high backscatter in muddy areas is sometimes noted. Many features can be resolved on the combined data set, including sand waves and rock outcrops as well as drag marks from anchors and trawls, dumped debris and ship wrecks. These data products (gridded data, contour lines, sun-illuminated images and backscatter images) are available in digital form for importing into GIS or other systems for analysis in conjunction with other data sets.

INITIAL RESULTS

During the first six months of operation, multibeam data has been collected in a number of environments around Long Island (including a detailed study in Shinnecock Inlet), in New York Harbor and Bight, and in the Hudson River. We describe here results from one of our first surveys which occurred in Long Island Sound immediately north of Port Jefferson Harbor which was surveyed during a two hour period on October 1, 1998.

Mount Misery Shoal extends 2 km into Long Island Sound immediately east of the entrance to Port Jefferson harbor (Fig. 2). We conducted a multibeam survey which encompassed the northern edge of the shoal and the deeper water (to 28 m deep) immediately north of the shoal (Figs. 3 and 4). The most prominent feature on the contoured bathymetry (Fig. 3) is the steep northern slope of the shoal which includes a major north-dipping ridge in the center of the study area and a smaller but similar feature to the west of the major ridge. This western ridge has the character of a fan or slump deposit, and it is located immediately north of a small channel or slump scarp. North of the steep slope the sea bed is quite flat, with a slight slope to the north and northwest. Prior sampling suggests that the flat area is made of fine-grained sediment.

These prominent slopes and ridges are observed on the sun-illuminated bathymetry (Fig. 4), but a number of smaller features are also apparent. Smaller features visible on the sun-illuminated bathymetry include sand waves and scoured depressions at the northern end of the major dipping ridge, sand waves on the smaller dipping ridge, and a number of elongate depressions in the flatter sea bed that have bumps at their western ends. The nearly symmetric scoured depressions at the northern edge of the major ridge (Fig. 5, left) suggest that they have been formed by tidal currents. Sand waves are also present on both sides of the major ridge, but their distribution is less symmetric as more prominent waves are to the west of the ridge. Elongate depressions (Fig. 5, right) are observed in the fine-grained sediments in the eastern part of the survey area. The multibeam data shows that these depressions extend east from large obstacles that range from 2 to 5 or more meters in size. Many of the obstacles are rounded, and they may be large boulders of glacial origin. Some of the obstacles are more angular, and they may be parts of sunken ships or barges. The elongate depressions are most probably formed by eastward-flowing currents. The scoured areas generally have elevated backscatter, suggesting coarser material there.

The digital data set can also be viewed in three dimensions in order to observe the spatial relationships of the various features. Fig. 6, top, shows the dipping ridges on the north flank of Mount Misery Shoal viewed from the north and illuminated from the west. On this view it is clearer that the sand wave field to the west of the ridge has a different character from the mound and sand wave field to the east of the ridge. This asymmetry in bed form distribution may be related to the existence of both tidal and storm flows at depth. Fig. 6, bottom, shows some of the boulders and elongate depressions, and we can see that some of the obstacles protrude above the sea bed.

We can interpret these images in terms of current flow at the sea bed (ca. 25 m water depth). Tidal flows have been important agents in scouring the bed near the major ridge and in creating sand waves on either side of the ridge. The depressions behind mounds are not symmetric, suggesting a greater effect of flow towards the east. Deep eastward current flow may occur during winter storms, and such flows may be important for transporting fine-grained materials in the area.

The usefulness of high-resolution bathymetry in coastal studies also being evaluated in an ongoing project to map the benthic habitat of the Hudson River being supported by NYS DEC. In this project (jointly undertaken by MSRC and LDEO), our multibeam bathymetric system is being used to map 35 miles of the river in depths greater than 15 feet (5 m). The data collected to date show the location of natural features (e.g., rocks, sand waves, mud deposits), man-made features (e.g., ship wrecks, dredge-spoil deposits, cargo dumped by ships and barges, cable crossings, bridge pilings), and the interaction between natural processes and man-made features (e.g., scour and drifting behind wrecks and pilings). This data will be integrated into existing data sets on natural resources to develop a new understanding of river-bed processes and their effect on habitat and organisms.

CONCLUSIONS

High-resolution bathymetric mapping using shallow-water multibeam techniques can provide new views of coastal sea floor and new insights into seabed processes. This information is needed for studies of sediment transport, contaminant distribution, benthic habitat, and cultural artifacts. Coastal mapping for scientific purposes is especially important in New York State because the last systematic bathymetric mapping in many areas was in 1930s using lead-line. Managers clearly have a need for high-resolution data from these important environments.

ACKNOWLEDGMENTS

The EM 3000 multibeam system was purchased and installed through a grant from the Office of Naval Research to MSRC/SUNY (N000149810306) and to the Lamont-Doherty Earth Observatory (LDEO). The successful operation of the system is due to the assistance of many, including Richard Perry and Dale Chayes (LDEO) and Henry Bokuniewicz, Mark Wiggins and Steve Cluett (MSRC). Matching funds from MSRC and SUNY are also acknowledged.

ACKNOWLEDGMENTS

The EM 3000 multibeam system was purchased and installed through a grant from the Office of Naval Research to MSRC/SUNY (N000149810306) and to the Lamont-Doherty Earth Observatory (LDEO). The successful operation of the system is due to the assistance of many, including Richard Perry and Dale Chayes (LDEO), Larry Mayer and John Hughes Clark (University of New Brunswick) and Henry Bokuniewicz, Mark Wiggins and Steve Cluett (MSRC). Matching funds from MSRC and SUNY are also acknowledged.

REFERENCES

Gardner J.V., Butman P.B., Mayer L.A., Clarke J.H., 1998. Mapping US continental shelves, Sea Technology, 39 (6) : 10-17.

Clarke J.E.H., Mayer L.A., Wells D.E., 1996. Shallow-water imaging multibeam sonars: A new tool for investigating seafloor processes in the coastal zone and on the continental shelf. Marine Geophysical Researches, 18: 607-629.

FIGURES

Click on the thumbnail image to see the larger image.

Figure 1: Cartoon of a multibeam system showing how the echo-sounding beams are formed by a combination of transmit and receive beam patterns.

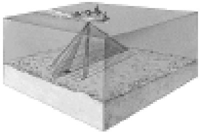

Figure 2: Map of Long Island showing the location of the study area in southern Long Island Sound.

Figure 3: Contour map of bathymetry in the study area. Contour interval is 1 meter, with labels at 5 m intervals.

Figure 4: Bathymetry of the study area illuminated from the northwest. The multibeam data was collected along east-west tracks, and there are sometimes small areas with no data between the swaths.

Figure 5: Left: close-up of sun-illuminated bathymetric image in the vicinity of a bathymetric ridge in the western part of the survey. Right: close-up of sun-illuminated bathymetric image in the vicinity of scour marks and tails in the eastern part of the survey area. White areas have no multibeam data.

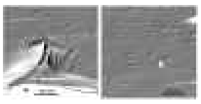

Figure 6: Top: perspective view of Mt. Misery Ridge, viewed from the north. Bottom: perspective view of obstacles in scour marks in the eastern part of the survey area, viewed from the north. For both images, the sun is located in the southwest (upper right). Parallel lines on the right side of the lower figure are artifacts (noisy pings).