Toward a model of sedimentation in Kettle Creek and Silver Bay, Northern Barnegat Bay, New Jersey

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Abstract

Estuarine sediment accumulations are a product of continental and marine processes. In Barnegat Bay, New Jersey, a micro-estuarine environment exists as a series of smaller estuaries along the western coast. This situation provides a microcosm for studying the interaction of sediment type as it relates to geomorphology and fluid flow within an estuary. Sediment sampling was conducted in Kettle Creek and Silver Bay over the past four years. By using GIS-plotted transects of sediment sampling and laboratory analyses of mean grain size and standard deviation, trends of sediment characteristics were established across the micro-estuaries.

Further data analysis using statistical and mapping software illustrate a pattern of spatial distribution and grouping of sediment types that was repeated in both Kettle Creek and Silver Bay. Fine silts ($<63\ \mu m$) accumulated in areas of fluvial input and throughout the middle of each micro-estuary, grading bayward to fine and then coarser sands along the coasts. Pleistocene relic sediments were found in isolated areas near the bay mouths of both Kettle Creek and Silver Bay. The spatial organization of morpho-sedimentary characteristics among the two micro-estuaries suggests a pattern may be repeated in other portions of the western margin of Barnegat Bay. This study establishes a replicable means of micro-estuarine analysis, with not only geomorphological, but ecological and biological implications as well.

Introduction

Barnegat Bay is a lagoon-type estuary that is located along the southeastern coast of New Jersey. It spans approximately 48 km in length and varies between 2 to 6.5 km in width (Lordi, 1997). Kettle Creek and Silver Bay are neighboring micro-estuaries along the northwestern coast of Barnegat Bay (Figure 1). Considering its size and importance to New Jersey's coast, Barnegat Bay has been the subject of relatively little sedimentological research. An early study of the bay as a whole concluded that sandy mud and muddy sand dominate the northwest area of the bay near the entrances to these micro-estuaries (Chizmadia et. al, 1984). Other studies in the bay focused on fluid flows and sediment distribution in the channels and flood tidal delta of Barnegat Inlet (Stauble and Cialone, 1995) and sedimentation associated with the inlet jetties (Fields, 1984).

The paucity of detailed geomorphological and sedimentological studies in Barnegat Bay has resulted in very general descriptions of the physical foundation of the bay and a lack of recognition of the many morpho-sedimentological constituents of the estuarine system. In particular, there is a lack of detailed information concerning the dissected western margin of Barnegat Bay. The micro-estuaries that occur along this margin represent a unique environment for study of the interaction of fluid flows and sediment distribution, and their relatively small size facilitates sampling. The repeated occurrence of such micro-estuaries along the coast of the bay allows us to compare sediment distribution and to determine if a pattern of sedimentation emerges among these environments. Each micro-estuary has areas of fluvial input as streams and rivers feed into their headward portions. Each also has a zone of coastal processes along its margins with natural as well as human produced features. Mouths of the micro-estuaries displayed the interaction between the more and less energetic processes characteristic of bays and microestuaries, respectively.

Methods

The study of the morpho-sedimentological features was conducted through a systematic sampling of the bottom sediments and their consequent analysis. Sampling sites (Figure 2) were chosen in Kettle Creek and Silver Bay along initial transects across the width and along the length of each micro-estuary. A surface grab sampler was used to collect approximately 60 g of sample while recording bathymetry. A Magellan GPS with a differential beacon receiver was used to obtain point location during collection.

Samples were labeled and stored in Ziploc bags at 4^{o}C to prevent degradation. Lab analysis included standard sediment processing to determine mean grain size. Approximately 12 g of sample was treated with 30 mas % hydrogen peroxide to eliminate organics and then deflocculated with 5 Calgon/distilled water solution overnight. Wet sieving through a 63 μm sieve with 2000 ml of distilled water separated fines (sediments with grain sizes less than 63 μm) from coarser sands. A Spectrex LPC ILI 1000 was used to obtain mean grain sizes of fines after a dilution series was made with distilled water. Coarser fractions were then oven dried at 75^{o}C and sonic sifted in a standard ATM Sonic Sifter through a series of sieves ranging from 1700 μm (2 φ) to 63 μm (4 φ). Relic sediments (in our case very coarse gravels) were hand sifted in larger sieves. Results of Spectrex and sonic sifting were then entered into an Excel spreadsheet to create a grain size histogram. Mean size, skewness, kurtosis, and standard deviation were determined for each sample.

Lab analysis yielded mean grain sizes of sediment in φ categories. The φ system is used to represent sediment size The φ size of a particle represents the $-\log_2$ of the particle size in mm. Statistical analysis allowed us to group sediments by not only mean grain sizes in φ, but aided in the determination of sorting characteristics of the data set. Mapping software was used to visualize the distribution of sediment types in each micro-estuary, and to relate spatially mean grain size as well as other sample characteristics.

In further data analysis, these characteristics were plotted against each other to search for correlations.Attributes of sampling points were entered into Arc View in New Jersey State Plane

Coordinates to create maps of bathymetry, mean grain size, and standard deviation. The data set is currently being evaluated using statistical programs to perform principal components analysis to identify further trends.

Results and discussion

Data from the overboard sediment sampling and existing general bathymetry were combined to obtain the most complete bathymetric portrayal to date of Kettle Creek and Silver Bay (Figure 3). We referenced recent maps of Barnegat Bay bathymetry before sampling and recorded depths as we sampled. We compared the values that we obtained to depths from hydrographic charts of the area. Sampling was conducted during the summers of 1998, 1999, and 2000. Since we have constantly returned to the same areas to take new samples and fill in gaps, we feel that the depth information gathered represents that of each micro-estuary during the most recent sampling we conducted.

As noted, the time of year that we sampled was consistent throughout the several years that this project has been underway, namely the summer months. Barnegat bay does not realize a significant change in tides from year to year that would affect the results obtained. We generally sampled at high tide so that we could access the shallowest areas by boat.

Depth varied between 0 and 2 m throughout each micro-estuary. Kettle Creek exhibited a 11.3 m depth throughout the center, grading to 0—0.3 m depth around its perimeter. Silver Bay exhibited a slightly deeper 1.5-2.0 m region in the southern portion of its center, otherwise grading from 1-1.3 m at its center to 0-0.3 m along the perimeter. Both micro-estuaries have a shallow subaqueous barrier at the transition between the smaller micro-estuary and the larger Barnegat Bay, grading from depths of 0.3 m at the barrier to 0.7-1.0 m and deeper into Barnegat Bay.

Figure 4 illustrates the distribution of mean grain sizes throughout Kettle Creek and Silver Bay. There are similar sediment distributions in both micro-estuaries with fine sediment dominating in the areas of fluvial input at the inland margin and central portion in each microestuary and ranging from 4 to 5 □. Fine sands grade to medium sands (4 to 1.25 □) from the center toward the bay shores and toward the bay mouth. Coarser sands are located near the bay mouth, in the range of —0.5 □. Further, there are occasional relic sediments which are part of the older drowned topography. Their grain sizes reach nearly -4 □ (16 mm).

The spatial distribution of standard deviations of the individual sediment samples throughout both micro-estuaries is shown in Figure 5. The lowest standard deviations (narrowest distribution of grain sizes) are evident towards the coastal areas of each micro-estuary whereas higher standard deviations are characteristic of the central area in each micro-estuary. This observation is consistent with the formational processes known to be dominant at either end of the micro-estuary - fluvial input and coastal wave action - and the merging of these two processes toward the middle portion. Fluvial input occurs in areas of groundwater flow, where rivers and streams feed the bay. Fluvial input is a low energy formational process that is generally responsible for bringing in silts and other fine particles into the micro-estuary. Coastal wave action is a higherenergy processs that can help accumulate sands and coarser particles in the micro-estuary. The convergence of the two processes mixes the two sediment types.

Figure 6 is a plot of standard deviation versus mean grain size of our sampling points. This bi-variate analysis shows that there are statistically significant clusters or groupings of sediment types which are related to the spatial distribution of morpho-sedimentary types. Bay mouth barrier samples of 0-2 □ mean grain size show the best grouping, with standard deviations centered between 0.5 and 1.25. Deep fluvial sediments of 4-6 □ show the next best grouping, with a standard deviation centered between 1 and 2. Pleistocene relics were generally coarse gravels with a great variety of sizes, and they exhibited a high standard deviation of 1.75 to 2. The mixed transition areas as well as some of the shallow beach samples showed greatest scattering among grain sizes and standard deviations.

Conclusions

A process-response model of sedimentation was observed in both Kettle Creek and Silver Bay, as sediment distribution is influenced by relative location and hydrological processes. The finer particle sizes are in areas of fluvial input to the inner portion and center of each micro-estuary. The more exposed bayward areas of each micro-estuary are characterized by sandier sediment along the beach and at the micro-estuary bay-mouth bar. Relic sediments are located near the bay mouth in areas devoid of modern deposition. Through standard sampling and lab analysis, there emerges a pattern of the morpho-sedimentary characteristics of these two micro-estuaries. These patterns form the basic substrate for the assemblages of benthic communities in the microestuaries and for the selective sequestering of nutrients and pollutants. They are the foundation of the ecological systems. The similarity between sediment distribution among Kettle Creek and Silver Bay suggests that this pattern of sedimentation may be repeated throughout the microestuaries along the western coast of Barnegat Bay.

Figure 1

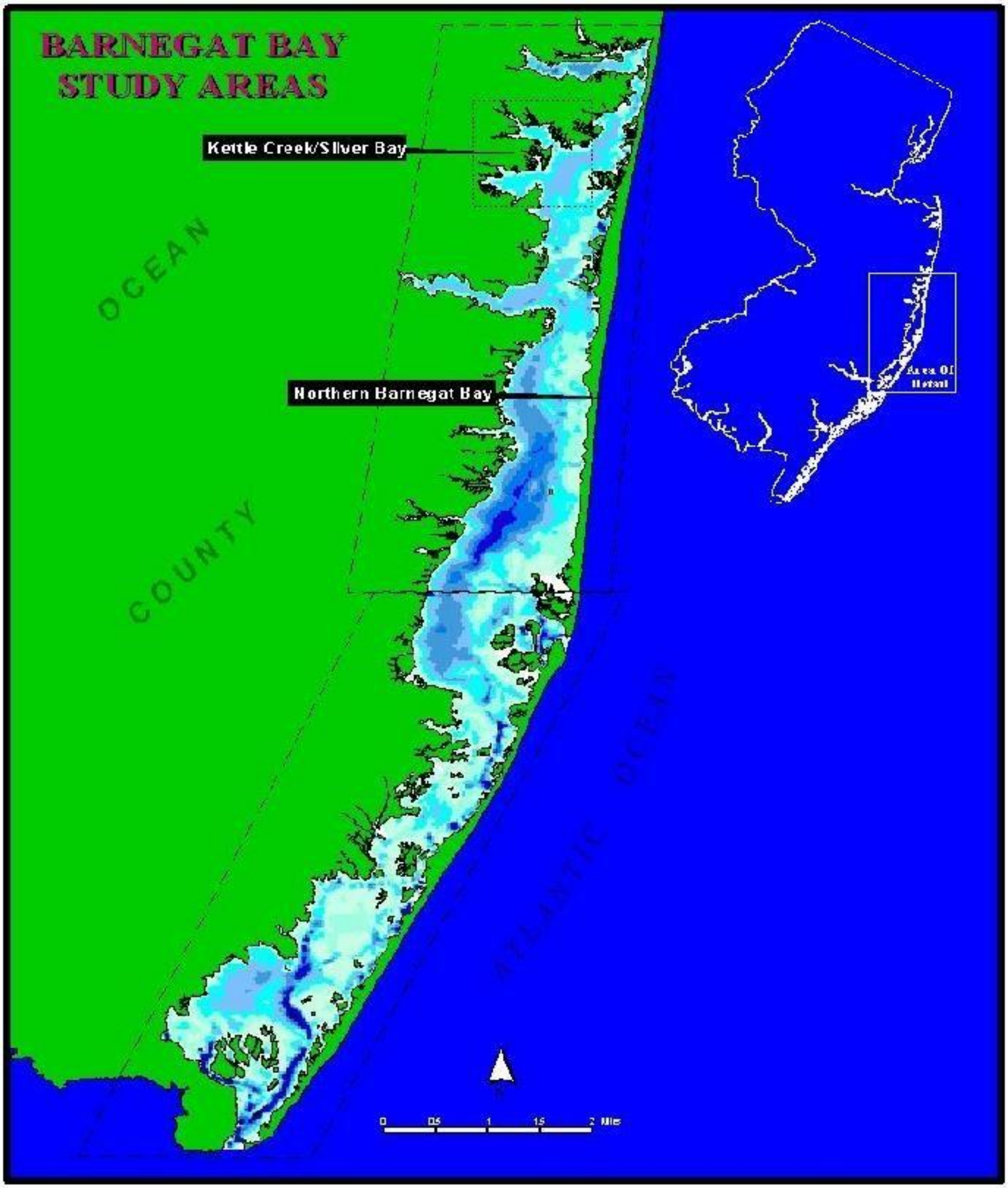

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Figure 2

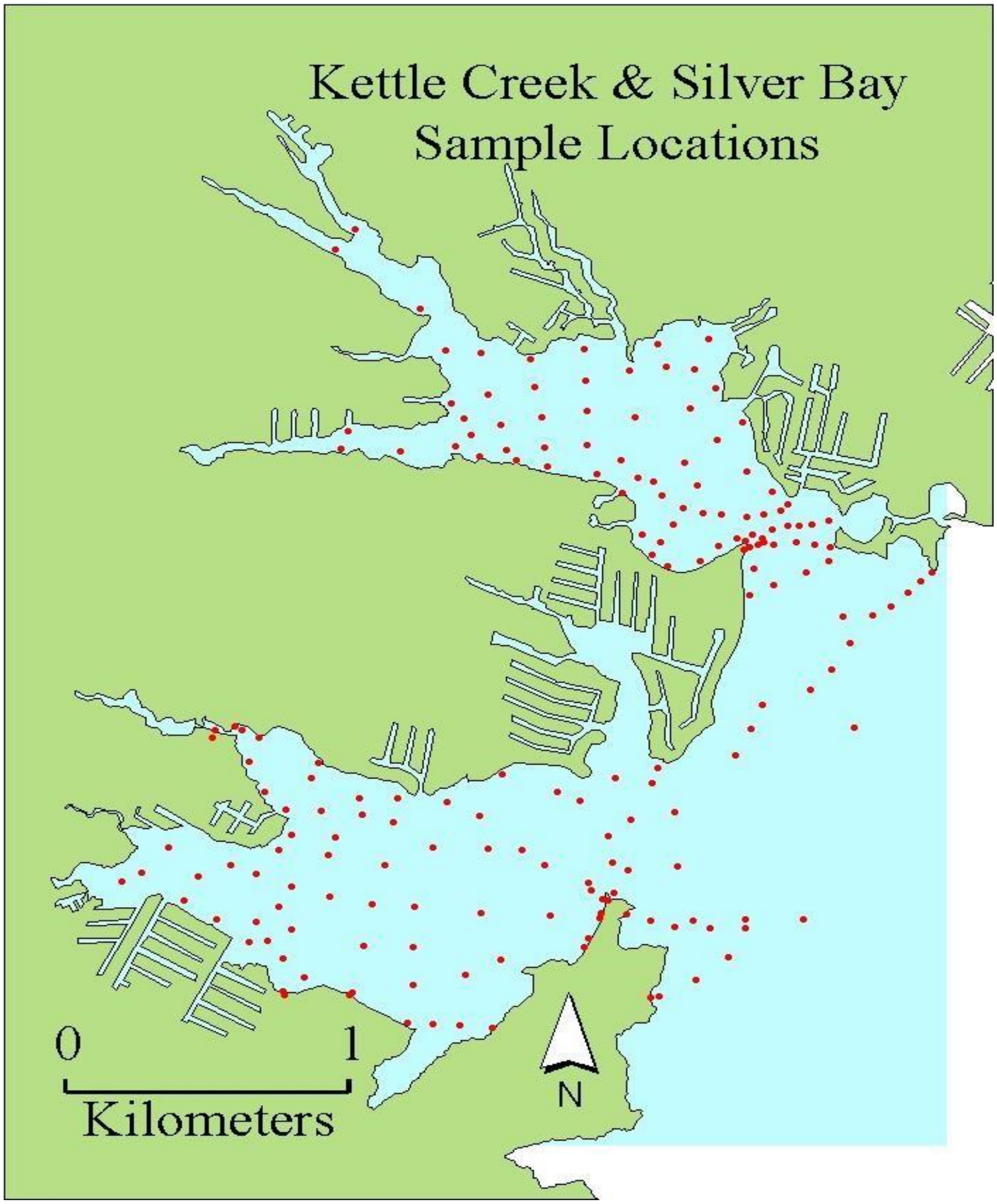
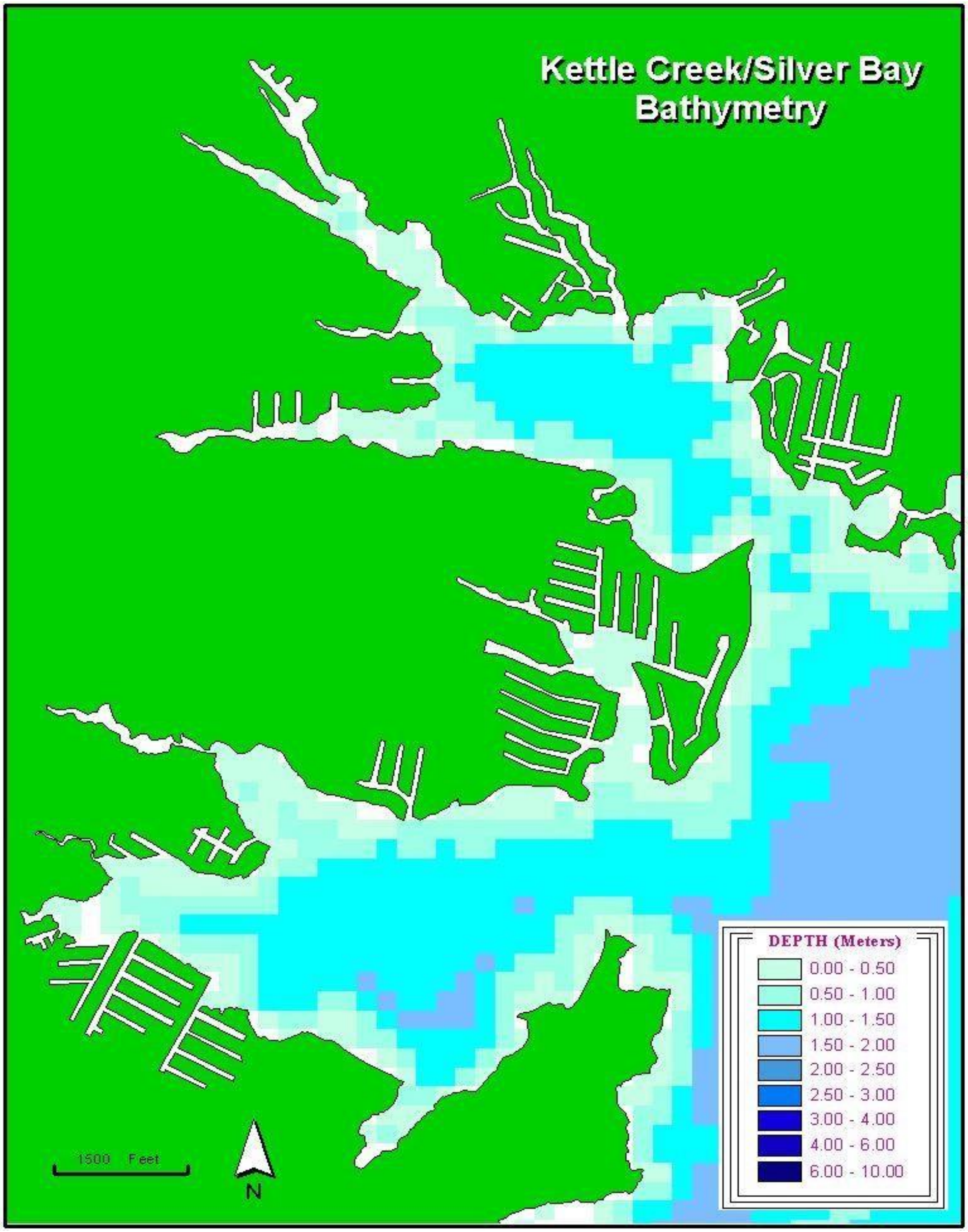


Figure 3



Kettle Creek/Silver Bay
Bathymetry
DEPTH (Meters)
0.00 - 0.50
0.50 - 1.00
1.00 - 1.50
1.50 - 2.00
2.00 - 2.50
2.50 - 3.00
3.00 - 4.00
4.00 - 6.00
6.00 - 10.00
1500 Feet
N

Figure 4

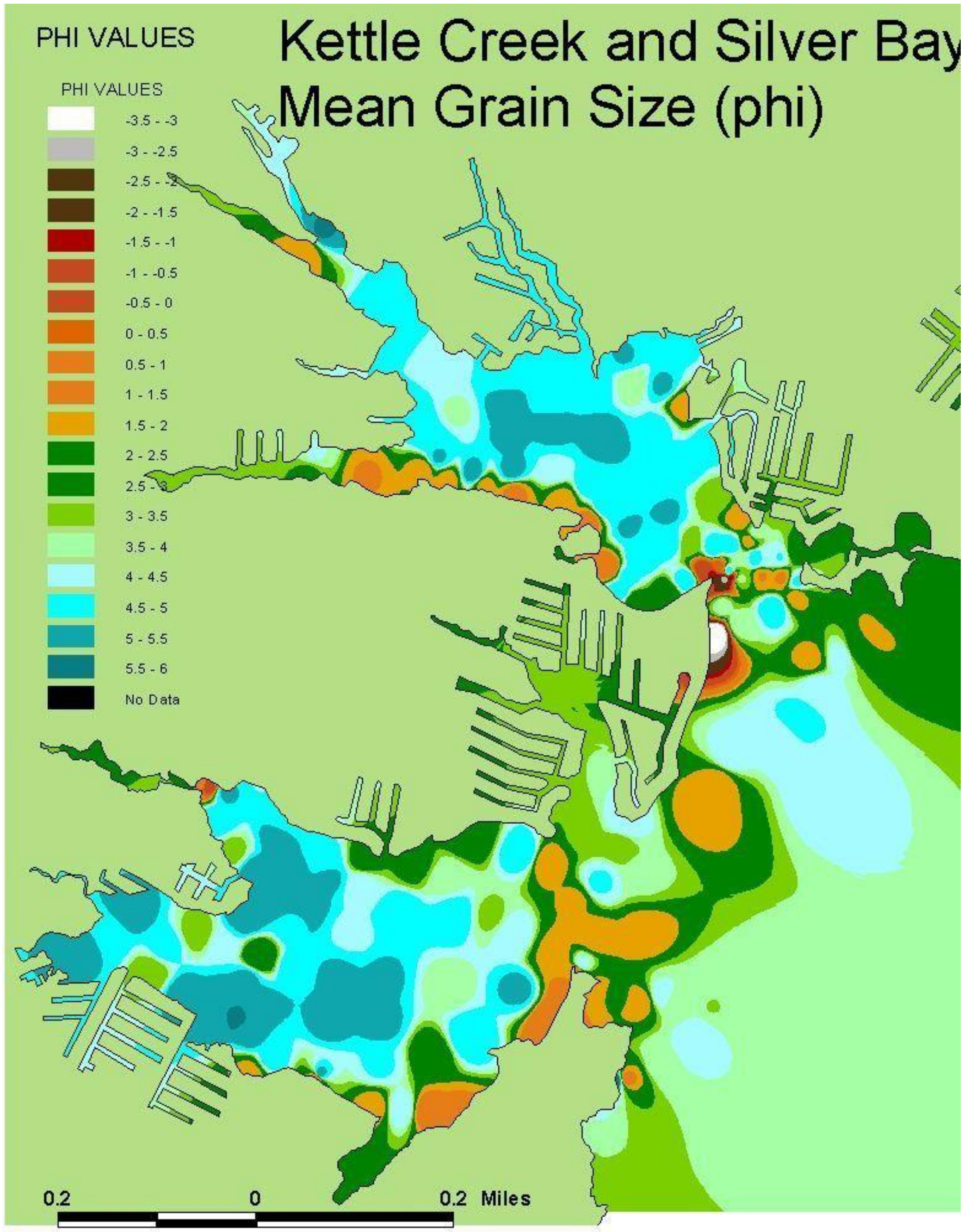

PHI VALUES
Kettle Creek and Silver Bay
Mean Grain Size (phi)
PHI VALUES
-3.5 - -3
-3 - -2.5
-2.5 - -2
-2 - -1.5
-1.5 - -1
-1 - -0.5
-0.5 - 0
0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 4.5
4.5 - 5
5 - 5.5
5.5 - 6
No Data
0.2
0
0.2 Miles

Figure 5

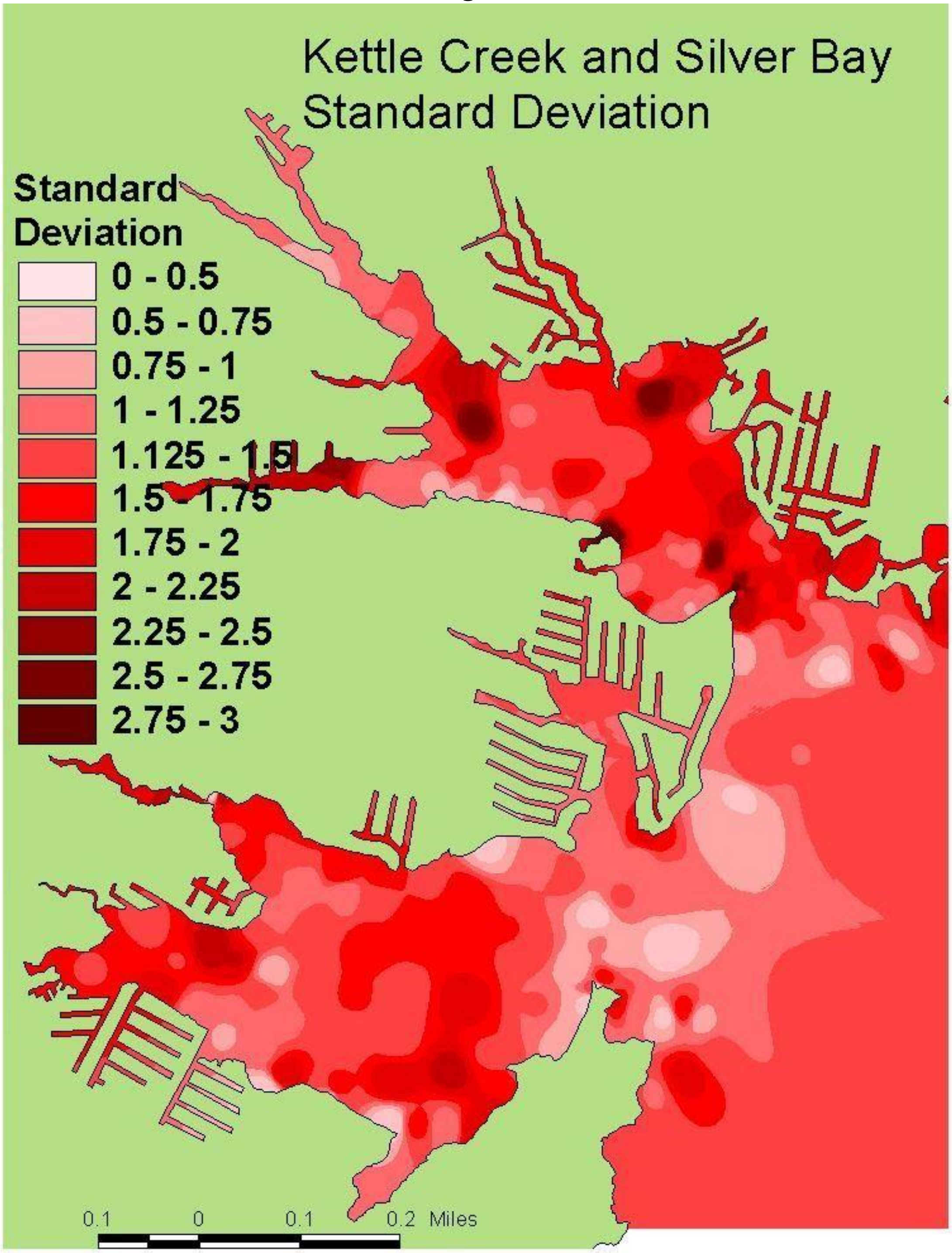
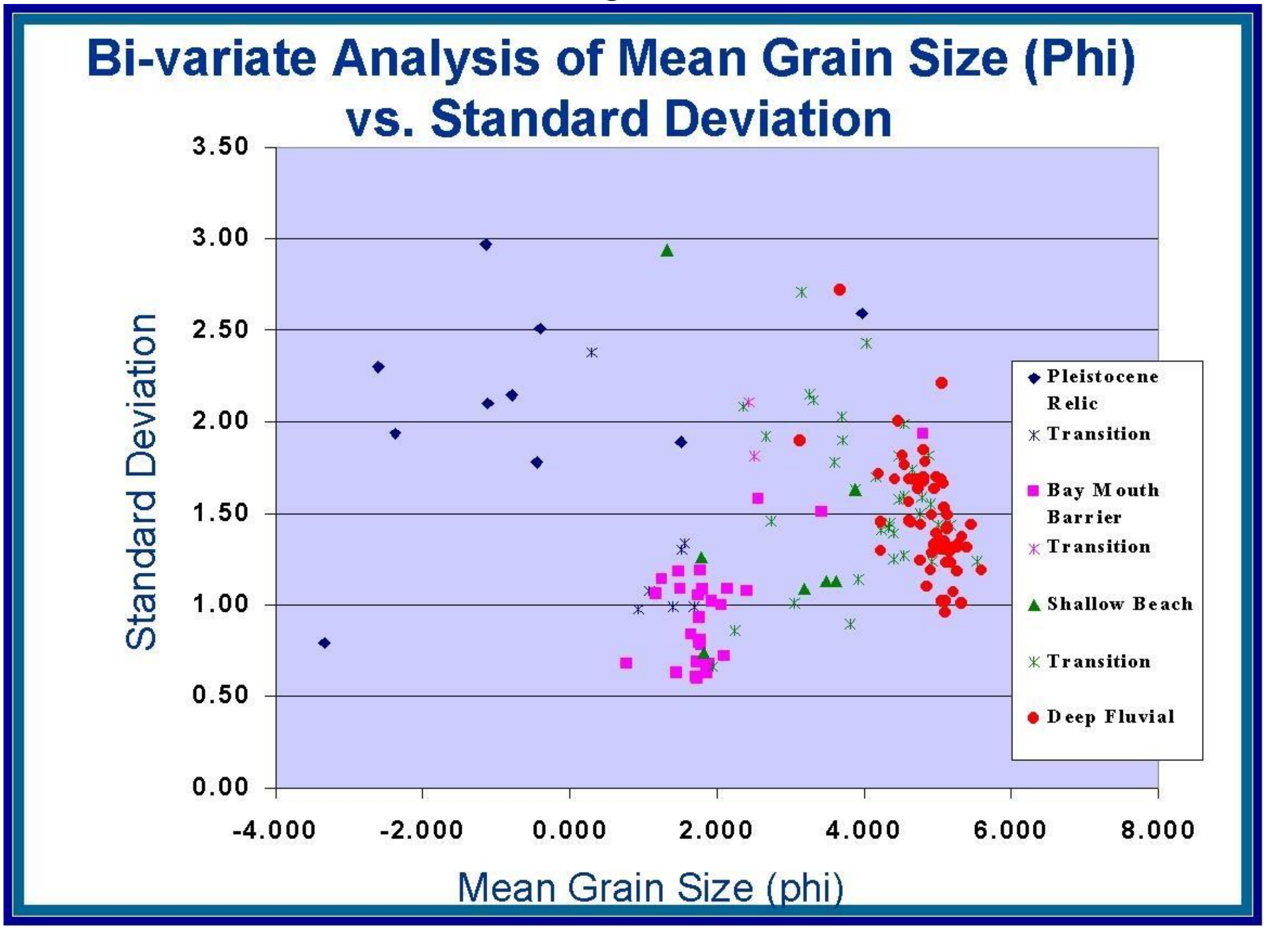

Kettle Creek and Silver Bay
Standard Deviation
Standard Deviation
0 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.25
1.125 - 1.5
1.5 - 1.75
1.75 - 2
2 - 2.25
2.25 - 2.5
2.5 - 2.75
2.75 - 3
0.1
0
0.1
0.2 Miles

Figure 6



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