YEAR 1 REPORT

MULTI-YEAR COOPERATIVE ASSESMENT OF SAND AND GRAVEL RESOURCES ALONG THE INNER CONTINENTAL SHELF OF MAINE

PROJECT MANAGER
Joseph T. Kelley

PRINCIPAL INVESTIGATORS
Joseph T. Kelley, University of Maine
Daniel F. Belknap, University of Maine
Stephen M. Dickson, Maine Geological Survey

Submitted to the Minerals Management Service
By the University of Maine and Maine Geological Survey

June, 2004

INTRODUCTION TO MULTI-YEAR COOPERATIVE

Beach erosion is arising as a critical and growing issue in southern Maine (Kelley and Anderson, 2000). State law precludes additional protective engineering structures along eroding beaches, leaving beach replenishment as the preferred method to cope with beach loss. Sand and gravel resources on land exist in this area, but transportation to the coast and road repair can add significantly to the expense of replenishment. Inland gravel pits are increasingly regulated in this growing suburban region. Thus, offshore borrow sites of aggregate are the most likely long-term sources of sand and gravel to replenish beaches. Herein we describe Year 1 data from a multi-year cooperative between the Minerals Management Service and the University of Maine and Maine Geological Survey to explore for and better define sand and gravel resources in federal waters offshore of the Maine coast.

PREVIOUS STUDIES AND GEOLOGIC FRAMEWORK

Sand and gravel are found in several geological settings on the northern New England inner shelf: shorefaces, lowstand shorelines, stratified moraines, and paleodeltas. (Figure 1)(Kelley et al., 2003). Seaward of major beaches, shoreface-sand deposits represent a significant repository of material. Off Saco Bay, for example, 56 million m^3 of sand line the shoreline. This sand is geologically linked to the adjacent beaches, however, and is not an appropriate source for replenishment. One exception to this might be the large dome of sand recognized seaward of Ogunquit Beach in Wells Embayment. This dome contains 12 million m^3 of sand, and although its origin and dynamics are unknown, it appears separate from the modern beach (Kelley et al., 2003).

Lowstand shorelines (shorelines from a lower-than-present stand of sea level) exist in many places in this region, but constructional beach deposits are widely recognized only off Cape Small, Saco Bay, Wells Embayment and the Merrimack River mouth (Figure 1). The drowned shorelines extend from the lowstand position, around 50-70 m depth, into shallower water, where pinning points of bedrock or glacial deposits allowed spits to prograde and littoral landforms to develop. The amount of sand in these features is unknown, but likely to be variable.

TABLE 1

Deposit	Knowledge*	Volume (m^3)	Depth (m)	Proximity (km)
Wells				
Lowstand	1	10^7-10^8	30-70	<25
Moraines	1	10^7	30-70	<25
Saco				
Lowstand	1-2	10^7-10^8	30-70	<25
Paleodelta	None	10^7	50-60	<25

Cape Small				
Lowstand	3	$>10^8$	30-60	25-50
Paleodelta	3	10^8	30-60	25-50
Merrimack Rive				
Lowstand	2	10^8	30-60	>50
Paleodelta	2	10^8	30-60	>50

* 1 = preliminary seismic and side scan only; 2 = seismic and cores; 3 = side scan, seismic and cores; 4 = multibeam

METHODS

In the summer of 2003, we collected multibeam and side scan sonar data simultaneously in outer Saco Bay (Figure 4). We used a digital Edgetech side scan sonar towfish with a topside Triton-Elics data processor. The range imaged varied between 100 m and 200 m.

Multibeam bathymetric data were gathered with a Simrad SM 2000 system. Water profiles were evaluated every hour, and data were processed with the Triton-Elics data processor.

All data are archived in a Geographic Information System; and have also been transmitted to the Maine Geological Survey for compilation with existing seafloor data.

Stratified moraines were recognized only off the Wells Embayment. These features represent glacial marginal positions, but are not composed simply of till. Rather, they appear to be ice-tunnel deposits that formed in the marine environment during deglaciation and were finally bulldozed into a linear form. They typically extend more than a kilometer in length, and are up to 10 m in height and 75 m in width. These features are one of the principal sources of sand and gravel on land, and are observed as far seaward as the lowstand shoreline complex (15 km, 60 m depth). Erosion of these deposits on the present coast was the source of sand and gravel for contemporary beaches. Erosion of the stratified moraines may have fed sand into lowstand shoreline deposits at times of lower-than-present sea level.

Paleodeltas are known from seaward of the Kennebec, Penobscot, Pleasant and Merrimack River mouths (Figure 1)(Belknap et al., 2002; Barnhardt et al., 1997; Oldale, 1983). To date, no paleodelta is recognized off the Saco River probably because of insufficient observations. Volumes of sand and gravel estimated in paleodeltas are very large (billions of m^3; Belknap et al., 2002). If the paleo-Saco

River had a sand discharge comparable to that of the present river, 15,000 m^3/yr (Kelley et al., 2003), then deposits that formed near the time of lowstand should contain millions of cubic meters. Because the river was incising through glacial deposits at that time, the actual value is probably much higher.

Earlier investigations in Saco Bay gathered both seismic reflection profiles and vibracores (Figure 2; Kelley et al., 2003) from inferred, lowstand shorelines. Sand was generally less than a meter in thickness and patchy in its spatial distribution, although only the region near the vibracore sites was closely examined (Figure 3). A more likely site for paleodelta formation exists to the southwest of the past coring site, a location closer to the present mouth of the Saco River. This area contains both complex bedrock-shaped bathymetric relief, as well as a gently, seaward sloping ramp. Known paleodeltas off the Kennebec and Merrimack Rivers possess similar ramp-like morphologies punctuated with outcrops of rock (Barnhardt et al., 1997; Oldale et al., 1983).

RESULTS

Depth in the study area (Figure 4) ranges between 23 and 65 m (Figures 2, 4, 5). The shallowest areas (A, Figure 5) are to the north, and are the seaward edge of a large rocky region. Bathymetric relief exceeds 10 m over horizontal distances less than 100 m. Numerous linear depressions on scales of hundreds of meters to meters cut through the shallowest area. Side scan sonar imagery (Figure 6) suggests that the shallow area (A, Figure 5) is largely bedrock with gravel-filled fractures. Similar areas have been observed all along the coast (Kelley et al., 1998).

There are three areas labeled B in Figure 5, and these range in depth between 40 m and 60 m. One area abuts area A and trends northeast to southwest. A steep scarp borders areas A and B in some places, and numerous shorelines occur in area B (Figure 3). Somewhat seaward of this, two other similar areas are labeled B in Figure 5. These appear to be rocky knobs surrounded by shoreline deposits and older glacial material that was reworked by waves during the lowstand of sea level. Side scan sonar imagery (Figure 6) reveals area B to be intermediate in acoustic reflectivity between areas A and C. In many locations in area B, sand outcrops on the seafloor (Figure 2), or it is covered by a thin veneer of mud (Figure 3).

Area C extends from about 50 m to 65 m depth (Figure 5. Side scan sonar imagery from this area shows a very low acoustic reflectivity, suggesting mud. It is possible that lowstand delta deposits are buried by mud here, as in Penobscot Bay (Belknap et al., 2002).

SEISMIC AND CORING TARGETS FOR 2004

In the summer of 2004, we plan to gather seismic reflection data within the study area of 2003 (Figures 4, 5, 6). In addition, we will try to gain additional side scan sonar coverage over areas of similar depth to the southwest (Figure 2). Constructional shoreline and paleodelta deposits are the target of the seismic work. Vibracoring will follow the seismic to ground truth the interpretations of sand and to ascertain the sand quality.

REFERENCES CITED

Barnhardt, W.A., Kelley, J.T., Belknap, D.F., Dickson, S.M., and Kelley, A.R., 1996, Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Piscataqua River to Biddeford Pool. Maine Geological Survey Geologic Map 96-6, 1:100,000.

Barnhardt, W.A., Kelley, J.T., Belknap, D.F., Dickson, S.M., and Kelley, A.R., 1996, Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Ogunquit to the Kennebec River. Maine Geological Survey Geologic Map 96-7, 1:100,000.

Barnhardt, W.A., Kelley, J.T., Belknap, D.F., Dickson, S.M., and Kelley, A.R., 1996, Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Cape Elizabeth to Pemaquid Point. Maine Geological Survey Geologic Map 96-8, 1:100,000.

Barnhardt, W.A., Kelley, J.T., Belknap, D.F., Dickson, S.M., and Kelley, A.R., 1996, Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Boothbay Harbor to North Haven. Maine Geological Survey Geologic Map 96-9, 1:100,000.

Barnhardt, W.A., Kelley, J.T., Belknap, D.F., Dickson, S.M., and Kelley, A.R., 1996, Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Rockland to Bar Harbor. Maine Geological Survey Geologic Map 96-10, 1:100,000.

Barnhardt, W.A., Kelley, J.T., Belknap, D.F., Dickson, S.M., and Kelley, A.R., 1996, Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Mt. Desert Island to Jonesport. Maine Geological Survey Geologic Map 96-11, 1:100,000.

Barnhardt, W.A., Kelley, J.T., Belknap, D.F., Dickson, S.M., and Kelley, A.R., 1996, Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Petit Manan Point to West Quoddy Head. Maine Geological Survey Geologic Map 96-12, 1:100,000.

Barnhardt, W.A., Belknap, D.F., and Kelley, J.T., 1997, Sequence Stratigraphy of Submerged River-Mouth Deposits in the Northwestern Gulf of Maine: Responses to Relative Sea-Level Changes. Geological Society of America Bulletin, v. 109, p. 612-630.

Barnhardt, W.A., Kelley, J.T., Dickson, S.M., and Belknap, D.F., 1998, Mapping the Gulf of Maine with side-scan sonar: A New Bottom-Type Classification for Complex Seafloors. Journal of Coastal Research v. 14, p. 646-659.

Belknap, D.F., Kelley, J.T., and Gontz, A.M., 2002, Evolution of the glaciated shelf and coastline of the northern Gulf of Maine, USA. Journal of Coastal Research, Special Issue 36, p. 37-55.

Kelley, J.T., and Anderson, W.A., 2000, The Maine shore and the Army Corps: a tale of two harbors, Camp Ellis and Wells, Maine, Maine Policy Review, v. 9., p. 20-35.

Kelley, J.T., Barnhardt, W.A., Belknap, D.F., Dickson, S.M., and Kelley, A.R., 1998, The Seafloor revealed: The geology of Maine's inner continental shelf. A report to the Regional Marine Research Program, Maine Geological Survey Open-file report Maine Geological Survey Open-File Report 98-6, 55 p.

Kelley, J.T., Dickson, S.M., Belknap, D.F., Barnhardt, W.A., and Barber, D.C., 2003, Distribution and Volume of Sand Bodies on the Rocky, Glaciated Inner Continental Shelf of the Northwestern Gulf of Maine. Journal of Coastal Research, v. 19, p. 41-56.

Oldale, R.N., Wommack, L.E. and Whitney, A.B., 1983 evidence of a postglacial low relative sea level stand on the drowned delta of the Merrimack River, western Gulf of Maine. Quaternary Research 33, p. 325-336.

FIGURE CAPTIONS

Figure 1. Map of the Maine coast, with boxes showing major sand deposits and patterns indication shoreface ramps (from Kelley et al., 2003).

Figure 2. Surficial geologic map of Saco Bay. Location of seismic line in Figure 3 is indicated. Area inside polygon contains lowstand shoreline deposits and possible paleodelta materials that are the focus of this study (from Kelley et al., 2003).

Figure 3. Seismic profile across lowstand shoreline with location of cores. The thin sand deposits and patchy nature of the sand is evident in the record (from Kelley et al., 2003).

Figure 4. Shaded area represents area covered by multibeam and side scan sonar records in Figures 5 and 6, respectively.

Figure 5. Multibeam record from area indicated in Figure 4.

Figure 6. Side scan sonar mosaic of area indicated in Figure 4. Dark tones are acoustically reflective, or hard rock, and gravel. Lighter tones are sand to mud-sized materials.