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The texture of surficial sediments in north-central Long Island Sound off Hammonasset Beach State Park, Connecticut

by

Poppe, L.J.[1], A.E. Harmon[1], Taylor, B.B.[1], Dann Blackwood[1], and Lewis, R.S.[2]

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[1] Branch of Atlantic Marine Geology, USGS, Quissett Laboratories, Woods Hole, MA 02543
[2] Long Island Sound Resource Center, Connecticut Geological and Natural Survey, Avery Point, Groton, CT 06340

ABSTRACT

Grain-size analyses were performed on 53 samples from a 13.4 km^2 area of northeastern Long Island Sound. The relative grain-size frequency distributions and related statistics are reported herein. Descriptions of the benthic character from video tapes and still camera photographs of the bottom at these stations, and 8 others, are also presented.

The southeastern part of the study area is characterized by coarse, moderately sorted sands. Gravelly sediments are confined to high-energy near-shore locations. Poorly sorted fine sands, silty sands, and sandy silts dominate the remainder of the study area. These textural distributions reflect the underlying geology, but are primarily a product of Holocene oceanographic conditions.

INTRODUCTION

The purpose of this study was to accurately measure the grain size distributions of the surficial sediment samples from this part of north-central Long Island Sound, to determine the frequency distributions, and to calculate statistical descriptions that adequately characterize these samples. These grain-size data will eventually be used to help describe the sedimentary processes active in this portion of north-central Long Island Sound, and to evaluate near-shore sand and gravel resources. Other potential uses for these textural data include benthic biologic studies that evaluate faunal distributions and relate them to habitats, and geochemical studies involving the transport and deposition of pollutants.

STUDY AREA

Long Island Sound, which is about 182 km long by a maximum of 32 km wide, is bordered on the north by the rocky shoreline of Connecticut and on the south by the eroding sandy bluffs of Long Island, New York. The study area (Figs. 1, 2) lies in north-central Long Island Sound offshore from Hammonasset Beach State Park and covers about 13.4 km^2. Water depths in the study area average about 12 m; maximum depths of 22 m occur in the central and southwestern parts of the study area.

The bedrock beneath the study area is believed to be composed of gneissic metamorphic rocks of pre-Mesozoic age (Lundgren and Thurrell, 1973; Rodgers, 1985; Needell and others, 1987; Lewis and Needell, 1987). The bedrock is unconformably overlain by two tills, one of pre-Wisconsinan age and one of late Wisconsinan age (Flint, 1971). Glacial lake deposits, stratified drift, and Holocene marine sediments variously overlie the bedrock and till (Lewis and Stone, 1991). The northward retreat of the late Wisconsinan ice sheet is marked in southeastern Connecticut by a northward succession of minor recessional moraines (i.e. the Hammonasset-Ledyard, Old Saybrook, and Mystic Moraines; Fig. 1) and associated outwash deposits (Goldsmith, 1980). The moraines in

Figure 1. Index map showing the location of the study area (striped polygon). Map also shows the locations of other sidescan sonar and sampling surveys (open polygons) being completed as part of this series (Twichell and others, 1995; Poppe and others, 1995; Zajac and others, 1995; Twichell and others, in press; Poppe and others, in press) and the major morainal complexes (solid black).

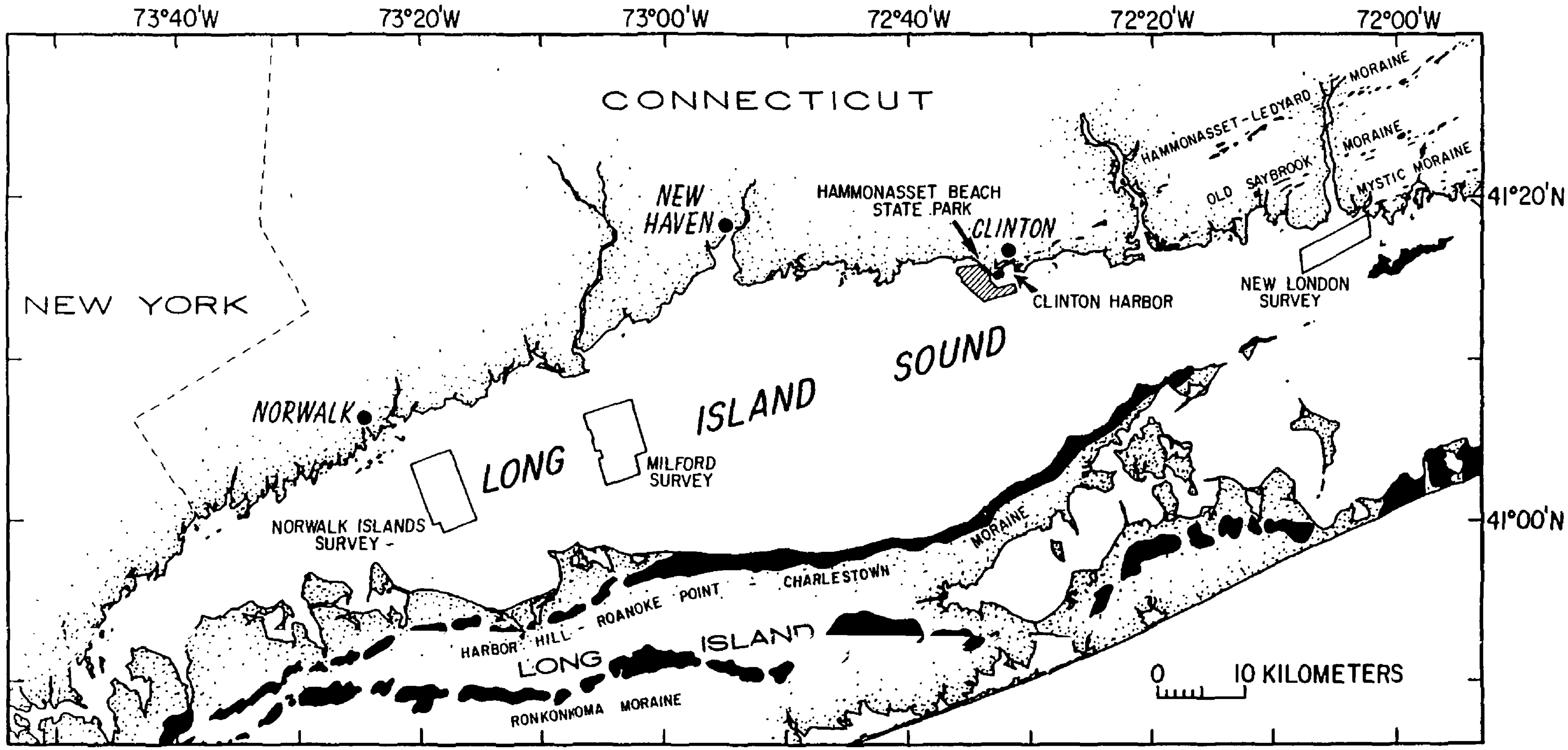
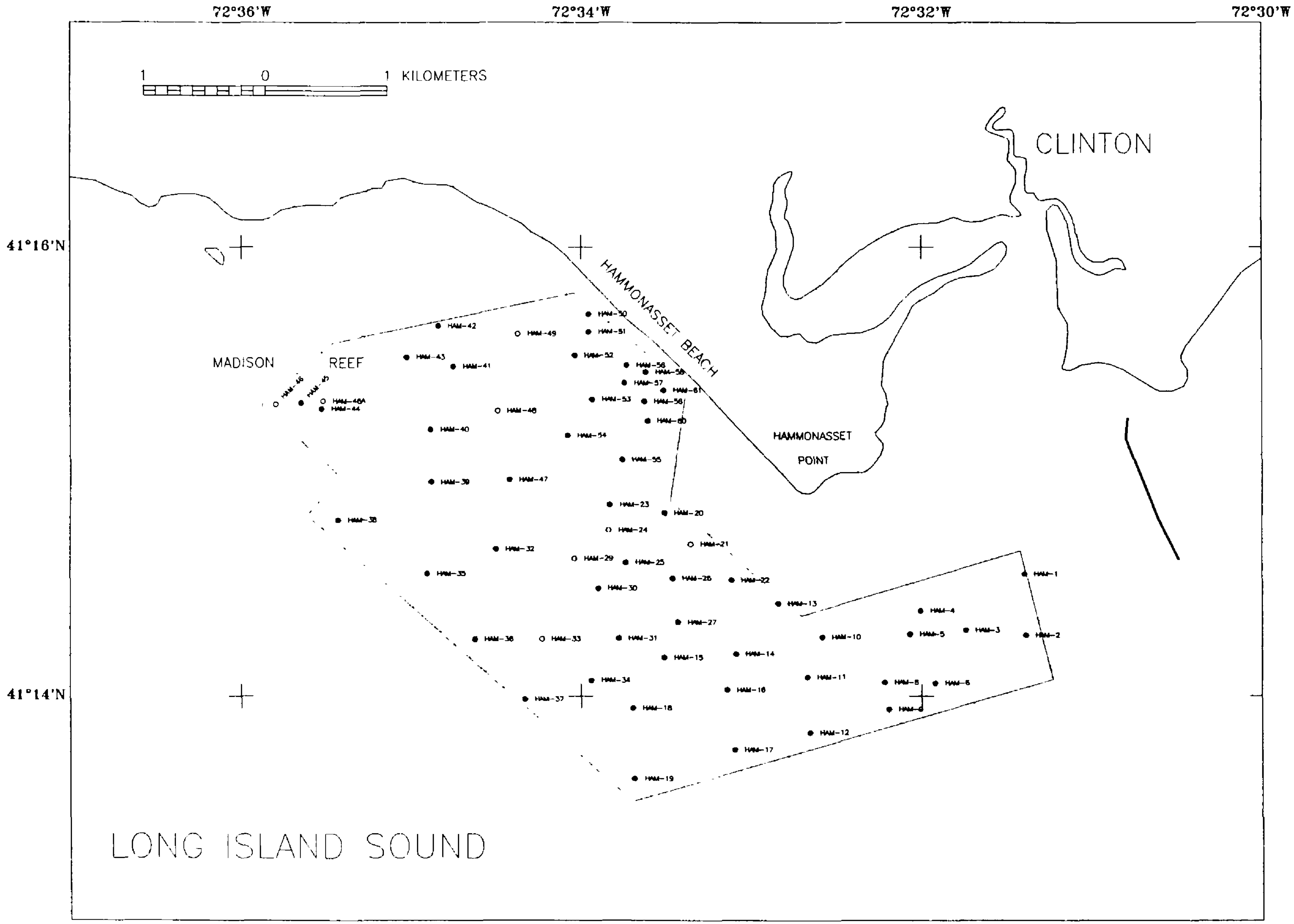


Figure 2. Map of north-central Long Island Sound off Hammonasset Beach State Park showing the station locations for this study. Stations where surficial sediment samples and bottom photographs were collected are shown as solid circles. Stations where only bottom photographs were taken due to the presence of boulders or bedrock are shown as open circles.



this series, prominently represented within the study area by the Hammonasset-Ledyard Moraine (Stone and others, 1992; Stone and Schafer, in press), are relatively linear, discontinuous, usually capped by boulders, and commonly aligned as double ridges that parallel the major recessional Harbor Hill-Roanoke Point-Charlestown and Ronkonkoma Moraine complexes on Long Island (Fig. 1). The Hammonasset-Ledyard Moraine passes offshore at Hammonasset Point and appears to correlate with a submerged moraine/lacustrine fan line south of New Haven to the west and the Ledyard Moraine to the northeast (Goldsmith, 1980; Stone and Schafer, in press).

Strong tidal currents have extensively eroded and reworked the sediments and continue to control sedimentary processes and surficial sediment distributions in eastern Long Island Sound. The irregular bottom topography and extensive lag deposits of boulders reflect this scour, transport, and reworking of the glacial and early post-glacial deposits (Lewis and Stone, 1991).

METHODS

Surficial sediment samples and bottom photographs were attempted at 61 locations during April and May, 1995 aboard the RV John Dempsey using a Van Veen grab sampler (Figs. 1 and 2). This grab sampler was equipped with Simrad-Osprey video and still camera systems; the video system was attached to an 8 mm video cassette recorder. These photographic systems were used to appraise intra-station bottom variability and to observe boulder fields and bedrock outcrops where sediment samples could not be collected (Appendix A). Surficial sediments (sediments from the sediment-water interface down to 2 cm) were subsampled from the grab sampler; these samples were frozen and stored for later analysis. Navigation was performed using a differential Global Satellite Positioning system.

A total of 53 samples were collected. The samples were thawed and visually inspected in the laboratory; an approximately 50 gram, representative split was analyzed. The sample to be analyzed was placed in a preweighed 100 ml beaker, weighed, and dried in a convection oven set at 75 ^{o}C. When dry, the samples were placed in a desiccator to cool and then weighed. The decrease in weight due to water loss was used to correct for salt; salinity was assumed to be 30 ^{o}/oo. The weight of the sample and beaker less the weight of the beaker and the salt correction gave the sample weight.

The samples were disaggregated and then wet sieved through a number 230, 62 μm (4ϕ) sieve using distilled water to separate the coarse and fine fractions. The fine fraction was sealed in a Mason jar and reserved for analysis by Coulter Counter (Shideler, 1976). The coarse fraction was washed in tap water and reintroduced into the preweighed beaker. The coarse fraction was dried in the convection oven at 75 ^{o}C and weighed. The weight of the coarse (greater than 62 μm) fraction is equal to the weight of sand plus gravel. The weight of fines (silt and clay) can also be calculated by subtracting the coarse weight from the sample weight. The coarse fraction was dry sieved through a number 10, 2.0 mm (-1ϕ) sieve to separate the sand and gravel. The size distribution within the gravel fraction was determined by sieving. Because biogenic carbonates commonly form in situ, they are not representative of the depositional environment from a textural standpoint. Therefore, bivalve shells and other biogenic debris greater than 0ϕ (1.0 mm) were manually removed from the samples and the weights corrected to mitigate this source of error.

If the sand fraction contained more than 16 grams of material (enough to run the analysis twice), a rapid sediment analyzer (Schlee, 1966) was used to determine the sand distribution. If less than 16 grams of sand were available, this fraction was dry sieved at whole ϕ intervals using a Ro-Tap shaker.

The fine fraction was analyzed by Coulter Counter; storage in the Mason jars prior to analysis never exceeded five days. The gravel, sand, and fine fraction data were processed by computer to generate the distributions, statistics, and data base (Poppe and others, 1985).

One limitation of using a Coulter Counter to perform fine fraction analyses is its ability to "see" only those particles for which it has been calibrated. Calibration for this study allowed us to determine the distribution down to 0.62 μm or about two-thirds of the 11ϕ fraction. Because clay particles finer than this diameter and all of the colloidal fraction were not determined, the value given for the 11ϕ fraction (Appendix B) is slightly lower than what is actually present.

RESULTS AND COMMENTS

Sample locations, water depths, and brief comments on the bottom photography are presented in Appendix A. Sample locations with low numerical designations (i.e. HAM-1 to HAM-19) tend to be located in the southeastern portion of the study area; sample locations with higher numerical designations (i.e. HAM-20 to HAM-61) are located in the northwestern portion of the study area (Fig. 2). The relative frequency distributions of the grain-size analyses are presented in Appendix B and the related statistics and verbal equivalents are presented in Appendix C. Size classifications are based on the method proposed by Wentworth (1929); the statistics were calculated using the method of moments (Folk, 1974). The verbal equivalents were calculated using the inclusive graphics statistical method (Folk, 1974) and are based on the nomenclature proposed by Shepard (1954).

The southeastern part of the study area is primarily characterized by moderately to moderately well sorted sands that have means between 1 and 2ϕ, have nearly symmetrical, unimodal distributions, and usually contain less than 15 percent fines (silt plus clay). These coarse-grained sandy sediments are usually associated with current ripples and often contain rounded shell hash. Linear patches of gravel (very fine granules) and shell hash are commonly in the troughs between the ripple crests. Earlier 3.5 kHz subbottom and sidescan sonar surveys (Poppe and others, 1995; Poppe and others, in press) have shown that sand waves of 1-2 m in height are common in this part of the study area.

The central and northwestern portions of the study area are characterized by a patchy distribution of faintly rippled sands and silty sands. The sands are finer grained (means between 2 and 3ϕ) and less well sorted than those in the southeastern part of the study area. The silty sands are poorly sorted, strongly finely skewed, very leptokurtic, and often bimodal. Burrowing, hermit and spider crabs, and gastropods (snails and welks) are common. Scattered patches of shell hash are present.

The finest grained sediments in the study area are poorly sorted, finely-skewed sandy silts. These sediments are restricted to the area just west of Hammonasset Point where they are apparently protected from strong tidal and storm conditions. Burrowing of the silts by shrimp, polychaetes, and amphipods is extensive; spider crabs are common.

Stations characterized by gravelly sediments are concentrated along Hammonasset Beach (HAM-50, HAM-58, HAM-61) and south of Hammonasset Point (HAM-13, HAM-22). The gravelly nature of the sediments in these areas is probably the result of the winnowing of finer grained sediments by storm- and tidally-induced wave and current action. Sandy patches within these areas are rippled and thin (less than about 5 cm), as evidenced by gravel at depth within the grab samples. Starfish, gastropods, and hermit crabs, inhabit these gravelly areas.

Sampling was not attempted at stations where bottom photography revealed the presence of boulders or bedrock. These bottoms would have prevented the collection of texturally representative sediment samples and risked damaging the sampling/photographic equipment. Numerous boulders were observed at stations HAM-21, HAM-24, HAM-29, and HAM-33. These stations extend in a linear band toward the southwest off Hammonasset Point and are associated with the offshore extension of the Hammonasset-Ledyard Moraine (Poppe and others, 1995; Poppe and others, in press; Fig. 1). Bedrock outcrops, associated with Madison Reef, occur in the northwestern part of the study area at stations HAM-46, HAM-46A, HAM-48, and HAM-49. Sponges, barnacles, seaweed, and other attached fauna/flora are locally common on the boulders and bedrock outcrops. A thin (>2 cm) layer of fine grained, presumably hemipelagic detritus covers both the bedrock outcrops and boulders. The limited thickness of this layer suggests that it is periodically removed by storm-generated currents.

Interested parties can obtain copies of the grain-size analysis data and an explanation of the variable headings in ASCII format and on 3.5" diskettes by contacting any of the authors. Videotapes showing the bottom character of the station locations can be viewed at the U.S. Geological Survey offices in Woods Hole, Massachusetts or at the Long Island Sound Resource Center at Avery Point, Groton, Connecticut.

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APPENDIX A

This table contains a list of the sample numbers, navigation (latitudes and longitudes) in degrees decimal minutes, water depths in meters, and comments on the bottom character.

SAMPLE	LATITUDE	LONGITUDE	DEPTH (M)	COMMENTS
HAM-1	41d14.5434'	-72d31.3972'	8	CURRENT RIPPLES, SCATTERED SHELLS AND SHELL HASH, DRIFTING SEAWEED
HAM-2	41d14.2700'	-72d31.3890'	11	CURRENT RIPPLES, SCATTERED SHELLS AND SHELL HASH
HAM-3	41d14.2918'	-72d31.7435'	1D	CURRENT RIPPLES, SCATTERED SHELLS AND SHELL HASH
HAM-4	41d14.381'	-72d32.008'	10	CURRENT RIPPLES, SHELL HASH CONCENTRATED IN RIPPLE TROUGHS, SCATTERED AND PATCHY GRAVEL
HAM-5	41d14.2763'	-72d32.0699'	10	CURRENT RIPPLES, SCATTERED SHELL HASH
HAM-6	41d14.2760'	-72d32.0651'	14	CURRENT RIPPLES, SCATTERED SHELL HASH
HAM-8	41d14.0623'	-72d32.2182'	12	CURRENT RIPPLES, SCATTERED SHELLS AND SHELL HASH
HAM-9	41d13.9410'	-72d32.1959'	20	CURRENT RIPPLES, SCATTERED SHELLS AND SHALL HASH, BLACK ORGANIC-RICH SEDIMENTS 2 CM DEEP WITH SOME EXPOSURES ON THE SEAFLOOR
HAM-10	41d14.2624'	-72d32.5845'	15	CURRENT RIPPLES, SCATTERED SHELL HASH, DARK GRAY ORGANIC-RICH SEDIMENTS 2 CM DEEP
HAM-11	41d14.0846'	-72d32.6720'	17	FAINT CURRENT RIPPLES, SHELL HASH, GASTROPODS
HAM-12	41d13.8370'	-72d32.6573'	22	FAINT CURRENT RIPPLES, ABUNDANT SHELL HASH, SOME ORGANIC-RICH CLASTS, HERMIT CRABS
HAM-13	41d14.4132'	-72d32.8432'	15	CURRENT RIPPLES, ABUNDANT SHELL HASH, HERMIT CRABS
HAM-14	41d14.1899'	-72d33.0932'	16	CURRENT RIPPLES, SHELL HASH CONCENTRATED IN RIPPLE TROUGHS, WORM TUBES
HAM-15	41d14.1731'	-72d33.5144'	14	FAINT CURRENT RIPPLES, CRAB, SCATTERED SHELL HASH, ABUNDANT AMPHIPOD TUBES
HAM-16	41d14.0293'	-72d33.1448'	16	CURRENT RIPPLES, SCATTERED SHELL HASH
HAM-17	41d13.7610'	-72d33.1016'	20	CURRENT RIPPLES, SHELL HASH CONCENTRATED IN RIPPLE TROUGHS
HAM-18	41d13.9468'	-72d33.7002'	17	FAINT CURRENT RIPPLES, SCATTERED SHELL HASH, AMPHIPOD TUBES
HAM-19	41d13.6341'	-72d33.6907'	20	CURRENT RIPPLES, SHELL HASH CONCENTRATED IN RIPPLE TROUGHS
HAM-20	41d14.8188'	-72d33.5142'	10	FAINT RIPPLES, SCATTERED SHELL HASH
HAM-21	41d14.6788'	-72d33.3600'	11	BOULDERS, SPONGES, BARNACLES, NO SEDIMENT SAMPLES
HAM-22	41d14.5177'	-72d33.1219'	15	CURRENT RIPPLES, SCATTERED AND PATCHY GRAVEL, SCATTERED SHELL HASH, STARFISH
HAM-23	41d14.8564'	-72d33.8333'	10	HEAVILY BIOTURBATED, ABUNDANT AMPHIPOD TUBES
HAM-24	41d14.7416'	-72d33.8404'	10	BOULDERS, SPONGES, BARNACLES, SILTY SAND IN BETWEEN ROCKS, NO SEDIMENT SAMPLES
HAM-25	41d14.597'	-72d33.740'	13	FAINT RIPPLES, ABUNDANT SHELL HASH
HAM-26	41d14.5267'	-72d33.4659'	14	SCATTERED GRAVEL AND SHELL HASH, SOME AMPHIPOD TUBES
HAM-27	41d14.330'	-72d33.436'	15	FAINT RIPPLES, SHELL HASH CONCENTRATED IN RIPPLE TROUGHS, AMPHIPOD TUBES
HAM-28	41d34.7819'	-72d34.1648'	10	FAINT RIPPLES, SCATTERED SHELL HASH, GASTROPODS, AMPHIPOD TUBES, SPIDER CRAB
HAM-29	41d14.6145'	-72d34.0395'	12	BOULDERS, SPONGES, BARNACLES, PATCHES OF SILTY SAND IN BETWEEN ROCKS, NO SEDIMENT SAMPLES
HAM-30	41d14.4805'	-72d33.9016'	13	FAINT RIPPLES, CRABS, SCATTERED SHELL HASH, SOME AMPHIPOD TUBES
HAM-31	41d14.2585'	-72d33.7807'	13	FAINT RIPPLES, SCATTERED SHELL HASH, CRABS, AMPHIPOD TUBES, GASTROPODS
HAM-32	41d14.6560'	-72d34.5005'	11	FAINT RIPPLES, SCATTERED SHELL HASH
HAM-33	41d14.2541'	-72d34.2308'	13	BOULDERS, THIN LAYER ONO SEDIMENT SAMPLES

SAMPLE	LATITUDE	LONGITUDE	DEPTH (M)	COMMENTS
HAM-34	41d14.0693'	-72d33.9398'	14	FAINT RIPPLES, SOME AMPHIPOD TUBES, SCATTERED SHELL HASH
HAM-35	41d14.546'	-72d34.904'	11	FAINT RIPPLES, AMPHIPOD TUBES
HAM-36	41d14.2519'	-72d34.6246'	13	FAINT RIPPLES, SOME SCATTERED SHELL HASH
HAM-37	41d13.9857'	-72d34.3311'	16	CURRENT RIPPLES, SCATTERED SHELL HASH
HAM-38	41d14.7861'	-72d35.4276'	10	FAINT RIPPLES, SCATTERED SHELL HASH, SKATE, HERMIT AND SPIDER CRABS, AMPHIPOD TUBES
HAM-39	41d14.9566'	-72d34.8832'	9	CURRENT RIPPLES, PATCHY SHELL HASH, HERMIT CRABS, GASTROPODS, AMPHIPOD TUBES, SPIDER CRABS
HAM-40	41d15.1899'	-72d34.8856'	8	CURRENT RIPPLES, SCATTERED SHELL HASH, BURROWS, AMPHIPOD AND WORM TUBES, WELKS, SPIDER CRABS
HAM-41	41d15.4702'	-72d34.7522'	8	SCATTERED SHELL HASH, WORM AND AMPHIPOD TUBES, BURROWS, HERMIT CRABS
HAM-42	41d15.6511'	-72d34.8394'	8	FAINT RIPPLES, CRAB TRACKS, SCATTERED SHELL HASH, HERMIT CRABS, WORM AND AMPHIPOD TUBES, BURROWS
HAM-43	41d15.5115'	-72d35.0273'	9	SCATTERED SHELL HASH, CRAB TRACKS, WORM AND AMPHIPOD TUBES, BURROWS
HAM-44	41d15.2818'	-72d35.5240'	8	FAINT RIPPLES, SCATTERED AND PATCHY SHELL AND SHELL HASH, BURROWS, AMPHIPOD AND WORM TUBES
HAM-45	41d15.3073'	-72d35.6461'	8	FAINT RIPPLES, SHELLS AND SHELL HASH, AMPHIPOD AND WORM TUBES, BURROWS, HERMIT AND SPIDER CRABS
HAM-46	41d15.3010'	-72d35.7979'	9	BOULDERS, HERMIT CRABS, GASTROPODS, NO SEDIMENT SAMPLES
HAM-46A	41d15.3160'	-72d35.5181'	8	BEDROCK, BOULDERS, BARNACLES, SPONGES, SEAWEED, SPIDER CRABS, THIN LAYER OF SEDIMENT ON BEDROCK, NO SEDIMENT SAMPLES
HAM-47	41d14.966'	-72d34.422'	9	FAINT RIPPLES, SCATTERED SHELL HASH, AMPHIPOD TUBES
HAM-48	41d15.2725'	-72d34.4900'	8	BEDROCK, SPONGES, SEAWEED, SPIDER CRABS, THIN LAYER OF SEDIMENT ON BEDROCK, NO SEDIMENT SAMPLES
HAM-49	41d15.616'	-72d34.369'	7	BEDROCK, BOULDERS, SPONGES, BARNACLES, SEAWEED, SPIDER CRABS, THIN LAYER OF SEDIMENT ON BEDROCK, NO SEDIMENT SAMPLES
HAM-50	41d15.7036'	-72d33.9559'	7	FAINT BEDFORMS, SCATTERED AND PATCHY GRAVEL AND SHELL HASH, HERMIT AND SPIDER CRABS
HAM-51	41d15.6246'	-72d33.9555'	8	SCATTERED SHELL HASH, WORM AND AMPHIPOD TUBES, BURROWS, HERMIT CRABS
HAM-52	41d15.519'	-72d34.038'	8	FAINT BEDFORMS, WORM AND AMPHIPOD TUBES, BURROWS, SCATTERED SHELL HASH
HAM-53	41d15.3222'	-72d33.9356'	8	FAINT RIPPLES, SCATTERED SHELL HASH, HERMIT CRABS, KELP
HAM-54	41d15.1633'	-72d34.0809'	9	SCATTERED SHELL HASH, WORM AND AMPHIPOD TUBES, BURROWS, HERMIT CRABS, TRACKS
HAM-55	41d15.056'	-72d33.761'	9	FAINT RIPPLES, SCATTERED SHELL HASH, BURROWS, ABUNDANT GASTROPODS AND HERMIT CRABS
HAM-56	41d15.4763'	-72d33.7356'	8	FAINT BEDFORMS, SCATTERED SHELLS AND SHELL HASH, BURROWS, SPIDER CRABS
HAM-57	41d15.3968'	-72d33.7490'	8	FAINT RIPPLES, SCATTERED AND PATCHY SHELL HASH, BURROWS
HAM-58	41d15.4457'	-72d33.6233'	7	FAINT RIPPLES, SCATTERED SHELL HASH AND GRAVELLY PATCHES, BURROWS, HERMIT CRABS
HAM-59	41d15.314'	-72d33.633'	8	FAINT RIPPLES, SOME GRAVEL, SCATTERED SHELL HASH
HAM-60	41d15.228'	-72d33.612'	9	FAINT RIPPLES, GRAVELLY PATCHES, SCATTERED SHELL HASH, SEAWEED, WELK, BURROWS, SPIDER CRABS, ABUNDANT AMPHIPOD TUBES
HAM-61	41d15.365'	-72d33.520'	8	CURRENT RIPPLES, GRAVELLY PATCHES, SCATTERED SHELLS AND SHELL HASH

APPENDIX B

This table contains the relative grain-size frequency distributions by weight in whole phi units for each sample. The -5ϕ fraction contains all sediment coarser than 32 mm; the 11ϕ fraction contains sediment with diameters between .001 and .00072 mm.

	CLAY				SILT				SAND				GRAVEL				
SAMPLE NUMBER	11ϕ	10ϕ	9ϕ	8ϕ	7ϕ	6ϕ	5ϕ	4ϕ	3ϕ	2ϕ	1ϕ	0ϕ	-1ϕ	-2ϕ	-3ϕ	-4ϕ	-5ϕ
HAM-1	0.51	1.21	1.56	1.96	2.78	3.95	3.58	34.45	49.48	0.34	0.17	0.00	0.00	0.00	0.00	0.00	0.00
HAM-2	0.05	0.11	0.11	0.13	0.18	0.28	0.41	3.75	38.10	38.99	15.70	2.17	0.00	0.00	0.00	0.00	0.00
HAM-3	0.17	0.43	0.50	0.63	0.90	1.35	1.17	3.37	20.32	48.89	19.48	1.59	1.20	0.00	0.00	0.00	0.00
HAM-4	0.08	0.16	0.19	0.27	0.39	0.52	0.35	0.59	11.13	45.18	39.04	1.66	0.45	0.00	0.00	0.00	0.00
HAM-5	0.02	0.03	0.03	0.05	0.08	0.10	0.07	0.38	5.64	34.03	49.33	6.21	4.03	0.00	0.00	0.00	0.00
HAM-6	0.01	0.01	0.01	0.01	0.02	0.03	0.02	0.01	6.41	47.72	41.81	2.66	1.28	0.00	0.00	0.00	0.00
HAM-8	0.10	0.22	0.25	0.28	0.40	0.45	0.45	2.84	35.62	58.61	0.78	0.00	0.00	0.00	0.00	0.00	0.00
HAM-9	0.45	1.25	1.60	1.72	2.11	2.24	1.55	4.19	23.16	59.43	1.16	1.16	0.00	0.00	0.00	0.00	0.00
HAM-10	0.51	1.27	1.49	1.73	2.53	3.30	2.30	14.33	60.72	11.38	0.43	0.00	0.00	0.00	0.00	0.00	0.00
HAM-11	0.35	0.87	1.03	1.08	1.44	1.72	0.99	13.88	69.94	8.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-12	0.08	0.17	0.16	0.18	0.23	0.26	0.37	2.06	36.27	59.18	0.39	0.39	0.26	0.00	0.00	0.00	0.00
HAM-13	0.55	1.46	1.78	2.08	3.18	4.76	6.42	10.17	18.73	20.27	9.59	5.18	2.43	2.39	10.91	0.00	0.00
HAM-14	0.42	1.02	1.20	1.32	1.58	1.64	1.57	29.93	59.40	1.64	0.27	0.00	0.00	0.00	0.00	0.00	0.00
HAM-15	0.32	0.76	0.91	1.08	1.77	3.97	15.10	34.62	40.78	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-16	0.50	1.15	1.31	1.61	2.20	2.59	1.72	12.89	62.33	13.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-17	0.11	0.22	0.19	0.17	0.20	0.21	0.17	2.07	39.69	52.72	2.76	1.48	0.00	0.00	0.00	0.00	0.00
HAM-18	0.48	1.27	1.81	2.23	2.55	3.07	2.07	12.80	59.44	14.02	0.00	0.26	0.00	0.00	0.00	0.00	0.00
HAM-19	0.13	0.26	0.27	0.29	0.37	0.39	0.20	6.67	58.56	32.47	0.39	0.00	0.00	0.00	0.00	0.00	0.00
HAM-20	0.39	1.08	1.72	2.43	3.75	6.77	15.75	35.14	19.82	10.83	2.32	0.00	0.00	0.00	0.00	0.00	0.00
HAM-22	0.15	0.41	0.56	0.65	0.88	1.32	2.66	13.20	24.98	38.61	9.57	2.21	0.71	4.09	0.00	0.00	0.00
HAM-23	0.48	1.37	1.95	2.57	3.35	3.78	3.84	46.04	28.43	7.52	0.66	0.00	0.00	0.00	0.00	0.00	0.00
HAM-25	0.46	1.45	2.23	3.02	3.93	4.57	4.97	33.79	36.80	7.22	1.51	0.00	0.07	0.00	0.00	0.00	0.00
HAM-26	0.60	1.88	3.02	4.23	3.71	6.59	12.50	31.30	28.47	6.07	1.21	0.40	0.00	0.00	0.00	0.00	0.00
HAM-27	0.49	1.36	2.04	2.66	2.87	2.35	3.20	38.99	43.67	2.29	0.00	0.00	0.09	0.00	0.00	0.00	0.00
HAM-28	0.50	1.51	2.43	3.27	3.98	4.03	6.82	46.55	29.59	1.08	0.23	0.00	0.00	0.00	0.00	0.00	0.00

SAMPLE NUMBER	CLAY			SILT				SAND					GRAVEL				
	11ϕ	10ϕ	9ϕ	8ϕ	7ϕ	6ϕ	5ϕ	4ϕ	3ϕ	2ϕ	1ϕ	0ϕ	-1ϕ	-2ϕ	-3ϕ	-4ϕ	-5ϕ
HAM-30	0.65	1.90	3.14	4.40	5.86	9.50	9.84	37.66	25.75	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-31	0.53	1.55	2.52	3.32	3.73	2.66	1.77	39.69	42.97	1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-32	0.37	1.04	1.49	1.94	2.49	3.18	4.01	52.14	31.80	1.28	0.26	0.00	0.00	0.00	0.00	0.00	0.00
HAM-34	1.11	3.73	6.40	8.89	12.21	12.32	7.31	19.12	27.62	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-35	0.64	2.08	3.44	4.42	5.33	5.68	5.18	52.07	20.95	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-36	0.42	1.40	2.33	3.28	4.41	3.72	3.37	41.51	38.75	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-37	0.35	1.12	1.76	2.33	2.46	1.91	1.13	7.12	64.30	17.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-38	0.32	1.07	2.03	3.43	5.20	6.20	4.60	52.62	22.84	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-39	0.54	1.72	2.99	4.48	5.81	6.05	4.42	53.57	19.83	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-40	0.46	1.44	2.58	3.90	5.52	6.05	3.73	57.46	17.78	0.84	0.23	0.00	0.00	0.00	0.00	0.00	0.00
HAM-41	0.41	1.26	2.02	2.84	4.24	5.72	6.79	11.04	25.38	36.19	3.45	0.61	0.04	0.00	0.00	0.00	0.00
HAM-42	5.29	2.67	7.74	3.54	5.38	5.97	4.12	0.52	9.18	23.51	29.76	2.15	0.15	0.00	0.00	0.00	0.00
HAM-43	0.23	0.72	1.20	1.79	2.86	5.04	14.02	8.37	27.41	33.63	4.07	0.59	0.06	0.00	0.00	0.00	0.00
HAM-44	0.64	2.05	3.43	4.95	6.38	6.45	5.24	56.76	13.39	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-45	0.30	1.03	1.99	3.09	5.04	6.84	14.63	46.82	15.76	3.76	0.47	0.27	0.00	0.00	0.00	0.00	0.00
HAM-47	0.17	0.49	0.73	0.93	1.39	3.29	11.39	59.49	21.71	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-50	0.11	0.33	0.58	0.94	1.64	2.77	7.09	7.10	4.77	4.69	11.50	13.45	17.49	20.58	6.96	0.00	0.00
HAM-51	0.26	0.77	1.20	1.69	2.63	4.04	7.56	6.17	21.85	42.89	9.75	0.57	0.64	0.00	0.00	0.00	0.00
HAM-52	0.25	0.80	1.40	2.06	2.64	3.18	2.02	2.10	22.79	56.97	5.78	0.00	0.00	0.00	0.00	0.00	0.00
HAM-53	0.34	1.14	2.09	3.26	4.92	7.89	9.60	4.66	28.50	36.55	0.85	0.00	0.22	0.00	0.00	0.00	0.00
HAM-54	0.88	2.61	4.08	5.79	8.79	15.55	17.37	34.54	10.11	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-55	0.73	2.22	3.63	5.21	7.77	13.95	22.05	31.63	10.80	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAM-56	0.21	0.59	0.92	1.47	3.26	13.88	57.81	10.49	7.48	3.61	0.28	0.00	0.00	0.00	0.00	0.00	0.00
HAM-57	0.07	0.20	0.35	0.56	1.43	7.06	21.11	5.33	23.12	36.96	3.05	0.76	0.00	0.00	0.00	0.00	0.00
HAM-58	0.11	0.33	0.54	0.80	1.25	2.28	2.78	1.15	16.62	31.81	17.34	4.73	9.81	10.44	0.00	0.00	0.00
HAM-59	0.32	0.97	1.58	2.46	4.16	7.81	10.37	6.35	18.83	34.27	11.69	1.01	0.17	0.00	0.00	0.00	0.00
HAM-60	0.86	2.65	4.55	6.74	10.24	15.83	13.94	9.72	18.53	13.78	2.67	0.50	0.00	0.00	0.00	0.00	0.00
HAM-61	0.16	0.48	0.76	1.11	1.73	2.49	2.33	3.60	22.07	38.47	4.19	5.22	13.13	1.86	2.39	0.00	0.00

APPENDIX C

This table contains the sample weight analyzed, percent gravel (>2.0 mm), percent sand (2.0 mm>x>0.062 mm), percent silt (0.063 mm>x>0.004 mm), percent clay (<0.004 mm), the verbal-equivalent sediment classification (Shepard, 1954), and the related method of moments statistics for each sample. Modes are given in the middle of whole phi intervals.

SAMPLE NUMBER	WEIGHT (GRAMS)	PERCENT GRAVEL	PERCENT SAND	PERCENT SILT	PERCENT CLAY	SEDIMENT CLASS	MEDIAN (ϕ)	MEAN (ϕ)	STANDARD DEVIATION	SKEWNESS	KURTOSIS	MODE 1 (ϕ)	MODE 2 (ϕ)	MODE 3 (ϕ)
HAM-1	37.4652	0.00	84.43	12.28	3.29	SAND	3.00	3.46	1.51	1.23	6.02	2.5		
HAM-2	38.4353	0.00	98.72	1.00	0.28	SAND	1.82	1.82	0.97	0.83	12.09	1.5		
HAM-3	37.4884	1.20	93.66	4.04	1.10	SAND	1.57	1.76	1.41	1.25	10.22	1.5		
HAM-4	39.2173	0.45	97.59	1.53	0.44	SAND	1.20	1.29	1.04	1.73	21.08	1.5		
HAM-5	39.9278	4.03	95.60	0.30	0.08	SAND	0.81	0.84	0.88	0.47	10.85	0.5		
HAM-6	38.3181	1.28	98.60	0.09	0.03	SAND	1.09	1.06	0.68	0.18	9.75	1.5		
HAM-8	37.6602	0.00	97.85	1.58	0.57	SAND	1.84	2.02	0.89	2.39	31.73	1.5		
HAM-9	37.3276	0.00	89.09	7.62	3.29	SAND	1.80	2.38	1.79	1.27	6.25	1.5		
HAM-10	35.5300	0.00	86.87	9.87	3.27	SAND	2.63	3.07	1.60	1.24	6.23	2.5		
HAM-11	33.4401	0.00	92.52	5.23	2.25	SAND	2.59	2.89	1.31	1.73	12.86	2.5		
HAM-12	37.3569	0.26	98.30	1.04	0.40	SAND	1.83	1.96	0.80	2.20	36.48	1.5		
HAM-13	36.7160	15.84	63.94	16.44	3.79	GRAVELLY SEDIMENT	1.96	1.93	3.02	0.06	0.15	1.5	-3.5	
HAM-14	34.1199	0.00	91.25	6.11	2.64	SAND	2.81	3.16	1.34	1.60	10.93	2.5		
HAM-15	32.3258	0.00	76.09	21.92	2.00	SAND	3.25	3.52	1.29	1.17	7.08	2.5		
HAM-16	34.9397	0.00	88.92	8.12	2.96	SAND	2.58	2.97	1.54	1.37	7.66	2.5		
HAM-17	37.8674	0.00	98.73	0.75	0.52	SAND	1.87	1.96	0.87	1.92	31.33	1.5		
HAM-18	34.0540	0.00	86.52	9.92	3.56	SAND	2.60	3.06	1.67	1.18	5.38	2.5		
HAM-19	35.7046	0.00	98.10	1.25	0.65	SAND	2.29	2.32	0.88	2.21	30.54	2.5		
HAM-20	32.1530	0.00	68.11	28.70	3.19	SILTY SAND	3.48	3.70	1.70	0.58	2.03	3.5		
HAM-21						BOULDERS								
HAM-22	36.3126	4.81	88.57	5.51	1.11	SAND	1.87	1.99	1.71	0.29	4.25	1.5		
HAM-23	33.8885	0.00	82.65	13.55	3.80	SAND	3.29	3.58	1.64	0.94	3.92	3.5		
HAM-24						BOULDERS								
HAM-25	33.8985	0.07	79.31	16.48	4.14	SAND	3.13	3.55	1.76	0.83	2.76	2.5		
HAM-26	33.3668	0.00	67.47	27.03	5.50	SILTY SAND	3.44	3.88	1.90	0.63	1.46	3.5		
HAM-27	37.1467	0.09	84.96	11.07	3.89	SAND	3.10	3.50	1.59	1.14	5.17	2.5		
HAM-28	32.6559	0.00	77.46	18.10	4.44	SAND	3.41	3.82	1.64	0.96	3.38	3.5		
HAM-29						BOULDERS								
HAM-30	34.6938	0.00	64.71	29.60	5.69	SILTY SAND	3.61	4.17	1.81	0.68	1.23	3.5		
HAM-31	33.8377	0.00	83.92	11.49	4.59	SAND	3.15	3.62	1.68	1.07	3.88	2.5		

SAMPLE NUMBER	WEIGHT (GRAMS)	PERCENT GRAVEL	PERCENT SAND	PERCENT SILT	PERCENT CLAY	SEDIMENT CLASS	MEDIAN (ϕ)	MEAN (ϕ)	STANDARD DEVIATION	SKEWNESS	KURTOSIS	MODE 1 (ϕ)	MODE 2 (ϕ)	MODE 3 (ϕ)
HAM-32	33.8165	0.00	85.48	11.62	2.90	SAND	3.32	3.57	1.39	1.24	6.92	3.5		
HAM-33						BOULDERS								
HAM-34	26.7220	0.00	48.03	40.73	11.24	SILTY SAND	4.27	4.86	2.23	0.20	-0.84	2.5	5.5	
HAM-35	32.7403	0.00	73.24	20.61	6.15	SILTY SAND	3.55	4.13	1.77	0.83	1.92	3.5	5.5	
HAM-36	35.4761	0.00	81.07	14.78	4.15	SAND	3.25	3.70	1.64	1.01	3.45	3.5		
HAM-37	35.4984	0.00	88.94	7.83	3.23	SAND	2.51	2.90	1.61	1.33	6.61	2.5		
HAM-38	33.9051	0.00	77.15	19.43	3.42	SAND	3.48	3.89	1.56	0.89	2.92	3.5	5.5	
HAM-39	32.6613	0.00	73.99	20.76	5.25	SILTY SAND	3.55	4.10	1.71	0.83	2.01	3.5	5.5	
HAM-40	33.5510	0.00	76.31	19.20	4.48	SAND	3.54	4.03	1.63	0.88	2.61	3.5	5.5	
HAM-41	35.5458	0.04	76.68	19.59	3.69	SAND	2.38	3.02	2.02	0.71	1.51	1.5		
HAM-42	30.1361	0.15	65.13	19.01	15.79	SILTY SAND	1.76	3.33	3.29	0.45	-0.66	0.5	8.5	5.5
HAM-43	36.2036	0.06	74.08	23.72	2.15	SILTY SAND	2.42	2.92	1.80	0.66	1.82	1.5	4.5	
HAM-44	32.6713	0.00	70.86	23.02	6.12	SILTY SAND	3.63	4.26	1.76	0.78	1.60	3.5	5.5	
HAM-45	33.3393	0.00	67.07	29.60	3.33	SILTY SAND	3.64	3.98	1.57	0.68	2.47	3.5		
HAM-46						BEDROCK								
HAM-46A						BEDROCK/BOULDERS								
HAM-47	33.6819	0.00	81.60	17.01	1.39	SAND	3.47	3.61	1.05	1.41	11.31	3.5		
HAM-48						BEDROCK								
HAM-49						BEDROCK								
HAM-50	40.6782	45.03	41.50	12.44	1.03	GRAVEL	-0.63	0.15	2.85	0.45	0.03	-2.5	3.5	
HAM-51	38.5832	0.64	81.23	15.91	2.22	SAND	1.91	2.50	1.85	0.81	2.82	1.5	4.5	
HAM-52	36.5561	0.00	87.64	9.90	2.46	SAND	1.78	2.34	1.75	1.19	5.24	1.5		
HAM-53	33.6617	0.22	70.55	25.67	3.56	SILTY SAND	2.43	3.18	2.04	0.64	0.87	1.5	4.5	
HAM-54	32.9078	0.00	44.91	47.51	7.57	SANDY SILT	4.29	4.80	1.80	0.51	0.41	3.5		
HAM-55	30.2655	0.00	44.43	48.99	6.58	SANDY SILT	4.25	4.66	1.77	0.50	0.68	3.5		
HAM-56	26.9446	0.00	21.86	76.42	1.72	SANDY SILT	4.49	4.55	1.21	0.26	4.02	4.5		
HAM-57	33.5613	0.00	69.22	30.16	0.62	SILTY SAND	2.40	2.86	1.59	0.42	0.44	1.5	4.5	
HAM-58	39.2375	20.25	71.65	7.12	0.98	GRAVELLY SEDIMENT	1.24	1.07	2.15	0.32	1.62	1.5	-2.5	
HAM-59	34.6700	0.17	72.16	24.80	2.87	SILTY SAND	2.15	2.87	2.10	0.56	0.74	1.5	4.5	
HAM-60	29.2900	0.00	45.19	46.75	8.06	SANDY SILT	4.34	4.42	2.33	0.18	-0.63	2.5	5.5	
HAM-61	38.7664	17.39	73.55	7.65	1.41	GRAVELLY SEDIMENT	1.60	1.49	2.21	0.26	1.74	1.5	-1.5	