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The texture of surficial sediments in eastern Long Island Sound near Falkner Island, Connecticut

by

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ABSTRACT

Grain-size analyses were performed on 38 samples from the vicinity of Falkner Island in eastern 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 12 others, are also presented.

Gravelly sediments and bouldery outcrops, which reflect environments of erosion or nondeposition, occur adjacent to Falkner and Goose Islands, over shoals extending northward and southward from the islands, and on isolated bathymetric highs in the northern part of the study area. Sands surround these gravelly deposits and dominate the remainder of the study area. Silty sands, which are the finest-grained sediments in the study area, occur in lower-energy, more-protected environments, such as in small patches just west and southeast of Goose Island.

INTRODUCTION

The Connecticut Coastal National Wildlife Refuge was established by an act of Congress on October 22, 1984, and later redesignated the Stewart B. McKinney National Wildlife Refuge. This Refuge includes Milford Point and four islands: the Chimon and Sheffield Islands off Norwalk, Ram Island at the mouth of the Mystic River, and Falkner Island (Giampa, 1986a; Fig. 1). Although Falkner Island covers about 5 acres at mean low water, the upland area of the island is only about 2.8 acres (Helander, 1988).

Falkner Island's inaccessibility has allowed it to remain relatively undeveloped and to become a refuge for rare and environmentally sensitive fauna and flora that have been unable to survive along the coastline proper. For example, the island is Connecticut's only significant habitat for Roseate Terns and the nesting area for 80 percent of Connecticut's population of Common Terns (Giampa, 1986a, b).

Goose Island, located about 1.5 km west-southwest of Falkner Island, also falls within the present study area. This flat-lying island, which is about 0.5 acre in size and awash during storm and perigee tides, is armored with boulders and gravel (Helander, 1988). Three other gravel-crested bathymetric highs, that are exposed during spring tides, surround Goose Island and include Stony Island, North Rocks, and Three Quarters Rock.

The purpose of this study was: 1) to measure the grain size distributions of the surficial sediment samples from eastern Long Island Sound near Falkner Island, 2) to determine the frequency distributions, and 3) 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 eastern 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

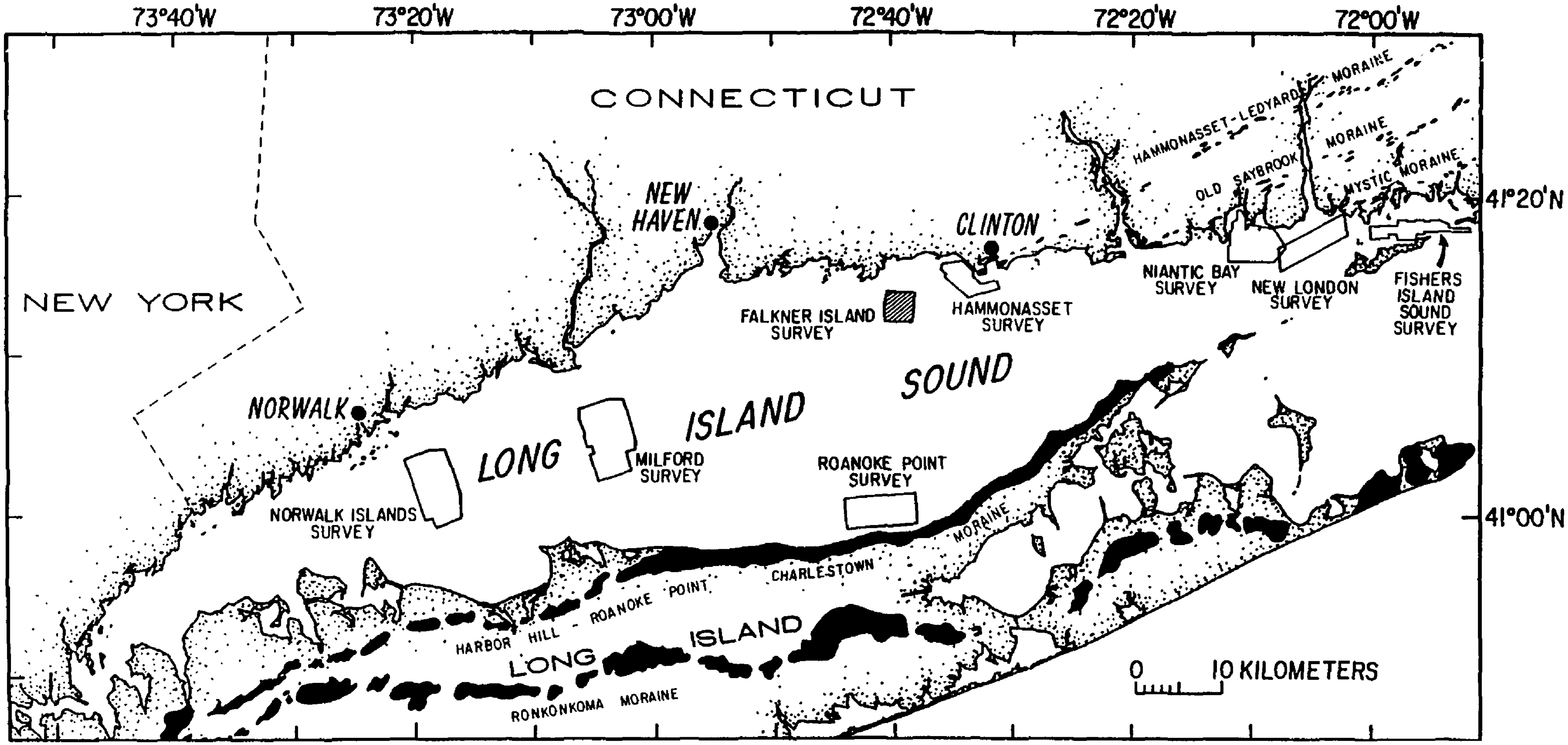

Figure 1. Index map showing the location of the Falkner Island study area (solid polygon). Map also shows the locations of other sidescan sonar and sampling surveys (open polygons) being completed as part of this series (Poppe and others, 1992; Poppe and others, 1994; Moffett and others, 1994; Twichell and others, 1995; Poppe and others, 1995a; Poppe and others, 1995b; Poppe and others 1996a; Poppe and others 1996b; Poppe and others, 1996c; Twichell and others, in press; Poppe and others, 1996d; Poppe and others, 1996e).

geochemical studies involving the transport and deposition of pollutants.

STUDY AREA

Long Island Sound is about 182 km long by a maximum of 32 km wide. It 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), which covers about 12.5 km^2, surrounds Falkner Island in northeastern Long Island Sound and lies about 4.4 km offshore from Guilford, Connecticut.

The bedrock beneath the study area is composed of gneissic and schistose metamorphic rocks of pre-Silurian age (Flint, 1971; Goldsmith, 1982; Rodgers, 1985). Onshore at nearby Sachem Head, bedrock units are exposed or only thinly covered (Ginsberg, 1976) and include the pink, medium to coarse grained Stony Creek Granitic Gneiss and the thinly bedded quartzite, mica schists, and dark gray granitic gneiss of the Plainfield Formation (Proterozoic?; Rodgers, 1985).

The bedrock across much of southeastern Connecticut is unconformably overlain by two tills, one of early Wisconsinan-Illinoian age and one of late Wisconsinan age (Lewis and Needell, 1987; Needell and others, 1987; Stone and Schafer, 1994). The till exposed on the eroding bluffs that surround the upland part of Falkner Island is fairly compact, stratified, and oxidized to a yellowish brown (Helander, 1988). These characteristics suggest that the Falkner Island till is composed of the older till (Schafer and Hartshorn, 1965; Gordon, 1980).

The northward retreat of the late Wisconsinan ice sheet is marked in southeastern Connecticut and beneath Long Island Sound by a northward succession of minor recessional moraines including the Hammonasset-Ledyard, Old Saybrook, and Mystic Moraines (Flint and Gebert, 1976; Goldsmith, 1982; Poppe and others, 1996d). Although earlier workers have described Falkner Island as a continuation of the Old Saybrook Moraine (Flint and Gebert, 1976), several lines of evidence suggest that the island is a drumlin (Stone and Schafer, personal communication, 1996). First, as stated above, the till on Falkner Island is of pre-Wisconsinan age, but the Old Saybrook Moraine is Late Wisconsinan (Schafer and Hartshorn, 1965). Second, the relief of the island itself is oriented approximately north-south, rather than the southwest-northeast trend that would be expected if Falkner Island were a continuation of the Old Saybrook Moraine (Flint, 1971). Third, the composition of the glacial drift on Falkner Island is more consistent with lodgement till rather than with ablation till. Finally, Falkner Island is located between the Old Saybrook and Hammonasset-Ledyard Moraine lines.

Deltaic and varved lake deposits of glacial Lake Connecticut variously overlie the bedrock and glacial drift around Falkner Island (Lewis and Stone, 1991; Stone and others, 1992). A marine mud facies, which occurs in quiet-water areas throughout the Long Island Sound basin, overlies these earlier deposits and records deposition during the postglacial Holocene eustatic rise of sea

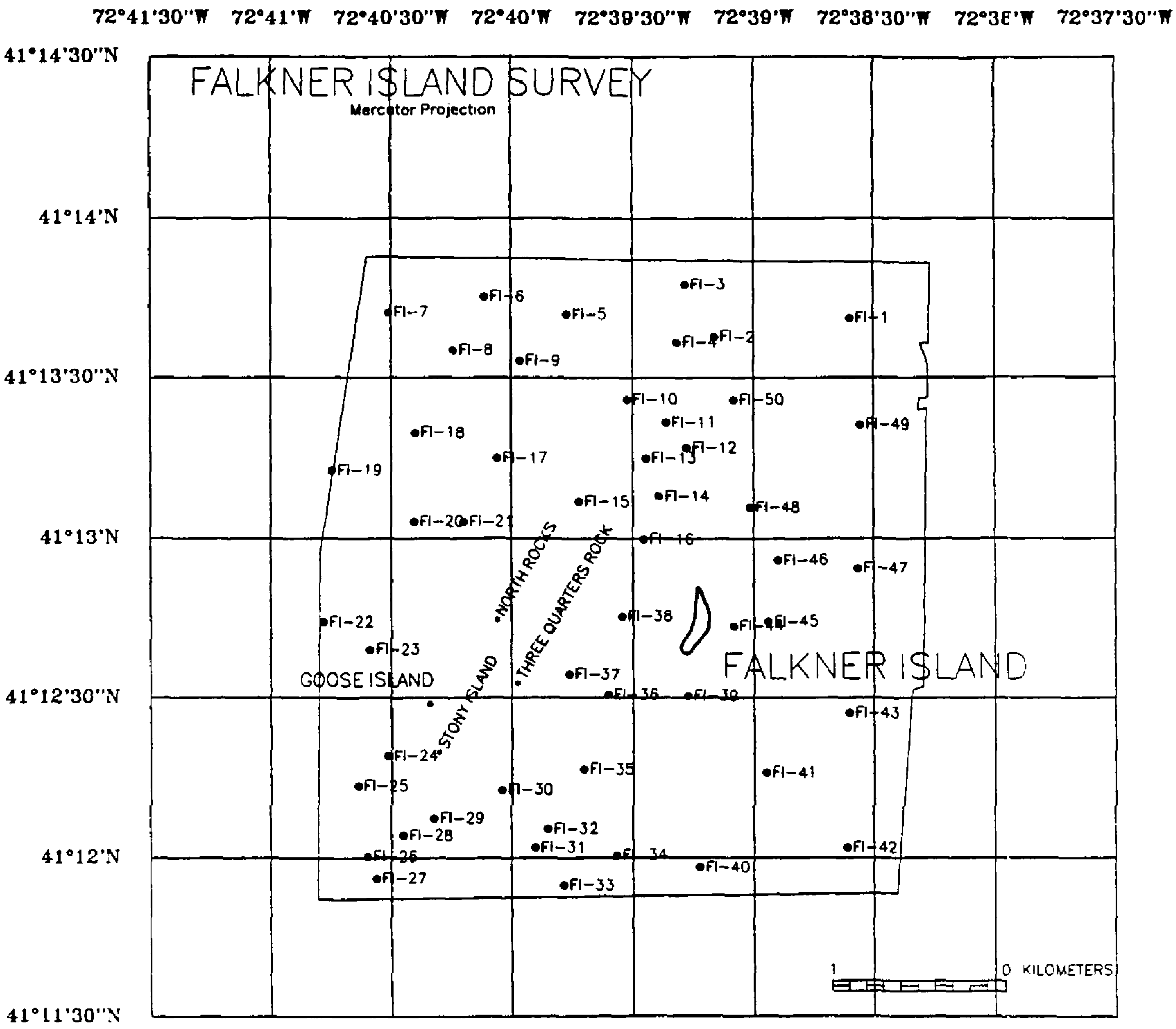

Figure 2. Map of the Falkner Island study area in eastern Long Island Sound showing the sampling and bottom photography station locations.

level.

Falkner Island has been ravaged by erosion. Estimates by Helander (1988) indicate that the upland area of the island has decreased by approximately 2.8 acres or 50 percent since 1818, when observations on island size were first conducted. These estimates also show that the rate of erosion is much greater on the north and south bluffs than on the east and west bluffs. For example, the east and west bluffs are eroding at 2.5 to 5.0 cm/yr, but the island's northern point has been abraded to a knife's edge and is presently eroding at a rate of about 25 cm/yr (Helander, 1988).

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

METHODS

Surficial sediment samples and bottom photographs were attempted at 50 locations during March, 1997 aboard the State of Connecticut Department of Environmental Protection vessel the RV JOHN DEMPSEY using a Van Veen grab sampler (Figs. 1 and 2). This grab sampler was equipped with 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 where sediment samples could not be collected (Appendix A). The 0-2 cm interval in the surficial sediments was 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 38 sediment samples were collected for grain size analysis. The samples were thawed and visually inspected in the laboratory. If the sample contained gravel, the entire sample was analyzed. If the sample was composed of only sand, silt, and clay, an approximately 50 gram, representative split was analyzed. The sample to be analyzed was placed in preweighed 100 ml beaker, weighed, and dried in a convection oven set at 75 °C. When dried, 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 25 °/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 °C and weighed. The weight of the coarse (greater than 62 μm) fraction is equal to the weight sand plus gravel. The weight 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 may not be 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, the sand fraction was dry sieved using a Ro-Tap shaker.

The fine fraction was analyzed by Coulter Counter. To minimize biologic or chemical changes, storage in the Mason jars prior to analysis never exceeded two 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 that it has only the ability to "see" those particles for which it has been calibrated. Calibration for this study allowed us to determine the distribution down to 0.7 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, a slight decrease in the 11ϕ (and finer) fraction is present in the size distributions (Appendix B).

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. FI-1) tend to be located in the northern portion of the study area; sample locations with higher numerical designations (FI-42) tend to be located in the southern or eastern portions 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).

Boulders and gravel occur in high-energy environments of erosion or nondeposition, such as in the shallows adjacent to Falkner and Goose Islands (e.g. FI-24, FI-39), over shoals extending northward (e.g. FI-12, FI-21) and southward from the islands (e.g. FI-29, FI-39), and on isolated bathymetric highs (e.g. FI-5). These coarse deposits are associated with outcrops of glacial till and, in the case of the occurrences adjacent to the islands, are probably lag deposits of the till still exposed on Falkner Island (Helander, 1988). Scattered patches of current-rippled sand and silty sand are occasionally present between the boulders (e.g. FI-28). Barnacles, sponges, mussels, hydrozoans, anemones, and seaweed commonly grow on the boulders. Starfish and rock crabs are also present.

Aprons of gravelly sand, which commonly armor finer-grained underlying sediments, occasionally surround the areas of boulders and gravel (e.g. FI-31, FI-32). These gravelly sands are very to extremely poorly sorted, coarse-skewed, and leptokurtic. Hydrozoans grow on the gravel; shells and shell debris are common. Scour features are typically present around isolated pieces of gravel.

Sand is the dominant sediment textural class within the study area. The sands are typically very fine grained (the average mean is 3.60 ϕ), nearly symmetrical to extremely fine-skewed, and very to extremely leptokurtic. The sands in the shallow areas between the islands and east of Falkner Island are well to moderately well sorted, but sorting decreases toward both the southern and northern parts of the study area where the sands are poorly to moderately sorted and poorly sorted, respectively. Current ripples were ubiquitously observed in the bottom video within the sandy areas. Rust-brown organic debris collects in the troughs of the ripples in lower-energy environments; very fine gravel- and coarse sand-sized shell hash concentrates in the troughs of ripples in the higher-energy environments. Scattered worm tubes, shrimp burrows, patchy amphipod communities, crab tracks, and snails increase in abundance with increasing silt content of the sands. Hermit crabs and starfish increase in abundance with decreasing silt content. Razor clam debris is occasionally common.

Finer-grained sediments are generally restricted to lower-energy, more-protected environments, such as enclosed bathymetric depressions (e.g. FI-50) and the areas just west and southeast of Goose Island (e.g. FI-23, FI-30, FI-35). These silty sands are poorly sorted, strongly fine-skewed, and very leptokurtic. Although these finer-grained sediments are faintly rippled, amphipods, polychete tubes, shrimp burrows, and snail and rock crab tracks are commonly present.

Interested parties can obtain copies of the grain-size analysis data, the associated statistics, and an explanation of the variable headings in ASCII format and on 3.5" diskettes for this and other bottom sampling and photographic studies completed as part of this series (Poppe and others, 1992; Poppe and others, 1995b; Poppe and others, 1996a, Poppe and others, 1996b) at the offices of the Coastal and Marine Geology Program of the U.S. Geological Survey in Woods Hole, Massachusetts or at the Long Island Sound Resource Center at Avery Point, Groton, Connecticut. Videotapes showing the bottom character of the station locations can be viewed at the offices of the U.S. Geological Survey in Woods Hole, Massachusetts.

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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. Stations are presented in chronological order.

SAMPLE	LATITUDE	LONGITUDE	DEPTH (M)	COMMENTS
FI-1	41d13.6874'	-72d38.5985'	16.6	CURRENT RIPPLES, TRACE OF RAZOR CLAM SHELLS AND SHELL DEBRIS, FEW WORM TUBES, HERMIT CRABS
FI-2	41d13.6289'	-72d39.1629'	19.7	CURRENT RIPPLES, TRACE OF SHELL DEBRIS, WORM TUBES
FI-3	41d13.7931'	-72d39.2836'	18.0	CURRENT RIPPLES, TRACE OF SHELL DEBRIS, SCATTERED WORM TUBES AND AMPHIPODS
FI-4	41d13.6110'	-72d39.3186'	22.1	CURRENT RIPPLES, WORM TUBES, SHRIMP BURROWS, AMPHIPODS
FI-5	41d13.6997'	-72d39.7705'	21.9	BOULDERS, GRAVEL, SPONGES, HYDROZOANS, SOME SEAWEED, RIPPLED SAND INBETWEEN THE ROCKS
FI-6	41d13.7532'	-72d40.1103'	18.3	CURRENT RIPPLES, SCATTERED SHELLS AND DEBRIS WITH SCOUR SHADOWS, WORM TUBES
FI-7	41d13.7048'	-72d40.5096'	18.8	CURRENT RIPPLES, TRACE OF SHELL DEBRIS WITH SCOUR MARKS AROUND THE SHELL FRAGMENTS
FI-8	41d13.5846'	-72d40.2414'	21.5	GRAVEL ARMORING SAND, HERMIT CRABS, RAZOR CLAM SHELLS AND DEBRIS
FI-9	41d13.5519'	-72d39.9627'	24.5	CURRENT RIPPLES
FI-10	41d13.4328'	-72d39.5218'	22.1	CURRENT RIPPLES, TRACE OF SHELL DEBRIS, WORM TUBES, HERMIT CRABS
FI-11	41d13.3609'	-72d39.3618'	21.1	GRAVEL, SAND PATCHES, SPONGES
FI-12	41d13.2835'	-72d39.2783'	9.2	GRAVEL, SPONGES, RAZOR CLAM DEBRIS, LOBSTER, HYDROZOANS
FI-13	41d13.2506'	-72d39.4461'	8.8	CURRENT RIPPLES, SCATTERED RAZOR CLAM SHELLS AND DEBRIS, STARFISH, SNAILS, SHRIMP
FI-14	41d13.1330'	-72d39.3917'	7.5	CURRENT RIPPLES, SCATTERED SHELL DEBRIS, WORM TUBES, HERMIT CRABS, SNAILS
FI-15	41d13.1156'	-72d39.7223'	8.7	CURRENT RIPPLES, SCATTERED RAZOR CLAM SHELLS AND DEBRIS, SOME GRAVEL, WORM TUBES, SHRIMP BURROWS, TRACKS, SNAILS
FI-16	41d12.9975'	-72d39.4543'	6.9	CURRENT RIPPLES, RAZOR CLAM SHELLS, TRACKS, TRACE OF SEAWEED
FI-17	41d13.2499'	-72d40.0589'	15.1	CURRENT RIPPLES, RAZOR CLAM SHELLS AND DEBRIS, ROCK AND HERMIT CRABS, TRACKS, SNAILS
FI-18	41d13.3298'	-72d40.4002'	10.0	BOULDERS, RIPPLED SAND BETWEEN THE ROCKS, SPONGES, HYDROZOANS, STARFISH, SNAILS, SCATTERED SEAWEED
FI-19	41d13.2119'	-72d40.7458'	11.1	CURRENT RIPPLES, WORM TUBES, SNAILS, TRACKS
FI-20	41d13.0526'	-72d40.4060'	12.9	FAINT RIPPLES, SCATTERED RAZOR CLAM SHELLS AND DEBRIS, WORM TUBES, SHRIMP BURROWS, AMPHIPODS
FI-21	41d13.0513'	-72d40.1982'	7.8	BOULDERS, SPONGES, HYDROZOANS
FI-22	41d12.7380'	-72d40.7818'	9.3	CURRENT RIPPLES, SOME SHELL DEBRIS, WORM TUBES, WELK
FI-23	41d12.6521'	-72d40.5891'	8.0	CURRENT RIPPLES, SCATTERED SHELL DEBRIS, WORM TUBES, SHRIMP BURROWS, SPIDER CRAB
FI-24	41d12.3183'	-72d40.5147'	9.4	BOULDERS, COBBLES, GRAVEL, HYDROZOANS, ABUNDANT SHELLS BETWEEN THE ROCKS

SAMPLE	LATITUDE	LONGITUDE	DEPTH (M)	COMMENTS
FI-25	41d12.2247'	-72d40.6415'	11.8	CURRENT RIPPLES, SOME SCATTERED SHELL DEBRIS, WORM TUBES
FI-26	41d12.0045'	-72d40.6007'	27.8	BOULDERS ON FATHOMETER (NO VIDEO)
FI-27	41d11.9353'	-72d40.5623'	30.7	CURRENT RIPPLES, NUMEROUS HERMIT CRABS, OAK LEAVES
FI-28	41d12.0702'	-72d40.4519'	18.9	BOULDERS, RIPPLED SANDY PATCHES, TRACES OF SHELL DEBRIS
FI-29	41d12.1240'	-72d40.3193'	15.1	BOULDERS, COBBLES, SPONGES, MUSSELS, HYDROZOANS, SAND BETWEEN BOULDERS
FI-30	41d12.2128'	-72d40.0402'	10.4	FAINT RIPPLES, WORM TUBES, SHRIMP BURROWS, AMPHIPODS, TRACKS, SNAILS, OAK LEAVES
FI-31	41d12.0326'	-72d39.9040'	28.7	GRAVELLY, SCATTERED SHELL DEBRIS, SCOUR FEATURES AROUND THE GRAVEL
FI-32	41d12.0910'	-72d39.8511'	24.0	GRAVELLY, SCATTERD SHELLS AND DEBRIS, HYDROZOANS, OAK LEAVES
FI-33	41d11.9143'	-72d39.7869'	27.7	CURRENT RIPPLES, TRACE OF SHELL DEBRIS
FI-34	41d12.0086'	-72d39.5682'	17.4	BOULDERS, GRAVEL
FI-35	41d12.2771'	-72d39.7046'	10.2	CURRENT RIPPLES, MUDDY, HEAVILY BURROWED BY WORMS AND SHRIMP, SCATTERED SHELL DEBRIS
FI-36	41d12.5089'	-72d39.6040'	9.1	CURRENT RIPPLES, SOME GRAVEL, SCATTERED SHELLS, SCOUR AROUND SHELLS
FI-37	41d12.5708'	-72d39.7638'	6.5	BOULDERS,SPONGES, HYDROZOANS, PATCHES OF RIPPLED SAND
FI-38	41d12.7558'	-72d39.5459'	5.5	CURRENT RIPPLES, WORM TUBES,SHRIMP BURROWS, SNAILS, TRACKS, SCATTERED SEAWEED
FI-39	41d12.5056'	-72d39.2738'	14.5	BOULDERS, GRAVEL, SPONGES, HYDROZOANS, CRABS, STARFISH, SAND PATCHES
FI-40	41d11.9709'	-72d39.2261'	25.2	CURRENT RIPPLES, SCATTERED SHELL DEBRIS, WORM TUBES,HERMIT CRABS
FI-41	41d12.2665'	-72d38.9497'	17.5	CURRENT RIPPLES, RAZOR CLAM SHELL DEBRIS
FI-42	41d12.0318'	-72d38.6118'	23.1	CURRENT RIPPLES, SCATTERED SHELL DEBRIS, SNAILS, TRACKS
FI-43	41d12.4514'	-72d38.6022'	12.9	CURRENT RIPPLES, SCATTERED RAZOR CLAM SHELLS AND DEBRIS
FI-44	41d12.7261'	-72d39.0856'	5.0	FAINT RIPPLES, BIOTURBATED, HEAVILY BURROWED BY SHRIMP AND WORMS
FI-45	41d12.7395'	-72d38.9422'	6.3	CURRENT RIPPLES, SNAILS, WORM TUBES
FI-46	41d12.9318'	-72d38.9006'	5.0	CURRENT RIPPLES, WORM TUBES
FI-47	41d12.9070'	-72d38.5671'	6.7	CURRENT RIPPLES, CLEAN WELL SORTED, TRACES OF SHELL HASH
FI-48	41d13.0980'	-72d39.0175'	5.8	CURRENT RIPPLES, SCATTERED SHELL DEBRIS, SEAWEED, SHRIMP BURROWS, WORM TUBES, SNAILS, ABUNDANT TRACKS
FI-49	41d13.3542'	-72d38.5536'	15.0	CURRENT RIPPLES, SCATTERED AMPHIPODS, WORM TUBES, RAZOR CLAM SHELLS, SNAILS, TRACKS
FI-50	41d13.4318'	-72d39.0835'	29.5	CURRENT RIPPLES, WORM TUBES, SNAILS

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
FI-1	1.00	2.14	2.97	3.24	2.84	0.79	0.70	51.62	34.36	0.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-2	1.45	2.26	2.82	3.13	2.31	1.05	2.17	50.22	32.91	1.70	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-3	3.25	3.79	5.90	6.34	4.58	1.28	0.63	46.40	27.84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-4	1.14	2.83	4.30	4.80	3.77	1.32	1.90	53.56	26.06	0.32	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-6	1.09	2.52	3.82	4.92	4.78	2.46	2.99	56.67	20.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-7	1.58	3.87	5.86	7.26	5.84	3.06	5.93	51.49	15.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-8	0.19	0.55	0.86	1.13	1.27	0.64	0.20	9.11	13.45	16.75	3.43	0.65	0.78	2.97	15.11	12.64	20.25
FI-9	0.90	2.38	3.52	4.37	5.77	3.41	0.65	39.69	28.10	10.18	0.31	0.0	0.0	0.71	0.0	0.0	0.0
FI-10	0.54	1.61	2.57	3.12	2.15	1.02	0.88	33.60	19.35	14.78	19.00	1.23	0.13	0.0	0.0	0.0	0.0
FI-13	0.38	1.00	1.37	1.29	0.76	0.25	1.25	59.50	32.98	1.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-14	0.34	0.73	0.66	0.50	0.37	0.30	0.70	71.33	23.13	1.93	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-15	0.40	0.97	1.21	1.22	0.98	0.49	0.52	56.15	34.95	3.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-16	0.61	1.72	2.54	2.79	2.34	0.90	0.80	67.90	20.04	0.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-17	0.90	2.53	3.72	4.14	3.17	1.71	1.76	58.18	23.88	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-19	0.45	1.25	1.84	2.10	1.95	1.04	0.42	61.67	28.92	0.36	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-20	0.85	2.38	3.31	3.49	2.25	1.22	1.54	65.16	19.03	0.76	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-22	1.00	2.37	2.73	2.70	2.17	1.49	1.53	58.83	27.18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-23	0.66	1.92	3.02	3.79	2.97	3.28	10.85	61.24	12.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-25	0.92	2.56	3.74	3.92	2.83	2.36	4.33	68.90	10.39	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.0
FI-27	0.34	0.93	1.35	1.45	1.32	0.78	1.57	63.74	27.40	1.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-30	2.55	8.30	14.28	17.44	10.17	7.39	10.18	18.59	9.24	1.51	0.18	0.18	0.0	0.0	0.0	0.0	0.0
FI-31	0.73	2.21	3.56	4.93	6.38	5.34	4.23	26.90	15.07	5.45	2.93	1.08	0.66	1.79	18.74	0.0	0.0
FI-32	0.42	1.21	2.09	2.72	2.58	2.95	5.37	22.03	14.86	11.66	9.80	5.70	3.96	4.56	10.09	0.0	0.0
FI-33	0.82	2.06	2.60	2.69	2.90	2.33	2.67	59.93	24.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-35	1.30	3.61	4.70	5.04	3.65	2.61	12.97	49.52	15.67	0.60	0.33	0.0	0.0	0.0	0.0	0.0	0.0
FI-36	0.20	0.50	0.60	0.61	0.67	1.37	6.00	41.81	11.69	8.81	25.18	2.43	0.13	0.0	0.0	0.0	0.0
FI-38	0.21	0.39	0.33	0.27	0.27	0.37	2.45	77.12	17.04	0.96	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-40	0.37	0.98	1.38	1.66	2.24	2.25	3.50	59.88	27.41	0.0	0.0	0.0	0.05	0.28	0.0	0.0	0.0

SAMPLE NUMBER	CLAY 11ϕ	10ϕ	9ϕ	SILT 8ϕ	7ϕ	6ϕ	5ϕ	SAND 4ϕ	3ϕ	2ϕ	1ϕ	0ϕ	GRAVEL -1ϕ	-2ϕ	-3ϕ	-4ϕ	-5ϕ
FI-41	0.28	0.82	1.24	1.56	1.64	1.32	4.45	51.97	36.72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-42	0.48	1.46	2.30	2.70	2.82	2.07	2.29	46.46	39.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-43	0.95	3.01	4.87	5.06	2.91	2.91	5.19	43.18	31.92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-44	0.57	1.52	2.14	2.63	3.43	3.21	7.90	67.21	11.08	0.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-45	0.18	0.42	0.50	0.53	0.53	0.46	2.59	71.47	22.94	0.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-46	0.34	0.80	0.99	1.09	1.07	0.76	0.65	61.95	32.34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-47	0.22	0.49	0.47	0.40	0.38	0.40	1.02	53.72	42.90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-48	0.14	0.38	0.54	0.61	0.77	0.92	5.43	64.85	26.36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-49	0.40	1.16	1.78	2.19	2.35	2.09	1.41	50.61	37.67	0.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FI-50	1.27	3.67	5.62	6.93	8.47	5.83	1.60	50.76	15.85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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)
FI-1	35.1914	0.00	86.33	7.56	6.11	SAND	3.30	3.73	1.74	1.14	4.34	3.5		
FI-2	36.5044	0.00	84.82	8.65	6.53	SAND	3.31	3.75	1.80	1.12	4.22	3.5		
FI-3	32.6290	0.00	74.24	12.83	12.93	CLAYEY SAND	3.48	4.39	2.30	0.68	0.40	3.5	7.5	
FI-4	33.7081	0.00	79.94	11.79	8.27	SAND	3.44	4.05	1.93	0.90	2.03	3.5		
FI-6	33.2262	0.00	77.42	15.15	7.44	SAND	3.52	4.13	1.86	0.89	2.03	3.5		
FI-7	31.5962	0.00	66.61	22.09	11.30	SILTY SAND	3.68	4.57	2.10	0.63	0.26	3.5	7.5	
FI-8	564.5700	51.75	43.39	3.25	1.61	GRAVEL	-2.33	-1.02	3.83	0.20	-0.92	-5.5	1.5	-3.5
FI-9	33.4757	0.71	78.28	14.20	6.80	SAND	3.27	3.77	2.09	0.60	1.55	3.5	6.5	
FI-10	37.2031	0.13	87.97	7.18	4.72	SAND	2.77	2.87	2.11	0.67	2.03	3.5	0.5	
FI-13	36.3347	0.00	93.70	3.55	2.75	SAND	3.27	3.39	1.21	1.77	14.11	3.5		
FI-14	35.3397	0.00	96.39	1.88	1.74	SAND	3.35	3.38	0.97	2.22	25.86	3.5		
FI-15	38.0931	0.00	94.21	3.21	2.58	SAND	3.21	3.33	1.23	1.69	13.44	3.5		
FI-16	35.6940	0.00	88.29	6.83	4.87	SAND	3.44	3.77	1.52	1.32	6.34	3.5		
FI-17	33.3823	0.00	82.07	10.79	7.15	SAND	3.45	3.97	1.80	1.01	2.96	3.5		
FI-19	35.6068	0.00	90.96	5.51	3.54	SAND	3.34	3.57	1.38	1.48	8.82	3.5		
FI-20	34.1874	0.00	84.95	8.51	6.54	SAND	3.46	3.91	1.70	1.13	4.21	3.5		
FI-22	36.1894	0.00	86.01	7.89	6.10	SAND	3.39	3.79	1.68	1.21	5.05	3.5		
FI-23	35.0656	0.00	73.52	20.89	5.59	SILTY SAND	3.62	4.10	1.60	1.06	3.78	3.5		
FI-25	33.4271	0.05	79.29	13.44	7.22	SAND	3.57	4.13	1.72	1.05	3.37	3.5		
FI-27	35.2885	0.00	94.24	5.13	2.63	SAND	3.34	3.48	1.21	1.67	12.57	3.5		
FI-30	30.7604	0.0	70.00	19.27	10.72	SILTY SAND	3.54	4.48	2.21	0.64	1.25	3.5	7.5	
FI-31	32.9811	21.19	51.43	20.87	6.50	GRAVELLY SEDIMENT	3.16	2.56	3.67	-0.15	-0.61	3.5	-3.5	6.5
FI-32	131.7930	18.61	64.05	13.62	3.72	GRAVELLY SEDIMENT	2.28	1.92	3.07	0.03	-0.12	3.5	-3.5	
FI-33	34.8963	0.00	83.93	10.59	5.48	SAND	3.43	3.84	1.63	1.18	4.92	3.5		
FI-35	31.3330	0.00	66.11	24.27	9.62	SILTY SAND	3.67	4.36	1.97	0.76	1.31	3.5	7.5	
FI-36	38.6147	0.13	89.92	8.65	1.30	SAND	3.04	2.55	1.70	0.33	1.86	3.5	0.5	
FI-38	37.5777	0.00	95.72	3.35	0.93	SAND	3.41	3.42	0.74	2.68	42.86	3.5		
FI-40	35.1613	0.33	87.28	9.66	2.73	SAND	3.37	3.57	1.33	1.20	9.21	3.5		

SAMPLE NUMBER	WEIGHT (GRAMS)	PERCENT GRAVEL	PERCENT SAND	PRECENT SILT	PRECENT CLAY	SEDIMENT CLASS	MEDIAN (Φ)	MEAN (Φ)	STANDARD DEVIATION	SKEWNESS	KURTOSIS	MODE 1 (Φ)	MODE 2 (Φ)	MODE 3 (Φ)
FI-41	34.1288	0.00	88.69	8.97	2.34	SAND	3.26	3.45	1.23	1.54	10.68	3.5		
FI-42	33.4722	0.00	85.88	9.88	4.24	SAND	3.23	3.60	1.56	1.22	5.43	3.5		
FI-43	32.3095	0.00	75.10	16.07	8.83	SAND	3.42	4.07	1.98	0.83	1.52	3.5	7.5	
FI-44	34.2264	0.00	78.60	17.17	4.23	SAND	3.57	3.97	1.45	1.22	5.67	3.5		
FI-45	36.8441	0.00	94.79	4.11	1.10	SAND	3.37	3.40	0.83	2.32	29.89	3.5		
FI-46	36.2340	0.00	94.30	3.57	2.13	SAND	3.28	3.40	1.11	1.91	16.74	3.5		
FI-47	36.6896	0.00	96.61	2.21	1.18	SAND	3.13	3.18	0.88	2.36	29.65	3.5		
FI-48	34.1422	0.00	91.20	7.74	1.06	SAND	3.36	3.42	0.88	1.96	21.85	3.5		
FI-49	34.0736	0.00	88.64	8.03	3.33	SAND	3.24	3.52	1.42	1.36	7.38	3.5		
FI-50	31.5494	0.00	66.62	22.83	10.55	SILTY SAND	3.67	4.60	2.08	0.58	0.04	3.5	6.5	