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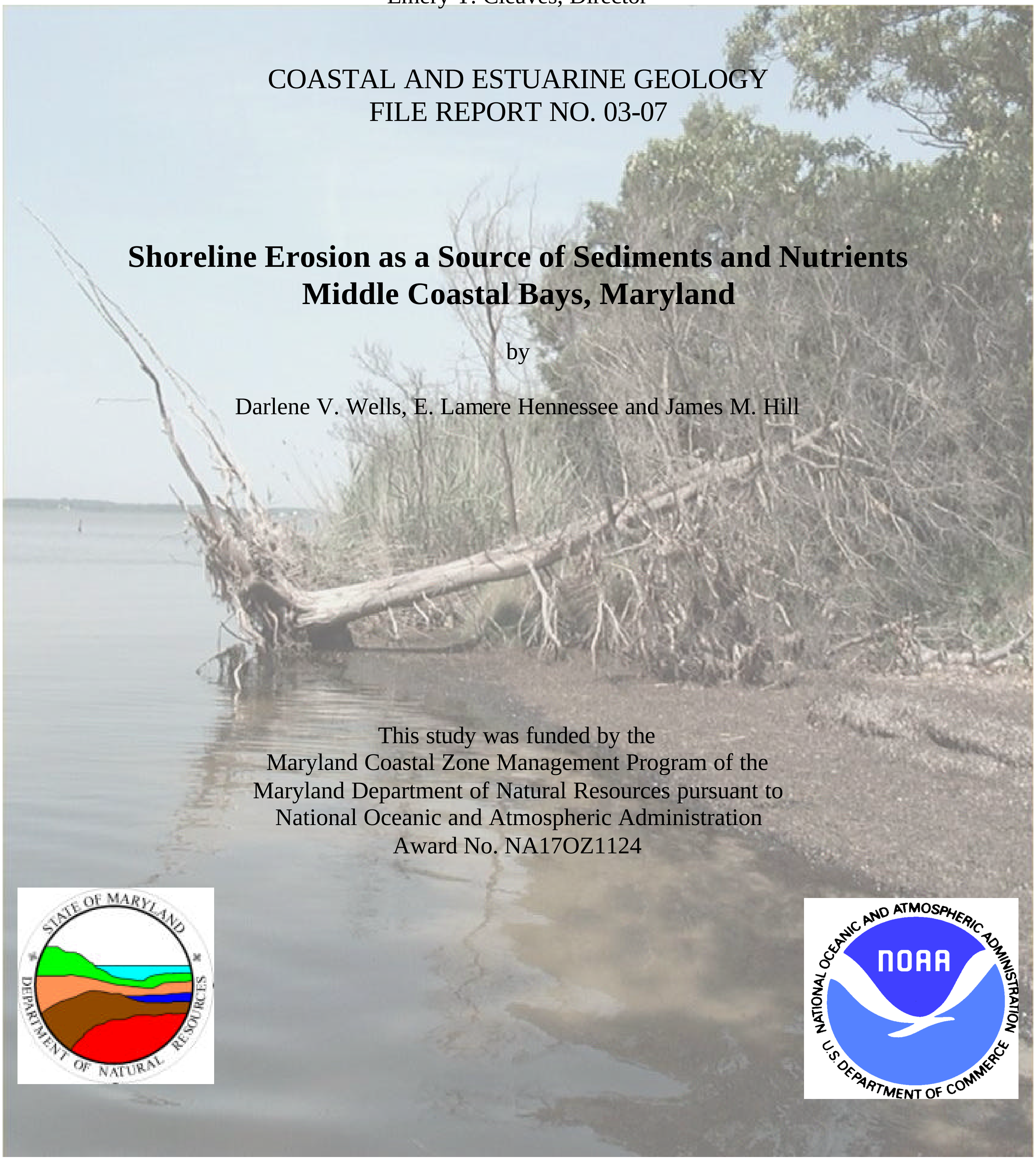

COASTAL AND ESTUARINE GEOLOGY
FILE REPORT NO. 03-07

Shoreline Erosion as a Source of Sediments and Nutrients Middle Coastal Bays, Maryland

by

Darlene V. Wells, E. Lamere Hennessee and James M. Hill

This study was funded by the
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Cover Photo: Eroding shoreline on Great Egging Beach, taken June 17, 2002

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EXECUTIVE SUMMARY

The Maryland Geological Survey (MGS) is engaged in a multi-year study to determine the flux of sediments and nutrients eroding from unprotected shorelines bordering Maryland's coastal bays. The first-year study focused on the northernmost bays – Assawoman Bay, Isle of Wight Bay, and the St. Martin River. The second-year study, summarized here, focused on the middle coastal bays – Sinepuxent Bay, Newport Bay, and the northern third of Chincoteague Bay.

The 19 sampling locations were selected on the basis of linear rates of shoreline change, as well as geology and geomorphology (marsh, bluff, or beach). At each site, MGS measured bank heights and collected sediment samples from marshes and beaches and from distinct geologic horizons within banks. Samples were analyzed for grain size composition, bulk density, total organics, total carbon (TC), total nitrogen (TN), total phosphorus (TP), and a suite of trace metals. The analytical results were then combined with coastal land loss estimates to determine sediment and nutrient loadings to the middle bays. Annual land loss was based on a digital comparison of two historical shorelines dating from 1942 and 1989.

Based on geomorphologic variability and differing rates of shoreline erosion, the study area shoreline was divided into 23 reaches, ranging in length from about 1,000 m to 67,000 m; most were less than 8,000 m long. A template of irregular polygons was constructed to demarcate the reaches, and total land loss (m^2) during the 47-year period was determined for each polygon. These "land loss" polygons provided a structure for organizing the results of the physical and chemical analyses. Each sampling site was associated with one or more of the land loss polygons. Mean bank heights and concentrations of the measured constituents (i.e., TN, TP, TSS, etc. in kg/m^3), averaged for each of the sampling sites, were used to calculate annual loadings (kg/yr) for each polygon.

From bulk density measurements, the sediments eroding from the shoreline in the middle coastal bays are twice as dense as those in the northern coastal bays. In the middle coastal bays, average dry bulk density values for bluff sediments and marsh sediment are 1.62 g/cm^3 and 0.76 g/cm^3, respectively. Average bulk density values for bulk and marsh sediments from the northern coastal bays are 1.39 g/cm^3 and 0.43 g/cm^3, respectively. However, the overall sediment loading per meter of shoreline in the middle coastal bays is less than that reported for the northern coastal bay shoreline. The difference is attributed to the lower average bank heights in the middle bays (0.61 m for middle bays vs. 0.79 m for northern bays).

During the 47-year period, shoreline erosion contributed 11.4 x 10^6 kg/yr of total sediments (solids) to the study area basins (Table ES-1). Of this total, approximately 61%, or 6.9 x 10^6 kg/yr, are total suspendable solids (TSS), an amount equal to about half of the TSS load from upland runoff. Annual total sediment loadings are greatest in Sinepuxent Bay (5.8 x 10^6 kg/yr, or 75.7 kg/yr per meter of shoreline), due in part to higher bank elevations and relatively dense bluff material. The rate of sediment loading from erosion in Newport Bay is 62.7 kg/yr per meter of shoreline; 75% of those sediments are suspendable solids.

In the study area, sand-sized sediments account for approximately 40% of the total sediments eroded from the shoreline. About half of the sand was eroded from the mainland shoreline of Sinepuxent Bay, certain reaches of which have undergone some of the highest rates of erosion in the study area. Thus, shoreline erosion accounts for approximately 1/4 of the sand entering the middle coastal bays.

Shoreline erosion is also a significant source of nutrients, contributing 4% of the total nitrogen loading and 9% of the total phosphorus loading to Maryland's middle coastal bays. In addition to nutrients, erosion contributes significant amounts of lead (Pb) and zinc (Zn), accounting for 12% and 24%, respectively, of the total loadings of these metals into the bays.

Table ES-1. Annual loadings (kg/yr) of sediments and nutrients contributed by shoreline erosion in the middle coastal bays. The length of the 1989 shoreline applies only to the shoreline included in the land loss polygons

Component	Sinepuxent Bay	Newport Bay	Northern Chincoteague Bay	Total
1989 Shoreline length (m)	76,672	58,872	66,603	202,146
Total Solids	5,801,555	3,689,654	1,860,591	11,351,800
Suspendable Solids	3,324,859	2,757,991	814,237	6,897,088
Carbon	163,756	152,225	57,297	373,279
Nitrogen	9,575	8,966	3,625	22,166
Phosphorus	1,557	1,197	677	3,431
Lead	141.4	68.0	31.8	241
Zinc	260.9	219.1	78.2	558

1. INTRODUCTION

The Maryland Coastal Bays Program has developed a four-pronged action plan to restore and protect the natural resources of the State's coastal bays (MCBP, 1999). The plan addresses (1) water quality, (2) fish and wildlife, (3) recreation and navigation, and (4) community and economic development. Meeting the goals associated with the first three of these depends in part on understanding the sediment and nutrient input contributed by shoreline erosion to the coastal bays. Shoreline erosion releases sediments to the water column. Finer-grained sediments tend to remain suspended in the water, reducing water clarity and affecting underwater habitat (e.g., reducing light penetration for submerged aquatic vegetation). The eventual deposition of eroded sediments contributes to the in-filling of navigational channels. Shoreline erosion also acts as a non-point source of nutrients (nitrogen and phosphorus), which affect the water quality of the coastal bays.

Although shoreline erosion has been identified as a source of sediments and nutrients to nearby waters, there has been little effort to quantify that input and to compare it to other sources. To provide this information, the Maryland Geological Survey (MGS) began a multi-year study to determine the flux of sediments and nutrients eroding from unprotected shorelines bordering Maryland's coastal bays. The first year of the study focused on the northernmost coastal bays: Assawoman Bay, Isle of Wight Bay, and the St. Martin River. The results of that study were detailed by Wells and others (2002). The second year of the study focused on the middle third of Maryland's coastal bays: Sinepuxent Bay, Newport Bay, and the northern third of the Chincoteague Bays. Results for the second year study are presented in this report.

OBJECTIVES

To estimate the nutrient and sediment loads contributed by shoreline erosion to the middle coastal bays of Maryland, MGS set the following objectives:

1. Identify unprotected reaches of shoreline at greatest risk of erosion, based on historical linear rates of change;
2. Measure certain physical, chemical, and biological properties of eroding sediments; and
3. Determine the volume of eroding sediments and the flux of sediments and nutrients into the middle coastal bays. Examine the flux of material from shoreline erosion in the context of existing nutrient budgets for the study area.

ACKNOWLEDGMENTS

This study was funded by the Coastal Zone Management Program of the Maryland Department of Natural Resources pursuant to National Oceanic and Atmospheric Administration Award No. NA17OZ1124. The authors extend their gratitude to the National Park Service for access to Assateague Island National Seashore and to the many private landowners who allowed access to their property, so that MGS might collect samples and measure bank heights. They also wish to thank Richard Ortt, Dan Sailsbury, and Geoff Wikel, who assisted with sample collection and laboratory analyses, and Stephen Van Ryswick and Sacha Lanham, who prepared and analyzed the sediments for grain size and chemical analyses.

2. PREVIOUS STUDIES

SHORELINE CHANGE AND COASTAL LAND LOSS STUDIES

The earliest comprehensive shoreline change information available for the coastal bays, excluding the upstream portions of some of the tributaries, comes from a 1949 study of tidewater Maryland by Singewald and Slaughter. The authors calculated rates of erosion by comparing two sets of shorelines, dating from *ca*. 1850 and *ca*. 1940. Conkwright (1975) updated their work, producing a series of maps that depict the 1850 and 1940 shorelines on 7.5-minute U.S. Geological Survey (USGS) topographic quadrangles. The most recent shorelines shown on the topographic base maps range between 1942 and 1972.

As part of his study on the origin, distribution, and rates of accumulation of sediments in Chincoteague Bay, Bartberger (1973, 1976, Bartberger and Biggs, 1970) used the shoreline change data reported by Singewald and Slaughter to estimate the volume of sediment contributed to that Bay from shore erosion,. Based on Bartberger's estimates, shore erosion contributes approximately 40 x 10^3 m^3/yr of sediment to Chincoteague Bay, approximately eight times the amount delivered by streams. Almost all of the eroded sediment comes from the mainland shore and bay islands, which consist largely of marsh. Bartberger assumed that shore-derived sediments consisted primarily of mud (silt plus clay fraction). Because the sand:mud ratio of sediments deposited on the bay floor was 1:1, he reasoned that an equal amount of sand was introduced into the bay from other sources, mainly from Assateague Island through overwash processes and wind deposits. Transport of sand through the active inlets, Ocean City Inlet and Chincoteague Inlet, is important only as a local source.

Later studies of coastal erosion in the region, notably those by the National Oceanic and Atmospheric Administration (NOAA, 1988) and Leatherman (1983), were more limited in area, for example, to the vicinity of the Ocean City Inlet or the Atlantic coast of Maryland. Volonté and Leatherman (1992) predicted future wetlands and upland losses for the mainland (western) shores of Assawoman and Isle of Wight Bays and their main tributaries, including the St. Martin River. As part of that study, they measured linear rates of shoreline change along 41 mi of shoreline (at 215 sites located approximately 1000 ft apart) for the period 1850-1989. Average rates of recession in the study area, reported by water body, range from -0.2 to -1.1 ft/yr (-6 to -34 cm/yr). Based on that study, Volonté and Leatherman concluded that marshy coastal bay shorelines undergo the highest rates of erosion.

Recently, MGS remapped and assessed shoreline change in Maryland's coastal bays (Hennessee and Stott, 1999; Hennessee and others, 2002a, Stott and others, 1999, 2000). The project involved digitizing historical and recent shoreline positions for the 450 mi (724 km) of shoreline defining the coastal bays. Using a geographic information system (GIS), MGS digitally updated nine 7.5-minute quadrangles covering the coastal bays and produced a corresponding series of *Shoreline Changes* maps. MGS also determined the area of land lost to shoreline erosion since the mid-1800s (Hennessee and others, 2002b). Between 1850 and 1989, Newport Bay lost 452 acres (annual rate of change = -0.07 acres/mile of shoreline/year). Sinepuxent Bay lost 283 acres (annual rate = -0.08 acres/mi/yr) from its western shore, but gained 1,017 acres (annual rate = +0.18 acres/mi/yr) along its eastern shore as Assateague Island migrated landward, for a net gain of 735 acres. Along the entirety of the Maryland section of Chincoteague Bay, the western shore lost 1,358 acres (annual rate = -0.17 acres/mi/yr), and the eastern shore, 304 acres (annual rate = -0.02 acres/mi/yr), for a total loss of 1,662 acres.

NUTRIENT BUDGET AND POLLUTANT LOADING STUDIES

In 1993, the Maryland Department of the Environment (MDE) conducted an assessment of Maryland's coastal bay aquatic ecosystem (UM and CESI, 1993). The authors reviewed existing data for trends in the overall quality of the bays' ecosystem. One objective was to assess terrestrial pollutant loadings. The study identified contributing sources and estimated pollutant loadings from point source discharges, surface runoff, and direct discharge of groundwater into the bays. Loadings from shoreline erosion were not considered. The pollutants included nitrogen, phosphorus, total suspended solids (TSS), metals (zinc and lead), and biochemical oxygen demand (BOD). Estimates of pollutant loadings from surface runoff were based on land use and land cover. The study identified several areas within the coastal bays, including Newport Bay, as areas exhibiting serious water quality problems due to such factors as poor flushing, development along the shorelines, and high nutrient loadings. Estimated loading rates for total nitrogen, total phosphorous, total suspended solids, zinc, lead and biochemical oxygen demand were very high for Newport Bay, compared to those observed in other areas of the coastal bays, specifically Sinepuxent and Chincoteague Bays, where water quality appeared to be good.

Impaired by nutrients (nitrogen and phosphorus) and fecal coliform, Newport Bay was placed on Maryland's list of water-quality-limited segments in 1996. As a result, the State was required, under Section 303(d) of the Federal Clean Water Act, to develop a total maximum daily load (TMDL) for the bay. A TMDL reflects the total pollutant loading of an impairing substance that a water body can receive and still meet water quality standards. In developing the TMDLs, MDE revised the nutrient loadings reported in the UM and CESI report (MDE, 2001). MDE recalculated nutrient loadings based on 1997 land use information and updated groundwater inputs based on data from a recent groundwater study (Dillow and Greene, 1999). Again, contributions from shoreline erosion were omitted. TMDLs were not modeled for Sinepuxent Bay or Chincoteague Bay.

To determine the nutrient and sediment loadings contributed by shoreline erosion to the northern coastal bays, Wells and others (2002) used the area of land lost measured by Hennessee and others (2002a) to design the sampling scheme for their study. They collected bank and marsh sediment samples at 16 locations long the mainland shorelines of Assawoman and Isle of Wight Bays and the St. Martin River. The bayside of Fenwick Island (i.e., the Town of Ocean City) was not included in the study since most of that shoreline had been altered or armored. Mean bank heights and concentrations of the measured constituents (i.e., TN, TP, TSS, etc. in kg/m^3), averaged for each of the sampling sites, were used to calculate annual loadings (kg/yr) for specific reaches of shoreline.

Wells and others (2002) found that between 1942 and 1989, shoreline erosion contributed an estimated 11.6×10^6 kg/yr of total sediments to the three northern coastal bays. Of the total sediment load, approximately 42%, or 4.9×10^6 kg/yr, were total suspendable solids (TSS). That was equivalent to about one-third of the TSS load from upland (surface) run-off. Annual total sediment loadings were greatest in the St. Martin River (6.9×10^6 kg/yr), due in part to relatively high bank elevations and dense bluff material. Sand-sized particles accounted for approximately 57% of the total sediments contributed from shoreline erosion. Of the total nitrogen and total phosphorus delivered annually to the system, shoreline erosion contributed up to 8.5%. Nutrient contributions from shoreline erosion slightly exceeded input from point sources. In addition to nutrients, erosion also contributed significant amounts of Pb and Zn, accounting for 4% and 9.5%, respectively, of the total loadings of those metals to the northern coastal bays.

3. STUDY AREA

GEOMORPHOLOGY

The study area is located on the Atlantic coast of the Delmarva Peninsula (Fig. 3-1) and includes the area extending from Ocean City Inlet south to just below Ricks Point on the western shore of Chincoteague Bay and Tingles Island on the eastern shore (approximately 38° 9' N latitude). The study area encompasses Sinepuxent Bay, Newport Bay, and a small portion of Chincoteague Bay proper (Fig. 3-2). Sinepuxent Bay and Chincoteague Bay are separated from the Atlantic Ocean by Assateague Island, which is part of the barrier island/southern spit unit of the Delmarva coastal compartment (Fisher, 1967).

Sinepuxent and Newport Bays are microtidal (<2 m tidal range) coastal lagoons. At their southern boundaries, they are contiguous with Chincoteague Bay. Sinepuxent Bay extends from the Ocean City Inlet south to South Point, located at the end of Sinepuxent Neck. Assateague Island separates Sinepuxent Bay from the Atlantic Ocean. Newport Bay is a flooded extension of Trappe Creek, one of the more significant streams emptying into the Maryland coastal bays. Sinepuxent Neck separates Newport Bay from Sinepuxent Bay (Fig. 3-2).

Generally, the bays are very shallow, averaging less than 1 m in depth. Depths greater than 2 m occur locally, primarily along the mainland shore of Sinepuxent Bay and mid-bay areas of Newport Bay. Depths exceeding 2.5 m are restricted to the dredged navigation channel, located in the Inlet area and West Ocean City Harbor and extending into northern Sinepuxent Bay (Wells and Ortt, 2001).

Salinities within the two bays vary depending on season and proximity to the inlet. Salinity in Sinepuxent Bay decreases with increasing distance from Ocean City Inlet, with lowest salinity at the mouth of Newport Bay. Here, salinity may be as low as 20 ppt in March or April as a result of fresh water input from Trappe Creek. Maximum salinity, measured during the summer, ranges from 30 ppt near the Inlet to 26 ppt in Newport Bay (Casey and Wesche, 1981). Salinity tends to be higher in the summer due to limited freshwater input and high evaporation.

Salt marshes border the bays along most of the mainland shore. Extensive marsh areas exist along both shores of Newport Bay and the upstream areas of Trappe Creek. These marshes are primarily composed of *Spartina patens* and, to a lesser degree, *Spartina alterniflora* and *Distichlis spicata*. (Bartberger, 1973). Less extensive marshes are found along the west side of Assateague Island. However, sparsely vegetated washover fans and lobes characterize much of the Sinepuxent Bay side of Assateague Island.

Inlets And Historical Shoreline Changes

Ocean City Inlet connects Sinepuxent Bay to the Atlantic Ocean. The inlet formed during a hurricane in 1933. The U.S. Army Corps of Engineers immediately stabilized the inlet with jetties to keep it open. This stabilization resulted in immediate changes in the configuration of the shoreline south (downdrift) of the inlet. The jetties interrupted the longshore transport of

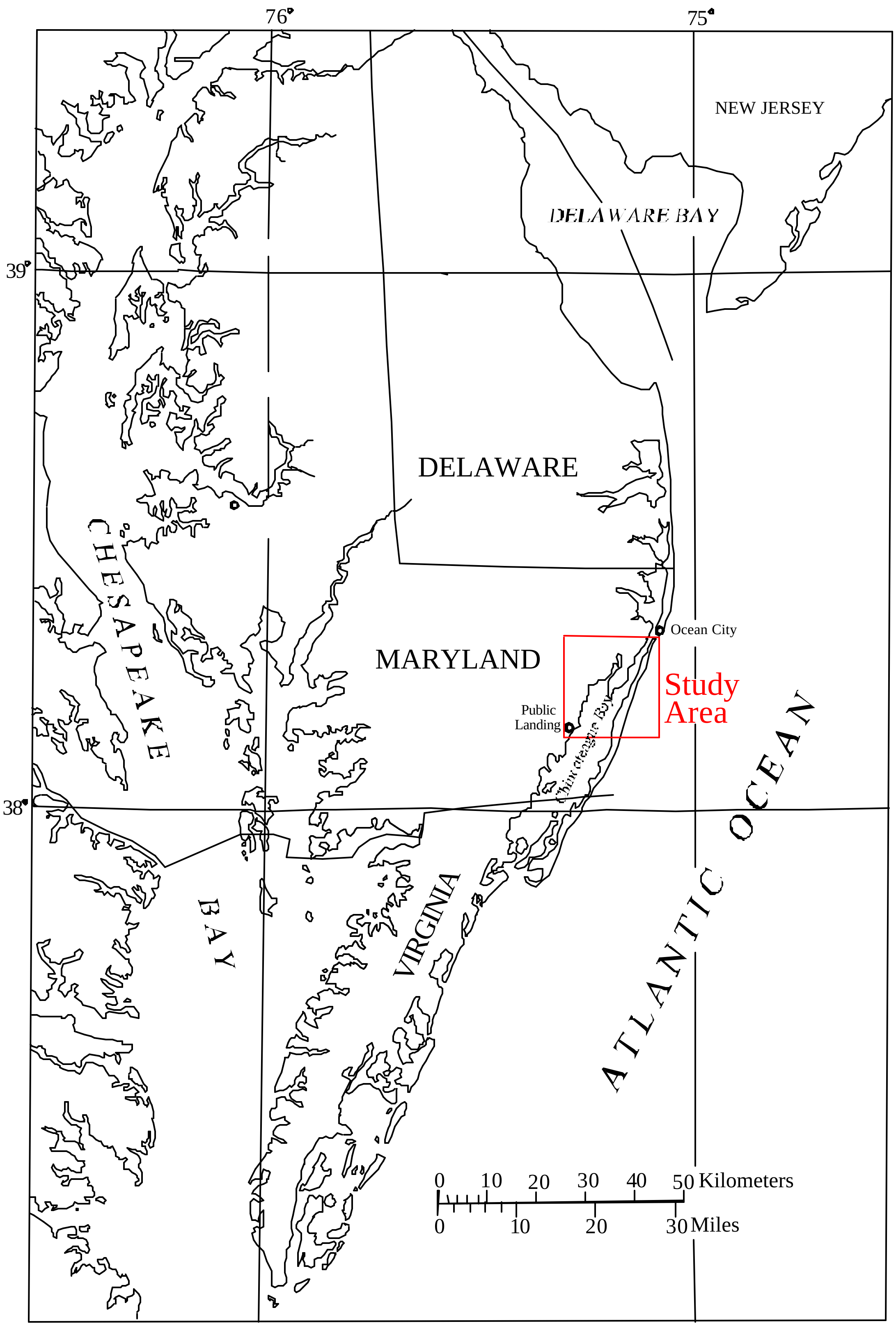


Figure 3-1. The Delmarva Peninsula, showing the location of the study area.

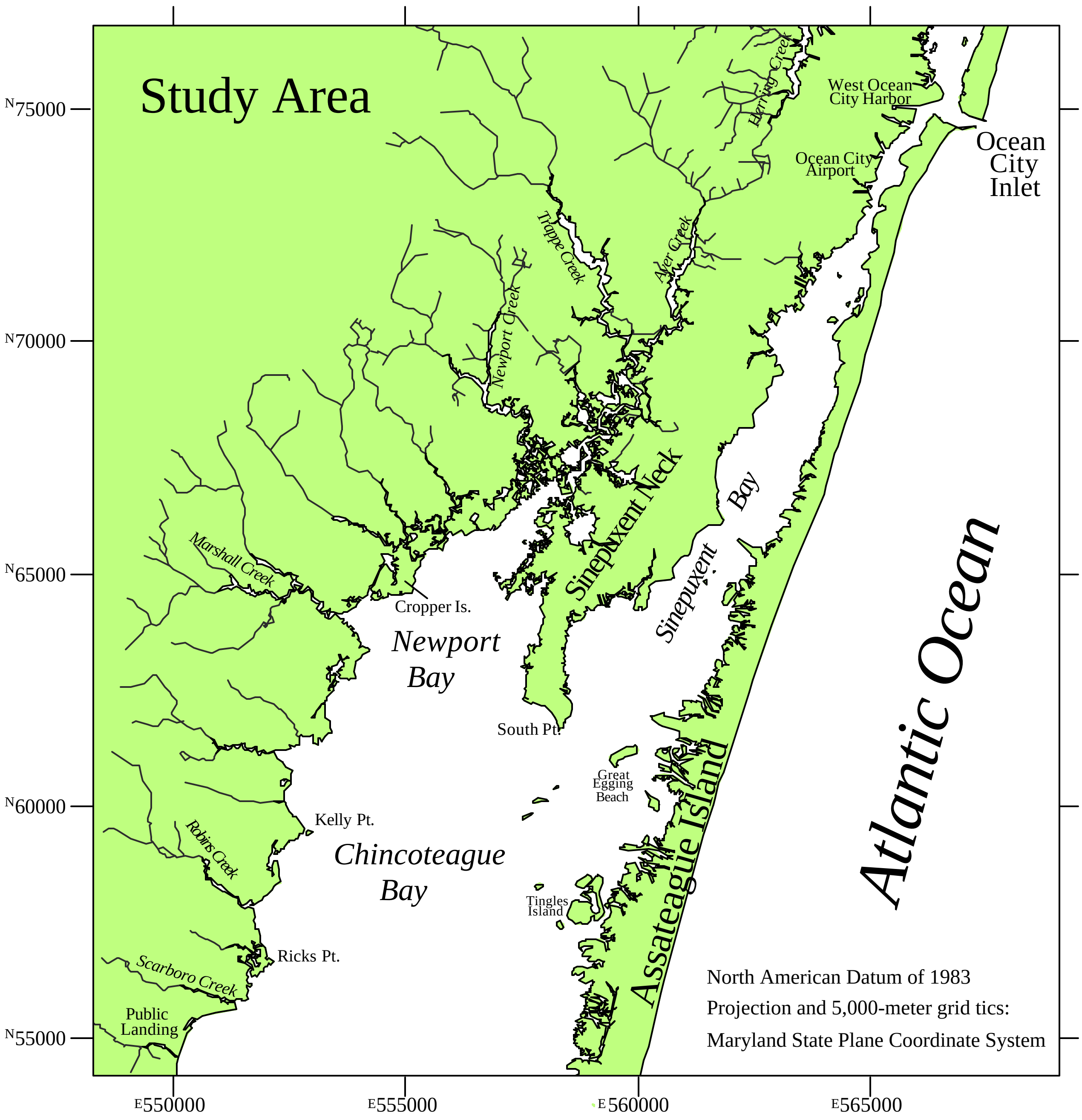


Figure 3-2. Study Area.

sand, essentially "starving" northern Assateague Island of sand and causing accelerated erosion. Northern Assateague Island and Sinepuxent Bay have undergone dramatic changes as a result. Although island width has been maintained by overwash processes (Leatherman, 1979), since 1943, portions of Assateague Island have migrated landward, as much as 350 m along the northernmost 2 km. As a consequence of this migration, Sinepuxent Bay has narrowed significantly. Since 1943, the surface water area of Sinepuxent Bay has decreased by 17%. When compared to the 1850 shoreline, the surface area of Sinepuxent Bay has decreased by 35% and its width, along the upper 4 km, by 50%.

Historically, several other inlets have been documented along the northern end of Assateague Island. Perhaps the most significant historical inlet, both in duration and size, was Sinepuxent Inlet, located in the southern part of the study area. Tingles Island represents the remnants of the flood tidal shoal formed by this inlet. Historical accounts indicate that this inlet existed for nearly half a century, from 1794 to 1832. It is unclear, though, whether the inlet was open continuously or if the numerous reports refer to repeated storm-cut openings at that location (Truitt, 1968). It is very likely that even earlier inlets may have existed at this site. Colonial charts, for example, indicate the existence of an inlet around 1690 (Amrhein, 1986).

During the mid-1800s, North Beach Inlet formed at a site across from South Point. Although it is unclear exactly when this inlet formed or how long it existed, early accounts indicate that the inlet was navigable and may have coexisted with the Sinepuxent Inlet, which was located just south of this site (Truitt, 1968). Great Egging Beach and Little Egging Beach Islands are remnants of the tidal shoal formed from North Beach Inlet.

During a storm in February 1920, an inlet was cut through the island at a site opposite Grays Cove near Snug Harbor (Hite, 1924). This inlet was navigable for several years, closing sometime before Ocean City Inlet formed (Gawne, 1966; Truitt, 1968). A broad marsh flat on the bay side of Assateague marks the remnants of this inlet's tidal delta.

During the Great March 1962 Storm, an inlet was cut through the island opposite Ocean City Airport. This inlet, which is indicated on the 1962 shoreline, was very shallow and had no commercial use as a navigation channel. Because the inlet did not adversely affect the Federal Navigation channel in Sinepuxent Bay, it was ineligible for closure by the Corps. However, when the Corps pumped sand from Sinepuxent Bay onto Assateague Island to repair a breach along the south jetty, material from that activity drifted into the inlet, closing it at low tide (U.S. Army Corps of Engineers, 1962).

More recently, during back-to-back coastal storms in the winter of 1998, Assateague Island was nearly breached at a site opposite Fassett Point (Ramsey and others, 1998). During the storms, a 1 to 1.5 meter-thick layer of sand was removed by overwash, exposing an extensive peat substrate along an 800 m stretch of the island. At this site, ocean shoreline migrated west about 100 m. The total width of the barrier island narrowed from 500 m to 350 m. The following fall, the U.S. Army Corps of Engineers filled in the breach, using 102,341 m^3 (133,849 yd^3) of sand pumped from nearby offshore borrow areas (Greg Bass, personal comm.)

GEOLOGY

Unconsolidated Coastal Plain sediments, the upper 60 m of which are Cenozoic in age, underlie the study area. Sediments of the Sinepuxent Formation (Qs) are exposed along much of Maryland's coastal area from Bethany Beach, Delaware, southward to the Maryland-Virginia border. The formation directly underlies the study area and is exposed in several non-marsh areas along the mainland shore of both bays (Fig. 3-3). However, Owens and Denny (1978) classified most of the shoreline marshes as Holocene (modern) deposits (Qtm).

The Sinepuxent Formation is composed of dark colored, poorly sorted, silty fine-to-medium sand with thin beds of peaty sand and black clay. Heavy minerals are abundant and consist of both amphibole and pyroxene minerals. All of the major clay mineral groups – kaolinite, montmorillonite, illite, and chlorite – are represented. The sand consists of quartz, feldspar, and an abundance of mica – muscovite, biotite, and chlorite. The preponderance of mica makes the Sinepuxent Formation lithologically distinct from older underlying units (Owens and Denny, 1979).

The Sinepuxent Formation, interpreted to be a marginal marine deposit, has been correlated with offshore Q2 deposits dating from 80,000 to 120,000 yr before the present (Toscano, 1992; Toscano and others, 1989; Toscano and York, 1992).

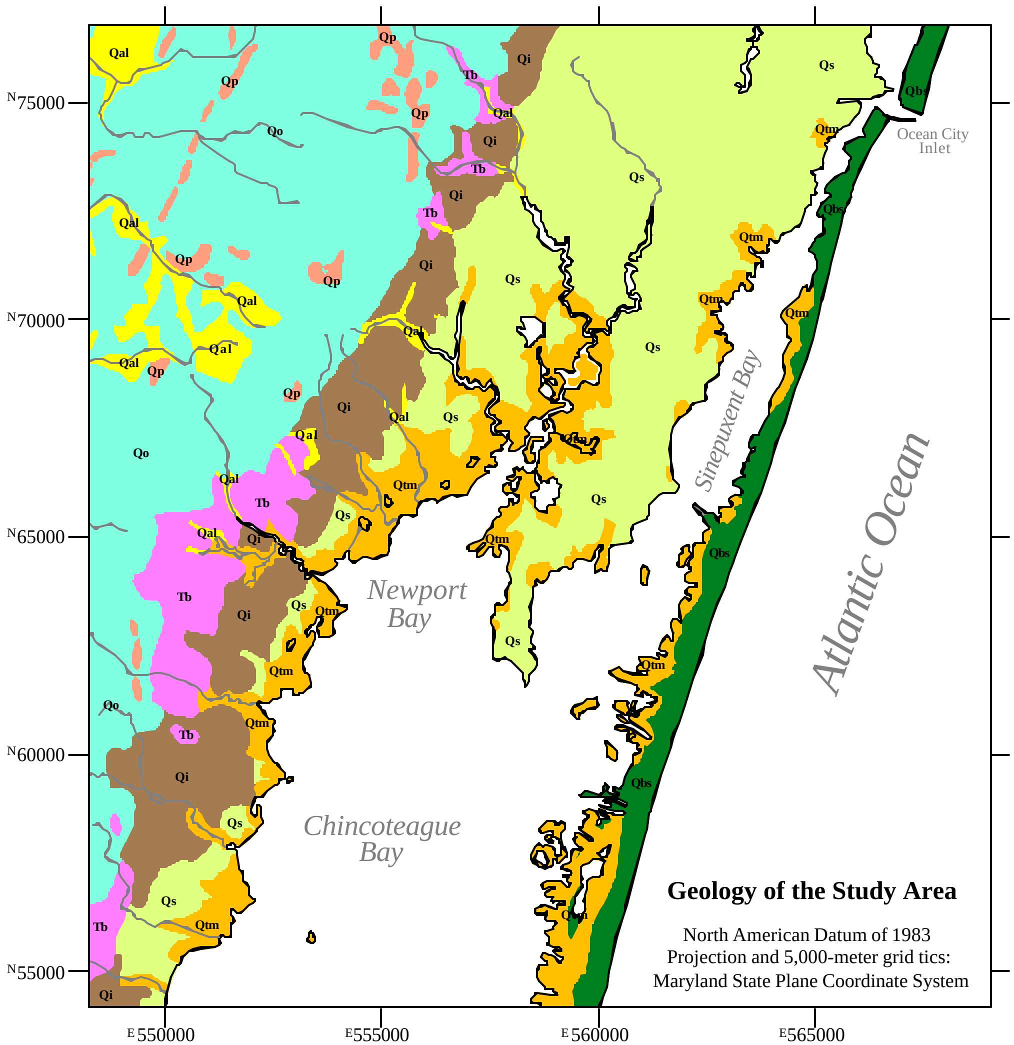
The western edge of the Sinepuxent Formation abuts the Ironshire Formation (Qi). Consisting of pale yellow to white sand and gravelly sand, the Ironshire Formation is thought to be a barrier-back barrier sequence (Owens and Denny, 1978). Although the Ironshire Formation sits unconformably above the Beaverdam Sand, at no point does it underlie the Sinepuxent Formation (Owens and Denny, 1979). The Ironshire Formation is exposed along the shoreline at Turpin Cove, opposite of Tingles Island.

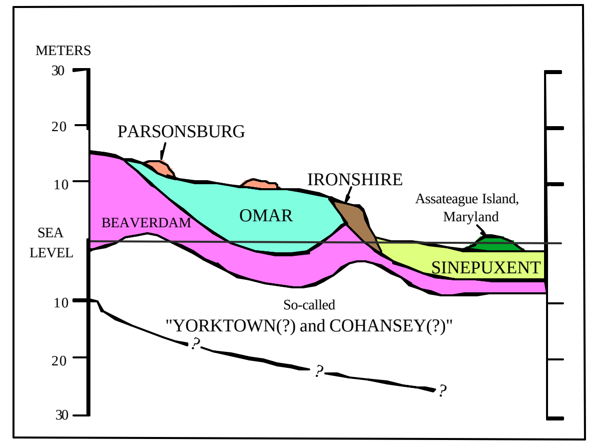
The Sinepuxent is underlain by the Beaverdam Sand (Tb), which is Pliocene in age. The exposed portion of the Beaverdam Formation is characterized by extensively cross-stratified sand, interbedded with clay-silt laminae. Unweathered Beaverdam Sand sediments may be pale blue-green or white; weathered sediments are orange or reddish brown. Due to the abundance of silt, the Beaverdam Sand is more cohesive than the Ironshire Formation.

The Omar Formation (Qo), thought to be early Pleistocene in age, is exposed west of the Ironshire Formation and lies directly above the Beaverdam. Within the study area, the Omar Formation consists of interstratified light-colored sand and dark-colored sand-silt-clay or silty clay. It is exposed along the upper reaches of several larger streams flowing into Newport and Chincoteague Bays.

Bay Bottom Sediments

Based on the textural analyses of surficial sediment samples (representing the top 5 cm of the sediment column) from Sinepuxent and Newport Bays and the northern third of Chincoteague Bay, the average textural composition of bay bottom sediments is 60% Sand, 26% Silt, and 14%





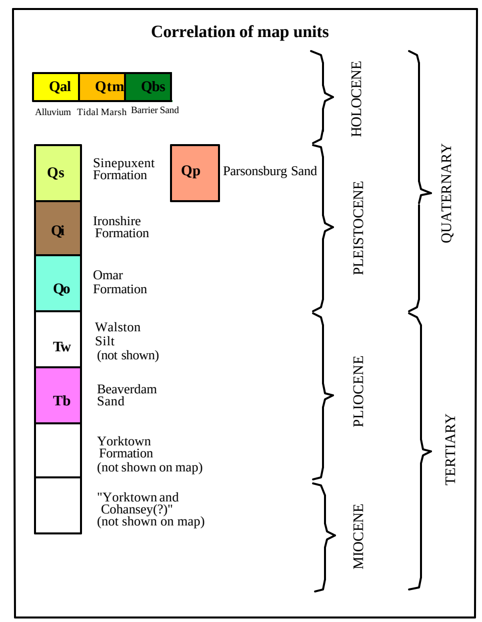


Figure 3-3. Geology of the study area. The cross-section illustrates the general relationship of geologic formations (modified from Owens and Denny, 1978 1979).

Clay (Wells and others, 1996). Sediments from Sinepuxent Bay are coarser-grained, with an average composition of 78% Sand, 14% Silt, and 7% Clay. The average composition of Newport Bay sediments is 32% Sand, 43% Silt, and 25% Clay. The average composition of Chincoteague Bay sediments is 60% Sand, 27% Silt, and 13% Clay.

In Sinepuxent Bay, the predominate sediment type is Sand, with some isolated pockets of Sandy Silt (Fig. 3-4). Coarser-grained sediments are transported into the bay by storm overwash across Assateague Island, by wind, or through Ocean City Inlet. With mean water depth in the bay less than 1 m, wind-generated waves constantly rework bottom sediments, removing finer-grained materials. These eventually settle in sheltered areas or in deeper water. The area of Clayey Silt on the east side of Lower Sinepuxent Neck reflects both lower energy conditions and proximity to an eroding marshy shoreline, which contributes muddy sediments.

In contrast, the bottom sediments of Newport Bay, where water depths average 1.2 m, consist of Clayey Silts (two samples were classified as Silty Clay) along the upstream and western shore areas. These fine-grained sediments reflect the low energy depositional conditions found in deeper mid-bay waters and sheltered upstream areas. In addition, Newport Bay is bordered by inundated salt marshes, which contribute muddy sediments through shore erosion. In the middle of lower Newport Bay, areas of Sand-Silt-Clay and Silty Sand occur. These areas represent transitional zones between higher-energy sand deposits and lower-energy Clayey Silt deposits.

Along the eastern half of upper Chincoteague Bay, Sand is the predominate sediment type with some isolated pockets of Sandy Silt and Clayey Silt. Coarser-grained sediment comes from a variety of sources, including storm overwash across Assateague Island, wind transport, or load transported through existing and former inlets. The area adjacent to Assateague Island is shallow, with water depths less than 1.5 m. Wind-generated waves constantly rework bottom sediments, removing finer-grained materials, which eventually settle in sheltered areas or in deeper water.

Sandy sediments grade into Sandy Silts, Silty Sands, and Sand-Silt-Clays in a westward direction across the bay. These sediments represent transitional zones between high-energy Sand deposits and low-energy Clayey Silt deposits. Along the northwestern margin of the study area, Clayey Silts occur in isolated pockets. Clayey Silts become more prevalent toward the southern end of the study area. This broad area of fine-grained Clayey Silts probably reflects both lower energy conditions and proximity to an eroding marsh shoreline that contributes muddy sediments.

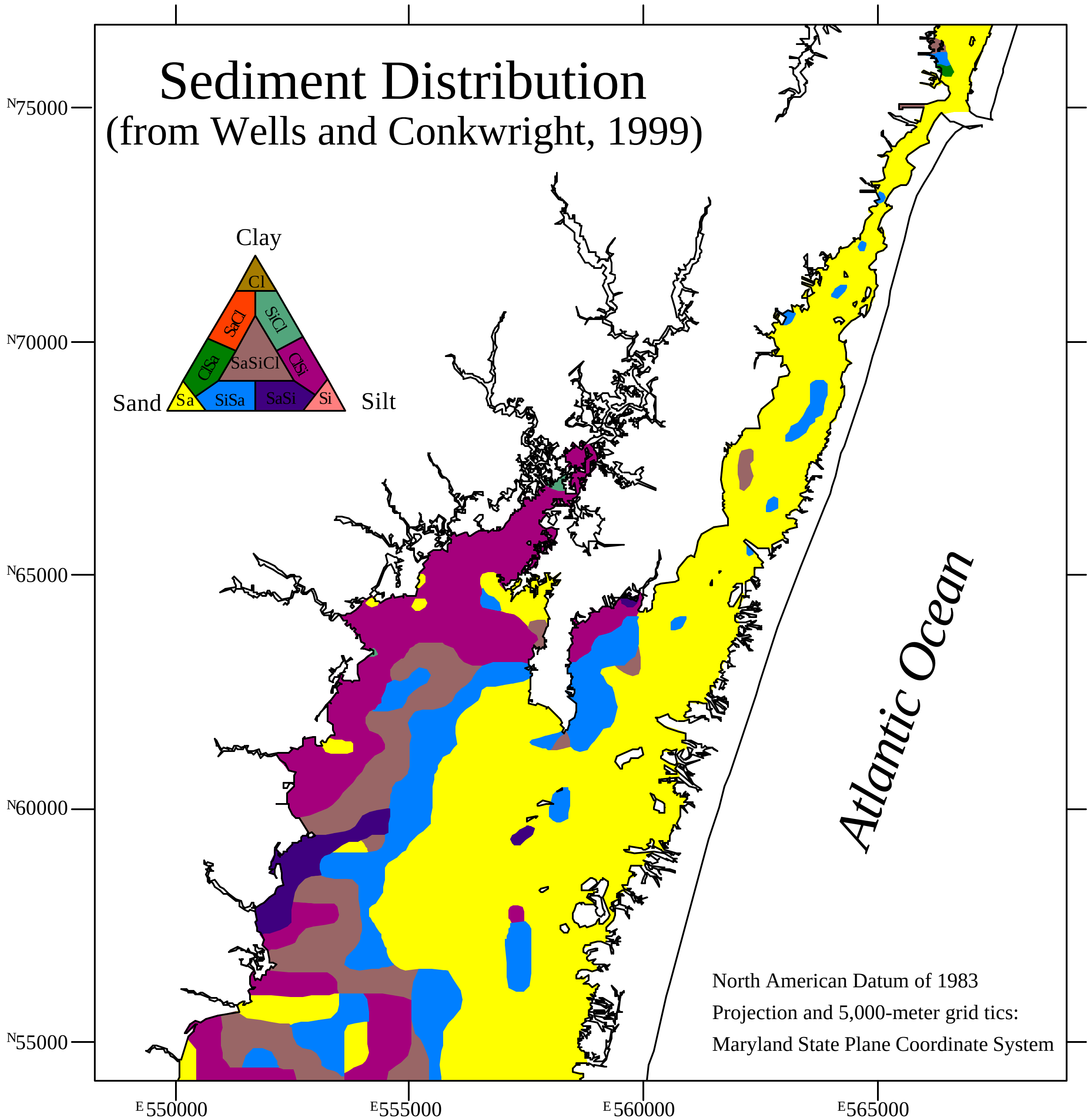


Figure 3-4. Distribution of bottom sediments, based on Shepard's (1954) classification.

4. METHODS

SELECTION OF SAMPLING SITES

Sampling locations were selected primarily on the basis of historical shoreline retreat, geology, geomorphology, and marsh type. Possible candidates were first chosen by identifying unprotected reaches of shoreline that had experienced relatively high rates of erosion, as shown on *Shoreline Changes* maps of the area. Within those reaches, researchers selected 20 sites that represented the:

1 Main water bodies in the study area,
2 Diverse geomorphology, namely, marsh, bluff, and beach,
3 Various geological formations exposed along area shorelines, and
4 Different types of vegetation in marshes bordering the rivers and bays.

Target Universal Transverse Mercator (UTM) coordinates of the 20 original sites were acquired from rectified digital aerial photography (Table 4-1). MGS then contacted property owners, identified from State Property Tax maps, to obtain permission to access the sites. One of the original sites was eliminated because MGS was unable to obtain such permission. In the end, MGS sampled 19 sites as representative of eroding shoreline material – 17 marsh sites and 2 bluff/beach sites (Fig. 4-1). To assess the biotic component of nutrient input, the University of Maryland Center for Environmental Science (UMCES) collected samples at Site 3 in Sinepuxent Bay and at Sites 15 and 17 in Chincoteague Bay. Results of the UMCES analyses will be detailed in a separate report.

Table 4 – 1. Sampling Sites. The one site that was eliminated is indicted by shading.

Site	Name	Location	UTM coordinates (NAD 83, meters)		Comments
			Northing	Easting	
1	Ocean City Airport	Sinepuxent Bay - west shore north of Coffins Pt.	4240024	490057	Marsh
2	Bat Creek	Sinepuxent Bay - west shore north of Snug Harbor; mouth of Bat Cr.	4238710	488970	Marsh
3	Grays Cove (Grays Pt.)	Sinepuxent Bay - west shore vicinity of Grays Cove/Grays Pt.	4236503	488087	Marsh; Joint site, sampled by both MGS and UMCES
4	Fassett Pt.	Sinepuxent Bay - west shore	4235321	487305	Bluff/beach
5	Sandy Cove	Sinepuxent Bay - west shore north of Sandy Pt.	4233815	486634	Marsh

Table 4 – 1. Sampling Sites. The one site that was eliminated is indicted by shading.					
Site	**Name**	**Location**	**UTM coordinates (NAD 83, meters)**		**Comments**
			Northing	**Easting**	
6	Rum Pt./ Green Pt.	Sinepuxent Bay - west shore between Rum Pt. and Green Pt. (border between marsh & farm land – look for erosion)	4231860	485167	Property owner would not give permission to sample
7	Ferry Landing	Sinepuxent Bay - west shore ferry landing on Lower Sinepuxent Neck	4230060	483319	Marsh
8	South Pt.	Newport Bay - east shore Lower Sinepuxent Neck between South Pt. and Island Pt.	4229299	482985	Beach
9	Geneazar	Newport Bay - east shore Lower Sinepuxent Neck in vicinity of Geneazar	4230732	482556	Marsh
10	Knot Pt.	Newport Bay - east shore outermost point	4232078	481917	Marsh
11	Catbird Cr.	Newport Bay - west shore Catbird Cr. and north	4233150	480960	Marsh
12	Cropper Island	Newport Bay - west shore across bay from Knot Pt.	4231894	480029	Marsh
13	Out Pt.	Newport Bay - west shore	4230710	479093	Marsh
14	Handys Hammock	Newport Bay - west shore	4228984	478249	Marsh
15	Kelly Pt.	Chincoteague Bay - west shore island just off Kelly Pt.	4226821	477747	Marsh; Joint site, sampled by both MGS and UMCES
16	Ricks Pt.	Chincoteague Bay - west shore	4224048	476842	Marsh
17	Tingles Island	Chincoteague Bay - east shore: Island on southwest lobe of island	4224761	483096	Island/Marsh; Joint site, sampled by both MGS and UMCES
18	Great Egging Beach	Chincoteague Bay - east shore - northwest lobe of island	1) 4228279 2) 4228253	484291 484244	Island/Marsh; Two sampling sites: 1) beach/berm 2) marsh

Table 4 – 1. Sampling Sites. The one site that was eliminated is indicted by shading.					
Site	**Name**	**Location**	**UTM coordinates (NAD 83, meters)**		**Comments**
			Northing	**Easting**	
19	Sandy Pt. Island	Sinepuxent Bay - east shore Assateague Island State Park	4231941	486847	Island/Marsh
20	Assateague Island	Sinepuxent Bay - east shore Assateague Island, opposite Fassett Pt. and Sandy Cove	4234428	488515	Overwash flat

FIELD METHODS

Sediment Sampling

Field teams accessed all sampling sites by boat. Once on site, they recorded actual UTM coordinates using a hand-held differential GPS unit, briefly described the site, and took photographs. Depending on the nature of the site (i.e., marsh, beach, or bluff), the teams used different methods to collect sediments for *in situ* bulk density determinations and for chemical and textural analyses.

At the bluff sites, several samples were collected from the bluff face, the beach, and offshore along a profile line perpendicular to the shore. Before collecting bluff samples, field personnel cut a shallow, vertical trench into the bluff face to expose an unweathered surface. Sediment samples were collected from each visually distinctive sediment layer by inserting a short length (15 to 25 cm) of clear, cellulose acetate butyrate (CAB) plastic tube (6.7 cm in diameter) horizontally into the bluff face. The tube was dug out of the bluff face, and its ends were trimmed in such a way that the inside of the tube was completely filled with sediment (no gaps). Sample tubes were capped and labeled. Grab samples collected on the beach and offshore were placed in Whirl-pak bags. Bluff height and the elevations of sediment horizons and sample locations along the bluff/beach profile were determined using a level and a stadia rod.

At marsh sites, a continuous sediment core was collected on a prominent neck or point of the marsh, approximately 1 m from the water's edge. The length of core needed at each site was determined by averaging several bank height measurements. Bank height was defined as the distance between the top of the marsh and the base of the erosional scarp at the marsh edge. The base of the scarp was usually underwater. Marsh cores were collected by vibrating or pounding 7.62 cm-diameter aluminum tubing into the marsh surface down to the desired depth. Sediment compaction was measured and recorded before the core was extracted. Following extraction, the liner was trimmed to the top of the sediment and sealed at both ends for transportation back to the lab. There, it was kept refrigerated until it was processed. A grab sample was collected approximately 0.3 m offshore adjacent to the core location.

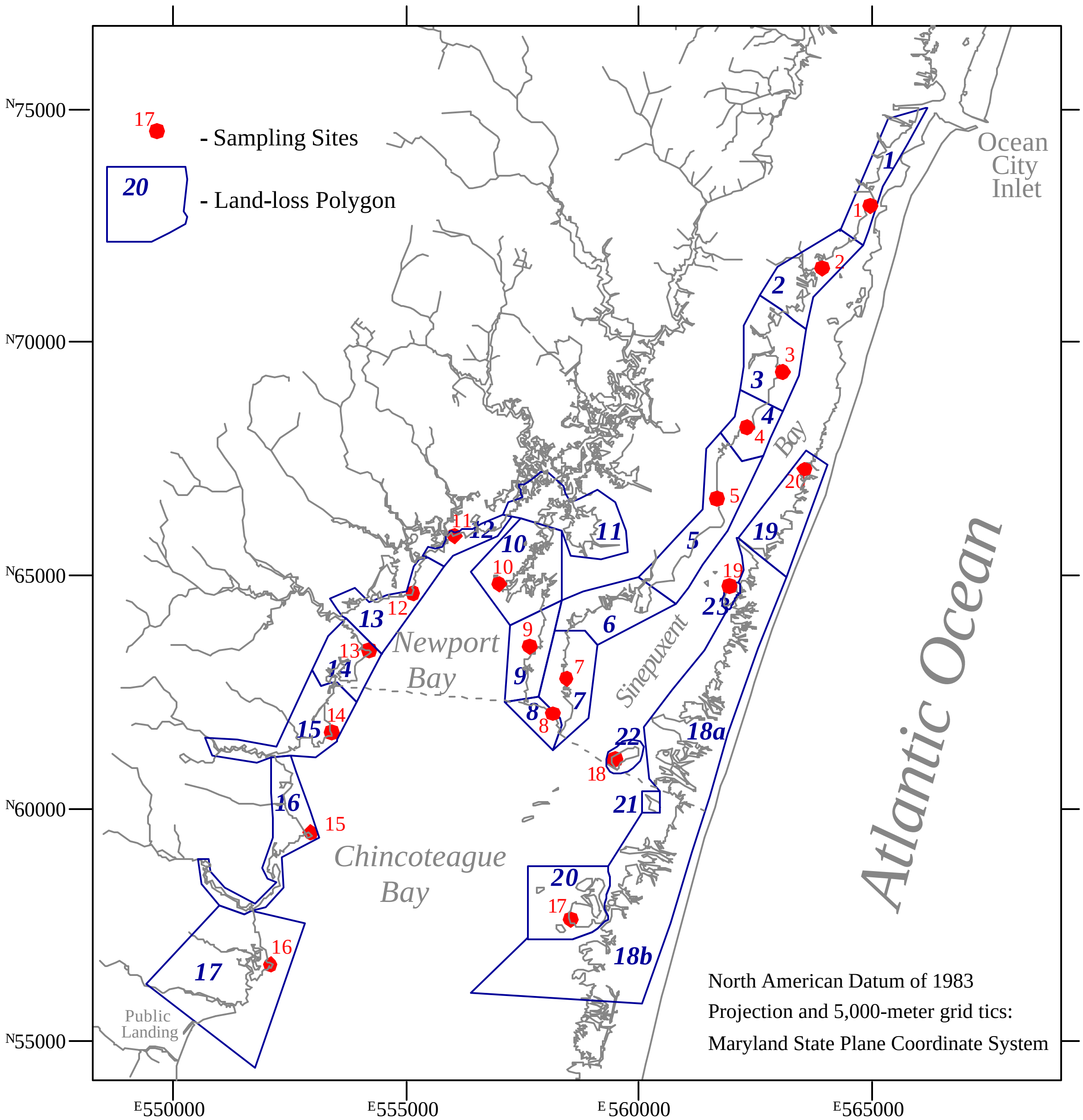


Figure 4-1. Locations of the sampling sites (red) and the land-loss polygons (blue). Also shown are the boundaries of the three bays as they are defined in this report.

LABORATORY METHODS

Quantifying Land Loss

The amount of land lost annually in the study area is based on a digital comparison of two historical shorelines, one dating from 1942 and the other from 1989. The 1942 shoreline was previously digitized from 1:20,000-scale NOAA coastal survey maps, also known as topographic (T-) sheets. The 1989 shoreline was previously interpreted from 1:12,000-scale orthophotography. At the time it was delineated, the 1989 shoreline was also classified by shoreline type (i.e., beach, structure, vegetated, or water's edge) (Hennessee, 2001). MGS used a geographic information system (GIS), MicroImages' TNTmips, to compare shoreline positions and quantify losses due to erosion.

Different stretches of shoreline erode at different rates. To account for this variability, MGS divided the study area shoreline into 23 segments. Shoreline reaches ranged in length from about 1,100 m to 67,400 m; most were less than 8,000 m long. To demarcate the reaches, MGS constructed a template of irregular, mostly contiguous, "land loss" polygons. The polygons were drawn in such a way that:

- They excluded the northern 8 kilometers of the Assateague Island bay side shoreline (eastern shore of Sinepuxent Bay), which is actively undergoing overwash.
- They contained all unprotected shoreline in the study area, except for Marshall Creek, including Massey Branch, and the upstream reaches of Trappe Creek.
- With the exceptions listed above, they initially included the 1942 and 1989 shorelines in their entirety.
- Based on researchers' field experience and an inspection of 1989 digital orthophotography, each contained, as far as practicable, similar types of shoreline (i.e., marsh or upland).
- In areas of changing geology, their boundaries coincided with the contacts between geologic formations.
- Generally, in the vicinity of a bay or tributary mouth, polygon boundaries coincided with the mouth (e.g., polygon P8), to allow the authors to report their results by water body.
- In the absence of any of the above criteria, polygon boundaries were drawn equidistant between sample locations. No polygon included more than one sampling site.

Each land loss polygon in the template was assigned a number, P#. The polygons are shown in Figure 4-1, and a description of their locations is presented in Table 4-2.

Table 4-2. Land loss polygons and associated sampling sites for middle Coastal Bays.

Land loss polygon	Location	Geology*	Associated sampling site
P1	Sinepuxent Bay, W shore: Upper Sinepuxent Neck; Ocean City Inlet south to Coffins Pt. (Ocean City quadrangle)	(P) – Mostly **Sinepuxent Formation (Qs)** except for small area of **Holocene Tidal Marsh Deposits (Qtm)** (S) **- Qs**	1
P2	Sinepuxent Bay, W shore: Upper Sinepuxent Neck; Coffins Pt. south to northern Grays Cove, including Snug Harbor (Ocean City and Berlin quadrangles)	(P) – Mostly **Qtm**, except **Sinepuxent Fm. (Qs)** at Coffins Pt. (S) **– Qtm**	2
P3	Sinepuxent Bay, W shore: Lower Sinepuxent Neck; northern Grays Cove south to unnamed point midway between Grays Pt. and Fassett Pt., including Grays Pt. (Berlin quadrangle)	(P& S) – Mostly **Qtm**	3
P4	Sinepuxent Bay, W shore: Lower Sinepuxent Neck; unnamed point midway between Grays Pt. and Fassett Pt. south to northern Sandy Cove, including Fassett Pt. (Berlin quadrangle)	(P) – Mostly **Qs** except for small area mid-way which is **Qtm**; (S) **- Qs**	4
P5	Sinepuxent Bay, W shore: Lower Sinepuxent Neck; northern Sandy Cove south to unnamed cove between Rum Pt. and Green Pt., including Sandy Pt., Salt Pt., and Rum Pt. (Berlin and Tingles Island quadrangles)	(P) – Mostly **Qs**, except some **Qtm** (S) – **Qtm**	5
P6	Sinepuxent Bay, W shore: Lower Sinepuxent Neck; unnamed cove between Rum Pt. and Green Pt. southwest to upland/marsh boundary where shoreline turns due south, including Green Pt. (Tingles Island quadrangle)	(P) **– Qtm** ; (S) – no sample in polygon	5
P7	Sinepuxent Bay, W shore: Lower Sinepuxent Neck; upland/marsh boundary at SW corner of P6 (opposite Spence Cove) south to South Pt. (Tingles Island quadrangle)	(P & S) – **Qs**	7

Table 4-2. Land loss polygons and associated sampling sites for middle Coastal Bays.			
Land loss polygon	**Location**	**Geology***	**Associated sampling site**
P8	Chincoteague Bay, N shore: Lower Sinepuxent Neck; South Pt. northwest to Island Pt. at confluence of Chincoteague and Newport Bays (Tingles Island quadrangle)	(P & S) **– Qs**	8
P9	Newport Bay, E shore: Lower Sinepuxent Neck; from Island Pt. northwest of South Pt. at confluence of Chincoteague and Newport Bays north to upland/marsh boundary in vicinity of Spence Cove (Tingles Island quadrangle)	(P) – Alternate **Qs** and **Qtm** (S) – **Qtm**	9
P10	Newport Bay, E shore: Lower Sinepuxent Neck and Newport Neck; Spence Cove to northern boundary of Tingles Island quadrangle (38° 15'), including Knot Pt. (Tingles Island quadrangle)	(P & S) – **Qtm**	10
P11	Newport Bay, N shore: Headward reaches of Newport Bay, including Gibbs Pond and Buddy Pond (Berlin and Tingles Island quadrangles)	(P) – **Qtm** (S) – no sample in polygon	10
P12	Newport Bay, W shore: Northern boundary of Tingles Island quadrangle (38° 15') south to vicinity of Cropper Pond and Catbird Cr. (Berlin and Tingles Island quadrangles)	(P & S) – **Qtm**	11
P13	Newport Bay, W shore: Vicinity of Cropper Pond and Catbird Cr. south to Marshall Cr. (Tingles Island quadrangle)	(P & S) – **Qtm; Ironshire Fm. (Qi)** exposed along south bank of Marshall Ck.	12
P14	Newport Bay, W shore: Marshall Cr. south to mouth of pond immediately west of Log Pt., including Out Pt. and Log Pt. (Tingles Island quadrangle)	(P & S) – **Qtm**	13
P15	Chincoteague Bay, W shore: Mouth of pond immediately west of Log Pt. south to Waterworks Cr., including Handys Hammock and Waterworks Cr. (Public Landing and Tingles Island quadrangles)	(P & S) – **Qtm**	14

Table 4-2. Land loss polygons and associated sampling sites for middle Coastal Bays.			
Land loss polygon	**Location**	**Geology***	**Associated sampling site**
P16	Chincoteague Bay, W shore Waterworks Cr. south to Robins Cr., including Windmill Pt., Kelly Pt., Peters Pond, and Robins Cr. (Public Landing quadrangle)	(P) – Mostly **Qtm**, except some **Qs** and **Qi** (S) – **Qtm**	15
P17	Chincoteague Bay, W shore Robins Cr. south to Public Landing, including Ricks Pt. and Cotter Cove (Public Landing quadrangle)	(P & S) – **Qtm**	16
P18	Chincoteague and Sinepuxent Bays, E shore: Assateague Island from vicinity of Tingles Island north to ferry landing between Little Egging Beach and Goose Pt. (Tingles Island quadrangle)	(P) – Equally **Holocene Barrier Sand (Qbs)** and **Qtm** (S) – No sample in polygon	19
P19	Sinepuxent Bay, E shore: Assateague Island from ferry landing between Little Egging Beach and Goose Pt. north to vicinity of northern border of Tingles Island quadrangle (38^{o} 15’) (Berlin and Tingles Island quadrangles)	(P) – Mostly **Qbs** except some **Qtm** (S) – **Qbs**	20
P20	Chincoteague Bay: Tingles Island, including Outward Tump (Tingles Island quadrangle)	(P & S) **– Qtm**	17
P21	Chincoteague Bay: Lumber Marsh (island) (Tingles Island quadrangle)	(P) – **Qtm** (S) – no sample in polygon	18
P22	Chincoteague Bay: Great Egging Beach (island) (Tingles Island quadrangle)	(P & S) – **Qtm**	18
P23	Sinepuxent Bay: Sandy Point Island (Tingles Island quadrangle)	(P & S) – **Qtm**	19
* within polygon (P) and at sampling site (S)			

Once it was constructed, the polygon template was merged first with the 1942 shoreline and then with the 1989 shoreline. Both shoreline/template files were edited:

- Small gaps in the shoreline were closed by drawing short, straight lines between the dangling shoreline segments.
- Man-made features, usually canals, present in one year but not the other, were deleted. Likewise, tributaries that existed in only one coverage were erased.
- In some cases, the headward reach of a small tributary extended further upstream in one year than in another. Likewise, some ponds and coves, particularly in or along marshes, were evident in only one coverage. These features were left unaltered.

- Within each of the land loss polygons, interior polygons were assigned one of the following attributes: "fastland," "island," or "water."

For each land loss polygon, the areas (m^2) covered by fastland, island, and water were recorded, by year, in an Excel spreadsheet. Likewise, the total length (m) of the 1989 shoreline, as well as the length of each type of shoreline (beach, structure, vegetated, water's edge) was recorded. For each polygon, land loss over the 47-year period was determined by subtracting water area in 1989 from water area in 1942. The difference in water area is equivalent to the area of land lost by erosion. A summary of area and shoreline changes for each polygon is presented in Table D-1 (Appendix D).

The land loss polygons provided a structure for organizing the results of the sediment, pore water, and plant tissue analyses. Each sample location was associated with one or more of the land loss polygons (Table 4-2). In the simplest case, where polygons and samples were co-located, the association is direct. For instance, the results for Site 11, located within polygon P12, are associated with polygon P12. For unsampled polygons, the association was based either on similarity in geology or shoreline type (marsh or upland), or on proximity.

<u>Bank Height</u>

At each sampling location, bank height measurements (m) were taken at several places and averaged for the site. The mean heights were assigned to the associated land loss polygon(s).

Sediments

<u>Core Processing</u>

Before opening the cores, MGS x-rayed them in their liners using a TORR-MED medical X-ray unit. The exposure settings were 84 to 90 kv for 6 to 8 sec at 5 milliAmps. Radiographic images were developed using a Xerox 125 xeroradiograph processor.

After x-raying was completed, each core was cut in half lengthwise. First, the aluminum liner was cut using a circular saw. The sediment core within the liner was then cut in half with a very sharp, stainless steel knife. The knife produced a clean cut through the plant roots and peat material, minimizing deformation of the core structure or shape. Lab personnel photographed and described the split core, noting changes in sediment and structure with depth. Xeroradiographs (x-rays), photographs, and core logs are presented in Appendix A. The core was divided into sections 10 to 25 cm long. The exact length depended on lithological changes observed in the split core and in the radiographs. Each section was split lengthwise into three or four subsamples, which were designated for specific analyses (i.e., bulk density, grain size, or chemical analyses). The sub-samples were placed in Whirl-Pak bags. Bulk density splits were processed first, before other splits were made (see next section).

Bulk Density and Water Content

For both bluff samples and cored marsh sediments, MGS used similar methods to determine bulk density and water content. Grab samples collected from the beach and nearshore were processed for water content only.

Bluff Samples

The entire sediment sample was removed from the plastic core tube and weighed. The length of the tube was recorded. The sample was then mixed to homogenize it. Exactly ¼ of the sample, by weight, was placed in a drying vessel, dried at 60°C, and then reweighed. The dried sample was saved for chemical analyses. The remaining ¾ of the sample was saved for grain size analysis.

Water content was calculated as the percentage of water weight to the total weight of wet sediment, as follows:

$$\%\ H_2O = \left(\frac{W_w}{W_t}\right) * 100 \qquad \textbf{Eq. 4-1}$$

where: W_w is the weight (g) of water, and
W_t is the weight (g) of wet sediment.

Wet and dry bulk densities (referred to in this study as "measured" bulk density, in g/cm^3 or Kg/m^3) were calculated as the wet weight or dried weight (g), respectively, of the subsample divided by ¼ of the volume of the entire bluff sample. Volume was calculated using the volume formula for a cylinder:

$$V = p\, r^2\, l \qquad \textbf{Eq. 4-2}$$

where: V is the volume (cm^3) of the subsample,
p is 3.14159,
r is the radius of the circumference of the CAB tube liner, or ½ the diameter (6.7 cm), and
l is the length (cm) of the core tube.

A second method was used to calculate bulk density (wet) using the water content of the sediment (Bennett and Lambert, 1971). This method assumes that average sediment grain density is 2.72 g/cm^3 and that the sample is fully saturated with water.

$$r_{(B\,\&\,L)} = \frac{W_t}{\frac{W_d}{2.72} + W_w} \qquad \textbf{Eq. 4-3}$$

where: $r_{(B\,\&\,L)}$ is the calculated bulk density, based on Bennett and Lambert,
W_t is the weight (g) of wet sediment,
W_d is the weight (g) of dry sediment, and
W_w is the weight (g) of water.

Cored Marsh Samples

Each section of core was weighed to determine the total weight of the section. Exactly ½ of the section, by weight, was placed in a drying vessel, dried at 60°C, and then reweighed. The dried sample was archived.

Water content and calculated wet bulk density, based on Bennett and Lambert, were calculated using Equations 4-1 and 4-3, respectively. Measured bulk densities were calculated as the wet and dried weights (g) of the subsample divided by ½ of the volume of the core section. The volume of the core section was calculated using Equation 4-2, where r = ½ the diameter of the aluminum tubing (7.62 cm diameter) and l = section length.

Dry bulk density of the core section was adjusted to account for any core compaction. For most of the cores, there was some compaction (compression) of the sediments during the insertion of the core liner. The amount of compaction was measured as the difference between the top of the marsh and the top of the sediment in the core liner once the liner was emplaced. The degree of compaction along the length of the core varied depending on sediment texture. However, for this study, MGS assumed that compaction was evenly distributed over the length of the core. Bulk densities were multiplied by a compaction correction calculated as:

$$c_{(c)} = 1 - \left(\frac{l_{(s)} - l_{(t)}}{l_{(s)}} \right) \qquad \textbf{Eq. 4-4}$$

where, $c_{(c)}$ is the compaction correction,
$l_{(s)}$ is the length or depth (cm) of the sediment column cored or sampled, and
$l_{(t)}$ is the length (cm) of the sediment core collected.

Grain Size Analysis

In preparation for grain size analysis, sediment samples underwent a cleaning process to remove soluble salts, carbonates, and organic matter. These constituents may interfere with the dispersal of individual sediment particles and, thereby, affect the subsequent separation of the sand and mud fractions. All sediment samples were treated first with a 10% solution of hydrochloric acid (HCl) to remove carbonate material, such as shells, and then with a 6% or 15% solution of hydrogen peroxide (H_2O_2) to remove organic material. A 0.26% solution of the dispersant sodium hexametaphosphate ($(NaPO_3)_6$) was then added to ensure that individual grains did not clump, or flocculate, during pipette analysis.

Marsh samples, which contained significant amounts of plant material, were wet-sieved through a 14-mesh (~1.4 mm) nylon screen to remove large plant roots and debris. The plant material was dried and weighed. Usually, plant matter was separated from sediments after the HCl treatment. However, for cores collected at sites sampled jointly by MGS and UMCES, samples were sieved prior to HCl treatment, and the plant fractions (> 1.4 mm) were saved for chemical analysis.

For each sample, the sand fraction was separated from the mud fraction by wet-sieving through a 4-phi mesh sieve (0.0625 mm, U.S. Standard Sieve #230). The sand fraction (i.e., particles > 0.0625 mm) was dried and weighed. The mud fraction (i.e., sediment passing through the #230 sieve) was analyzed using a pipette technique to determine the proportions of silt and clay (Krumbein and Pettijohn, 1938). The mud fraction was suspended in a 1000-ml cylinder in a solution of 0.26% sodium hexametaphosphate. The suspension was agitated and, at specified times thereafter, 20 ml pipette withdrawals were made. The rationale behind this process is that larger particles settle faster than smaller ones. By calculating the settling velocities of different sized particles, withdrawal times can be determined. At the time of withdrawal, all particles larger than a specified size have settled past the point of withdrawal. Sampling times were calculated to permit the determination of the total amount of silt and clay (4 phi) and clay-sized (8 phi) particles in the suspension. Withdrawn samples were dried at 60°C and weighed. From these dry weights, the percentages of sand, silt, and clay were calculated for each sample and classified according to Shepard's (1954) nomenclature (Fig. 4-2).

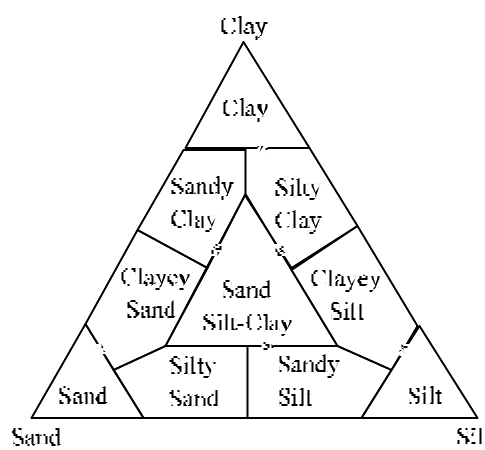


Figure 4-2. Shepard's (1954) classification of sediment types.

Chemical Analysis

Sample Preparation

Before marsh samples were dried and ground, they were processed using a commercially available food blender and plastic (styrene copolymer) processor containers. Between 50 to 100 g of wet core sample, roots and all, were mixed with 50 to 100 ml of ultra-pure water. The slurry was processed at hi/liquefy for 1 minute or until no visible pieces of plant material remained. The processed slurry was then transferred to an evaporating dish and dried at $60^{o}C$.

The dried marsh samples and the bluff samples dried for bulk density/water content determinations were ground in tungsten-carbide vials using a ball mill, placed in Whirl-Pak bags, and stored in a desiccator.

Total Carbon and Nitrogen Analysis

Untreated, ground sediments were analyzed for total nitrogen, carbon, and sulfur (NCS) using a Carlo Erba NA1500 analyzer. Approximately 10 to 15 mg of dried sediment were weighed into a tin capsule. The exact weight of the sample, to the nearest µg, was recorded. To ensure complete combustion during analysis, 15 to 20 mg of vanadium pentoxide (V_2O_5) were added to the tin capsule and mixed with the sediment. The capsule was then crimped to seal it and stored until analysis.

The encapsulated sediment sample was dropped into a combustion chamber, where the sample was oxidized in pure oxygen. The resulting combustion gases (N, C, H, and S), along with pure helium, the carrier gas, were passed through a reduction furnace to remove free oxygen and then through a sorption trap to remove water. Separation of the gas components was achieved by passing the gas mixture through a chromatographic column. A thermal conductivity detector was used to measure the relative concentrations of the gases.

The NA1500 Analyzer was configured for NCS analysis using the manufacturer's recommended settings. As a primary standard, 5-chloro- 4-hydroxy- 3-methoxy-benzylisothiourea phosphate was used. Blanks (tin capsules containing only vanadium pentoxide) were run every 12 samples. Replicates of every fifth sample were run. As secondary standards, at least one standard reference material (SRM) (NIST SRM #1646 – Estuarine Sediment; NIST SRM #2704 – Buffalo River Sediment, or the National Research Council of Canada PACS-1 – Marine Sediment) was run every six or seven samples. Comparisons of the results of the SRMs to the certified values are presented in the discussion of quality assurance and quality control (Appendix C).

Total Phosphorus and Metals

Activation Laboratories, Ltd. (Actlabs) of Tucson, Ariz., analyzed bluff and marsh sediments for 22 elements including total phosphorus. The lab used a four-acid, "near total" digestion process, followed by analysis of the digestate by inductively coupled plasma emission spectroscopy (ICP-OES). The four-acid digestion employed perchloric ($HClO_4$), hydrochloric (HCl), nitric (HNO_3), and hydrofluoric (HF) acids. Quality assurance was checked using the method of bracketing standards (Van Loon, 1980). The SRMs, similar to the sediments being analyzed, included the same standards used in the total nitrogen, carbon, and sulfur analyses. Actlabs' results of the analyses of the SRMs are listed in Appendix B. Analytical results for the bluff and marsh core samples are listed in Appendix C.

DATA REDUCTION

Average concentrations of nutrients (total carbon, nitrogen, and phosphorus), specific metals (Pb and Zn), and textural components (total solids, sand, silt, and clay) were calculated for each core or bank/bluff site by averaging the concentrations of the individual core samples or bluff samples, normalized to bank height. Mean site concentrations were then assigned to specific land loss polygons (see Table 4-2) to calculate the component loadings for the polygons. Equations for the data reductions, along with detailed explanations and calculation tables, are presented in Appendix D.

5. RESULTS AND DISCUSSION

FIELD AND LAB OBSERVATIONS

Within the study area, sediment samples were collected primarily along marsh shorelines. Site 4, on the mainland side of upper Sinepuxent Bay, was the only bluff sampled. Here, a narrow beach fronts a bluff 2 to 2.5 m high. Bluff sediments consist predominately of yellow to reddish-brown silty sands (Fig. 5-1). At the base of the bluff, hard bluish-gray mud, resistant to erosion, forms a shelf upon which beach sand lies. The shoreline along this site is characteristic of an eroding headland (Sinepuxent Formation).

Beach (Site 8) and mixed beach-marsh shorelines (Sites 18 and 20) were sampled. Site 8 (Fig. 5-2), located on the southwest side of Sinepuxent Neck, is characterized by a narrow beach backed by a low sandy berm, separating the beach from a mixed marsh wood area. A core collected at this site contained a hard sandy mud 30 cm below the surface. Sites 18 and 20 are located on the bay side of Assateague Island where sand is the dominant sediment. Site 18 is on an island, which is probably a remnant of a flood shoal associated with a former inlet. Site 20 is located within an overwash area.

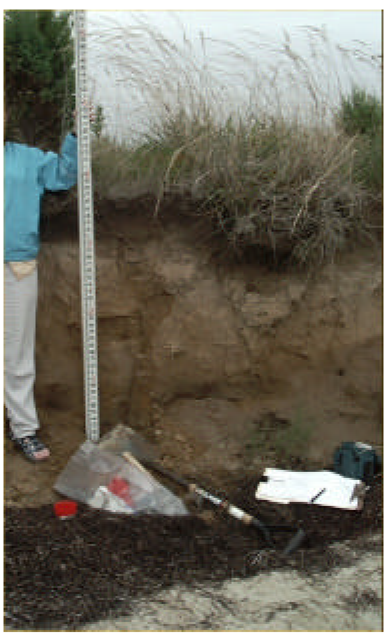


Figure 5-1. Bluff at Site 4.

Figure 5-2. Beach at Site 8, located on west side of Sinepuxent Neck.

Pocket beaches (lengths less than 50 m) are less common along the middle bays' mainland shore than they are in the northern bays (Wells and others, 2002). Pocket beaches may reflect a localized sand source (e.g., sandy facies in the underlying Sinepuxent Formation), nearshore sediment transport processes, or a combination of both. In Rehoboth Bay, Delaware, Schwimmer (2001) observed that sandy beaches occur where eroding shoreline intersects upland areas. Subtle variations in lithologies at marsh sites may be related to antecedent topography, as well as to local sediment transport processes.) In this study, pocket beaches were noted at two mainland shoreline sites (Sites 12 and 14), both within extensive Quaternary tidal marsh deposits in Newport Bay.

The remaining sites are located on prominent points along marshy shorelines composed of either Holocene tidal marsh deposits or Sinepuxent deposits. Most marsh shorelines are convoluted and edged by a 0.4 to 0.8 m erosional scarp, which is often undercut beneath the root mat layer. Features observed along the marsh shoreline include neck and cleft, pinched necks, stacks and isolated islands (Fig. 5-3), all of which are indicative of wave attack (Fig. 5-4), a significant erosional process operating in the coastal bays (Schwimmer, 2001).

Figure 5-3. The main features developed along a marsh shoreline due to wave erosion (from Schwimmer, 2001).

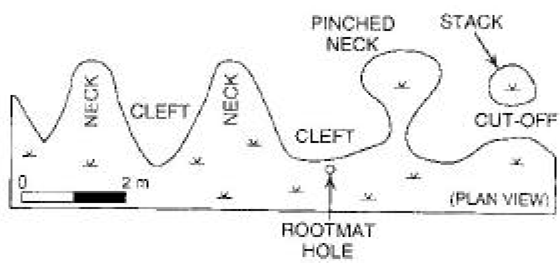


Figure 5-4. Convoluted marsh shoreline at Site 16, Ricks Point in Chincoteague Bay. This stretch of shoreline, normal to the direction of maximum fetch, is subjected to high wave energy.

The marsh vegetation consists primarily of *Spartina alterniflora* with *Spartina patens* and *Limonium.* At Sites 8, 14, and 18, *Phragmites* is widespread. At several sites, the marsh surface and scarp are armored with live mussels (*Modiolus sp*).

Based on an examination of the sediment cores, sediment characteristics vary both vertically and laterally across a given site, and from site to site. Marsh sediments are predominately sandy muds with significant plant material and organic matter (peat). Bulk organic content ranges from less than 1% to 50% dry weight, which is less than the organic content observed in cores collected in the northern coastal bays. At almost all of the marsh sites, sand content decreases with depth. At several sites (Sites 1, 9, 12,and 14), a sand layer was observed at ~60 cm below the sediment surface. Generally, the active (live) root zones range from depths of 20 cm to 50 cm below the marsh surface. In some cores, a redox boundary was evident just below the active root zone. Unlike the cores collected in the northern coastal bays, those collected in the middle coastal bays (with the exception of Core 2; 71-92 cm) did not contain any obvious “spongy” layers (i.e., layers characterized by very low bulk density, <0.25 g/cm^3).

LAND LOSS (AREA AND VOLUME)

For the 47-year period between 1942 and 1989, Table 5-1 shows land lost and rates of erosion for the middle coastal bays. Over that period, the 202 km of shoreline lost about 1.2 x 10^6 m^2 of land to erosion. On average, the shoreline retreated a total of -9.3 m, at an annual rate of -20 cm/yr. Rates of loss varied widely depending on location (Fig. 5-5). The bay shorelines of Assateague Island (P18) experienced minimal erosion, -2 cm/yr. Rates reached a maximum of -56 cm/yr along the upper mainland (western) shore of Sinepuxent Bay (P4). These annual erosion rates are on the same order of magnitude as those reported for other Delmarva coastal bays. Wells and others (2002) reported average erosion rates ranging from –4 cm/yr to –39 cm/yr for Maryland’s northern coastal bays. For marsh shorelines in Rehoboth Bay, erosion rate averaged between –14 cm/yr and –43 cm/yr over a three year period (Schwimmer, 2001).

Table 5-1 also shows volumetric losses, the result of multiplying the change in a polygon’s land area by the associated bank height (see Appendix D, Table D-1 for calculations for each polygon). The calculation assumes uniform bank height throughout the polygon and vertical, as opposed to sloping, banks. Except for Site 4, bank heights in the study area are less than 1 m in elevation.

Table 5-1. Volume (m^3) and rate of land loss during the 47-year period between 1942 and 1989 and linear rates (m/yr) of shoreline erosion, by bay. Negative numbers indicate erosion. Values given reflect only the shoreline and land area within the polygons (Fig. 4-1).

Basin	1989 shoreline length (m)	Rate of shoreline change (m/yr)	Change in land area (m^2)	Mean bank height (m)	Volume loss for period (m^3)	Rate of volume loss (m^3/yr)
Sinepuxent Bay	76,672	-0.26	-578,083	0.59	338,232	7,196
Newport Bay	58,872	-0.16	-391,893	0.70	297,781	6,336
N.Chincoteague Bay	66,603	-0.12	-207,636	0.53	112,401	2,392
Total	202,146		-1,177,613		748,414	15,924
Average		-0.20		0.61		

Over the course of the 47 years, the total volume of sediment lost to shoreline erosion amounted to 748 x 10^3 cubic meters (m^3). Annually, that translates to 15.9 x 10^3 cubic meters per year (m^3/yr). Annual volumetric losses in Sinepuxent Bay and Newport Bay are about the same, between 6 x 10^3 and 7 x 10^3 cubic meters per year. In terms of loss per linear length of shoreline, Newport Bay has the highest loss per linear meter of shoreline (0.1 m^3/m/yr); northern Chincoteague Bay has the lowest (0.04 m^3/m/yr). On the other hand, based on the annual rate of change in shoreline position, Sinepuxent Bay has the greatest change, with a mean rate of change (0.26 m/yr erosion), twice that of Newport Bay and north Chincoteague Bay (0.15 m/yr and 0.12 m/yr erosion, respectively). Depending on one's perspective, one measure may be more useful than the other. Waterfront property owners, for example, may be most concerned about how rapidly the shoreline is approaching their homes. Coastal zone managers, attempting to minimize turbidity, may be more interested in volumetric losses.

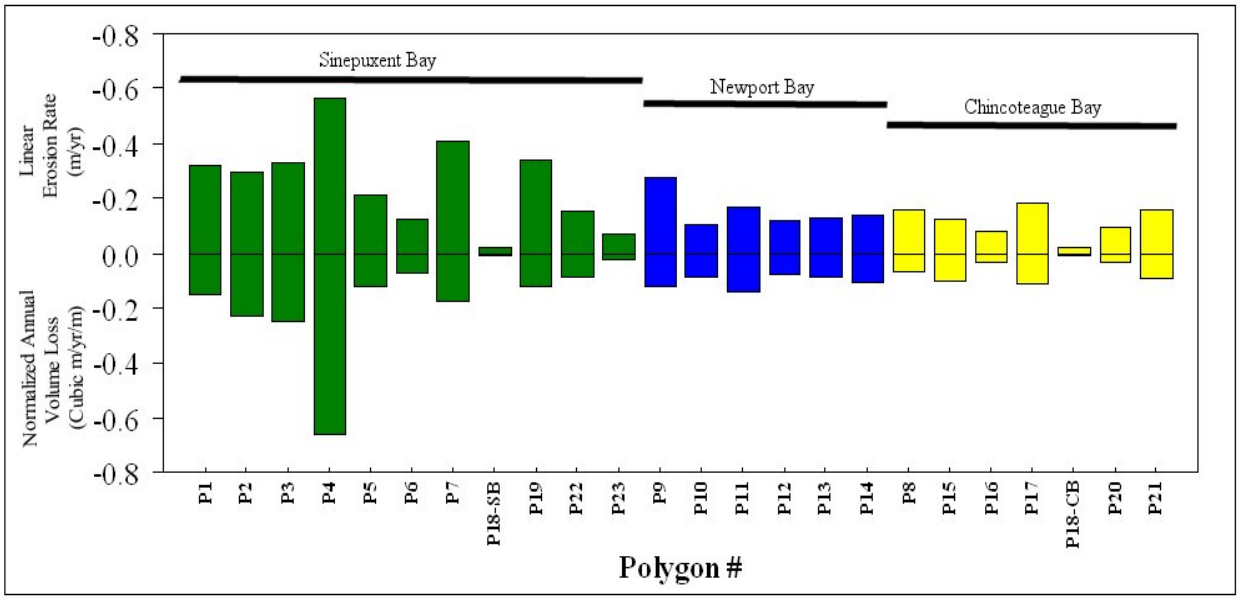


Figure 5-5. Comparison of linear erosion rate and volumetric loss for each land loss polygon. To normalize differences in polygon areas, volume loss for each polygon is divided by shoreline length within the polygon; losses are given as volume (m^3 or cubic meter) per year per linear meter of shoreline.

SEDIMENTS

Bulk Density

Bulk density, a determination of the total solids in a volume of sediment, is one of the most important parameters measured in this study. Used to convert the volume of land lost to mass loadings, bulk density is calculated by two different methods. First, it is measured directly. A known volume of sediment is weighed and assumed to reflect the *in situ* density of shoreline sediments, accounting for all air pockets, clastics, plant material, etc. Second, bulk density is calculated as a function of water content (Bennett and Lambert, 1971). Results of both methods, reported in Appendix C, are discussed below. Measured dry bulk density, calculated by the first method, is the number used in the mass loading calculations.

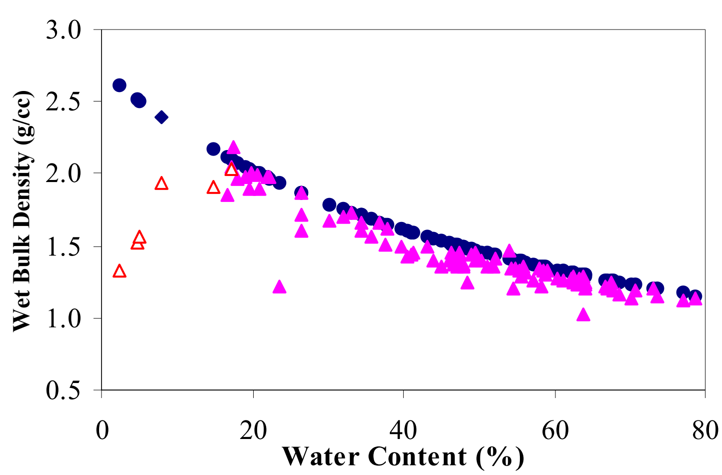
The measured dry bulk density of sediments ranges from 0.24 to 1.80 g/cm^3, averaging 0.83 ± 0.42 g/cm^3. Highest bulk densities (i.e., >1.65 g/cm^3) are associated with sediments sampled from the bluff site (Site 4) and sand banks (Sites 8 and 18A) and with sediments having high sand content. The average dry bulk density of bluff and sand bank sediments is 1.53 ± 0.13 g/cm^3, identical to the average bulk density of 1.5 g/cm^3 used by Ibison and others (1990, 1992) in a similar study in Virginia.

The measured dry bulk density of marsh sediments ranges from 0.24 to 1.70 g/cm^3, averaging 0.76 ± 0.37 g/cm^3. This average value is almost twice that reported for the marsh sediments in the northern coastal bays (Wells and others, 2002). At most sites, higher bulk densities correspond to the sandy sediments found at the tops of cores. Densities tend to decrease with depth below the marsh surface. The lowest bulk density observed was measured between 71 and 93 cm below the marsh surface at Site 2. This density corresponded to a peat layer, consisting of abundant plant material, organic matter, and mud (silt and clay), but very little sand.

Water Content

Water content of marsh samples ranges from 17 to 79%, averaging 49 ± 16%. On average, bluff and beach sediments contain very little water (mean = 12% ± 7%). For sediments that are saturated with water, particularly marsh samples, water content is inversely related to bulk density (Fig. 5-6). Water content, which reflects the volume of pore space between solid particles, is a function of grain size, grain shape, and the packing of grains. Measured wet bulk density is typically 8% less than the calculated Bennett and Lambert values (B&L bulk density). The difference is attributable to incomplete saturation with water, as with the bluff samples, and to the deviation of the average specific gravity (i.e., density) of the solids in the sediment from the constant, 2.72 g/cm^3, used by Bennett and Lambert (Eq. 4-3). Marsh sediments contain varying amounts of organic matter, which reduces the overall (average) density.

Figure 5-6. Measured wet bulk density as a function of water content. The smooth curve defined by (blue) diamonds represents bulk density calculated using Bennett and Lambert's equation (Eq. 4-3). Measured wet bulk density values (triangles) agree very well with Bennett and Lambert values (R^2 = 0.86). The open triangles correspond to bluff and sand bank samples (Sites 4 and 18A).



Texture (Grain size composition)

The average textural composition of the clastics (i.e., mineral or abiotic component) eroded from the middle coastal bays' shoreline is 45% Sand, 36% Silt, and 19% Clay. The sand:mud ratio is approximately 1:1 (Table 5-2) and differs from the 2:1 ratio reported for the northern coastal bays. Sand is the most abundant component, followed by silt. Gravel, found in trace amounts, represents less than 0.1 % of the grain size composition.

Table 5-2. Average* textural composition of sediments eroded from the shoreline**.**

Basin	Gravel %	Sand %	Silt %	Clay %
Sinepuxent Bay	0.02	48.33	33.99	17.66
Newport Bay	0.08	30.25	45.72	23.94
N. Chincoteague Bay	0.00	63.88	21.88	14.24
Study Area	0.04	45.28	35.64	19.05

* Average percentages are based on total annual loadings (Kg/yr) for each clastic component; refer to Table 5-6.

Bluff and beach sediments consist almost entirely of clastics (% dry weight). The bulk of the clastics consists of sand-sized particles, except for the mud unit at the bottom of Core 4; that mud is a Sandy-Silt. Gravel is present in trace amounts (less than 0.1%) in the bluff sediments.

Marsh sediments contain between 50 and 99% clastics, the textural composition of which varies with depth below the marsh surface. Plant root mass (i.e., plant material and roots retained on a 14-mesh or 1.4 mm sieve) ranges from <1 to 34% (dry weight).

At all mainland shoreline sites except Site 7, sand is a major clastic component in the upper 20 cm and decreases with depth below the marsh surface. At depth, sediments consist predominately of Silty-Clay and Clayey-Silt (mud). The decrease in sand explains the down-hole decrease in bulk density observed in the cores. There is a significant relationship between sand content and measured dry bulk density ($R^2 = 0.63$, *P*-value = 0.0014). The up-core increase in sand reflects a changing local depositional environment. As the shoreline erodes and encroaches on the core site, the site is subjected to increasingly more sand deposited by storm waves and wind. Cores were collected within 1 to 1.5 m of the marsh edge, within the observed wrack line.

Conversely, sand is the major component at depth in the cores collected along the Assateague Island shoreline and islands (Sites 17, 18, 19, and 20). In cores collected at Sites 17 and 18, the top 20 cm consist of finer-grained sediment, Clayey-Silt and Sand-Silt-Clay, overlying sand. The upward fining trend in texture reflects a shift in the local depositional environment.

Nutrients

Table 5-3 lists summary statistics (mean and standard deviation) for each of the measured nutrients, grouped by type of sample (e.g., bluff, marsh). Nutrient contents of the sediments sampled, particularly the marsh sediments, are lower compared to the sediments collected from the northern coastal bays. The lower contents reflect the overall higher sand content of individual samples.

Table 5-3. Summary statistics (average and standard deviation) for each of the elements measured in the samples. BDL indicates below detection limit for the analytical method.

	Marsh sediments		**Bluff sediments**		**Plant fraction (> 14 mesh)**	
	Aver.	**Std.**	**Aver.**	**Std.**	**Aver.**	**Std.**
Nutrients (%)						
Carbon (C)	4.41	2.89	0.12	0.048	31.3	5.9
Nitrogen (N)	0.258	0.155	0.011	0.005	1.00	0.148
Phosphorus (P)	0.02	0.009	0.008	0.006	0.069	0.035
Sulfur (S)	0.943	0.69	BDL	---	2.28	0.85
Metals (ppm)						
Silver (Ag)	0.52	0.324	0.61	0.12	0.443	0.141
Aluminum (Al, %)	4.02	2.39	1.86	1.65	1.94	0.481
Beryllium (Be)	1.31	0.2	1.04	0.023	BDL	---
Bismuth (Bi)	2.16	1.44	2.83	0.83	3.08	1.38
Cadmium (Cd)	0.815	0.543	0.503	0.196	1.24	0.69
Cobalt (Co)	10.9	19.5	88.8	90.0	11.05	3.05
Copper (Cu)	12.9	7.6	8.06	2.71	23.5	6.83
Iron (Fe, %)	1.89	0.91	1.03	1.02	2.09	0.64
Manganese (Mn)	205	79	123	101	203	313
Molybdenum (Mo)	4.4	2.47	1.41	0.85	11.6	4.82
Nickel (Ni)	30.3	15.6	13.2	7	21.5	9.89
Lead (Pb)	22.5	19.1	5.4	11.6	35.1	14.5
Strontium (Sr)	151	51	55	38	80	25
Titanium (Ti, %)	0.319	0.109	0.19	0.181	0.169	0.044
Vanadium (V)	60.5	28	25.1	23.6	70.7	15.8
Yttrium (Y)	16.2	11.2	5.92	5.17	15.7	4.76
Zinc (Zn)	52.4	24.1	26.7	18.1	73	23

Total carbon content measured in all bluff, beach, and core sediments ranges from less than 0.1% to 12.86%. Bluff and beach sediments contain the least amount of total carbon, averaging 0.27 ± 0.3%. Carbon content of marsh sediments ranges from 2.29 to 23.4%, averaging 11 ± 6.2%. The average carbon content of the plant material (i.e., >14 mesh) is 32.6 ± 4.7%. Total carbon in the sediments is directly proportional to the total biotic component, accounting of one-third of the total organic content (Fig. 5-7).

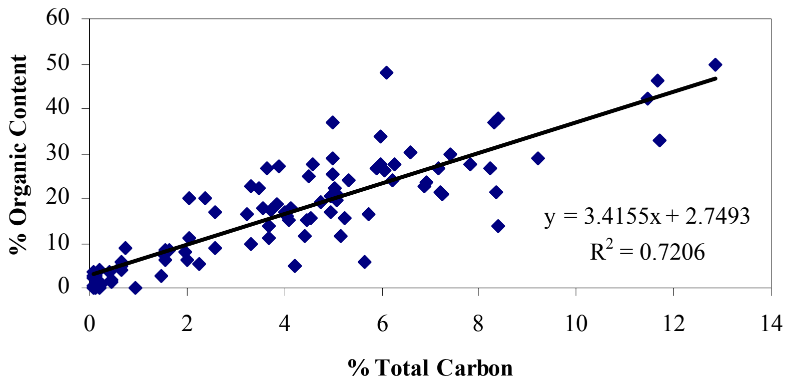


Figure 5-7. Total carbon content versus organic content of the sediment. Superimposed on the plot are the regression line and the equation defining the relationship.

Total nitrogen content measured in bluff and marsh sediments ranges from 0.004 to 0.62%. As with carbon content, bluff samples contain the least amount of total nitrogen, averaging 0.02%. Average nitrogen content in marsh sediment is 0.26 ± 0.16%. Total nitrogen content of the plant fraction averages 1.00 ± 0.15%.

Generally, for all of the sediments measured, nitrogen content correlates well with carbon content ($R^2 = 0.96$). Depending on the nature of the organic source, nitrogen is expected to maintain a fairly constant proportionality with carbon content, as shown in Table 5-4, which lists the C:N ratios for the different samples. The mean C:N ratio for marsh plant samples, 31.4, is higher than both the mean ratio of 11.5, obtained from bottom samples collected in the middle coastal bays (Wells and others, 1996), and Redfield's ratio of 5.7 for planktonic organisms (Redfield and others, 1963). The intermediate C:N ratio of 16.9, found in the marsh sediment, reflects a combination of organic material types.

Total phosphorus content measured in bluff and marsh sediment ranges from less than 0.001% to 0.072%. Marsh sediments contain an average of 0.035 ± 0.014%. Total phosphorus content of the plant fraction is higher, averaging 0.069 ± 0.035%. Compared to nitrogen, phosphorus is not as strongly correlated with carbon ($R^2 = 0.41$). The low phosphorus levels and high C:P and N:P ratios indicate that phosphorus is not mineralized (i.e,. as apatite). Phosphorus is being recycled, rather than accumulating in the sediments.

Although not considered a nutrient, sulfur is closely related to nutrient cycling. In sediments, sulfur occurs primarily as inorganic metal sulfides and elemental sulfur. These sulfur species form as a result of a bacterially-mediated reaction involving the oxidation of organic carbon.

Under anaerobic conditions, dissolved sulfate (SO_4^{-2}) from seawater acts as the oxidant (Berner, 1967, 1970; Goldhaber and Kaplan, 1974). During the process, sulfate is reduced to sulfide. The sulfide reacts with ferrous iron (Fe^{+2}), forming an iron monosulfide precipitate, which further reacts with elemental sulfur to form FeS_2 (pyrite and its polymorph, marcasite) (Berner, 1970). The process results in the enrichment and preservation of sulfur in the sediments and the simultaneous depletion of organic carbon.

Table 5-4. Comparison of mass ratios of C, N, and P observed in different samples.

	C:N	**C:P**	**N:P**
Plant (>14 mesh) (this study)	31.4	504.7	15.5
Marsh sediments (this study)	16.9	129.2	7.6
Middle coastal bay bottom sediments (Wells and others, 1996)	11.5	38.8	3.4
Plankton (Redfield and others, 1963)	5.7	41.0	7.2

Sulfur content measured in bluff and marsh sediments ranges from below the detection limit (BDL) to 3.43%. Bluff and beach samples contain little or no sulfur. Average sulfur content in marsh sediments is 0.94 ± 0.69%. Sulfur content in the plant fraction is significantly higher, averaging 2.28 ± 0.85%. At most marsh sites, sulfur content increases with depth below the marsh surface. The behavior of sulfur is consistent with the environmental conditions. The beach and bluff sites are oxic, and sulfides are unstable. Marsh sites represent an anoxic environment in which sulfides become increasingly stable with depth.

Metals

In addition to the three nutrients (N, C, and P) and sulfur, sediment samples were analyzed for 21 other elements, including 17 metals. Summary statistics for the metals are listed in Table 5-3. A cursory assessment of the results suggests that Cu, Mo, Pb, and Zn are concentrated in the plant roots. Also, Pb and Zn concentrations in marsh sediments are very similar to those in the northern coastal bays.

Because the sediments analyzed in this study vary significantly from one another in texture and plant content, several techniques were used to evaluate the behavior of the nutrients and metals. One technique, the use of enrichment factors (EF), allows for the comparison of sediments obtained from different environments and/or analyzed by different methods (Sinex and Helz, 1981; Wells and others, 1994).

An enrichment factor is defined as:

$$EF_{(x)} = \frac{(X / Fe)_{sample}}{(X / Fe)_{reference}} \qquad \textbf{Eq. 5-1}$$

where: $EF_{(x)}$ is the enrichment factor for the metal *X*,
X/Fe_{sample} is the ratio of the concentrations of the metal *X* to Fe in the samples, and
$X/Fe_{reference}$ is the ratio of the concentrations of the metal *X* to Fe in the reference material, such as an average crustal rock.

Fe is used for normalizing because anthropogenic sources of Fe are small compared to natural sources (Sinex and Helz, 1981). Taylor's (1964) average composition of the continental crust is used as the reference material.

Table 5-5 presents mean EF values, referenced to Taylor's average crustal material, for six metals, Co, Cu, Mn, Ni, Pb, and Zn, for which there are comparable data from other estuaries and coastal bays (Sinex and Helz, 1981). Mean EF values for marsh and bluff sediments lie within the range of values obtained for other coastal bays not affected by industry. When the mean EF values of the various sediment sources within the bay system (i.e., marsh vs. bottom sediments) are compared, several trends become apparent. For example, Zn enrichment is about the same for marsh and bottom sediments. Marsh sediments are enriched in Pb and Zn. Except for Pb, for which EF values are lower, enrichment factors are very similar to those observed in marsh sediments from the northern coastal bays (Wells and others, 2002).

Table 5-5. Comparison of average enrichment factors of certain metals measured in the different groups of sediments from the middle coastal bays. Enrichment factors are referenced to the earth's average crustal composition (Taylor, 1964) and calculated using Equation 5-1.

	Co	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**
Marsh sediments (this study)	2.89 ±8.12	0.82 ±0.64	0.76 ±0.37	1.43 ±0.99	5.67 ±3.13	2.35 ±0.59
Bluff sediments (this study)	1.42 ±0.86	0.48 ±0.04	0.65 ±0.09	0.71 ±0.085	3.18 ±2.48	1.65 ±0.18
Bay bottom sediments (Wells and others, 1996)	–	0.32 ±0.16	0.91 ±0.36	0.60 ±0.24	0.37 ±1.03	2.30 ±0.36

Regression Analysis

Regression analysis is another approach used to evaluate the geochemical behavior of nutrients and metals. MGS has routinely employed this technique for evaluating sediments in the Chesapeake Bay and the coastal bays (Hill and others, 1990; Wells and others, 1994, 1996, 1999). Hill and others (1990) initially devised the method for long-term monitoring of bottom sediments in the vicinity of the Hart-Miller Island Dredged Material Containment Facility in northern Chesapeake Bay. This technique is a sensitive indicator that can be used to measure anthropogenic loading, differences in source material, or changes in geochemical environment. The analysis is based on the association of an element, in this case, a nutrient or metal, with other physical components of the soils or sediments. In this study, the behavior of an element is determined by correlating its concentration with the associated grain size (adjusted by the clastic content) and plant content of the sediment, as shown in Equation 5-2.

$$\mathbf{X = \mathit{a}(Sand) + \mathit{b}(Silt) + \mathit{c}(Clay) + \mathit{d}(Plant)} \qquad \textbf{Eq. 5-2}$$

where:

X	is the element (nutrient or metal) of interest,
a, b, c*, and *d	are the determined coefficients (see Table 5.5),
Sand, Silt, and Clay	are the grain size fractions of the sample multiplied by the clastic fraction, and
Plant	is the plant (>14 mesh) fraction

A least-squares fit of the data is obtained using a multiple stepwise regression analysis. The results of this analysis are presented in Table 5-6. Equation 5-2 states that the elemental composition of a sediment sample is a linear combination of end member components (i.e., Sand, Silt, Clay, and Plant). For any given component, the associated coefficient is the concentration of the element in the pure end member. Organic matter (non-clastic) smaller than 14 mesh is not included in the equation.

The results of this analysis indicate that the association of the elements with the different grain size fractions is relatively uniform throughout the study area. If there were a significant variation among the samples, the correlation of the regression fit would be poorer. Although R^2 values are somewhat lower than those obtained from similar regression analyses of nutrient and metal data in the northern coastal bays (Wells and others, 2002), the associations are excellent nonetheless, providing a higher confidence level in extrapolating the data across the region when calculating input values.

Regression analysis also indicates that plant matter (> 14 mesh) is a significant factor in more than half of the elements analyzed. This is shown in the Rank column in Table 5-6. The rank, ranging from 1 to 4, is the order of the plant material coefficient, 1 being the most concentrated and 4, the least. In ten of the 16 elements included in the regression analysis, plant matter is either the most or second-most concentrated component. Analytical results of the isolated plant material (Table 5-3) are directly comparable to the determined plant coefficient. Consequently, the plant component must be taken into account when determining nutrient input due to shoreline erosion, especially in soils or sediments with high organic matter content and root material, such as those found in marshes.

Table 5-6. Coefficients of multiple-stepwise regression of nutrient and metal data. The determined value is the elemental concentration and the factors are the clastic (Sand, Silt, and Clay) and plant fractions of the samples, values of are which substituted into Equation 5-2.						
		Estimates of coefficient				
Element (X)	**Rank (Plant)**	***a* (Sand)**	***b* (Silt)**	***c* (Clay)**	***d* (Plant)**	**R^2**
Nutrients (%)						
C	1	---	---	15.7	27.2	90
N	1	---	---	1.02	1.2	91
P	2	0.007	0.017	0.053	0.039	91
Metals (ppm)						
Cu	1	5.43	1.88	40.8	61.6	86
Mo	1	2.72	---	12.2	20.3	82
Ni	1	18.9	25.9	46.8	151	86
Pb	1	9.86	17.7	51.2	68	86
V	2	8.65	4.18	216	90.1	99
Zn	2	12.3	46.3	151	128	96
Ag	2	0.483	978	---	0.532	91
Fe(%)	3	0.36	1.92	6.08	1.38	96
Mn	3	82	359	340	130	95
Ti(%)	3	0.15	0.48	0.58	0.26	94
Y	3	2.46	14.6	42	10.3	93
Al(%)	---	1.12	2.81	13.9	---	89
Be	4	0.88	1.05	3.01	0.47	98

SEDIMENTS AND NUTRIENT LOADINGS

The annual loads (kg/yr) of nutrients and sediments for each of the basins of the middle coastal bays are summarized in Table 5-7. Shoreline included in the land loss polygons accounts for approximately 98% of the total shoreline (202 km) in the study area. The remaining shoreline, the northern bay side shoreline of Assateague Island, is predominantly accretional as a result of overwash processes (refer to *Inlets And Historical Shoreline Changes* discussion in *Study Area* chapter), and, therefore, not included in this study.

During the 47-year period between1942 and 1989, shoreline erosion contributed an estimated 11.4 x 10^6 kg/yr of total sediments into the middle coastal bays. Of the total sediments, approximately 61%, or 6.9 x 10^6 kg/yr, are total suspendable solids (TSS). In this study, suspendable solids consist of fine-grained clastics (silt and clay, or mud fraction) and the organic fraction. Annual total sediment loadings are greatest in Sinepuxent Bay (5.8 x 10^6 kg/yr, or 75.7 kg/yr per m of shoreline), due in part to higher bank elevations and relatively dense bluff material (Polygon 4). Average bulk density of sediments collected from bluffs is 1.62 g/cm^3. The annual rate of sediment loading from shore erosion in Newport Bay is 62.7 kg/yr per meter of shoreline, with 75% of those sediments being suspendable solids. Much of the shoreline bordering Newport Bay is low-lying marsh composed of highly organic, fine-grained sediments. Total sediment loading from shore erosion in northern Chincoteague Bay is the lowest of the three basins – 27.9 kg/yr per meter of shoreline, 44% of which is TSS.

Sand-sized sediments account for approximately 40% of the total sediments eroded from the shoreline in the middle coastal bays. About half of the sand comes from the Sinepuxent Bay mainland shoreline, portions of which have some of the highest rates of erosion in the study area (Fig. 5-8). The eroded sand probably remains in the vicinity of its source, as indicated by the sand samples collected immediately offshore of the bluff sites. Except under extremely high flow conditions, sand is generally not considered suspendable.

Table 5-7. Summary of annual loadings of sediments and nutrients contributed by shoreline erosion in the middle coastal bays. The length of the 1989 shoreline applies only to the shoreline included in the land loss polygons (Fig. 4-1).

Component	Basin			Total
	Sinepuxent Bay	Newport Bay	North Chincoteague Bay	
1989 Shoreline length (m)	76,672	58,872	66,603	202,146
Annual volume (m^3/yr)	7,196	6,336	2,392	15,924
Total Sediments (Solids) (kg/yr)	5,801,555	3,689,654	1,860,591	11,351,800
Total Organics (kg/yr)	679,272	618,549	222,602	1,520,423
Carbon (kg/yr)	163,756	152,225	57,297	373,279
Nitrogen (kg/yr)	9,575	8,966	3,625	22,166
Phosphorus (kg/yr)	1,557	1,197	677	3,431
Lead (Pb) (kg/yr)	141.4	68.0	31.8	241
Zinc (kg/yr)	260.9	219.1	78.2	558
Total Clastics (kg/yr)	5,122,283	3,071,105	1,637,989	9,831,377
Gravel (kg/yr)	923	2,533	0	3,456
Sand (kg/yr)	2,475,773	929,130	1,046,324	4,451,227
Silt (kg/yr)	1,741,146	1,404,207	358,354	3,503,707
Clay (kg/yr)	904,441	735,235	233,282	1,872,958

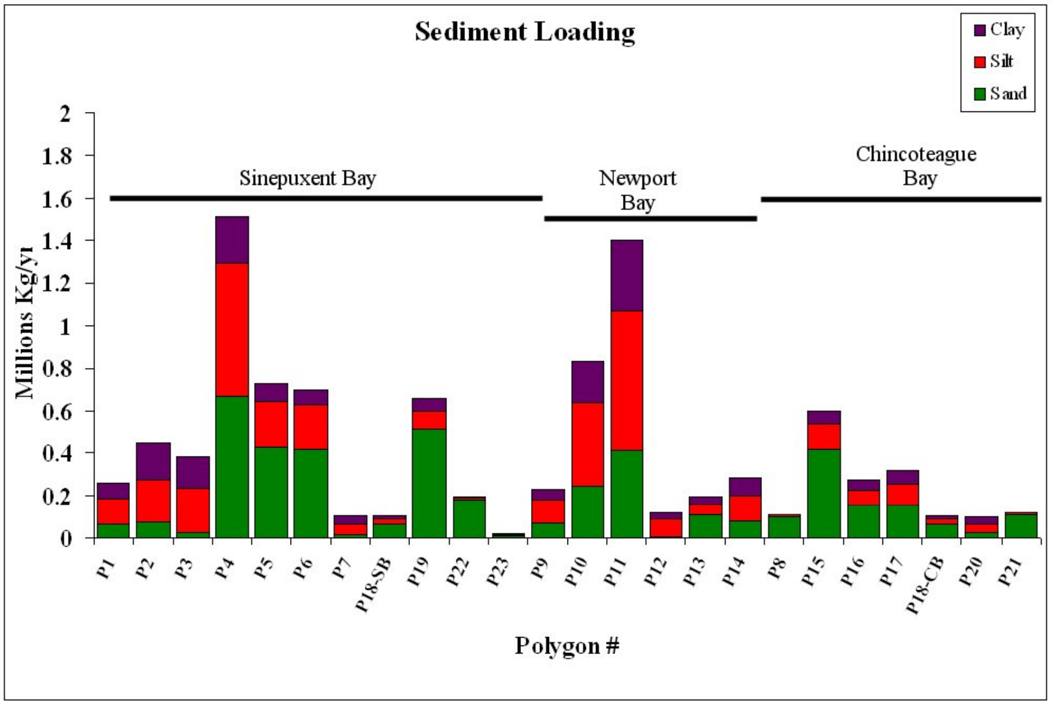


Figure 5-8. Loadings of sand, silt, and clay for each land loss polygon. Gravel, which accounts for less than 1% of the total sediment load, is not shown. Only sediments collected in Polygons 4 and 13 contained gravel.

Comparison with existing models and previous studies

Table 5-8 summarizes total nitrogen (TN) and total phosphorus (TP) loads from various sources for the middle coastal bays, based on data from UM and CESI (1993). For comparison, the loading estimates for TN and TP contributed by shore erosion (this study) are included in the table. Table 5-9 summarizes the total nitrogen and phosphorus loads for Newport Bay based on MDE's (2002) TMDL study. Sinepuxent and Chincoteague Bays are not included on Maryland's 2002 List of Impaired Surface Waters 303(d) and, therefore, do not require TMDL determinations. The estimates from the UM and CESI and the MDE reports are presented in this discussion as the range of values for nitrogen and phosphorus loadings to the middle coastal bays.

For Newport Bay, the UM and CESI estimates for total nitrogen and phosphorus loadings are about one-third higher than those reported by MDE. UM and CESI attributed a large proportion of the runoff (included in their "Diffused source") loading to feedlot operations, the discharge from which was assumed to enter streams directly. MDE considered the UM and CESI feedlot calculations to be too high (Sajan Pokharel, pers. comm.). Instead, MDE treated feedlot operations as confined and used urban land use loading rates to calculate their loadings. Although MDE used the UM and CESI loading coefficients to calculate runoff based on land use, they updated the land use acreage using 1997 data. Also, in MDE's nutrient budget for

Newport Bay, there are no phosphorus loadings from groundwater or atmospheric sources. The loading estimates reported by MDE are more conservative, representing an annual baseline loading for the study area. MDE loading estimates were used in developing TMDLs for Newport Bay. Neither report considered contributions from shore erosion.

Table 5-8. Annual total nitrogen (TN) and total phosphorus (TP) loadings (kg/yr) to the middle coastal bays, based on the UM and CESI (1993) report. Total loadings contributed from shoreline erosion are included for comparison.

Total Nitrogen loadings (kg/yr)					
Basin [1]	**Point source [1]**	**Diffuse sources [2]**	**Atmospheric sources [3]**	**Shore erosion (this study)**	**Total loading**
Sinepuxent	10	22,566	35,820	9,575	**67,971**
Newport	36,939	220,842	20,342	8,966	**287,089**
Study portion of Chincoteague Bay	0	66,806	82,435	3,625	**152,866**
Total	**36,949**	**310,214**	**138,597**	**22,166**	**507,926**
Total Phosphorus loadings (kg/yr)					
Sinepuxent	2	2,182	1,442	1,557	**5,183**
Newport	3,318	17,921	819	1,197	**23,255**
Study portion of Chincoteague Bay	0	6,840	3,318	677	**10,835**
Total	**3,320**	**26,943**	**5,579**	**3,431**	**39,272**

[1] Point source data for nitrogen and phosphorus were developed by Coastal Environmental Services, Inc., based on information from the Maryland Dept. of the Environment. Data are for 1990-91.
[2] Non point sources include surface water inputs (runoff), groundwater inputs and inputs from chicken rendering operations. Loading from direct groundwater discharge into the northern coastal bays (from Snug Harbor to Maryland/Delaware line) were estimated using Ritter (1986) coefficients: TN= 123,804 kg/yr and TP=9,420 kg/yr.
[3] Atmospheric inputs represent total nitrogen and phosphorus deposition in wet-fall directly to the surface of bay waters, based on an average annual rainfall of 43.8 inches/yr reported for 1990. Concentrations of TN andTP are from Smullen and others (1982).

Shoreline erosion represents a significant source of TN and TP loadings to Maryland's middle coastal bays. Based on the UM and CESI (1993) nutrient budget, shore erosion accounts for 4% of the total nitrogen and 9% of the total phosphorus delivered to the middle coastal bays (Fig. 5-9). For Newport Bay, the nitrogen and phosphorus contributions from shore erosion are comparable – 3 to 5% for nitrogen and 5 to 7% for phosphorus, depending on the nutrient budget used for comparison. However, for Sinepuxent Bay, shore erosion contributes 14% of the total nitrogen and 30% of the total phosphorus delivered to that bay.

The N:P (mass ratio) loading ratio for material eroded from the shoreline in the middle coastal bays is about 6.5:1, which is lower than the loading ratio (10:1) reported for the northern coastal bays (Wells and others, 2002). The ratio is also lower than the loading ratios based on

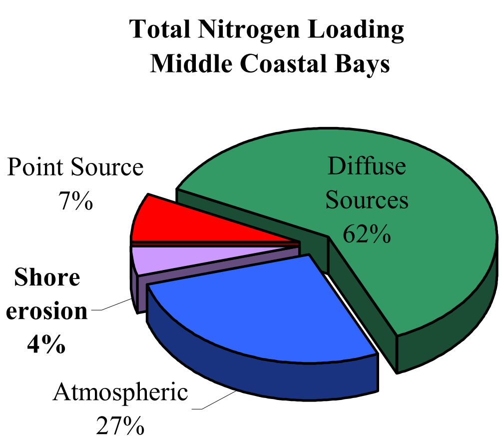
UM and CESI data (N:P = 13:1) and MDE data for Newport Bay (N:(P = 11.2:1). The lower ratio may reflect a general depletion of nitrogen and/or enrichment of phosphorus in sediments.

Table 5-9. Annual total nitrogen (TN) and total phosphorus (TP) loadings (kg/yr) to Newport Bay, based on TMDL study for the same study area (MDE, 2002). Total loadings contributed from shoreline erosion are included for comparison.

Nutrient	Point source	Ground-water [1]	Atmospheric Deposition	Runoff	Shore erosion	Total
Nitrogen	55,575	22,230	16,673	90,773	8,966	**194,217**
Phosphorus	3,236	0	0	12,945	1,197	**17,378**

[1] The direct groundwater loads for TN were estimated based on methods described by Dillow and Greene (1999). Direct discharge to Newport Bay was separated out from the total reported by John Dillow. MDE did not report groundwater loads for TP.

In Table 5-10, annual TSS, Pb, and Zn loadings from the UM and CESI report are compared with estimates from this study (MGS). The annual TSS loading reported by UM and CESI represents suspended solids delivered by overland runoff and is about 1.6 times the TSS contributed by shoreline erosion for the study area. However, in Sinepuxent Bay, the annual contribution of TSS from shoreline erosion is four times the input from runoff. In Newport Bay, the annual TSS load from overland runoff is three times that contributed from shoreline erosion. The drainage area for Newport Bay is approximately four times that of Sinepuxent Bay, accounting for the higher TSS loading.



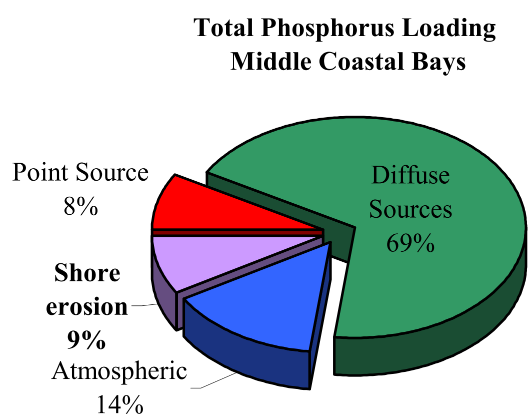


Figure 5-9. Total annual nitrogen and phosphorus loads entering the middle coastal bays, revised to include contributions from shoreline erosion. Pie charts depict annual loads based on loadings reported by UM and CESI (1993).

The sand:mud ratio of sediments contributed from shoreline erosion in the study area is 4:5. In other words, slightly more mud (silt and clay) than sand is eroding from the shorelines. However, the sand:mud ratio of 2:1 for bay bottom sediments, based on sediment studies conducted by Wells and others (1996), does not reflect this relatively low proportion of sand. When taking into account the mud contributed from run-off, approximately 8.6 x 10^6 kg/yr, assuming the TSS reported by UM and CESI has the same percentage of organics as the sediment contributed from shoreline erosion (i.e. 22% organics), the sand:mud ratio of total clastic sediment input to the middle bays is even smaller, 1:3. Other sources of sand have to be considered, specifically, sand input from overwash and eolian (wind) transport, and loads transported through the Inlet. To bring the sand:mud ratio to 2:1, these processes would have to contribute on the order of 20 x 10^6 kg/yr of sand into the middle bays.

Table 5-10. Comparison of the UM and CESI (1993) loadings and MGS estimates from shoreline erosion for total suspended solids (TSS), Pb and Zn. All loadings are in Kg/yr.

	UM and CESI (1993)			**MGS (This Study)**		
Basin	**TSS[1]**	**Pb[2]**	**Zn[2]**	**TSS**	**Pb**	**Zn**
Sinepuxent	885,638	294	294	3,324,859	141	261
Newport	8,778,318	1,445	1,445	2,757,991	68	219
N. Chincoteague	1,422,341	50	50	814,237	32	78
Total	**11,086,297**	**1,789**	**1,789**	**6,897,088**	**241**	**558**

[1] TSS loadings calculated using coefficients for each land use based on national average values reported by the U.S. EPA.
[2] Pb and Zn loadings for urban land use only based on work by Schueler (1987); no coefficients available for non-urban land use

Shoreline erosion contributes significant amounts of Pb and Zn, accounting for 12% and 24%, respectively, of the loadings of these metals into the middle coastal bays. However, these percentages may be high because the UM and CESI annual loading values for Pb and Zn were based on runoff from urban land only (Schueler, 1987). Runoff coefficients for other non-urban land were unavailable at the time the UM and CESI (1993) report. The UM and CESI annual loading values did not include any input from point sources or atmospheric sources.

6. CONCLUSIONS

To meet the goals of the Maryland Coastal Bays Program, further understanding of sediment and nutrient cycling is necessary. Central to this understanding is the development of an all-inclusive sediment and nutrient budget for the coastal bays. Until recently, contributions from shoreline erosion had generally been excluded from sediment and nutrient budgets. This study of the middle coastal bays, along with last year's study of the northern coastal bays, provides initial estimates of the sediment and nutrient loads contributed by shoreline erosion. Findings from this study of the middle coastal bays include:

- Rather than relying on general sediment density estimates, this study directly measured sediments for bulk density, thereby improving the accuracy of nutrient load estimates.

- The nutrient content of shoreline sediments in the middle coastal bays, particularly of marsh sediments, is lower – about half the amount – than the nutrient content measured in northern bay sediments. Lower nutrient content reflects the overall higher sand content of individual sediment samples.

- Although sediments eroding from middle coastal bay shorelines are twice as dense as those in the northern coastal bays, the overall sediment loading per meter of shoreline in the middle coastal bays is less than that reported for the northern coastal bays (56.2 kg/yr/m versus 69.7 kg/yr/m). This difference is largely due to the lower average bank heights assigned to polygons in the middle coastal bays (0.61 m for middle bays; 0.79 m for northern bays).

- While shoreline erosion contributes a considerable load of suspendable solids into the study area, the contribution is, on average, about 2/3 the load from overland runoff. In Sinepuxent Bay, the TSS load from shoreline erosion is four times that contributed from upland runoff. Conversely, the annual TSS load from overland runoff into Newport Bay is three times that contributed from shore erosion. In Newport Bay, the bulk of the TSS is delivered from Trappe Creek and Ayers Creek.

- Shoreline erosion contributes approximately 4.45×10^6 kg/yr, or about 1/4 of the sand entering the middle coastal bays. Presumably, upland runoff contributes an insignificant amount of sand. Therefore, other sources, including sand carried across Assateague Island by wind and overwash, and transported through the Inlet, account for ¾ of the total sand entering the bays. Sand is important in maintaining a healthy balance of bottom habitats in the bays.

- Shoreline erosion contributes 4% of the total nitrogen and 9% of the total phosphorus delivered to Maryland's middle coastal bays. These percentages are very similar to those reported for the northern coastal bays. However, the relative proportion of nutrient loadings from shoreline erosion varies depending on basin and on the size of the associated drainage area. For example, shore erosion contributes 14% of the total nitrogen and 30% of the total phosphorus delivered to Sinepuxent Bay. That bay has a relatively small drainage basin and, therefore, receives a comparatively smaller load from run-off.

- In addition to nutrients, shoreline erosion contributes 241 kg/yr of Pb and 558 kg/yr of Zn, accounting for 12% and 24 % of the total loadings of those metals, respectively, to the bays.

RECOMMENDATIONS

- The load calculations presented in this study are based on two assumptions: 1) the component concentrations, averaged for each site, reflect the average lithology along the shoreline within a given polygon and 2) bank heights are uniform throughout any given land loss polygon; the banks themselves are vertical, rather than sloping. To refine these estimates, additional fieldwork and analyses are required.

- Loadings reflect the average annual input over a 47-year period (between 1942 and 1989). The assumption is that contribution rates also apply for the period between 1989 and the present and will continue for some time in the future. Additional studies should examine contributions from future erosion, based on projected rates of sea level rise and the resulting changes in shoreline configuration (refer to Volonté and Leatherman, 1992).

- Additional studies are needed to quantify the contribution of sediments from overwash and aeolian transport across Assateague Island and sediments carried in through the Inlet.

- Data from this study indicate that marsh sediments are enriched in Pb and Zn. Most certainly marsh sediments are enriched in other metals and pollutants, particularly when one considers that marshes (wetlands) are touted as “filtering buffers” for pollutants entering a water body. Since marsh shorelines are those eroding most rapidly, the pollutants eventually enter the water body. Additional studies are needed to fully understand the impact that eroding marshes have on the nutrient budgets and the fate of pollutants.

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APPENDIX A

Site descriptions (field notes, photos, cross sections, profiles)

Core logs (core descriptions, lithology, radiographs, photos)

Note: In the radiographs, sediment layers with more plant material, which is nearly transparent to x-rays, appear as darker areas in the image. Layers with higher percentages of clastics (i.e., sand-, silt-, and clay-sized minerals) are denser or more opaque to x-rays and appear as lighter areas. White layers represent denser lenses of sediment, not necessarily composed of sand, but containing a higher percentage of clastics (non-plant material).

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 1: Ocean City Airport.

Site ID: 1
Site name: Ocean City Airport
Location: just north east of runway

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4240024	490057

Date: 6/17/02
Time: 1145 EDT; super high tide
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): marsh
Extent (length) of reach (ft):
Land use/cover along reach: fields, runways for airport

Comments: : At time of site visit, super high tide conditions

Site description: Station (core) on point of marsh north east of end of runway; small marsh island (pinched stack); vegetation almost entirely *S. alterrnaflora;*

Reach description: Extensive stretch of shoreline characterized by narrow marsh (~100-200 ft wide), backed by woods and open fields (airport); some mosquito ditching; small islands offshore offer some protection; popular spot for boaters.

Plants:

Species	Percent
S. alternaflora	100

Samples: Samples taken 6/17/02

ID	Type*	Location/Descpt.
Core 1	BD;GS;TM	On pt., 1 meter long
No offshore sample taken		

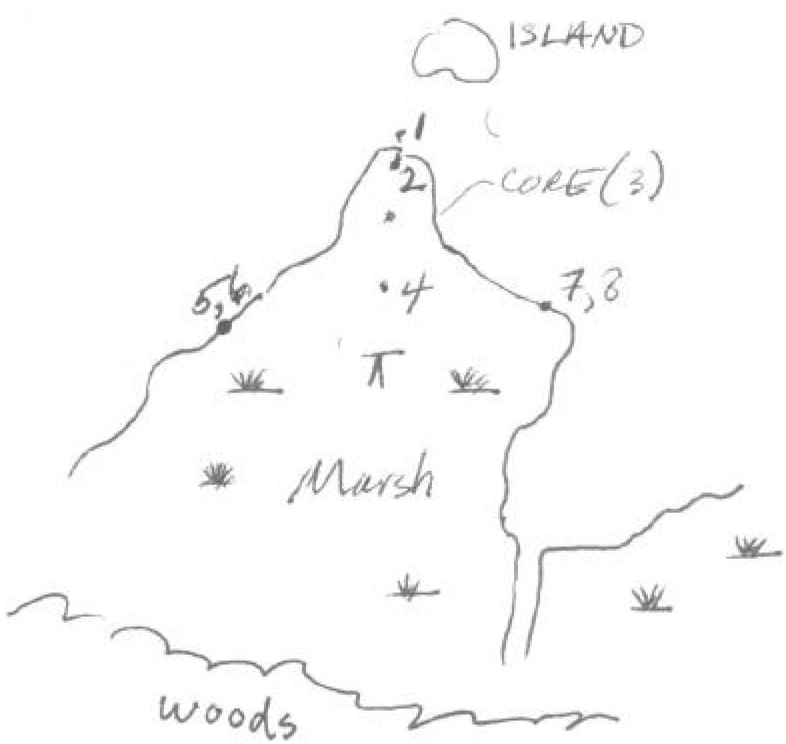
*Type = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
2	1	1203	Back marsh
2	2	1203	Pt. w/Geoff
2	3	1215	Site from water

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 1: Ocean City Airport.

Plan view (sample locs; site features, reach & beach extents)
-Note:



Average bank height-1.5617 ft

Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1	4.53	4.39	4.25	28	1.92	Bank height
2	6.47	6.31	6.15	32		
3	4.36	4.23	4.11	25		Core site
4	4.26	4.18	4.13	13		
5	4.53	4.46	4.38	15	0.815	Bank height
6	5.38	5.275	5.17	21		
7	4.51	4.41	4.31	20	1.795	Bank height
8	6.32	6.205	6.09	23		

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 2-Bat Creek.

Site ID: 2
Site name: Bat Creek
Location: Just north of Snug Harbor, Sinepuxent Bay

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4238710	488970

Date: 6/17/02
Time: 1245 EDT
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): Marsh
Extent (length) of reach (ft): 75 meters
Land use/cover along reach: Woods, golf course

Comments: At time of site visit, super high tide conditions**;** Core not as muddy as others

Site description: Site on point of marsh on north side of mouth of Bat Creek; channel cuts along point; thick marsh grass (*S. alternaflora*) predominant, some bare (sandy) patches

Reach description: Reach part of extensive marsh bordering Bat Creek; marsh extends ~1000 ft backed by woods and golf course.

Plants:

Species	Percent
S. alternaflora	95%
Beach lavender	5%

Samples: Samples taken 6/17/02

ID	Type*	Location/Descpt.
Core 2	BD, GS, TM	1 meter from pt.
2 off	Grab, GS	1 meter offshore

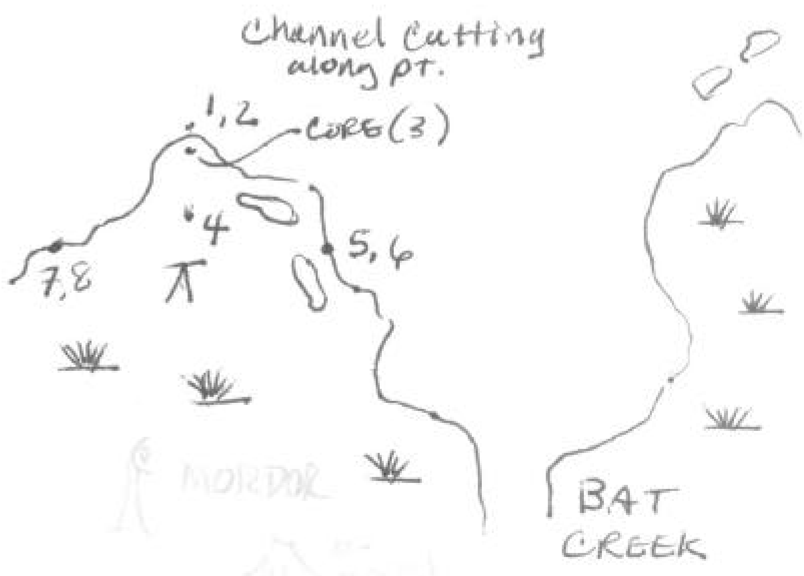
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
2	4	1249	Point
2	5	1249	Back marsh
2	6	1249	Close up- bare spots w/shells
2	7	1249	Looking north
1	6	1253	Pt 2-panaramic view
1	7	1253	Pt 2-panaramic view
1	8	1309	Site from offshore

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 2-Bat Creek.

Plan view (sample locs; site features, reach & beach extents)



Average bank height- 2.57 ft

Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1	4.92	4.66	4.40	52	2.39	Bank height
2	7.32	7.05	6.78	54		
3	4.45	4.19	3.95	50		Core site
4	4.24	4.135	4.03	21		
5	4.59	4.43	4.27	32	3.525	Bank height
6	8.12	7.955	7.79	33		
7	4.66	4.32	3.98	68	1.8	Bank height
8	6.47	6.12	5.77	70		

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site –3, Grays Cove/Point.

Site ID: 3
Site name: Grays Cove/Point
Location: Upper west shore, Sinepuxent Bay

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4236503	488087

Date: 4/29/02
Time: 1825 UTC
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): Marsh
Extent (length) of reach (ft): ~75 meters
Land use/cover along reach: Forested, residential, farm fields

Site description: Low marsh transected by ditching, ~700 to 1000 ft to wood line; houses behind wood line.

Reach description: Reach approx. ¼ to ½ miles, convoluted marsh shoreline with ditching

Plants:

Species	Percent
S. alternaflora	40
S. patens	40
Beach Lavender	5

Samples: Samples taken 4/29/02

ID	Type*	Location/Descpt.
Site 3	core	36" from water edge
3-off	grab	12" from shoreline

Comments: No apparent compression in core taken; took plant samples

Photos:

Card	#	Date/Time (EDT)	Subject
1	1	4/29/02 2:09 p	Site bayward
1	2	2:09 p	Ditch
1	3	2:18 p	Close up; erosion
1	4	2:18 p	Site north
1	5	2:27	Court's marker

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site –3, Grays Cove/Point.

Plan view (sample locs; site features, reach & beach extents)

Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1	4.72	4.36	4.02	70	2.48	
2	7.20	6.84	6.48	72		
3	6.69	6.18	5.66	103	1.99	
4	4.70	4.19	3.68	102		
5	7.85	7.46	7.05	80	2.98	
6	4.87	4.48	4.09	78		
7	4.31	4.13	3.97	34		

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 4 - Fassett Point.

Site ID: 4
Site name: Fassett Point
Location: Sinepuxent Bay, upper western shore

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4235321	487305

Date: 1st visit: 4/29/02; 2nd visit: 7/25/02
Time: 1940 UTC(1nd visit); 1600 UTC
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): Bluff
Extent (length) of reach (ft): ~2000 meters
Land use/cover along reach: agricultural, residential
Comments

Site description: Site at low bluffs, ` 1.5 m high; backed by large grassy lawn/field surrounding historical brick house; some small bushes near edge of bluff; very narrow beach, in some spots non-existent; sampled at area where beach was covered with "wrack"
Reach description: Active farm fields (corn, soybeans); houses with extensive lawns, small marsh to south; riprap to north of pt

Plants:

Species	Percent
Grass- cultivated lawn	90
Cedar trees	1
Various scrub plants	4

Samples: Samples taken 7/25/02

ID	Type*	Location/Descpt.
14-T	GS;TM, BD	Top section of bluff
14-M	"	Middle section
14-B	"	Bottom section
14-Beach	GS	Mid beach grab
14-Off	GS	Grab offshore

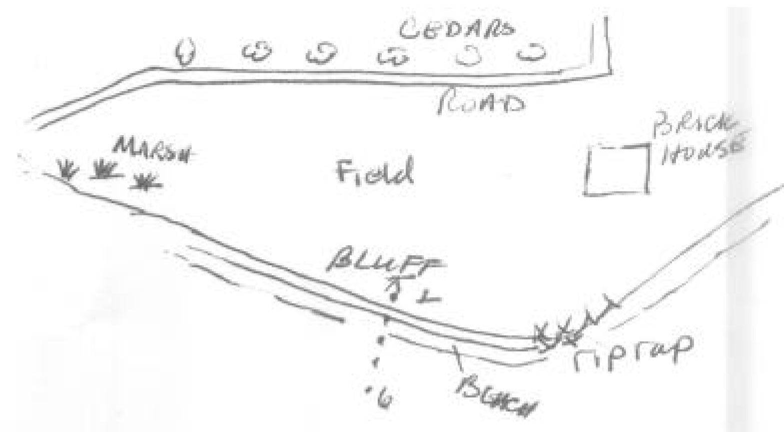
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Date/Time	Subject
1	4/29/02; 1435 EDT	Bluff
1	1435	Site from offshore
2	7/25/02; 1201	Site- beach
2	1211	Sacha w/rod at bluff
2	1212	Closse up of rod
2	1233	To the north
2	1233	House

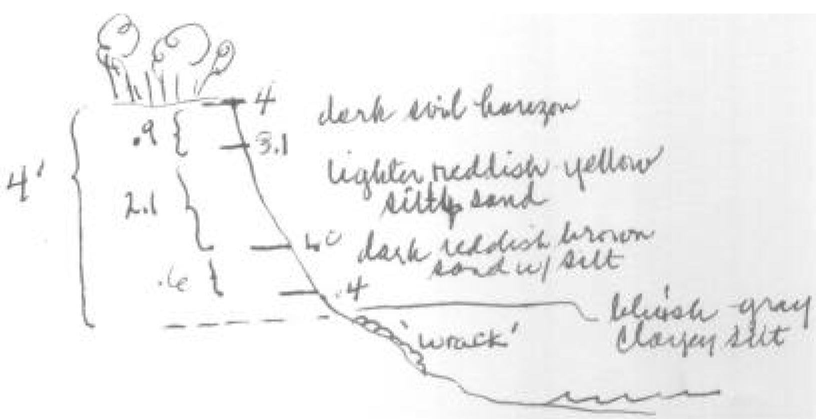
Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 4 - Fassett Point.

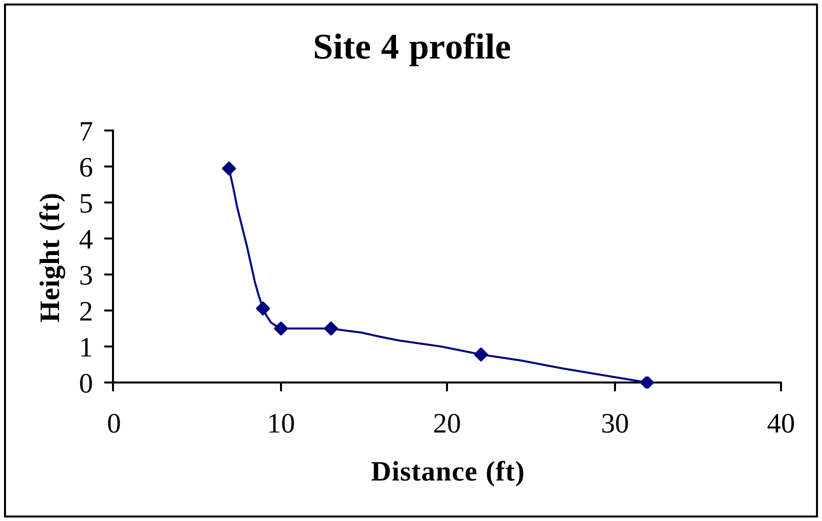
Plan view (sample locs; site features, reach & beach extents)



Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1	4.70	4.665	4.63	7	5.935	Top of bluff
2	8.59	8.545	8.50	9	2.055	Base of bluff; bluff hght=3.885'
3	9.15	9.10	9.05	10	1.5	Beach
4	9.18	9.115	9.05	13	1.485	mid beach
5	9.94	9.83	9.72	22	0.77	Water line
6	10.76	10.60	10.44	32	0.0	In water

Stratigraphic section





Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 5 -- Sandy Cove.

Site ID: Site 5
Site name: Sandy Cove
Location: Sinepuxent Bay, mainland shore

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4233815	486634

Date: 4/29/02
Time: 1920 UTC
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): Marsh
Extent (length) of reach (ft): 1,000 ft
Land use/cover along reach: field; forest
Comments

Site description: Site on point along marsh ~1000 ft long; high marsh with *Spartina patens*, many small bushes; *S. alterniflora* along edge up to HWM

Reach description: Reach truncated to north with rip-rap and to the south with drainage canal. Woods and farm fields backing marsh.

Plants:

Species	Percent
S. patens	80
S. alterniflora	5

Samples: Samples taken 4/29/02

ID	Type*	Location/Descpt.
Core 5	GD,GS, TM	~3 ft from waters edge
Off 5	Grab-GS	~1 ft from shoreline

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Car	Frame	Date/Time	Subject
1	1	4/29/02; 3:13 EDT	Site –looking north
1	2	4/29/02; 3;13 EDT	Site – looking south

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 5 -- Sandy Cove.

Plan view (sample locs; site features, reach & beach extents)

Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Hgt (ft)	Comments
1	4.50	4.30	4.10	40	1.19	Bank Hgt (ft)
2	6.58	6.28	5.99	59	-0.79	1.98
3	5.72	5.49	5.25	47	0.0	Water line
4	3.98	3.79	3.59	39	1.7	
5	4.38	4.24	4.10	28	1.25	
6	4.49	4.44	4.39	28	1.05	

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 7- Ferry Landing.

Site ID: Site 7

Site name: Ferry Landing

Location: Sinepuxent Bay, mainland shoreline, lower Sinepuxent Neck

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4230060	483319

Date: 4/30/01

Time: 2210 UTC

Described by: DVW

Shoreline type (e.g., marsh, bluff, beach): Marsh

Extent (length) of reach (ft): ~500 yds

Land use/cover along reach: Woods, houses

Comments

Site description: Site on point of low-lying marsh, transected by ditching; highly irregular shoreline; S. alterniflora dominant.

Reach description: Predominately marsh, ~100 yards between ditching; marsh 200 yds wide, backed by tree line, homes.

Plants:

Species	Percent
S. alterniflora	99

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
C-7	Core-BD,TM, GS	On point; 2.2 ft from waters edge
Off-7	GS	1 ft offshore

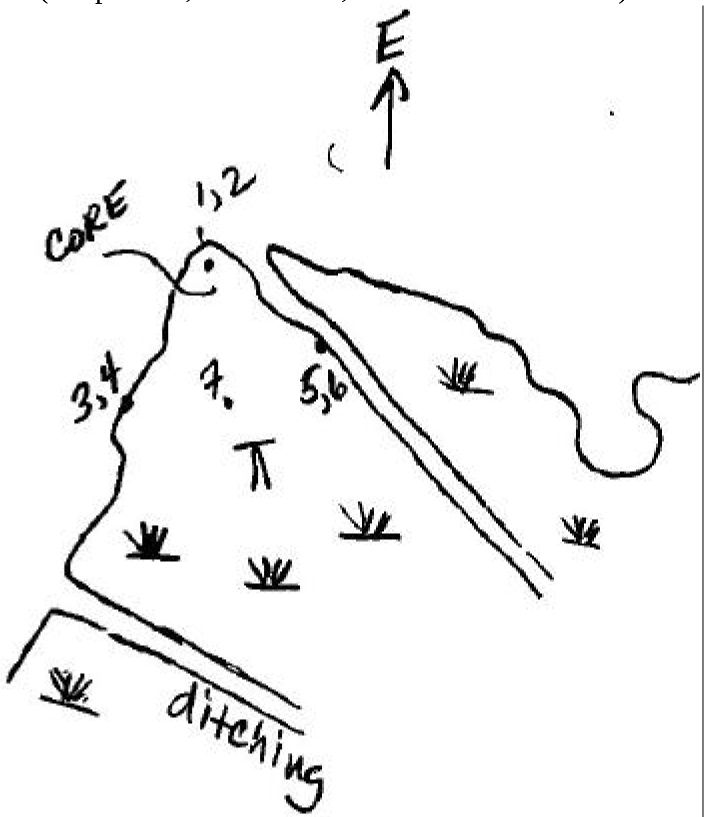
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
1	49	4/30/01;1819 EDT	Point-east
1	50	4/30/01;1820 EDT	South toward boat ramp

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 7- Ferry Landing.

Plan view (sample locs; site features, reach & beach extents)



Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1		6.18		0	1.57	
2		4.61				Near core location
3		5.98			1.16	
4		4.82				
5		7.47			2.65	In ditch-bank hgt.
6		4.82				
7		4.59				

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 8-South Point.

Site ID: Site 8
Site name: South Point-Johnson House
Location: On Newport Bay just north of South Point, Sinepuxent Neck

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4229299	482985

Date: 4/30/02
Time: 1631 UTC
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): Beach
Extent (length) of reach (ft): 800 yds
Land use/cover along reach: Mixture of marsh (drained), agric fields, and houses
Plants:

Species	Percent
S. patens	60
Phragmites	35
Beach lavender	5
Poison ivy	

Site description: Site on narrow sandy beach backed by small 'berm' built up w/wrack and sand; *Phragmites* starting to take over, become more prevalent northward

Reach description: Shoreline gently concave, dominated by sandy beach; Extensive marsh meadow behind site; small pond. Area transected with ditching.

Photos:

Card	Frame	Date/Time	Subject
1	21	4/30/02; 1228 EDT	Looking south
1	22	1229 EDT	Looking north
1	23	1229 EDT	Looking east

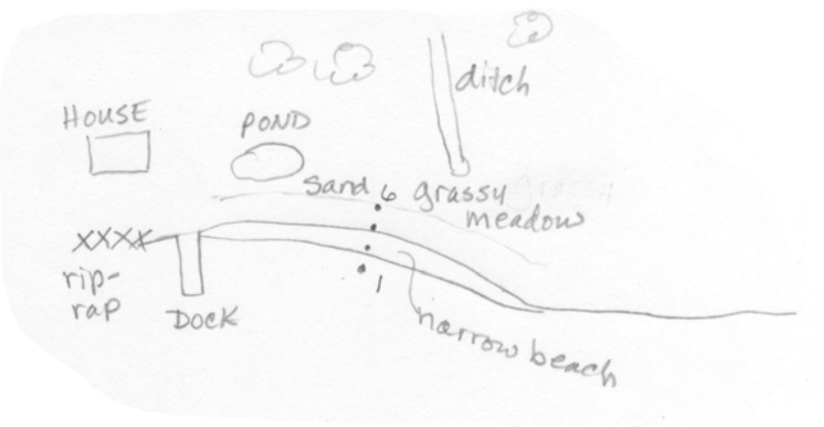
Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
C-8	CoreGS, TM, BD	Pland line on back beach
8-beach	GS	Beach grab
Off-8	GS	Grab offshore-~1 ft

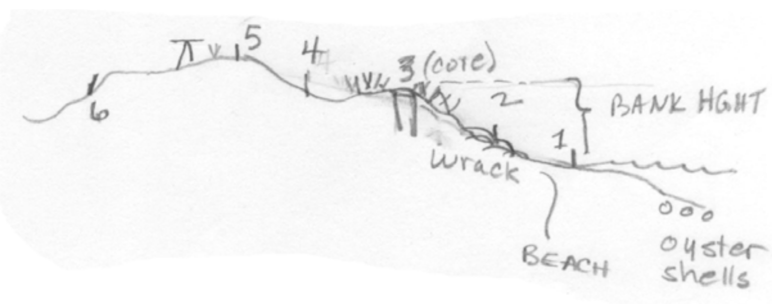
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 8-South Point.

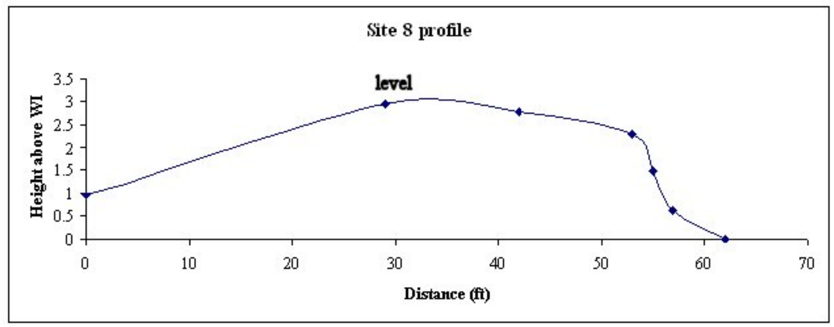
Plan view (sample locs; site features, reach & beach extents)



Stratigraphic section



Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Hgt (ft)	Comments
1	6.30	6.13	5.97	33	0.0	Water line
2	5.64	5.50	5.36	28	0.63	
3	4.78	4.65	4.52	26	1.48	-1.48-bank height
4	3.95	3.83	3.71	24	2.3	
5	3.41	3.355	3.28	13	2.775	Tripod btwn 4. and 5
6	5.23	5.185	4.94	29	0.945	



Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 9- Genesar Estate.

Site ID: 9
Site name: Genesar Estate
Location: East shoreline of Newport Bay, mid point on Sinepuxent Neck

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4230732	482556

Date: 4/30/02
Time: 1715 UTC
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): Marsh
Extent (length) of reach (ft): ~500 yds
Land use/cover along reach: marsh back by woods, field, houses
Comments

Site description: Site on eroding point, small island on tip; thickly vegetated, mixed S. alterniflora and S. patens and other species

Reach description: Reach highly convoluted shoreline; with pinced necks, stacks and clefts.

Plants:

Species	Percent
Spartina alterniflora	70
S. patens	20
Limonium sp.	5
Iva frutescens	5

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
9A	Core-GS,TM, BD	2.5' from water edge
Off-9	Grab-GS	.3 m offshore
9B	Core-	2.6' from edge

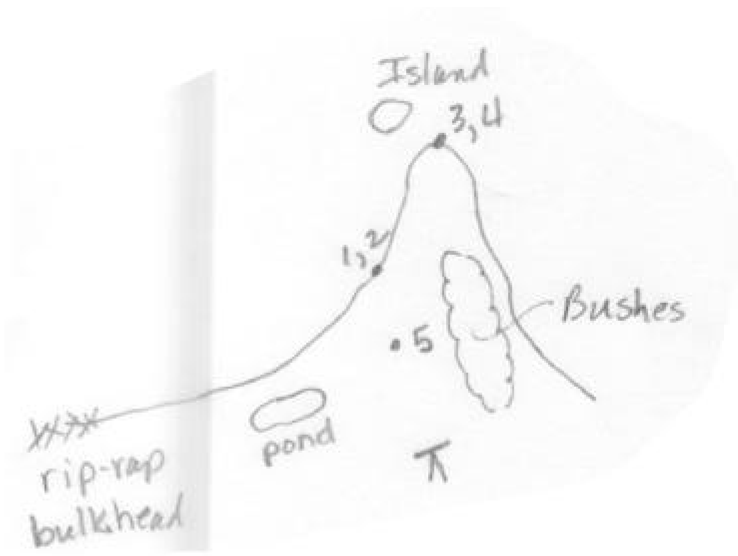
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
1	24	4/30/02; 1313 EDT	Looking north
1	25	1313 EDT	Looking south
1	26	1313	Close-up core site w/Rich taking core

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 9- Genesar Estate.

Plan view (sample locs; site features, reach & beach extents)

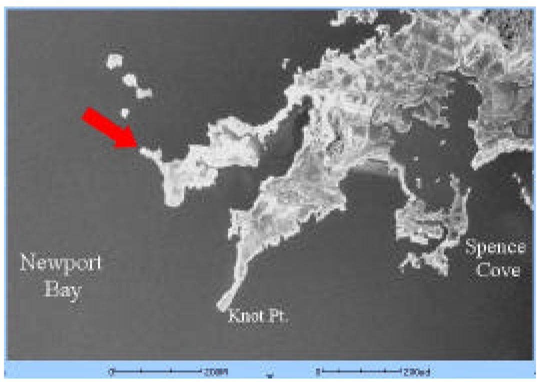


Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1	6.88	6.54	6.21	67	1.92	Bank height
2	4.95	4.62	4.29	66		
3	5.79	5.42	5.05	74	0.98	Bank height at point
4	4.80	4.44	4.08	72		
5		4.01				
6		4.48				

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 10- Knott Point.

Site ID: 10
Site name: Knott Point
Location: Upper eastern shoreline, Newport Bay

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4232078	481917



Date: 4/30/02
Time: 1745 UTC
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): marsh
Extent (length) of reach (ft):
Land use/cover along reach: marsh
Comments

Site description: Site on point of eroding marsh peninsula on upper eastern shore of Newport Bay; *Spartina alterniflora* dominate grass; low marsh, some mussel shells covering surface with bare spots; point of marsh being undercut by channel

Reach description: Reach part of extensive marsh peninsula and marsh islands; shoreline very convoluted/irregular; numerous islands.

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
C10	Core-BD,TM, GS	2.5 ft from edge
Off-10	Grab-GS	1 ft offshore point

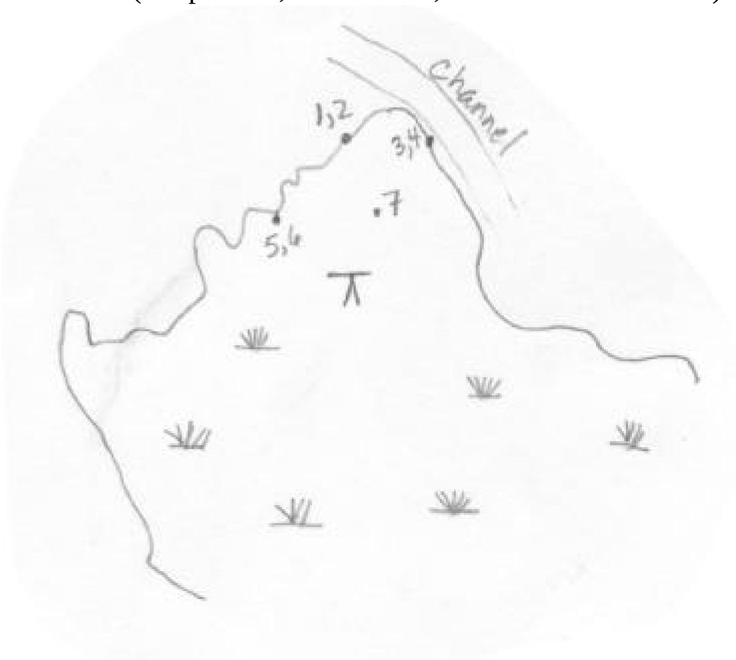
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Plants:

Species	Percent
Spartina alterniflora	90
Limonium sp.	5

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 10- Knott Point.

Plan view (sample locs; site features, reach & beach extents)



Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1	6.53	6.31	6.09	44	1.67	Bank height
2	4.85	4.64	4.43	42		
3	10.40	10.19	9.98	42	4.9	Bank height
4	5.50	5.29	5.08	42		
5	6.29	6.19	6.08	21	1.62	Bank height
6		4.57				
7	4.62	4.51	4.40	22		

Photos:

Card	Frame	Date/Time	Subject
1	27	4/30/02; 1402 EDT	Core site
1	28	1404	Rich and Darlene- looking west
1	29	1405	Collecting core- looking southeast

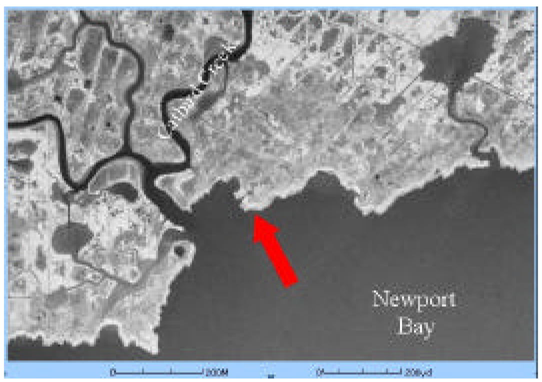
Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 11- Catbird Creek.

Site ID: Site 11

Site name: Catbird Creek

Location: Upper western shore, Newport Bay, east of mouth of Catbird Creek

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4233150	480960



Date: 4/30/02

Time: 1833 UTC

Described by: DVW

Shoreline type (e.g., marsh, bluff, beach): marsh

Extent (length) of reach (ft): 1000 yds

Land use/cover along reach: marsh

Comments

Site description: Site on point of marsh east of the mouth of Catbird Creek; *S. alterniflora* dominant plant; backed with low bushes, trees; abundant mussels covering surface near water edge

Reach description: Extensive marsh, ½ to ¾ mile wide, backed with forest, farms; entire marsh transected with ditching, has interior ponds/open water

Plants:

Species	Percent
Spartina alterniflora	95
Iva frutescens	

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
C 11	Core- BD, GS, TM	2.4' from water's edge
Off 11	Grab- GS	Offshore, 1 ft from shore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
1	30	4/30/02; 1427 EDT	South
1	31	1427 EDT	Looking NE
1	32	1427 EDT	Back marsh, woods

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 11- Catbird Creek.

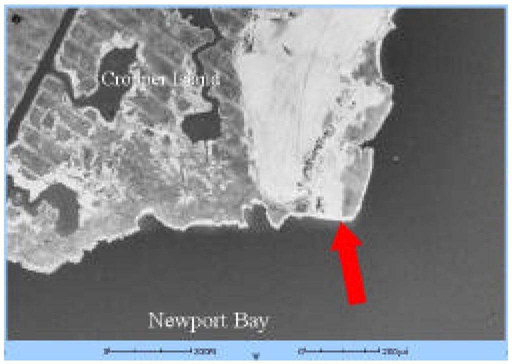
Plan view (sample locs; site features, reach & beach extents)

Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1		6.87			2.37	Bank height
2		4.50				
3		6.18			1.9	Bank height
4		4.28				
5		4.38				
6		7.15			2.43	Bank height
7		4.72				

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 12 – Cropper Island.

Site ID: Site 12
Site name: Cropper Island
Location: Mid- western shoreline, Newport Bay

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4231894	480029



Date: 4/30/02
Time: 1900 UTC
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): Marsh
Extent (length) of reach (ft): 1000 yrds
Land use/cover along reach: mixed marsh, fields, lawn

Site description: Site on point of broad marsh with pocket beaches, stand of cedars; Mix *Spartina alterniflora* and *S. patens*

Reach description: Extensive marsh with ditching; cut grass in places.

Plants:

Species	Percent
Spartina alterniflora	60
S. patens	30
Limonium sp.	4
Iva frutescens	5
Cedar trees	1

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
C 12	Core- GS, BD, TM	2.4 ft from edge
Off -12	Grab - GS	1 ft offshore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

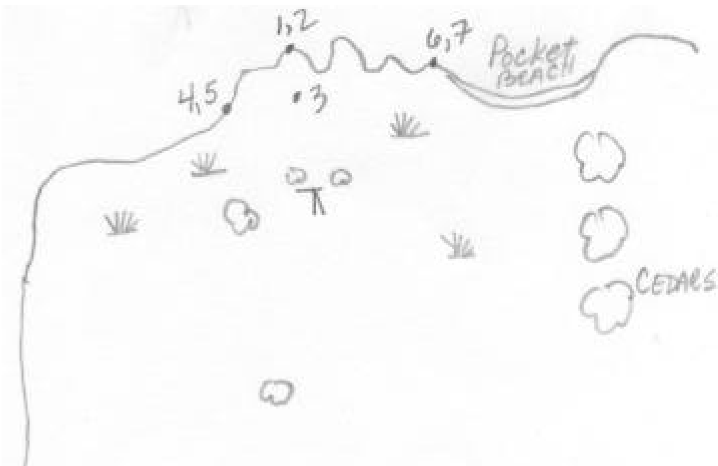
Photos:

Card	Frame	Date/Time	Subject
1	33	4/30/02; 1459 EDT	Core site and Darlene
1	34	1459 EDT	Site looking SE
1	35	1459 EDT	SE cedar trees

Comments: Wrack line ~12 ft from edge, very thick wrack

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 12 – Cropper Island.

Plan view (sample locs; site features, reach & beach extents)



Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1		6.65			1.9	Bank height
2		4.75				
3		4.73				
4		6.14			1.68	Bank height
5		4.46				
6		7.29			2.72	Bank height
7		4.57				

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 13 – Out Pt..

Site ID: Site 13

Site name: Out Point

Location: Western shore (mainland), Newport Bay

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4230710	479093

Date: 4/30/02

Time: 1914 UTC

Described by: DVW

Shoreline type (e.g., marsh, bluff, beach): Marsh

Extent (length) of reach (ft):

Land use/cover along reach: marsh, forest

Comments

Site description: Site on point of marsh, facing NE, grasses very thick, *S. alterniflora* dominant

Reach description: Extensive marsh, ¾ to ½ mile wide, backed by woods.

Plants:

Species	Percent
Spartina alterniflora	99

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
Core13	GS, TM, BD	3.0 ft from edge
Off 13	GS	~1 ft from shore

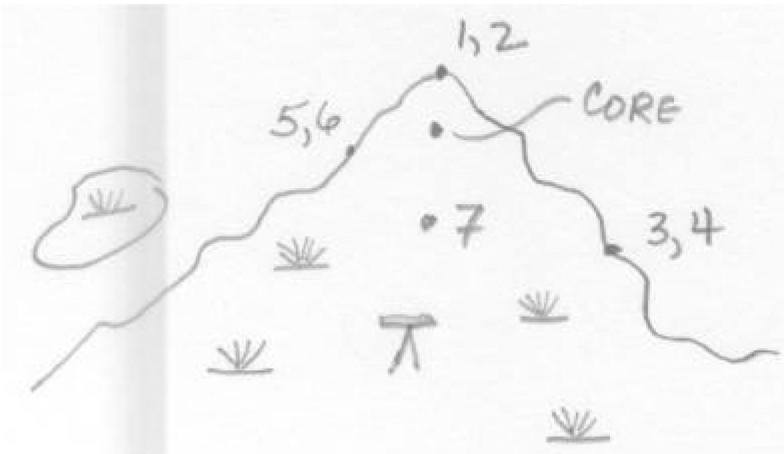
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Fr	Date/Time	Subject
1	36	4/30/02; 1523 EDT	Site looking East
1	37	1523 EDT	Site looking SW
1	38	1523 EDT	Site looking north

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 13 – Out Pt..

Plan view (sample locs; site features, reach & beach extents)



Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1		7.75		3.29		Near core site
2		4.46				
3		6.84		2.39		
4		4.45				
5		6.27		1.68		
6		4.59				
7		4.42				

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 14 – Handy Hammock.

Site ID: Site 14

Site name: Handy Hammock

Location: Wester shore (mainland), upper Chincoteague Bay

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4228984	478249

Date: 4/30/02

Time: 1942 UTC

Described by: DVW

Shoreline type (e.g., marsh, bluff, beach): Marsh

Extent (length) of reach (ft):

Land use/cover along reach:

Site description: Site on point of marsh; small pond at point surrounded by marsh; bushes, some Phragmitespocket beach just north of core site

Reach description: Extensive marsh, with pockets of trees

Plants:

Species	Percent
S. alterniflora	70
Phragmites	5
Lavender	5
Bushes	20

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
Core 14	BD, GS, TM	3.1 ft from edge
14	GS	1 ft offshore

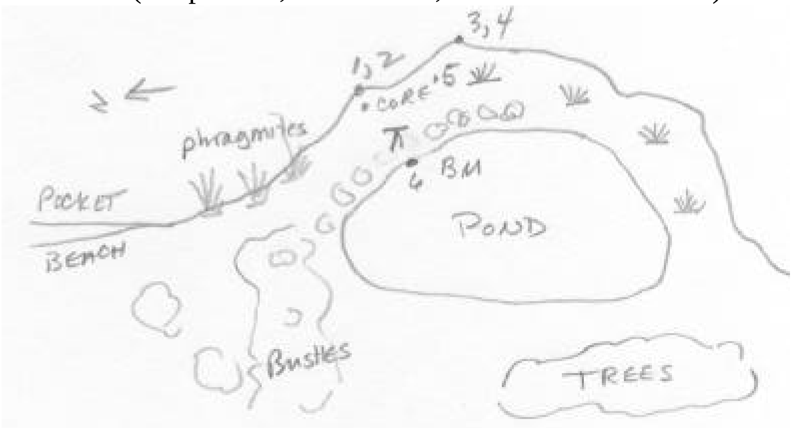
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Ca	Frame	Date/Time	Subject
1	39	4/30/02; 1559 EDT	Site with boat
1	40	1600 EDT	
1	41	1601 EDT	Pond
1	42	1602 EDT	BM- Md waterway Improvement; Hydro “HANDY 1986”

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 14 – Handy Hammock.

Plan view (sample locs; site features, reach & beach extents)

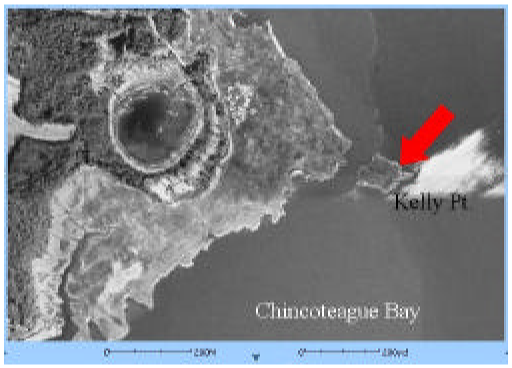


Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from le (ft)	Bank Hgt (ft)	Comments
1		7.78			3.16	Core site
2		4.62				
3		4.32			2.3	
4		6.62				
5		4.10				
6		4.39				BM- "HANDY 1986"

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 15 – Kelly Pt.

Site ID: Site 15
Site name: Kelly Pt. (UMCEES site)
Location: Western shore (mainland); upper Chincoteague Bay

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4226821	477746.7



Date: 4/30/02
Time: 2050 UTC
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): Marsh
Extent (length) of reach (ft):
Land use/cover along reach: marsh
Comments - Weather worsened; very stormy

Site description: Site on point island, smaller island off site; marsh with *S. alterniflora* dominant grass

Reach description: convoluted shoreline with islands, extensive marsh, backed by woods, farms.

Plants:

Species	Percent
S. alterniflora	99

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
Core 15	BD, GS, TM	3 ft from edge
Off 15	GS	Grab sample 1 ft offshore

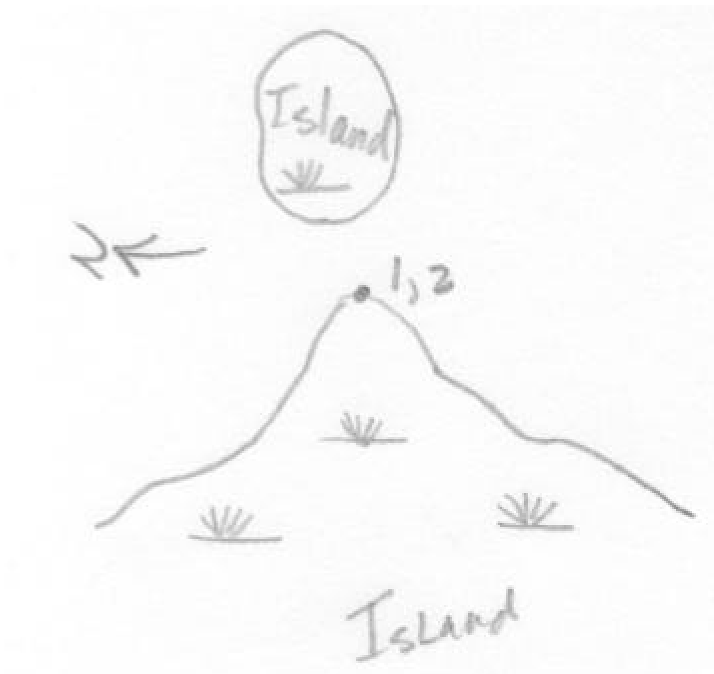
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
1	43	4/30/02; 1645 EDT	Site (pt.)
1	44	1659 EDT	Rich and Dan

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 15 – Kelly Pt.

Plan view (sample locs; site features, reach & beach extents)

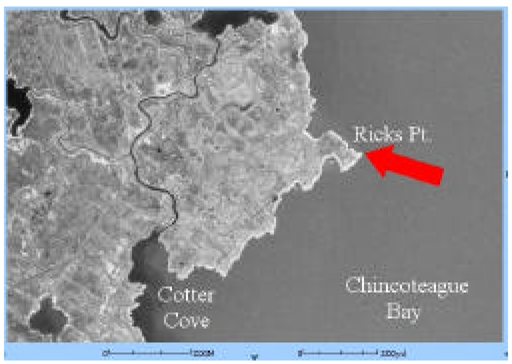


Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1		5.64			1.49	Core site
2		4.15				

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 16 – Rick's Pt..

Site ID: Site 16
Site name: Rick's Pt.
Location: Western (mainland) shore, Chincoteague Bay

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4224048	476842



Date: 4/30/02
Time: 2130 UTC
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): marsh
Extent (length) of reach (ft):
Land use/cover along reach:

Site description: On narrow point of marsh, grasses and some small bushes; shoreline very convoluted

Reach description: part of an extensive marsh backed by trees and farm fields.

Plants:

Species	Percent
S. alterniflora	90
bushes	

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
Core 16	GS, BD, TM	3 ft from edge
16 off	GS	Grab 1 ft from shoreline

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

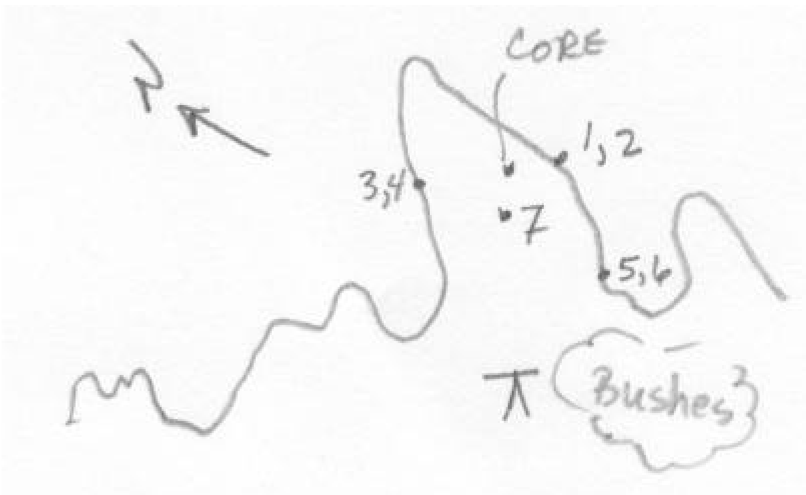
Photos:

Card	Frame	Date/Time	Subject
1	45	4/30/02; 1737 EDT	Core site
1	46	1738 EDT	Site looking south
1	47	1738 EDT	Site back
1	48	1739 EDT	Site looking south

Comments: Site is southern-most location in study area; very stormy NOT GOOD

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 16 – Rick's Pt..

Plan view (sample locs; site features, reach & beach extents)



Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1		6.14			1.82	
2		4.32				
3		7.27			2.63	
4		4.64				
5		6.26			1.69	
6		4.57				
7		4.14				

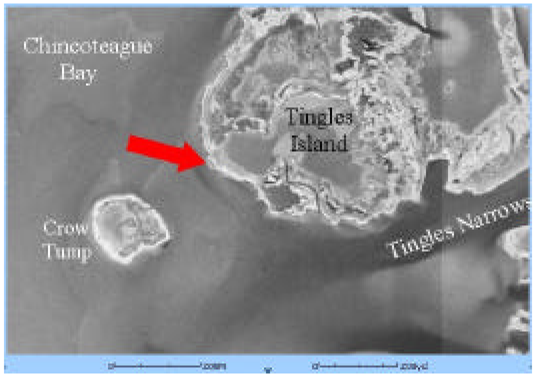
Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 17 – Tingles Island

Site ID: Site 17

Site name: Tingles Island

Location: Eastern shore, Chincoteague Bay (bay-side of Assateague Island)

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4224768	483096



Date: 4/30/02

Time: 1407 UTC

Described by: DVW

Shoreline type (e.g., marsh, bluff, beach): marsh

Extent (length) of reach (ft):

Land use/cover along reach:

Comments

Site description: Site on small island; sparse grasses (S. alterniflora); edge of island slumping w/less vegeataion; horse dung; lots of birds

Reach description: marsh island characterized by interior channels, ponds (open water)

.

Plants:

Species	Percent
S. alterniflora	100

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
Core 17	GS; TM; BD	3.7 ft from edge
Off 17	GS	1.5 ft from shoreline

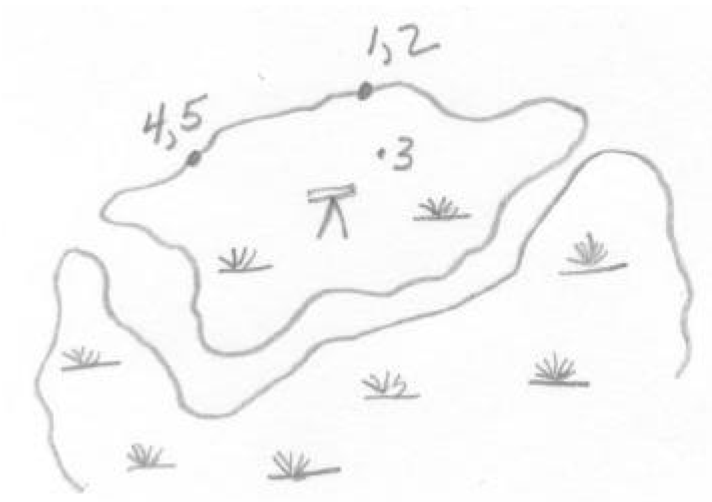
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
1	18	4/30/02; 1019 EDT	Site looking north
1	19	1020 EDT	Site looking east
1	20	1021 EDT	Site looking west

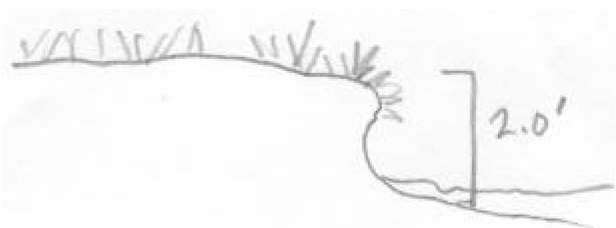
Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 17 – Tingles Island

Plan view (sample locs; site features, reach & beach extents)



Stadia readings (see fig to left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1	4.93	4.715	4.50	43	1.115	
2	6.06	5.83	5.60	46		
3	4.66	4.515	4.36	30		
4	6.30	6.09	5.88	42	1.39	
5	4.90	4.70	4.50	40		

Stratigraphic section



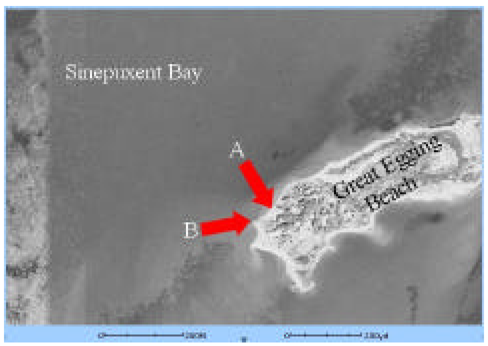
Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 18 – Great Egging Beach

Site ID: Site 18

Site name: Great Egging Beach

Location: Island opposite of South Pt., Sinepuxent Bay (facing Chincoteague Bay)

UTM Zone 18 NAD83, m	Northing	Easting
Actual- A	4228279	484291
B	4228253	484244



Date: 6/17/02

Time: 1810 UTC

Described by: DVW

Shoreline type (e.g., marsh, bluff, beach): beach/marsh mix

Extent (length) of reach (ft):

Land use/cover along reach:

Site description: Profile A - Narrow beach backed by grasses and woods, truncated by thick Phragmites stand to north and marshy point to south; Profile B – narrow marsh along point, backed by bushes, series of hard mud "steps' offshore.

Photo (above). At Profile A, looking north.

Reach description: Island shoreline a mixed of marsh, beaches, and wooded edge; interior of island forested.

Plants: along shoreline

Species	Percent
Phragmites	70
S. alterniflora	15
Iva frutesscens	5
Mixed hardwoods, pines	5

Samples: Samples taken 4/30/02

ID	Type*	Location/Descpt.
Core 18B	BD; GS; TM	On point- first step (taken at very high tide- site was flooded)
18B Off	GS	Grab taken offshore
18A-T	BD;GS;TM	Bank cut- top
18A-M	BD;GS;TM	Bank cut- middle
18A-B	BD;GS;TM	Bank cut- bottom
18A Off	GS	

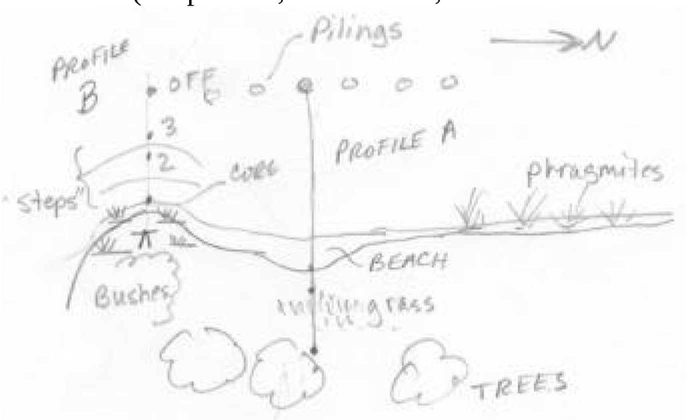
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
1	4	6/17/02; 13:30 EDT	Profile A bankcut
1	5	13:39 EDT	Profile A- north
1	6	13:39 EDT	Profile A- south
1	7	14:17 EDT	Profile B: point
1	8	14:19 EDT	Level of pt. B
1	9	14:33 EDT	Island from offshore
1	10	14:34 EDT	"

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 18 – Great Egging Beach

Plan view (sample locs; site features, reach & beach extents)



Comments: Series of pilings offshore marking former shoreline??

Stadia readings Profile B (see figure at left for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
		4.85		0	0	Level-water line
1	5.18	5.13	5.08	10	-0.28	Core site
2	5.43	5.34	5.25	18	-0.49	
3	6.29	6.19	6.09	20	-1.34	Bottom of bank cut Bank height
Off	6.95	6.56	6.17	78	-1.71	

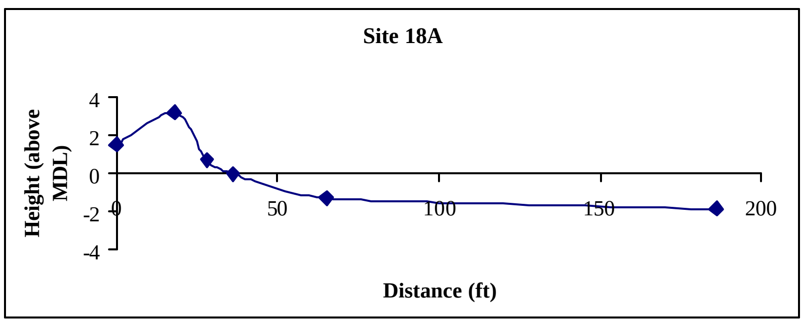
Photo: Profile B, looking south

Great Egging Beach (island) from offshore. Note the series pilings offshore.

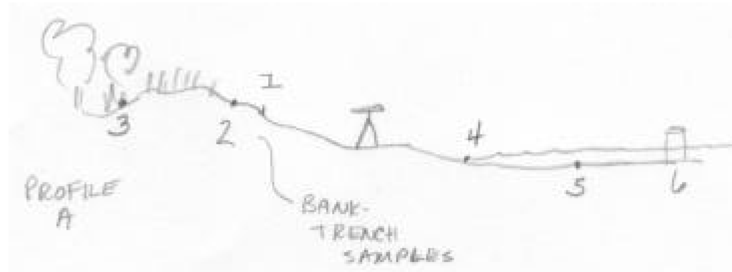
Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 18 – Great Egging Beach

Stadia readings Profile A (see figure at right for locations)

Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft) Above MWL	Comments
3	4.23	4.09	3.95	28	1.51	Behind berm
2	2.48	2.43	2.38	10	3.17	Top of bank cut on berm
1*	5.54	5.49	5.44	10	0.11	Bank cut; rod in trench (see below for sampling locations
		4.88		0	0.72	Level
4	5.64	5.60	5.56	8	0.0	Water line
5	7.15	6.87	6.78	37	-1.27	Offshore sample
6	8.25	7.46	6.67	158	-1.86	Piling offshore
					Sample Hgt	
1*		2.2			2.31	Top sample
		1.3			1.41	Middle
		0.5			0.61	Bottom



Profile section- A



At Profile A, looking north to point (Profile B).

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 19 – Sandy Pt. Island

Site ID: Site 19
Site name: Sandy Pt. Island
Location: East side of Sinepuxent Bay, south of Verazanno Bridge

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4231941	486847

Date: 4/29/02
Time: 2114 UTC
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): Marsh
Extent (length) of reach (ft):
Land use/cover along reach: State Park
Comments:

Site description: Small island south of bridge; site on NW point of marsh ; convoluted shoreline; low marsh; spotty vegetation along shore, evident of extension wave wash and grazing by ponies.

Reach description: Entire island is very low, flat; reach punctuated by numerous mosquito ditching.

Plants:

Species	Percent
S. alterniflora	100

Samples: Samples taken 4/29/02

ID	Type*	Location/Descpt.
Core 19	BD; GS; TM	3 ft from shoreline
19 Off	GS	Grab; 1.5 ft offshore

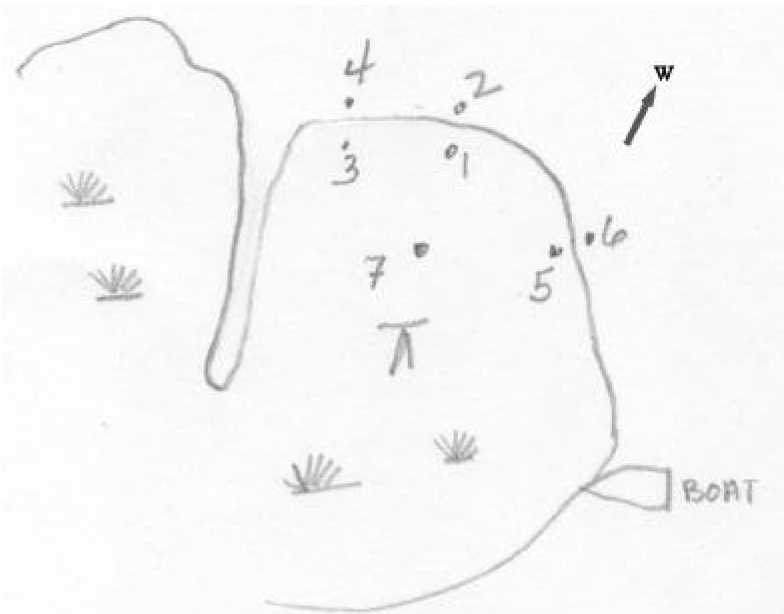
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
1	14	4/29/02; 16:56 EDT	Rick taking core
1	15	16:56 EDT	Level looking east
1	16	16:57 EDT	Site looking north
1	17	16:57 EDT	Site looking south

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 19 – Sandy Pt. Island

Plan view (sample locs; site features, reach & beach extents)



Stadia readings (see fig to right for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1	4.85	4.40	4.20	65	1.44	Bank height
2	6.26	5.84	5.42	84		
3	5.50	5.00	4.49	101	0.8	Bank height
4	6.32	5.80	5.28	104		
5	4.82	4.46	4.11	71	1.4	Bank height
6	6.22	5.86	5.49	73		
7	4.49	4.30	4.12	37		

Photo right: At core site, looking southeast toward Assateague Island

Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 20 – Assateague Island shoreline opposite of Sandy Cove, Sinepuxent Bay

Site ID: Site 20

Site name:

Location: Assateague Island shoreline opposite of Sandy Cove, Sinepuxent Bay

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4234428	488515

Date: 4/29/02

Time: 2000 UTC

Described by: DVW

Shoreline type (e.g., marsh, bluff, beach): washover fan

Extent (length) of reach (ft):

Land use/cover along reach: National park

Comments

Site description: Eroding shoreline marsh; broad expanse of sand flat; sparse grasses (S. alterniflora), backed by large shrubs (bay berry and marsh elder).

Reach description: **C**onvoluted marsh/overwash areas, pocket beaches.

Plants:

Species	Percent
S. alterniflora	
Myrica	
Iva	

Samples: Samples taken 4/29/02

ID	Type*	Location/Descpt.
Core 20	BD; BS; TM	3 ft from edge
20 Off	GS	1 ft offshore

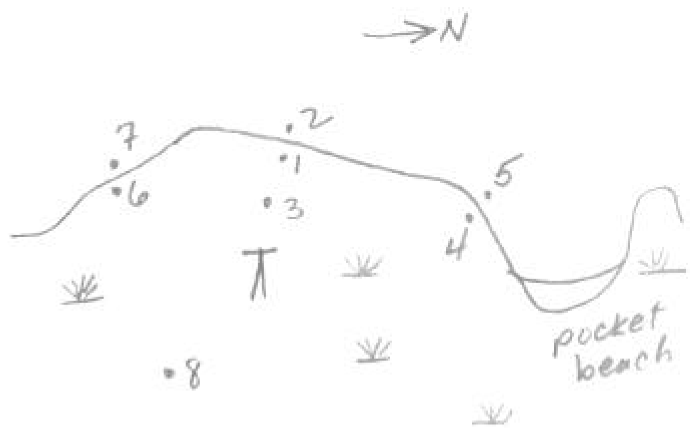
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
1	3	4/29/02; 15:39 EDT	
1	4	15:39 EDT	
1	5	15:39 EDT	
1	8	15:40 EDT	Surveying
1	9	15:41 EDT	Horses
1	11	15:55 EDT	Site looking south
1	12	15:55 EDT	Core site
1	13	15:56 EDT	Site looking north

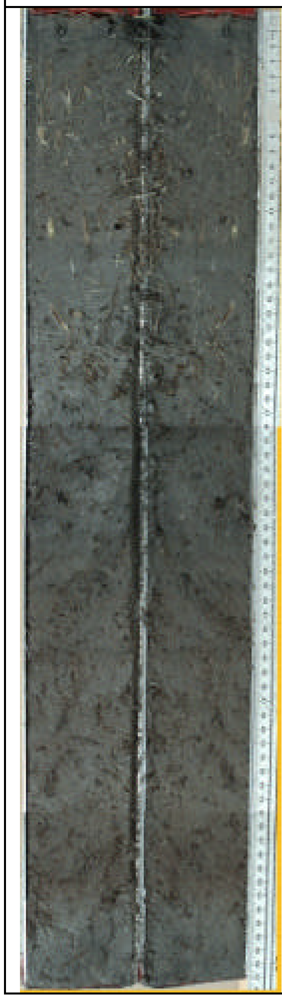
Shore Erosion as a Source of Sediments & Nutrients, Middle Coastal Bays, Maryland (CZM Grant M02-075 CZM 046)
SITE/SAMPLE FIELD DESCRIPTION: Site 20 – Assateague Island shoreline opposite of Sandy Cove, Sinepuxent Bay

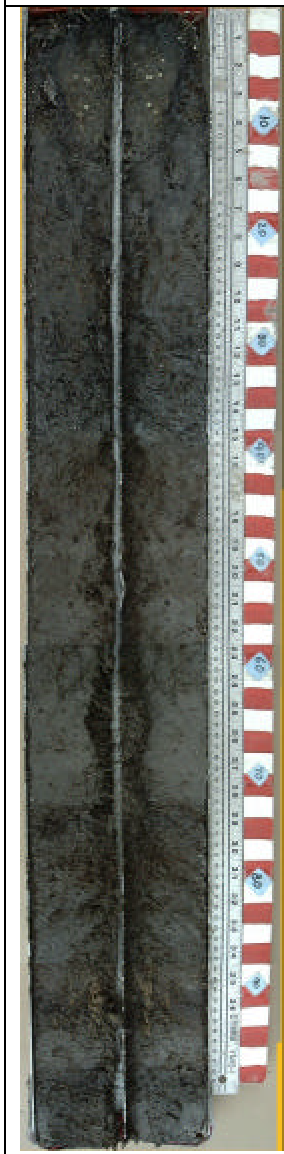
Plan view (sample locs; site features, reach & beach extents)

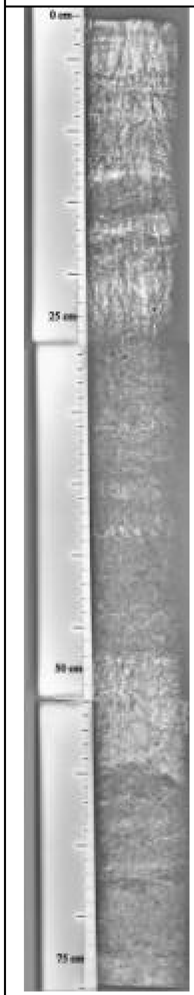


Stadia readings (see fig to right for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
1	4.22	4.08	3.94	28		Near core site
2	5.96	5.76	5.62	34	1.68	Bank Height
3	4.19	4.11	4.03	16		
4	4.32	4.20	4.09	23		
5	5.45	5.33	5.21	24	1.13	Bank Height
6	4.57	4.31	4.07	50		
7	5.46	5.19	4.93	53	0.88	Bank Height
8		4.70				

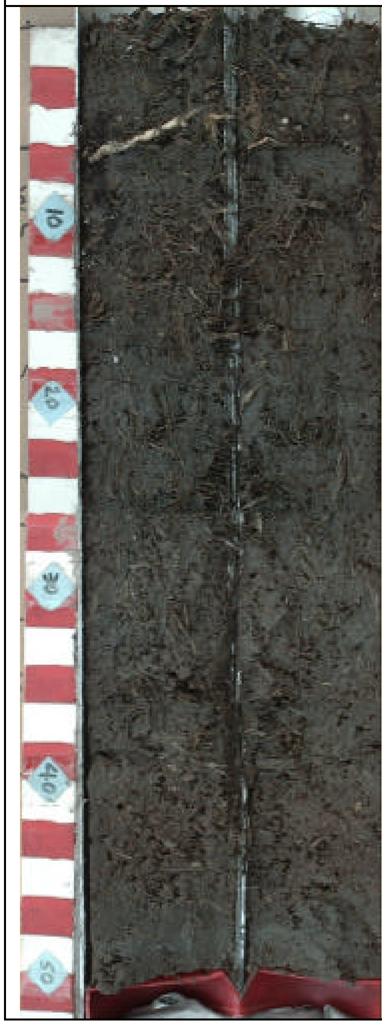
Photo: On site looking north toward small pocket beach

Site #1- Ocean City Airport, Sinepuxent Bay Total length – 67.0 cm Date collected – 6/17/02 Date processed - 8/12/02			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-3	10 YR 2/2	Active root zone; Dusky yellowish brown silty mud, roots, very compact, live crab (~0.5 cm)
	3-15	10 YR 3/2	Active root zone; Dark yellow brown silty mud, roots
	15-21.5	5 Y 3/1	Active root zone; Darker brownish black firm silty mud
	21.5-26.5	10 YR 3/2	Active root zone to ~ 26.5 cm; Dark yellow brown spongy peaty mud
	26.5-29	10 YR 2/2	Darker dusky yellow brown silty mud
	29-35.5	10 YR 3/2	Dark yellow brown silty mud, less firm, more watery, some peat
	35.5-44	5 YR 2/2	Dusky brown peaty mud, somewhat watery, plant material
	44-57	10 YR 3/2	Dark yellow brown peaty mud, plant material
	57-60.5	5 YR 2/2	Dusky brown muddy peat
	60.5-67	5 YR 2/1	Brownish black denser clayey mud, very little plant material

Site # 2 - Bat Creek, Sinepuxent Bay Total length – 103.0 cm Date collected – 6/17/02 Date processed – 8/5/02			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-3.5	N1	Active root zone; Black sandy mud with shells, live mussels and roots
	3.5-17	5 Y 4/1 to 5 YR 2/1	Active root zone: Olive gray muddy sand and brownish black muddy sand; distinct division along borrow with small crab; anoxic zone follows burrow down, very firm at top gradually becoming more watery with depth; roots present
	17-28	5 Y 3/1	Active root zone; Olive gray silty mud with peat pockets; roots, somewhat mottled appearance with reddish peat; Active root zone ending at ~28 cm
	28-36	10 YR 2/2	Dusky yellow brown mud with peat, spongy layer, roots in more horizontal orientation
	36-61.5	Mottled; 5 YR 3/2 10 YR 2/2	Grayish brown mud mottled with dusky yellow brown peaty mud, gradually lighter with depth, also gets more firm, lot of root material
	61.5-71	5 Y 3/2	Olive gray, firm smoother consistent mud
	71-75.5	5 YR 2/2	Sharp boundary; Dusky brown muddy peat, very dark compared to overlying layer
	75.5-89	10 YR 2/2	Indistinct change to dusky yellow brown peaty mud, bottom of section contains large mass of roots
	89-91	5 YR 2/1	Brownish black anoxic layer of peat
	91-96.5	5 YR 2/2	Dusky brown peaty mud
	96.5-99	5 YR 2/1	Sharp boundary, brownish black muddy peat
	99-103	10 YR 2/2	Dusky yellow brown, layered, fissiled; drier peaty layer

Site #3 – Gray's Cove, Sinepuxent Bay Total length – 67.5 cm Date collected – 4/29/02 Date processed – 7/22/02				
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-5	Mottled; 10 YR 2/2 N2	Active root zone; Dusky yellow brown silty mud with abundant roots, slightly reduced zone around some roots, mussel at top
		5-11	10 YR 3/2	Active root zone; Gradually lighter to dusky yellow brown mud with roots
		11-13	5 YR 2/2	Active root zone; Darker band, dusky brown mud
		13-21	5 Y 2/1	Active root zone; mud
		21-27.5	10 YR 2/2	Active root zone; Dusky yellow brown peat with mud, spongy layer, live roots extend through this layer
		27.5-37	5 YR 2/1	Active root zone; Less dense, more watery dusky brown mud, some peat; Live roots down to ~ 38 cm
		37-46	10 YR 3/2	Mostly dead roots, fibrous more horizontal network below ~ 38 cm
		46-52	5 Y 2/2	Indistinct change to more dense mud, brownish black
		52-57.5	5 YR 2/4	Irregular contact, to more spongy layer, mud to more brownish in hue
		57.5-67.5	10 YR 2/2	Dusky yellow brown mud, fairly consistent, more dense, some peat clasts

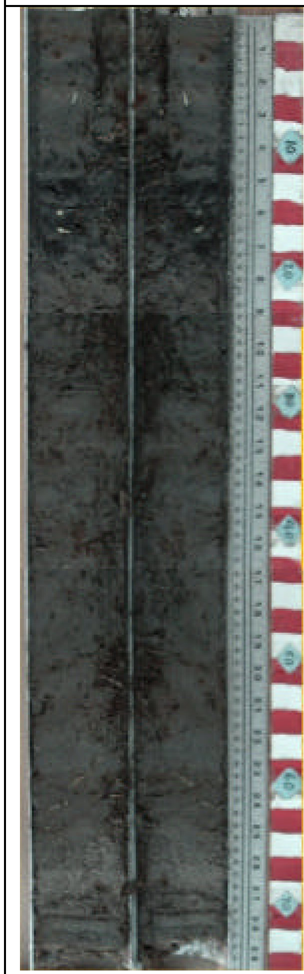
Site #5 – Sandy Cove, Sinepuxent Bay	Total length –37.5cm	Date collected – 4/29/02	Date processed – 9/6/02
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	Surface		Layer of decaying SAV, very dark brown to black (N2)
	0-5.5	N2	Active root zone; Mud to fine sand, very dark almost black, roots
	5.5-17.5	Mottled; 10 YR 6/6 10 YR 4/2 5 YR 2/1	Active root zone; indistinct transition to muddy sand, very dry; mottled dark yellowish orange to dark yellowish brown to brownish black, anoxic (reduced) layer around roots, silty sand, very dry, gradually gets more clayey down core
	17.5-21.5	5 Y 3/2	Active root zone; Olive gray firm mud with some roots and peat
	21.5-22.5	5 Y 2/1	Active root zone; Banded layer, olive black to dark yellowish brown mud with peat
	22.5-23	10 YR 4/2	
	23-24	5 Y 2/1	
	24-37.5	5 Y 3/1 to 5 Y 2/1	Active root zone to ~28 cm; Very firm silty mud, dark olive gray, gradually darkening to olive black, roots and peat

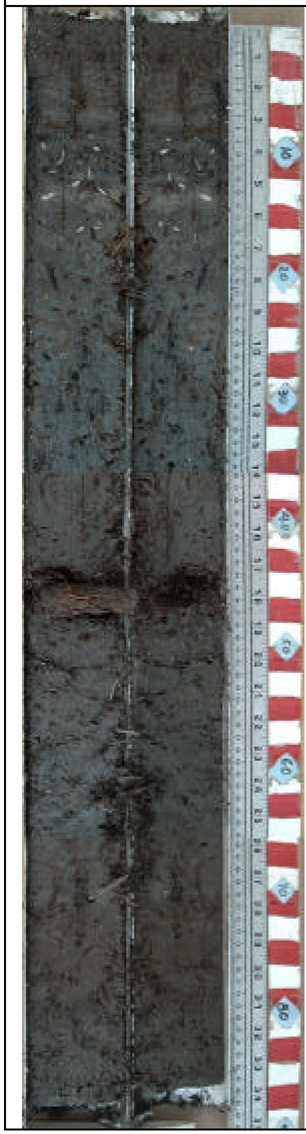
Site #7 – Ferry Landing, Sinepuxent Bay Total length – 49.5 cm Date collected – 4/30/02 Date processed – 9/10/03			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-6.5	10 YR 2/2	Active root zone; Dusky yellow brown silty mud with roots and plant material, mussels on top
	6.5-10.5	5 YR 2/2 with 5 YR 2/1	Active root zone; Dusky brown silty mud with brownish black zone (possible remnant root), lots of roots and plant material
	10.5-13.5	10 YR 3/2	Active root zone; Dark yellow brown spongy peaty mud
	13.5-18.5	5 YR 2/1	Active root zone; Brownish black mud, firmer with depth, plant material
	18.5-24	5 Y 2/1	Active root zone; Olive black mud with plant material, peat, muddier than surrounding layers
	24-27	N2	Active root zone; Grayish black peaty mud
	27-40	Mottled; 5 YR 2/1 5 YR 2/2	Active root zone ending at 36 cm; Brownish black mottled with darker brown peaty mud, upper more firm, gradually gets more watery toward bottom of section
	40-47	5 YR 3/2	Grayish brown peat with mud, distinct color change from rest of core
	47.49.5	5 Y 2/1	Olive black mud, less plant material

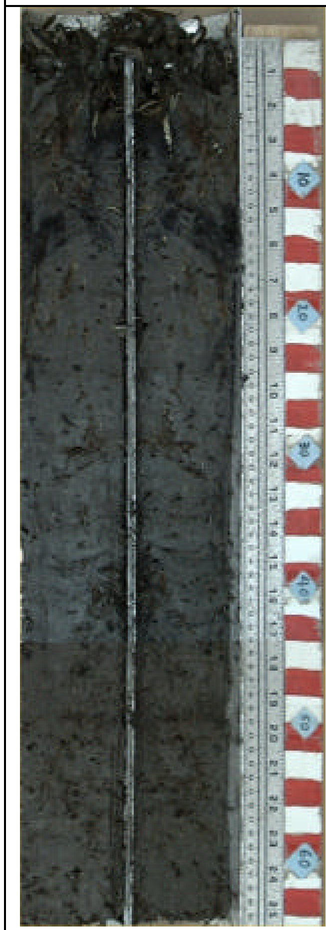
Site #8 – South Pt., Senator Johnson’s House, Chincoteague Bay Total length – 37.5 cm Date collected – 4/30/02 Date processed – 8/07/02

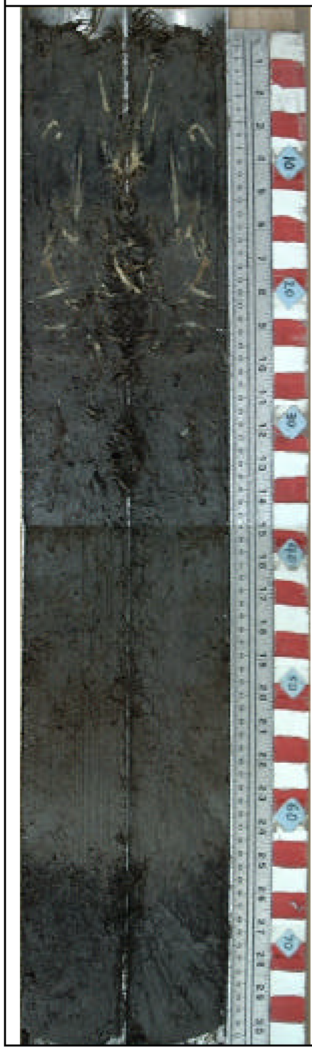
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-6.5	Mixed; 5YR 3/2 10 YR 6/4	Dark grayish brown composted grasses mixed with sand
	6.5-15	Mixed; 10 YR 6/4 5 YR 3/2	Large shell fragment at ~ 8-9 cm, sand is medium to coarse, sand content increases gradually with depth to ~ 15 cm where becomes almost all sand, some plant stems
	15-29	10 YR 6/4	Grayish yellow brown medium to coarse sand, very subtly banded maybe due to water content, some heavy mineral laminae; clay stringers
	29-30	5 YR 3/2	Thin layer of grayish brown medium to coarse sand with heavy minerals and or plant content
	30-32/33	10 YR 6/4	Grayish brown medium to coarse sand with very sharp angular contact between 32 and 33 cm
	32/33-37.5	5 YR 3/4	Moderately brown very compacted mud (clay)

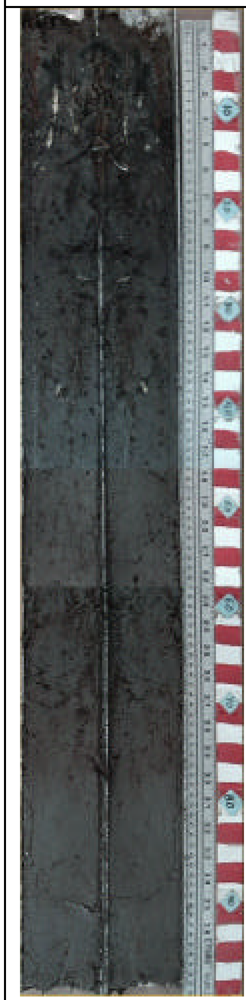
Site #9A – Genesar Estate, Newport Bay Total length – 34 cm Date collected – 4/30/02 Date processed – 9/06/02			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-2.5	5 Y 4/2	Active root zone; Olive gray muddy sand with roots, becomes more compact with depth
	2.5-6	5 Y 5/2 with 5 YR 3/4	Active root zone; Lithe olive gray with moderate brown sandy mud, oxidized pockets, hint of lamination
	6-10.5	5 Y 4/2	Active root zone; Olive gray very compact sandy mud, roots, some peat
	10.5-16	Mottled; 5 Y 4/2 5 Y 3/2	Active root zone; Mottled olive gray to dark olive gray with roots
	16-19	5 YR 3/2	Active root zone; Grayish brown alternating faint light and dark, laminar, dull to shinny, suggests textural changes
	19-21	10 YR 3/2	Active root zone; Dusky yellowish brown
	21-34	5 Y 3/2	Active root zone; slight mottle, overall olive gray, less dense, more spongy mud with lots of plant material, few roots

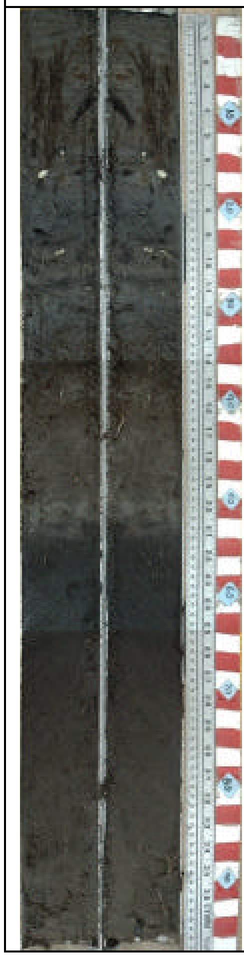
Site #9B- Genesar Estate, Newport Bay Total length – 73 cm Date collected – 4/30/02 Date processed – 1/9/03			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-5	Banded;10 YR 3/2; 5 YR 4/4, 5 YR 3/1	Active root zone; Laminated alternating mud and muddy sand, dark yellow brown, moderate brown to grayish brown, roots
	5-6.5	10 YR 6/2	Active root zone; Pale yellowish brown sandy layer
	6.5-11.5	10 YR 2/2	Active root zone; similar to top, gradually becoming more mottled with next section, signs of redox (redox boundary??)
	11.5-17.5	Mottled;10 YR 2/2; and N1	Active root zone; mottled black to dusky yellow brown mud
	17.5-32.5	10 YR 3/2 with 10 YR 4/2 to 5 YR 3/1	Subtly banded dark yellowish brown to brownish gray mud, gradually lighter toward bottom of section at 62.5 cm, plants, roots, H_2S odor; becomes more saturated with water ~33-48 cm whereas top was drier
	32.5-33.5	10 YR 4/2	
	33.5-62.5	5 YR 4/1	
	62.5-66.25	10 YR 5/2	Sharp boundary, medium yellow brown medium sandy layer
	66.25-73	Banded;10 YR 6/2 5 YR 2/2; 10 YR 3/2	Very sharp boundary; Pale yellow brown fine sand with thin peat partings (~2 cm thick), very bottom is muddy sand with plant fibers and peat

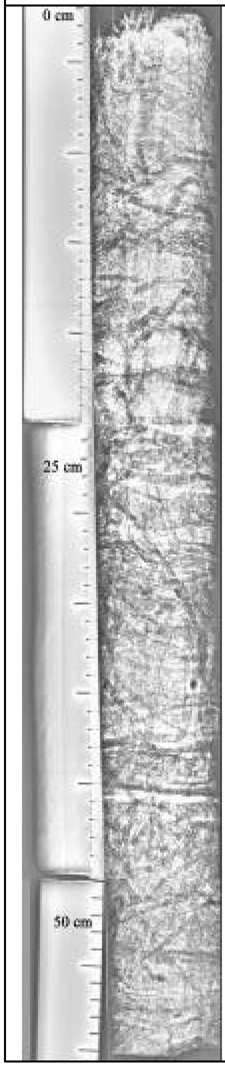
Site #10 – Knott Pt., Newport Bay Total length – 86.5 cm Date collected – 4/30/02 Date processed – 1/10/03				
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-7	5 YR 3/2	Active root zone; grayish brown; live grass (*S. alterniflora*) on the surface
	7-13	Mottled; 10 YR 3/2; 5Y 2/1	Active root zone; dark yellowish brown mottled with olive black
	13-14.5	5 Y 4/2	Active root zone; light olive gray fine sand
	14.5-25.5	5 YR 3/2	Active root zone; grayish brown mottled with redox roots
	25.5-45	5 YR 3/2	Grayish brown with no active roots, very large amount of peaty material, extremely spongy
	45-47.5	10 YR 4/2	Chunk of wood at 45-47.5 cm
	47.5-71.0	5 YR 3/2	
	71-86.5	10 YR 3/2	Dark yellowish brown, dead roots, some peaty material, spongy

Site #11- Catbird Creek, Newport Bay Total length – 65.0 cm Date collected – 4/30/02 Date processed – 1/13/03			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-16.25	Mottled; N1 5 YR 4/4 10 YR 2/2	Active root zone; Thick layer of shells ~4 cm thick at surface (mussels), moderate brown mottled with black changing to dusky yellowish brown mud, very firm, root oxidation, several thick active roots
	16.25-37	5 Y 3/2	Active root zone; Olive gray mud, less firm than the surface, fewer active roots, begin to see some peaty material
	37-51		No active roots below 37 cm, otherwise same as the section above
	51-65	10 YR 3/2	Dark yellowish brown mud, very spongy and very peaty

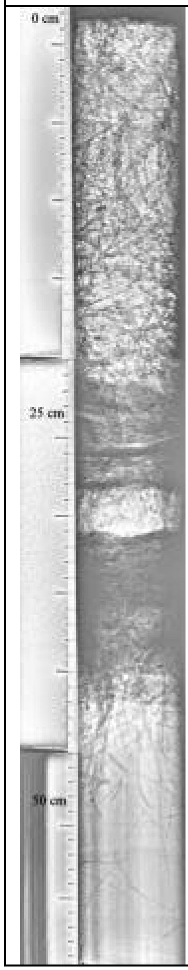
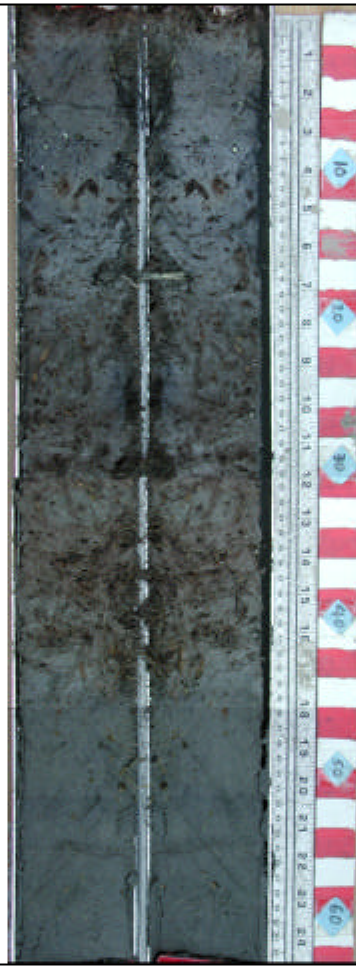
Site #12 – Cropper Island Total length – 76.0 cm Date collected – 4/30/02 Date processed – 1/15/03			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-8	10 YR 3/2	Active root zone; Dark yellowish brown firm sand
	8-13.5	5 Y 2/1	Active root zone; Olive black fine sand, very sandy, reduction zone
	13.5-20	5 Y 4/2	Active root zone; Light olive gray sand, still firm with increase in peat
	20-35	5 Y 2/1	Active root zone; Olive black, sandy to 25 cm, silty mud below 25 cm, increase peat, becomes spongy
	35-49.25	5 Y 3/2	Active root zone down to ~39 cm; Olive gray mud, increase in peat, spongier than above
	49.25-56.5	10 YR 3/2	Dusky yellowish brown peaty mud, extremely peaty, spongiest section of the core
	56.5-63.5	5 Y 4/1	Olive gray mud, decrease in peat content, very firm
	63.5-76	5 YR 2/1	Brownish black mud, spongy from 63.5 cm to ~70 cm, firm below ~70cm, more peat than section above

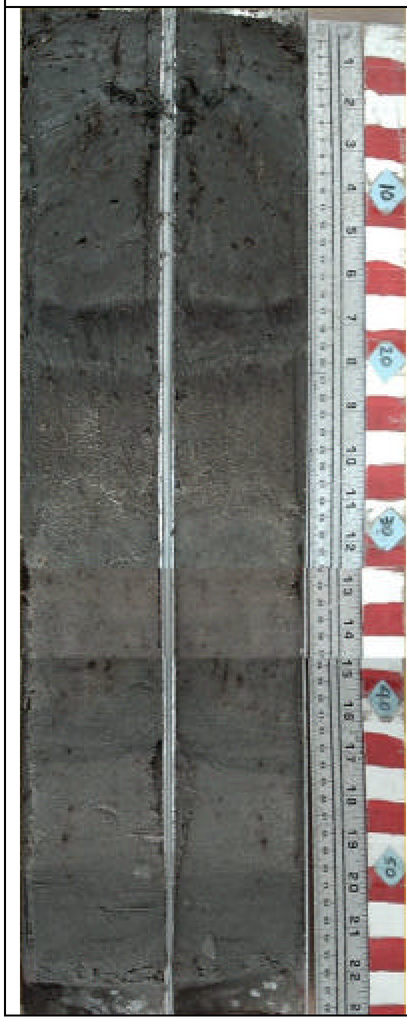
Site #13 – Out Pt., Newport Bay	Total length – 96.5 cm	Date collected – 4/30/02	Date processed – 1/15/03
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-12	Mottled; 5 YR 4/2 N2 5 YR 3/4	Active root zone; grayish brown sand mottled with grayish black and moderate brown, several mussels and grasses on surface, dense root matter and moderate peat, very firm
	12-27	Mottled; 5 Y 2/1 N2	Active root zone; olive black with grayish black, sand becoming silty and changing over to mud by 27 cm, fewer roots with increase peat, less firm, slight sponginess
	27-37	5 Y 3/2	Active root zone; olive gray silty mud, very peaty with fewer active roots, becoming more spongy
	37-61		Same color with absence of active roots, less peat than above but remains spongy
	61-76	7.5 YR 3/2	Dark brown silty mud, very peaty with extreme sponginess
	76-96.5	5 Y 3/2	Olive gray muddy silt, drastic peat decrease, less spongy, peat increases slightly again below 90 cm with very fine plant material

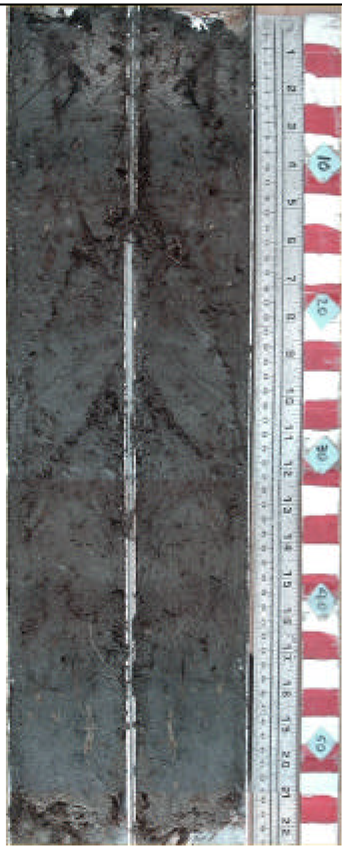
Site #14 – Handys Hammock, Chincoteague Bay Total length – 95.5 cm Date collected – 4/30/02 Date processed – 1/10/03			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-14	Mottled; 5 Y 4/1, 5 YR 4/4, fade to 10 YR 3/2	Active root zone; very thin anoxic N1 (black) layer on surface, no sign of root activity above 4 cm, active roots appear lateral from another location, olive gray sand with moderate brown mottles, fades to dark yellowish brown at 14 cm, little peat below 4 cm, firm down to ~26 cm
	14-17.75	5 Y 3/2	Active root zone; olive gray sand with slight increase in mud, little fine peat
	17.75-23.5	Mottled; 5 Y 3/1, N1	Active root zone; olive gray, silty clay mud, mottled with black
	23.5-26	10 YR 3/2	Active root zone; dusky yellowish brown sand
	26-32	10 YR 2/1 5 YR 3/2	Active root zone; small (~1.5 cm) band Olive gray mud, drastic increase in peat, very spongy
	32-49.5	5 YR 2/2 with 5 YR 3/2 and 10 YR 2/2	Active root zone; mud texture, mix of dusky brown, grayish brown, dusky yellowish brown, even more peat than above, still very spongy
	49.5-53	5 Y 4/1	Active root zone; olive gray, firm, silty clay mud, decrease in peat
	53-73	5 YR 2/1	Active root zone to ~59 cm; brownish black with gradual fade to dark yellowish brown near bottom of core, firm, still little peat present, starts as silty texture, increasing sand as depth increases, coarser sand at deeper depth
	73-95.5	10 YR 4/2	Fading to dark yellowish brown, (73 cm is center of fade), slight amount of peat, medium grain sand, still very firm

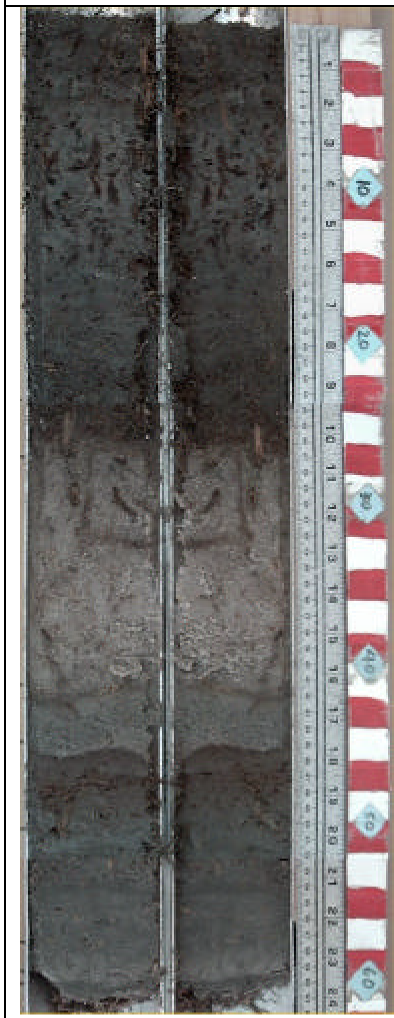
<table>
<tr><td colspan="5">Site #15 – Kelly Pt., Chincoteague Bay   Total length – 58.5 cm   Date collected – 4/30/02   Date processed – 8/2/02</td></tr>
<tr><th>Radiograph</th><th>Photograph</th><th>Interval (cm)</th><th>Color (Munsell Color Standard, GSA, 1991)</th><th>Description</th></tr>
<tr><td rowspan="9">
</td><td rowspan="9">
</td><td>0-2</td><td>5 Y 4/1</td><td>Active root layer; olive gray with reddish brown oxidized layer around roots with mussel shells; Overall core appearance of banding with no obvious spongy layer</td></tr>
<tr><td>2-6</td><td>Mottled; 5 YR 2/1 with N2</td><td>Active root layer; mottled brownish black to grayish black muddy silty sand</td></tr>
<tr><td>6-15.6</td><td>5 YR 2/2
5 Y 4/2
5 Y 2/1</td><td>Active root layer; mottled dusky brown to red olive gray to olive black silty muddy sand, large peat pockets, large roots, definite boundary, sandier layers</td></tr>
<tr><td>15.6-18</td><td>5 Y 3/2</td><td>Active root layer; olive gray very fine sandy mud to muddy sand, dense layer</td></tr>
<tr><td>18-28</td><td>5 Y 4/4</td><td>Active root layer; olive gray muddy sand, lighter than above, roots somewhat mottled, very subtle; occasional peat clast</td></tr>
<tr><td>24-41</td><td>5 Y 2/1</td><td>Active root layer; olive black muddy very fine sand, thin layers of sandy sediments, more mica in sandier layers, sand decreases down the core</td></tr>
<tr><td>41-52</td><td>5 Y 3/2</td><td>Active root layer; olive gray very fine sandy mud, roots</td></tr>
<tr><td>52-53.5</td><td>5 Y 3/1</td><td>Active root layer to ~53 cm; light brownish black, active roots are very fine</td></tr>
<tr><td>53.5-58.5</td><td>5 Y 3/2</td><td>Olive gray sandy mud</td></tr>
</table>

Site #16 – Ricks Pt., Chincoteague Bay Total length – 52 cm Date collected – 4/30/02 Date processed – 1/21/03			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-4	10 YR 4/2	Dark yellowish brown sand, grass and mussels on surface, active roots throughout entire core, sandy texture down to ~22.5cm, top 2 cm slightly spongy, very firm below 2 cm down to ~45 cm
	4-6	Mottled; 10 YR 4/2 with 5 YR 2/1	Dark yellowish brown sand with brownish black mottles
	6-47	Mottled; 5 Y 5/2 with 10 Y 2/1	Starts as light olive gray sand mottled with greenish black, colors fade slowly from light olive gray to olive gray in the mid 30’s (depth) to dusky yellowish brown. Increase in mud content below ~22.5 cm with slight increase in sponginess below ~42 cm
		5 Y 3/2	
		10 YR 2/2	
	47-52	5 YR 3/2	Grayish brown mud, very spongy with very high peat content

Site #17 – Tingles Island, Chincoteague Bay Total length – 62.5 cm Date collected – 4/30/02 Date processed – 7/23/02				
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-2	10 YR 3/2	Active root zone; dusky yellow brown mud, lots of root material
		2-16	Mottled; 5 YR 2/1 to 5 Y 2/1	Active root zone; mottled brownish black to olive black, more dense, hard mud, plant roots
		16-26	10 YR 2/2	Active root zone; dusky yellow brown, more watery mud, some decayed roots, plant material
		26-33	5 YR 2/2	Active root zone; dusky brown mud, slightly lighter than above, roots, peat layers; fibrous, more horizontal packing of plant material starting at ~26 cm
		33-38	5 YR 3/2	
		38-42	5 YR 2/2	Peaty layer, grayish brown mud, less dense than other layers
		42-45	5 Y 2/1	Very dark layer, olive black mud
		45-51	5 Y 4/2	Distinct change to sandier, homogenous section of olive gray silty, very dense, fine to very fine sand
		51-52.5	5 Y 3/2	Section has distinct color banding and muddy packing (1 mm at 55 cm. Darker olive gray layer at 51-52.5 cm, medium olive gray, very consistent to bottom of core, occasional plant material
		52.5-62.5	5 Y 4/2	

Site #18B – Great Egging Beach, Sinepuxent Bay Total length – 56 cm Date collected – 6/17/02 Date processed – 1/21/03			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-5/6	5 Y 3/2	Active root zone; couple faint grass blades on surface, very few roots throughout active root zone, olive gray mud, peaty at surface down to ~20.5 cm, thin interbedded sand layer between 5/6 cm
	5/6-16	10 YR 2/2	Active root zone; dusky yellowish brown, clay-silty mud down to ~21 cm as well as spongy down to ~21cm
	16-16.5	5 Y 4/1	Active root zone; thin band of olive gray
	16.5-18	10 YR 2/2	Active root zone; dusky yellowish brown
	18-21	5 Y 2/1	Active root zone; Olive black spongy mud
	21-35	10 YR 3/2 fade to 10 YR 4/2	Active root zone down to 31 cm; sharp boundary switch to very sandy texture, very dark yellowish brown fade to dark yellowish brown, extremely firm from 21 cm to bottom of core, no peat present from 21-56 cm
	35-44.5	5 Y 4/2	Firm light olive gray sand
	44.5-50	5 Y 5/2	Light olive gray; very slight hint of olive color, very close to light/medium gray, very firm sand
	50-56	5 Y 3/2	Olive gray; closer to medium/dark gray than above, very firm sand

Site #19 – Sandy Pt. Isl., Sinepuxent Bay Total length – 55.5 cm Date collected – 4/29/02 Date processed – 1/22/03			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-1	5 YR 2/1	Brownish black sand, little peat, firm
	1-6	10 YR 5/2	Pale brown, sandy texture, fine amount of peat, very firm
	6-8.5	10 YR 2/2	Dusky yellowish brown mud, slight increase in peat, less firm than above
	8.5-10	5 Y 2/1	Olive black mud with peat
	10-14	5 YR 3/4	Moderate brown peaty mud with interbedded ~1 cm thick sand layer between 12 and 14 cm
	14-27.5	5 YR 3/2	Grayish brown mud, spongy peat layer
	27.5-44	5 YR 3/4	Moderate brown mud, extremely spongy, layer of highest peat content
	44-55.5	Mottled; 5 Y 4/1 with N2	Olive gray sand mottled with grayish black, decrease in peat and dead roots, firm

Site #20 – Assateague Island, Sinepuxent Bay Total length – 60.5 cm Date collected – 4/29/02 Date processed – 1/22/03			
Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
	0-5	5 YR 3/2	Active root zone; grayish brown firm sand, some peaty material, few grasses on surface
	5-27	10 YR 2/2 fade to 5 YR 2/2	Active root zone to ~25cm; dusky yellowish brown silty mud fading to dusky brown silty mud, increase in peat content, fairly firm near top, interbedded sand layer between 10-11 cm, peat drastically increases at ~21 cm where becomes spongy from 21-27 cm
	27-41.5	10 YR 6/2	Pale yellowish brown sand, distinct boundary, much less peat, very firm
	41.5-45	10 YR 4/2	Dark yellowish brown finer sand, very firm
	45-50.5	5 YR 3/4	Moderate brown mud, very peaty and very spongy
	50.5-57.5	5 Y 4/2	Light olive gray to moderate gray sand, less peat than above, interbedded mud layer from 54-54.25 cm
	57.5-60	5 Y 5/2	Light olive gray sand with another interbedded mud layer from 59.5 to 60 cm
	60-60.5	5 Y 3/2	Olive gray firm sand, decrease in peat, several roots extrude from bottom of core that appear to be inactive/peaty roots

APPENDIX B
Quality Assurance/Quality Control

Textural Analyses

The techniques used to determine grain size composition are based on traditional analytical methods developed for the sedimentology lab. Still, some analytical error is inherent in the methodology. For example, results can be affected by the technician's level of skill and/or changes in laboratory conditions, such as sudden temperature changes. Furthermore, no standard reference material includes the broad range of particle sizes and shapes contained in natural sediment. To maximize the consistency of textural analyses, several checks are used to monitor results. Calculated gravel, sand, silt, and clay percentages are checked against (1) field descriptions of the samples, (2) calculated water content, and (3) calculated weight loss of the sample during processing. These comparisons are made to determine if the grain size composition matches the visual description of the sample and/or falls within an expected Shepard's (1954) class with respect to water content and weight loss. Any discrepancy is flagged, and the results are reviewed to determine if reanalysis is warranted.

Specifically, the criteria for each of the internal checks are as follows:

(1) Calculated gravel, sand, silt, and clay percentages and Shepard's classification are compared with the field description of the sediment. If the results seem to indicate a very different sample from the one described, then the sample is reanalyzed.

(2) Gravel, sand, silt, and clay percentages are compared to calculated water content. For each of the sediment types, Table B-1 lists the typical mean and range of values for water content, based on bottom sediments collected in Isle of Wight and Assawoman Bays. The mean and range of values for marsh sediments collected as part of this study fall within expected values for water content (Table B-2).

(3) Sample loss (% dry weight) during cleaning is calculated for each sample. The calculated water content, which is usually measured shortly after the sample is collected, is used to determine weight loss. If the sediment dries out, even slightly, before it is sub-sampled for textural analysis, then weight loss is underestimated and, in some instances, negative. The weight lost during the cleaning process is related to sediment type, that is, grain size composition, as well as to the organic and/or carbonate content of the sediment. Organic-rich, fine-grained bay bottom sediments (i.e., Silty Clay and Clayey Silt) may lose 20% to 30% dry weight during cleaning (Tables B-1 and B-2). Sand, which is relatively clean plant material and organics, usually losses the least weight and often shows a negative weight loss, due to errors inherent in water content determinations. In this study, some of the core sediments lost up to 50% dry weight during the cleaning process due to the very high amount of plant material (Table B-2), part of which was removed during the initial sieving step to separate out the root fraction (*i.e.*, > 14 mesh).

Table B-1. Mean and range of water content and calculated weight loss after cleaning for each sediment type (Shepard's (1954) classification), based on sediments collected in Isle of Wight and Assawoman Bays (Wells and others, 1994). Means are rounded to the nearest whole percentage.				
Sediment type	**Water content (% wet weight)**		**Weight loss (% dry weight)**	
	Mean	**Range**	**Mean**	**Range**
Sand	22	17 - 27	1	-4 - 6
Silty-Sand	39	31 - 47	7	- 12
Clayey-Sand	47	41 - 53	3	0 -6
Sandy-Silt	48	42 - 54	13	5 - 21
Clayey-Silt	60	53 - 67	20	13 - 27
Silty-Clay	70	67 - 73	28	23 - 33
Sand-Silt-Clay	56	49 - 63	13	2 - 24

Table B-2. Mean and range of water content and calculated weight loss after cleaning for each sediment type (Shepard's (1954) classification), based on sediments collected for this study. Means and ranges are rounded to the nearest whole percentage.					
Sediment type	**N**	**Water content (% wet weight)**		**Weight loss (% dry weight)**	
		Mean	**Range**	**Mean**	**Range**
Sand	21	23	2 – 45	3	0 – 9
Silty-Sand	15	37	5 – 49	11	2 – 20
Sandy-Silt	2	16	15 – 17	4	3.8 – 4.1
Clayey-Silt	38	59	33 – 77	24	5 – 48
Silty-Clay	4	66	55 – 79	29	11 – 50
Sand-Silt-Clay	14	52	41 - 64	23	10 – 37

For this study, no sediment samples were flagged for repeated textural analyses.

Nitrogen, Carbon and Sulfur Analyses

As part of MGS's QA/QC protocol, several standard reference materials (SRMs) are used as secondary standards and run every 6 to 7 samples (unknowns). Table B-4 compares MGS results with certified SRM values for total carbon, nitrogen, and sulfur. The detection limit for this method is 0.001% for all three elements. There is excellent agreement between SRM values and MGS's results.

Table B-3. Results of nitrogen, carbon, and sulfur analyses of NIST SRM 1646 (Estuarine Sediment) and National Research Council of Canada SRM PACS-1 (Marine Sediment) compared to the certified or known values. MGS values were obtained by averaging the results of all SRM analyses run during this study. All samples were analyzed over a four-week period.

Component	NIST SRM 1646 – Estuarine Mud			PACS-1 – Marine Sediment		
	Certified values*	MGS results		Certified values	MGS results	
	Value ±Std Dev	Mean value ±Std Dev	% Recovery	Value ±Std Dev	Mean value ±Std Dev	% Recovery
Nitrogen	0.18	0.16 ± 0.01	90	0.26	0.27 ± 0.01	103
Carbon	1.72	1.59 ± 0.03	92	3.69	3.55 ± 0.21	96
Sulfur	0.96	1.00 ± 0.02	104	1.32	1.21 ± 0.15	92

* The value for carbon is certified by NIST. The sulfur value is the non-certified value reported by NIST. The NIST did not report nitrogen for the SRM. The value for nitrogen was obtained from repeated analyses in-house and by other laboratories (Haake Buchler Labs and the U.S. Dept. of Agriculture).

In addition to SRMs, replicate analyses were done on every seventh sediment sample. The relative standard deviation for the replicate analyses may be used to determine analytical variability of the method with respect to concentration. The relative standard deviation plots for total nitrogen and carbon show that generally variability is less than 10 percent regardless of concentration (Figs. B-1 and B-2).

Elemental Analyses (ICP)

For elemental analyses completed by Activation Laboratories, Ltd. (Actlabs), quality assurance was confirmed in the following manner. The set of sediment samples sent to Actlabs contained a series of SRMs and replicate samples, the identities of which were not revealed to Actlabs. MGS also requested that Actlabs run a reagent blank every 20 samples. The three SRMs used were (1) NIST-SRM #1646a – Estuarine Sediment, (2) NIST-SRM #2704 – Buffalo River Sediment, and (3) National Research Council of Canada PACS-2 – Marine Sediment. These SRMs closely resembled the types of sediments being analyzed (i.e., fine-grained marine sediment). Results of the analyses of the three standard reference materials are compared to the certified values in Table B-5.

Actlabs also ran a replicate of every tenth sample; independent of the blind replicates that MGS included. The relative standard deviation for the replicate analyses were calculated and used to determine analytical variability with respect to concentration. A plot of the relative standard deviation (RSD) versus the concentration of total phosphorus shows no obvious trends between variability and concentration (Fig. B-3).

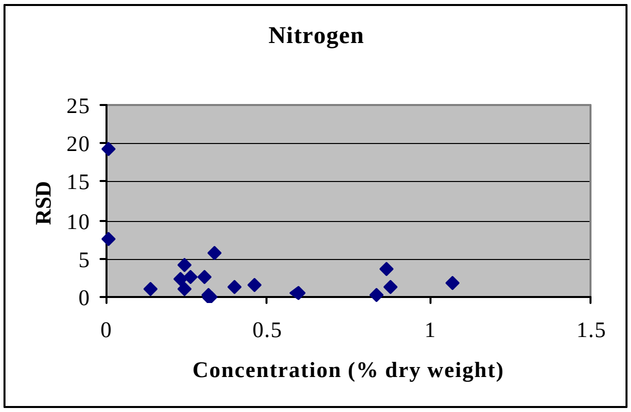
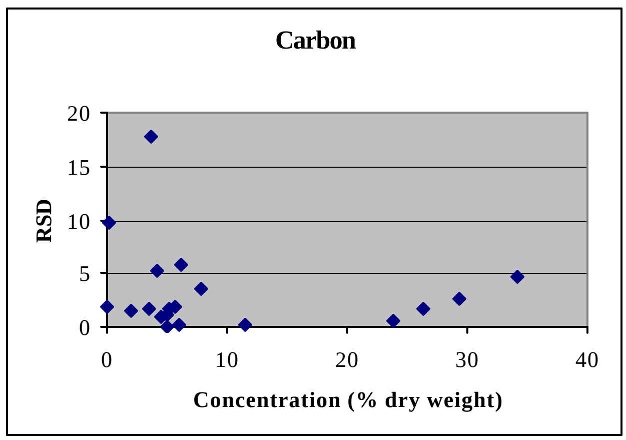


Figure B-1. Relative standard deviation (%) vs. concentration of total nitrogen for the suite of replicate analyses.

Figure B-2. Relative standard deviation (%) vs. concentration of total carbon for the suite of replicate analyses.



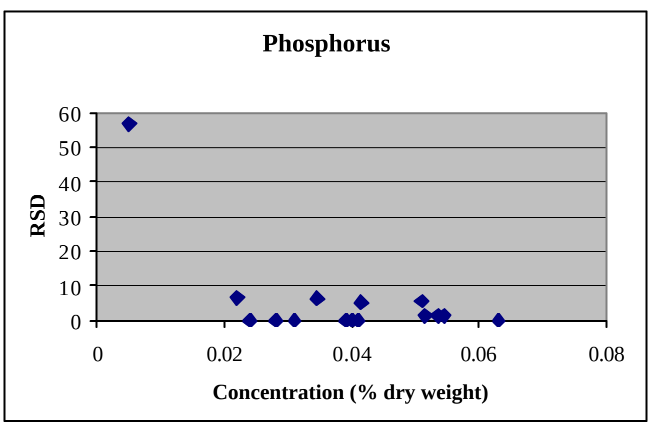


Figure B-3. Relative standard deviation (%) vs. concentration of total phosphorus for the suite of replicate analyses.

Table B-4. Comparison of certified values to the analytical results from Actlabs for the SRMs. Values in parentheses are non-certified values. "NA" indicates that no value was reported for the element. No certified value for P for NIST 8704 was available; value given is MGS in-house results.

Element	NIST 1646a (Estuarine Mud)			PACS-2 (Marine Mud)			NIST 8704 (Buffalo River Mud)		
	Certified values	Actlab Results		Certified values	Actlab Results		Certified values	Actlab Results	
	Conc. ±Std dev	**Conc. ±Std dev**	***% recovery***	**Conc. ±Std dev**	**Conc. ±Std dev**	***% recovery***	**Conc. ±Std dev**	**Conc. ±Std dev**	***% recovery***
Ag (ppm)	<0.3	0.25 ± 0.31	***82.78***	1.22 ±0.14	1.2 ±0.1	***96.3***	NA	0.7 ±0.2	
Al (%)	2.297 ±0.018	1.93 ±0.18	***84.07***	6.62 ±0.32	5.5 ±1.2	***83.4***	6.1 ±0.18	4.3 ±1.1	***71.2***
Be ppm)	(1.00)	-1.00 ±0.00		1.00 ±0.2	-0.60 ±0.9	***-59.9***	NA	1.54 ±0.1	
Bi (ppm)	NA	-0.01 ±2.72		NA	-1.1 ±1.9		NA	-2.0 ±0.0	
Ca (%)	0.519 ±0.02	0.57,±0.06	***110.06***	1.965 ±0.18	2.0 ±0.1	***102.8***	2.641 ±0.083	2.6 ±0.1	***99.6***
Cd (ppm)	0.148 ± 0.007	0.72 ±1.00	***489.09***	2.11 ±0.15	3.1 ±1.0	***148.5***	2.94 ±0.29	4.5 ±1.4	***152.8***
Co (ppm)	(5)	3.97 ±1.28	***79.41***	11.5 ±0.3	9.5 ±3.2	***83.0***	13.57 ±0.43	12.2 ±2.8	***90.2***
Cu (ppm)	10.01 ± 0.34	12.08 ±1.94	***120.71***	310 ±12	299.0 ±17.1	***96.5***	NA	87.4 ±6.5	
Fe (%)	2.008 ±0.039	2.03 ±0.24	***101.14***	4.09 ±0.06	4.0 ±0.2	***97.1***	3.97 ±0.1	3.8 ±0.2	***96.3***
K (%)	0.864 ±0.016	0.88 ±0.15	***102.25***	1.23 ±0.05	1.2 ±0.2	***100.9***	2.001 ±0.041	1.9 ±0.2	***93.5***
Mg (%)	0.388 ±0.009	0.42 ±0.03	***106.97***	1.472 ±0.133	1.4 ±0.1	***95.6***	1.2 ±0.018	1.1 ±0.1	***94.0***
Mn (ppm)	234 ± 2.8	258.28 24.16	***110.37***	440 ±19	450.7 ±14.1	***102.4***	544 ±21	572.7 ±14.0	***105.3***
Mo (ppm)	(1.8)	1.97 ±1.66	***109.32***	5.43 ±0.28	5.3 ±2.5	***98.1***	NA	3.1 ±2.6	
Na (%)	0.741 ±0.017	0.78 ±0.09	***104.93***	3.71 ±0.185	3.4 ±0.2	***90.5***	0.553 ±0.015	0.6 ±0.0	***106.9***
Ni (ppm)	(23)	25.29 ±4.41	***109.94***	39.5 ±2.3	42.7 ±0.4	***108.2***	42.9 ±3.7	44.3 ±3.5	***103.2***
P (ppm)	***270 ±10***	296.00 11.40	109.63	960 ±44	***940.0 ±102.7***	***97.9***	(837 ±22.7*)	958.0 ±25.9	***114.5***
Pb (ppm)	11.7 ±1.2	12.98 ±4.01	***110.91***	183 ±8	189.7 ±9.2	***103.6***	150 ±17	155.4 ±15.8	***103.6***
S (%)	(0.352)	0.36 ±0.04	***101.04***	1.29 ±0.13	1.1 ±0.1	***86.3***	NA	0.3 ±0.0	
Sr (ppm)	(68)	74.28 ±10.95	***109.23***	276 ±30	274.0 ±15.2	***99.3***	NA	129.0 ±11.0	
Ti (%)	0.456±0.021	0.46 ±0.05	***100.75***	0.443 ±0.032	0.4 ±0.0	***89.3***	0.457 ±0.02	0.4 ±0.0	***88.7***
V (ppm)	44.84 ±0.76	48.39 ±6.44	***107.91***	133 ±5	137.6 ±5.9	***103.4***	94.6 ±4	97.8 ±3.8	***103.4***
Y (ppm)	NA	9.03 ±1.06		NA	16.8 ±4.5		NA	21.9 ±4.9	
Zn ppm)	48.9 ±4.6	58.11 ±12.36	***118.84***	364 ±23	362.7 ±14.1	***99.6***	408 ±15	387.6 ±12.0	***95.0***

APPENDIX C
Data Tables

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates were calculated from sample weight loss due to cleaning. $Kg/m^3 = g/cm^3 * 1000$.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Bulk Density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval (cm)	Lower interval (cm)	Wet (g/cm^3)	Dry (g/cm^3)	Plant (%>14 mesh)	Clastic %	Reactive organics/ carbonates (%)	Total organics (%)		
1-1	0	15	1.40	**0.70**	16.77	75.16	8.07	24.84	0.89	617.27
1-2	15	29	1.36	0.60	7.24	82.06	10.70	17.94	0.89	530.46
1-3	29	44	1.21	0.40	6.59	76.31	17.10	23.69	0.89	354.18
1-4	44	60.5	1.24	0.40	0.59	79.07	20.34	20.93	0.89	358.03
1-5	60.5	67	1.42	0.68	1.12	84.95	13.93	15.05	0.89	599.32
2-1	0	16	1.36	0.72	20.98	63.17	15.85	36.83	0.89	639.59
2-2	16	35	1.28	0.48	4.30	78.62	17.08	21.38	0.89	429.18
2-3	35	55	1.27	0.46	1.93	77.46	20.60	22.54	0.89	414.95
2-4	55	71	1.33	0.54	0.64	78.93	20.43	21.07	0.89	484.85
2-5	71	92	1.14	0.24	10.41	50.01	39.58	49.99	0.89	217.33
2-6	92	103	1.20	0.32	3.47	67.23	29.30	32.77	0.89	284.61
3-1	0	21	1.26	0.49	11.05	78.57	10.38	21.43	1.00	488.32
3-2	21	37	1.15	0.30	5.93	73.42	20.65	26.58	1.00	303.35
3-3	37	52	1.28	0.48	3.65	88.46	7.89	11.54	1.00	481.10
3-4	52	67.5	1.28	0.46	0.70	73.57	25.73	26.43	1.00	463.43

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Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Bulk Density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval (cm)	Lower interval (cm)	Wet (g/cm^3)	Dry (g/cm^3)	Plant (%>14 mesh)	Clastic %	Reactive organics/ carbonates (%)	Total organics (%)		
5-1	0	6	1.89	1.52	0.57	96.64	2.78	3.36	1.00	1522.44
5-2	6	17.5	1.89	1.50	0.99	95.10	3.91	4.90	1.00	1498.30
5-3	17.5	27	1.62	1.01	0.55	91.02	8.42	8.98	1.00	1005.35
5-4	27	33	1.73	1.16	0.34	92.13	7.53	7.87	1.00	1158.32
7-1	0	13.5	1.13	0.34	28.53	53.63	17.84	46.37	0.89	299.62
7-2	13.5	24	1.17	0.37	15.85	70.10	14.06	29.90	0.89	326.47
7-3	24	40	1.13	0.26	34.19	57.87	7.94	42.13	0.89	231.08
7-4	40	49.5	1.19	0.35	4.34	70.93	24.74	29.07	0.89	309.56
8-1	0	15	1.21	0.93	1.83	98.17	0.00	1.83	1.00	928.05
8-2	15	32.5	1.86	1.55	0.09	99.91	0.00	0.00	1.00	1546.20
8-3	32.5	37.5	2.18	1.80	0.02	95.86	4.12	4.14	1.00	1803.23
9A-1	0	10.5	1.66	1.05	2.57	97.43	0.00	2.57	0.92	964.23
9A-2	10.5	21	1.44	0.76	4.58	90.19	5.23	9.81	0.92	695.21
9A-3	21	34	1.22	0.51	12.38	51.85	35.77	48.15	0.92	469.28
9B-1	0	11.5	1.70	1.15	1.62	93.81	4.57	6.19	0.96	1105.48

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates were calculated from sample weight loss due to cleaning. $Kg/m^3 = g/cm^3 * 1000$.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Bulk Density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval (cm)	Lower interval (cm)	Wet (g/cm^3)	Dry (g/cm^3)	Plant (%>14 mesh)	Clastic %	Reactive organics/ carbonates (%)	Total organics (%)		
9B-2	11.5	18.5	1.44	0.85	3.71	83.16	13.13	16.84	0.96	814.52
9B-3	18.5	33	1.26	0.54	8.25	74.87	16.88	25.13	0.96	520.62
9B-4	33	48	1.33	0.55	7.47	75.99	16.54	24.01	0.96	526.57
9B-5	48	63	1.24	0.45	11.05	66.06	22.90	33.94	0.96	432.38
9B-6	63	73	1.98	1.54	0.47	99.22	0.31	0.78	0.96	1478.42
10-1	0	13	1.36	0.71	5.76	89.10	5.14	10.90	0.94	664.81
10-2	13	27	1.45	0.85	2.92	94.79	2.29	5.21	0.94	795.98
10-3	27	47.25	1.21	0.55	3.88	82.61	13.51	17.39	0.94	513.32
10-4	47.25	71	1.35	0.57	3.71	77.79	18.50	22.21	0.94	530.36
10-5	71	86.5	1.21	0.43	5.69	69.86	24.45	30.14	0.94	406.45
11-1	4	16.25	1.25	0.64	6.09	72.29	21.62	27.71	0.92	592.11
11-2	16.25	35	1.41	0.75	2.41	86.36	11.23	13.64	0.92	690.01
11-3	35	51	1.36	0.65	3.39	80.52	16.09	19.48	0.92	601.68
11-4	51	65	1.32	0.58	5.86	73.22	20.92	26.78	0.92	532.42
12-1	0	13.5	1.61	1.18	2.19	91.37	6.44	8.63	0.95	1119.60

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates were calculated from sample weight loss due to cleaning. $Kg/m^3 = g/cm^3 * 1000$.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Bulk Density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval (cm)	Lower interval (cm)	Wet (g/cm^3)	Dry (g/cm^3)	Plant (%>14 mesh)	Clastic %	Reactive organics/ carbonates (%)	Total organics (%)		
12-2	13.5	25.5	1.46	0.78	9.16	83.68	7.16	16.32	0.95	738.67
12-3	25.5	43	1.27	0.50	7.26	72.22	20.51	27.78	0.95	474.04
12-4	43	58	1.19	0.38	8.96	62.30	28.75	37.70	0.95	362.15
12-5	58	63.5	1.47	0.67	1.53	83.13	15.34	16.87	0.95	637.02
12-6	63.5	76	1.46	0.74	1.95	84.24	13.81	15.76	0.95	698.07
13-1	1.5	12	1.51	0.94	5.79	79.77	14.45	20.23	0.89	842.65
13-2	12	27	1.35	0.66	6.00	84.30	9.70	15.70	0.89	591.19
13-3	27	42	1.29	0.57	4.63	83.03	12.34	16.97	0.89	513.38
13-4	42	57	1.31	0.54	4.31	75.88	19.80	24.12	0.89	481.77
13-5	57	76	1.24	0.46	4.64	73.46	21.91	26.54	0.89	408.20
13-6	76	96.5	1.44	0.74	1.84	77.91	20.26	22.09	0.89	658.18
14-1	0	9	1.67	1.17	0.65	93.95	5.40	6.05	1.00	1166.44
14-2	9	18	1.60	1.05	3.19	80.11	16.70	19.89	1.00	1049.10
14-3	18	32	1.40	0.75	3.31	77.24	19.45	22.76	1.00	753.20
14-4	32	50	1.24	0.45	7.38	86.35	6.26	13.65	1.00	447.64

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates were calculated from sample weight loss due to cleaning. $Kg/m^3 = g/cm^3 * 1000$.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Bulk Density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval (cm)	Lower interval (cm)	Wet (g/cm^3)	Dry (g/cm^3)	Plant (%>14 mesh)	Clastic %	Reactive organics/ carbonates (%)	Total organics (%)		
14-5	50	62	1.49	0.85	2.45	85.01	12.54	14.99	1.00	848.95
14-6	62	79	1.87	1.38	0.52	92.55	6.93	7.45	1.00	1375.91
14-7	79	95.5	1.97	1.60	0.45	94.44	5.11	5.56	1.00	1597.59
15-1	0	16	1.42	0.84	2.67	94.35	2.97	5.65	0.91	770.31
15-2	16	30	1.36	0.71	5.97	81.44	12.59	18.56	0.91	647.30
15-3	30	44	1.33	0.59	5.02	94.98	0.00	5.02	0.91	540.61
15-4	44	58.5	1.35	0.61	1.38	88.55	10.07	11.45	0.91	556.70
16-1	0	13	1.57	1.01	1.87	88.94	9.19	11.06	0.90	900.49
16-2	13	25	1.49	0.90	2.12	91.45	6.43	8.55	0.90	806.62
16-3	25	40	1.45	0.76	1.60	79.87	18.53	20.13	0.90	680.40
16-4	40	52	1.03	0.37	5.45	81.07	13.48	18.93	0.90	332.51
17-1	0	18.5	1.41	0.75	3.81	82.18	14.01	17.82	0.87	651.26
17-2	18.5	33	1.35	0.62	3.77	71.08	25.15	28.92	0.87	538.92
17-3	33	45	1.24	0.47	2.07	83.35	14.58	16.65	0.87	406.46
17-4	45	62.5	1.99	1.58	0.20	96.12	3.68	3.88	0.87	1376.56

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates were calculated from sample weight loss due to cleaning. $Kg/m^3 = g/cm^3 * 1000$.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Bulk Density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval (cm)	Lower interval (cm)	Wet (g/cm^3)	Dry (g/cm^3)	Plant (%>14 mesh)	Clastic %	Reactive organics/ carbonates (%)	Total organics (%)		
18B-1	0	10.5	1.40	0.78	2.98	72.89	24.13	27.11	0.96	752.16
18B-2	10.5	21	1.38	0.74	2.97	73.51	23.52	26.49	0.96	704.45
18B-3	21	32	2.00	1.60	0.14	99.26	0.59	0.74	0.96	1536.31
18B-4	32	44.5	2.05	1.70	0.04	99.69	0.27	0.31	0.96	1624.41
18B-5	44.5	56	1.96	1.61	0.01	97.87	2.12	2.13	0.96	1539.96
19-1	0	14	1.35	0.74	3.64	95.23	1.13	4.77	0.95	705.70
19-2	14	29	1.22	0.40	11.33	63.05	25.63	36.95	0.95	383.75
19-3	29	44	1.25	0.45	11.37	72.24	16.39	27.76	0.95	425.59
19-4	44	55.5	1.72	1.26	1.77	98.23	0.00	1.77	0.95	1199.12
20-1	0	14	1.40	0.71	5.95	84.11	9.94	15.89	0.92	649.17
20-2	14	27	1.24	0.45	8.98	72.48	18.55	27.52	0.92	407.84
20-3	27	45	1.97	1.54	0.75	98.87	0.37	1.13	0.92	1408.29
20-4	45	60.5	1.66	1.09	2.56	91.07	6.37	8.93	0.92	1000.01
4-T	118.3	86.0	1.52	1.45	0.00	97.53	2.47	2.47	1.00	1445.93
4-M	86.0	12.2	1.94	1.79	0.00	97.29	2.71	2.71	1.00	1790.62

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates were calculated from sample weight loss due to cleaning. $Kg/m^3 = g/cm^3 * 1000$.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Bulk Density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval (cm)	Lower interval (cm)	Wet (g/cm^3)	Dry (g/cm^3)	Plant (%>14 mesh)	Clastic %	Reactive organics/ carbonates (%)	Total organics (%)		
4-B	12.2	0	1.91	1.63	0.00	96.23	3.77	3.77	1.00	1626.93
18A-T	75	53.3	1.33	1.30	0.00	99.57	0.43	0.43	1.00	1300.69
18A-M	53.3	27.4	1.57	1.49	0.00	100.00	0.00	0.00	1.00	1490.21
18A-B	27.4	0.00	2.04	1.68	0.00	100.00	0.00	0.00	1.00	1684.65
2-Off						64.50	35.50	35.50		
3-Off						83.93	16.07	16.07		
4-Beach						100.00	0.00	0.00		
4-Off						98.90	1.10	1.10		
5-Off						97.72	2.28	2.28		
7-Off						85.16	14.84	14.84		
8-Beach						97.37	2.63	2.63		
8-Off						94.32	5.68	5.68		
9-Off						89.39	10.61	10.61		
10-Off						80.99	19.01	19.01		
11-Off						77.06	22.94	22.94		

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates were calculated from sample weight loss due to cleaning. Kg/m^3 = g/cm^3 * 1000.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Bulk Density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval (cm)	Lower interval (cm)	Wet (g/cm^3)	Dry (g/cm^3)	Plant (%>14 mesh)	Clastic %	Reactive organics/ carbonates (%)	Total organics (%)		
12-Off						83.49	16.51	16.51		
13-Off						83.71	16.29	16.29		
14-Off						95.53	4.47	4.47		
15-Off						77.70	22.30	22.30		
16-Off						86.90	13.10	13.10		
17-Off						65.57	34.43	34.43		
18B-Off						99.58	0.42	0.42		
19-Off						99.56	0.44	0.44		
20-Off						97.22	2.78	2.78		

Table C-1. Sample data: physical properties (cont.). **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Bulk density calculated using Bennett and Lambert (1971) method.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Water content (% wet weight)	Bulk Density (Bennet & Lambert) (g/cm^3)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Shepard's (1954) classification
	Upper interval	Lower interval							
1-1	0	15	50.31	1.46	0.00	35.97	37.54	26.48	Sand-Silt-Clay
1-2	15	29	55.91	1.39	0.00	25.91	47.72	26.38	Sand-Silt-Clay
1-3	29	44	66.91	1.26	0.00	9.29	54.90	35.81	Clayey-Silt
1-4	44	60.5	67.50	1.26	0.00	13.80	47.77	38.43	Clayey-Silt
1-5	60.5	67	52.21	1.43	0.00	14.28	50.99	34.72	Clayey-Silt
2-1	0	16	47.26	1.50	0.00	33.24	40.18	26.58	Sand-Silt-Clay
2-2	16	35	62.34	1.31	0.00	17.14	43.16	39.70	Clayey-Silt
2-3	35	55	63.43	1.30	0.00	7.12	51.11	41.76	Clayey-Silt
2-4	55	71	59.07	1.35	0.00	12.03	43.87	44.10	Silty-Clay
2-5	71	92	78.68	1.16	0.00	1.58	45.28	53.14	Silty-Clay
2-6	92	103	73.16	1.20	0.00	5.45	44.59	49.96	Silty-Clay
3-1	0	21	61.21	1.33	0.00	11.21	54.21	34.58	Clayey-Silt
3-2	21	37	73.54	1.20	0.00	7.19	49.98	42.83	Clayey-Silt
3-3	37	52	62.49	1.31	0.00	6.06	53.59	40.34	Clayey-Silt
3-4	52	67.5	63.91	1.30	0.00	1.90	52.59	45.51	Clayey-Silt
5-1	0	6	19.62	2.03	0.00	97.31	2.22	0.47	Sand
5-2	6	17.5	20.86	2.00	0.00	78.16	17.57	4.27	Sand
5-3	17.5	27	37.95	1.65	0.00	18.03	58.98	22.98	Clayey-Silt
5-4	27	33	33.08	1.73	0.00	15.55	57.80	26.66	Clayey-Silt

Table C-1. Sample data: physical properties (cont.). **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Bulk density calculated using Bennett and Lambert (1971) method.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Water content (% wet weight)	Bulk Density (Bennet & Lambert) (g/cm^3)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Shepard's (1954) classification
	Upper interval	Lower interval							
7-1	0	13.5	70.27	1.23	0.00	15.49	46.81	37.71	Clayey-Silt
7-2	13.5	24	68.64	1.25	0.00	17.05	49.27	33.69	Clayey-Silt
7-3	24	40	76.96	1.17	0.00	17.69	45.55	36.77	Clayey-Silt
7-4	40	49.5	70.73	1.23	0.00	12.07	55.81	32.12	Clayey-Silt
8-1	0	15	23.54	1.94	0.00	99.36	0.78	-0.14	Sand
8-2	15	32.5	16.77	2.11	0.00	100.07	0.26	-0.34	Sand
8-3	32.5	37.5	17.38	2.09	0.00	39.93	48.40	11.67	Sandy-Silt
9A-1	0	10.5	36.89	1.66	0.00	51.83	35.60	12.57	Silty-Sand
9A-2	10.5	21	47.54	1.50	0.00	21.76	56.75	21.49	Sand-Silt-Clay
9A-3	21	34	58.15	1.36	0.00	8.25	54.28	37.47	Clayey-Silt
9B-1	0	11.5	32.12	1.75	0.00	42.69	39.12	18.19	Silty-Sand
9B-2	11.5	18.5	41.16	1.59	0.00	26.95	51.80	21.26	Sand-Silt-Clay
9B-3	18.5	33	57.12	1.37	0.00	10.98	53.81	35.22	Clayey-Silt
9B-4	33	48	58.62	1.35	0.00	4.46	58.65	36.89	Clayey-Silt
9B-5	48	63	63.58	1.30	0.00	6.97	54.32	38.71	Clayey-Silt
9B-6	63	73	22.29	1.97	0.00	98.46	1.04	0.51	Sand
10-1	0	13	47.86	1.49	0.00	52.57	33.38	14.05	Silty-Sand
10-2	13	27	41.37	1.59	0.00	59.09	29.24	11.67	Silty-Sand
10-3	27	47.25	54.69	1.40	0.00	9.35	61.82	28.83	Clayey-Silt

Table C-1. Sample data: physical properties (cont.). **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Bulk density calculated using Bennett and Lambert (1971) method.

Sample ID	**Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)**		**Water content (% wet weight)**	**Bulk Density (Bennet & Lambert) (g/cm^3)**	**Gravel (%)**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Shepard's (1954) classification**
	Upper interval	**Lower interval**							
10-4	47.25	71	57.95	1.36	0.00	6.54	58.22	35.24	Clayey-Silt
10-5	71	86.5	64.06	1.29	0.00	1.58	61.37	37.05	Clayey-Silt
11-1	4	16.25	48.60	1.48	0.00	22.17	57.29	20.55	Sand-Silt-Clay
11-2	16.25	35	46.89	1.51	0.00	5.01	67.87	27.12	Clayey-Silt
11-3	35	51	52.03	1.44	0.00	2.35	69.33	28.32	Clayey-Silt
11-4	51	65	56.15	1.38	0.00	1.31	66.03	32.67	Clayey-Silt
12-1	0	13.5	26.47	1.87	2.85	90.48	3.64	3.03	Sand
12-2	13.5	25.5	46.31	1.51	0.50	72.98	16.10	10.42	Silty-Sand
12-3	25.5	43	60.42	1.33	0.00	5.12	59.33	35.56	Clayey-Silt
12-4	43	58	67.74	1.26	0.00	1.16	56.52	42.32	Clayey-Silt
12-5	58	63.5	54.03	1.41	0.00	3.34	57.35	39.31	Clayey-Silt
12-6	63.5	76	49.42	1.47	0.00	57.41	25.90	16.69	Silty-Sand
13-1	1.5	12	37.60	1.65	0.00	71.95	17.89	10.16	Silty-Sand
13-2	12	27	51.09	1.45	0.00	45.52	32.57	21.91	Sand-Silt-Clay
13-3	27	42	55.52	1.39	0.00	10.02	55.51	34.48	Clayey-Silt
13-4	42	57	58.75	1.35	0.00	1.75	52.47	45.78	Clayey-Silt
13-5	57	76	63.15	1.30	0.00	2.29	53.56	44.15	Clayey-Silt
13-6	76	96.5	49.01	1.48	0.00	3.56	61.44	35.00	Clayey-Silt
14-1	0	9	30.17	1.79	0.00	77.92	15.06	7.02	Sand

Table C-1. Sample data: physical properties (cont.). **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Bulk density calculated using Bennett and Lambert (1971) method.

Sample ID	**Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)**		**Water content (% wet weight)**	**Bulk Density (Bennet & Lambert) (g/cm^3)**	**Gravel (%)**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Shepard's (1954) classification**
	Upper interval	**Lower interval**							
14-2	9	18	34.38	1.71	0.00	60.74	23.58	15.68	Silty-Sand
14-3	18	32	46.22	1.52	0.00	48.26	31.15	20.60	Sand-Silt-Clay
14-4	32	50	63.81	1.30	0.00	15.51	60.63	23.86	Clayey-Silt
14-5	50	62	43.20	1.56	0.00	68.79	20.03	11.17	Silty-Sand
14-6	62	79	26.53	1.87	0.00	89.96	6.31	3.73	Sand
14-7	79	95.5	19.06	2.05	0.00	93.74	4.06	2.21	Sand
15-1	0	16	40.56	1.60	0.00	81.67	8.67	9.67	Sand
15-2	16	30	48.02	1.49	0.00	61.51	21.57	16.92	Silty-Sand
15-3	30	44	55.44	1.39	0.00	18.58	47.67	33.76	Clayey-Silt
15-4	44	58.5	54.71	1.40	0.00	15.39	42.24	42.37	Silty-Clay
16-1	0	13	35.78	1.68	0.00	74.25	17.50	8.26	Silty-Sand
16-2	13	25	39.64	1.62	0.00	72.27	17.40	10.33	Silty-Sand
16-3	25	40	47.53	1.50	0.00	8.01	54.92	37.07	Clayey-Silt
16-4	40	52	63.88	1.30	0.00	14.93	43.70	41.37	Clayey-Silt
17-1	0	18.5	47.10	1.50	0.00	19.50	45.13	35.38	Clayey-Silt
17-2	18.5	33	54.20	1.41	0.00	44.14	30.13	25.73	Sand-Silt-Clay
17-3	33	45	62.51	1.31	0.00	39.55	31.79	28.66	Sand-Silt-Clay
17-4	45	62.5	20.76	2.00	0.00	91.19	6.49	2.32	Sand
18B-1	0	10.5	43.90	1.55	0.00	34.02	39.00	26.98	Sand-Silt-Clay

Table C-1. Sample data: physical properties (cont.). **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Bulk density calculated using Bennett and Lambert (1971) method.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Water content (% wet weight)	Bulk Density (Bennet & Lambert) (g/cm^3)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Shepard's (1954) classification
	Upper interval	Lower interval							
18B-2	10.5	21	46.61	1.51	0.00	39.51	36.99	23.50	Sand-Silt-Clay
18B-3	21	32	19.96	2.02	0.00	96.01	3.06	0.92	Sand
18B-4	32	44.5	17.28	2.10	0.00	99.72	0.28	0.00	Sand
18B-5	44.5	56	18.09	2.07	0.00	97.90	2.10	0.00	Sand
19-1	0	14	44.93	1.53	0.00	81.80	11.28	6.92	Sand
19-2	14	29	66.89	1.26	0.00	11.80	50.06	38.13	Clayey-Silt
19-3	29	44	64.01	1.29	0.00	43.12	33.80	23.08	Sand-Silt-Clay
19-4	44	55.5	26.46	1.87	0.00	96.25	2.62	1.13	Sand
20-1	0	14	49.41	1.47	0.00	67.48	16.86	15.66	Silty-Sand
20-2	14	27	64.04	1.29	0.00	51.83	25.35	22.81	Sand-Silt-Clay
20-3	27	45	22.06	1.97	0.00	96.99	3.01	0.00	Sand
20-4	45	60.5	34.32	1.71	0.00	87.05	8.67	4.28	Sand
4-T	118.3	86.0	4.78	2.51	0.08	57.72	31.95	10.25	Silty-Sand
4-M	86.0	12.2	7.84	2.40	0.06	42.79	41.75	15.39	Silty-Sand
4-B	12.2	0	14.88	2.17	0.00	24.17	58.83	16.99	Sandy-Silt
18A-T	75	53.3	2.33	2.62	0.00	99.43	0.38	0.19	Sand
18A-M	53.3	27.4	4.96	2.51	0.00	99.49	0.28	0.23	Sand
18A-B	27.4	0.00	17.27	2.10	0.00	98.27	1.73	0.00	Sand
2-Off			73.82	1.20	0.00	20.52	44.59	34.89	Sand-Silt-Clay

Table C-1. Sample data: physical properties (cont.). **Off** denotes offshore grab sample. Site 4 is a bluff site and site 18 (A) is a dune ridge: T, M and B denoting top, middle and bottom of bluff/ridge. All other sites are coring sites (marsh). Bulk density calculated using Bennett and Lambert (1971) method.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm); Bluff sample - height above base (cm)		Water content (% wet weight)	Bulk Density (Bennet & Lambert) (g/cm^3)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Shepard's (1954) classification
	Upper interval	Lower interval							
3-Off			69.92	1.23	0.00	7.71	49.91	42.37	Clayey-Silt
4-Beach			10.95	2.29	0.07	98.21	8.82	-7.10	Sand
4-Off			20.11	2.02	0.41	90.33	7.06	2.20	Sand
5-Off			22.34	1.96	0.39	81.55	10.71	7.34	Sand
7-Off			60.55	1.33	0.00	0.68	56.37	42.95	Clayey-Silt
8-Beach			9.96	2.32	1.33	98.44	0.18	0.05	Sand
8-Off			14.87	2.17	1.28	97.92	0.43	0.38	Sand
9-Off			53.58	1.42	0.00	9.81	62.69	27.49	Clayey-Silt
10-Off			52.28	1.43	0.00	11.52	63.97	24.50	Clayey-Silt
11-Off			61.55	1.32	0.00	0.77	60.82	38.41	Clayey-Silt
12-Off			52.18	1.43	0.00	38.94	35.28	25.79	Sand-Silt-Clay
13-Off			60.03	1.34	0.00	5.38	56.07	38.55	Clayey-Silt
14-Off			22.90	1.95	0.11	93.56	3.78	2.55	Sand
15-Off			56.24	1.38	0.00	9.90	52.96	37.15	Clayey-Silt
16-Off			46.92	1.51	0.00	14.43	53.76	31.81	Clayey-Silt
17-Off			73.18	1.20	0.00	20.14	42.03	37.83	Sand-Silt-Clay
18B-Off			18.59	2.06	0.09	97.45	11.28	-8.82	Sand
19-Off			19.16	2.05	0.00	97.27	1.85	0.88	Sand
20-Off			58.48	1.36	0.00	63.35	26.49	10.16	Silty-Sand

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
1-1	0.0	15.0	0.24	4.50	0.039	0.608	0.70	4.46	1.26	BDL
1-1 R	0.0	15.0	0.24	4.48	0.039	0.609	0.81	4.95	1.13	BDL
1-2	15.0	29.0	0.22	4.12	0.036	0.929	0.75	8.38	1.36	BDL
1-3	29.0	44.0	0.42	6.94	0.036	1.768	0.55	4.52	1.29	2.94
1-4	44.0	60.5	0.45	7.25	0.034	1.028	0.45	4.45	1.32	BDL
1-5	60.5	67.0	0.27	4.10	0.034	1.489	0.45	5.16	1.58	BDL
2-1	0.0	16.0	0.25	4.99	0.040	0.784	0.63	2.97	1.17	BDL
2-2	16.0	35.0	0.41	7.21	0.040	1.404	0.55	5.65	1.37	BDL
2-3	35.0	55.0	0.44	6.88	0.042	1.000	0.58	8.14	1.50	BDL
2-4	55.0	71.0	0.32	5.06	0.038	1.172	0.32	8.90	1.57	BDL
2-4 R	55.0	71.0	0.32	5.06		1.188				
2-5	71.0	92.0	0.62	12.86	0.041	3.433	BDL	3.29	1.17	3.64
2-5 R	71.0	92.0			0.041		BDL	3.48	1.24	BDL
2-6	92.0	103.0	0.59	11.71	0.036	2.247	BDL	5.35	1.22	BDL
3-1	0.0	21.0	0.46	8.36	0.049	1.391	0.63	3.87	1.23	BDL
3-2	21.0	37.0	0.44	8.22	0.035	1.268	0.46	5.88	1.07	2.28
3-3	37.0	52.0	0.31	5.14	0.037	1.171	0.32	9.78	1.48	BDL
3-4	52.0	67.5	0.40	6.07	0.039	1.681	0.31	8.28	1.44	BDL
3-4 R	52.0	67.5	0.40	6.08		1.685				

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
3-1P	0.0	21.0	0.87	29.37	0.053	1.470	0.65	2.01	BDL	BDL
3-1P R	0.0	21.0	0.84	28.81	0.054	1.494	0.63	2.04	BDL	BDL
3-2P	21.0	37.0	0.99	40.38	0.047	2.079	BDL	1.26	BDL	BDL
3-3P	37.0	52.0	0.83	26.29	0.050	2.664	0.33	2.51	1.30	2.44
3-3P R	37.0	52.0	0.83	25.96		2.417				
3-4P	52.0	67.5	1.27	37.67		4.111				
4-1	Top		0.02	0.09	0.018	BDL	0.71	2.99	1.03	3.60
4-2	Middle		0.02	0.13	0.019	BDL	0.48	3.57	BDL	2.97
4-3	Bottom		0.02	0.09	0.021	BDL	0.61	3.40	1.08	5.89
4-3 R	Bottom				0.023		0.68	3.64	1.03	BDL
5-1	0.0	6.0	0.03	0.41	0.001	0.015	2.50	0.55	BDL	BDL
5-2	6.0	17.5	0.04	0.65	0.020	0.024	0.75	2.24	BDL	BDL
5-3	17.5	27.0	0.16	2.57	0.039	0.474	1.10	10.30	1.52	BDL
5-4	27.0	33.0	0.13	1.97	0.046	0.351	0.79	6.90	1.48	BDL
7-1	0.0	13.5	0.58	11.66	0.052	1.225	0.43	3.46	1.13	BDL
7-1 R	0.0	13.5			0.051		0.44	3.15	1.16	2.96
7-2	13.5	24.0	0.36	7.42	0.037	1.348	0.49	3.76	1.15	BDL
7-3	24.0	40.0	0.59	11.46	0.043	2.300	0.39	3.20	1.02	BDL
7-3 R	24.0	40.0	0.59	11.44		2.314				

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
7-4	40.0	49.5	0.56	9.22	0.039	1.464	0.40	3.81	1.11	BDL
8-1	0.0	15.0	0.05	0.94	0.007	0.018	BDL	0.60	BDL	BDL
8-2	15.0	32.5	0.01	0.12	0.002	BDL	BDL	0.27	BDL	BDL
8-3	32.5	37.5	0.06	0.65	0.027	0.012	0.49	2.56	1.01	BDL
9A-1	0.0	10.5	0.11	1.49	0.029	0.219	0.39	2.88	BDL	BDL
9A-2	10.5	21.0	0.20	3.30	0.038	1.040	0.67	3.81	1.19	BDL
9A-3	21.0	34.0	0.34	6.11	0.049	1.922	0.48	4.22	1.29	BDL
9A-3 R	21.0	34.0	0.33	5.86		1.837				
9B-1	0.0	11.5	0.11	1.54	0.031	0.226	0.43	2.57	BDL	BDL
9B-1 R	0.0	11.5			0.031		0.39	2.48	BDL	BDL
9B-2	11.5	18.5	0.17	2.58	0.033	0.734	0.58	3.08	1.08	BDL
9B-2 R	11.5	18.5			0.036		1.38	3.87	1.10	BDL
9B-3	18.5	33.0	0.29	4.99	0.041	1.730	0.39	2.98	1.14	BDL
9B-4	33.0	48.0	0.27	5.31	0.030	1.481	0.46	2.72	1.20	BDL
9B-5	48.0	63.0	0.32	5.98	0.036	1.548	0.39	4.31	1.22	BDL
9B-6	63.0	73.0	0.01	0.27	0.002	0.134	BDL	0.47	BDL	BDL
10-1	0.0	13.0	0.23	3.68	0.039	0.532	0.42	3.49	BDL	BDL
10-1 R	0.0	13.0	0.23	3.22		0.534				
10-2	13.0	27.0	0.13	2.25	0.025	0.642	0.35	3.15	BDL	BDL

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Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
10-3	27.0	47.3	0.24	3.73	0.031	1.283	0.48	4.07	1.38	BDL
10-4	47.3	71.0	0.28	5.05	0.033	1.279	0.41	4.38	1.28	BDL
10-5	71.0	86.5	0.38	6.58	0.030	1.131	0.35	3.90	1.24	BDL
11-1	4.0	16.3	0.30	4.58	0.064	0.611	0.48	4.21	1.43	BDL
11-2	16.3	35.0	0.24	3.68	0.040	1.366	0.46	3.21	1.34	BDL
11-2 R	16.3	35.0			0.040		0.47	4.48	1.41	BDL
11-3	35.0	51.0	0.32	5.06	0.034	2.436	BDL	4.17	1.24	BDL
11-3 R	35.0	51.0	0.32	5.11		2.453				
11-4	51.0	65.0	0.35	5.88	0.037	1.330	BDL	4.40	1.32	BDL
12-1	0.0	13.5	0.10	1.57	0.014	0.209	BDL	2.49	BDL	2.97
12-2	13.5	25.5	0.14	3.24	0.019	0.496	0.36	2.50	BDL	BDL
12-3	25.5	43.0	0.31	6.25	0.036	1.095	0.47	2.51	1.19	BDL
12-4	43.0	58.0	0.45	8.38	0.052	0.883	BDL	4.17	1.39	BDL
12-5	58.0	63.5	0.25	4.01	0.043	0.591	0.42	4.81	1.43	BDL
12-6	63.5	76.0	0.31	5.25	0.063	0.537	BDL	3.55	1.41	BDL
12-6 R	63.5	76.0	0.31	5.31	0.063	0.543	BDL	3.48	1.49	BDL
13-1	1.5	12.0	0.21	4.97	0.034	0.692	BDL	2.81	BDL	BDL
13-2	12.0	27.0	0.28	4.56	0.048	0.841	0.30	4.00	1.19	BDL
13-3	27.0	42.0	0.33	4.94	0.031	1.970	BDL	9.24	1.61	BDL

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Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
13-4	42.0	57.0	0.43	6.22	0.035	2.583	BDL	9.37	1.77	3.70
13-5	57.0	76.0	0.47	7.18	0.034	2.063	0.43	3.67	1.38	BDL
13-6	76.0	96.5	0.22	3.48	0.040	1.223	0.48	3.96	1.47	BDL
14-1	0.0	9.0	0.14	1.99	0.038	0.099	BDL	3.49	BDL	BDL
14-1 R	0.0	9.0	0.14	2.01		0.100				
14-2	9.0	18.0	0.14	2.05	0.043	0.343	BDL	3.47	1.02	BDL
14-3	18.0	32.0	0.20	3.33	0.049	0.654	0.31	3.66	1.08	BDL
14-3 R	18.0	32.0			0.053		0.33	4.09	1.10	BDL
14-4	32.0	50.0	0.52	8.40	0.055	0.828	BDL	6.79	1.24	BDL
14-4 R	32.0	50.0			0.054		BDL	6.12	1.28	BDL
14-5	50.0	62.0	0.28	4.45	0.041	0.648	BDL	2.44	BDL	BDL
14-6	62.0	79.0	0.09	1.52	0.035	0.250	BDL	2.04	BDL	BDL
14-7	79.0	95.5	0.03	0.64	0.034	0.114	BDL	1.79	BDL	2.04
15-1	0.0	16.0	0.32	5.65	0.072	0.576	BDL	3.06	BDL	BDL
15-1 R	0.0	16.0	0.32	5.73		0.578				
15-2	16.0	30.0	0.25	3.86	0.040	1.056	BDL	4.22	1.08	BDL
15-3	30.0	44.0	0.28	4.21	0.043	1.396	BDL	8.06	1.58	BDL
15-4	44.0	58.5	0.29	4.44	0.040	1.332	BDL	4.85	1.51	BDL
15-1P	0.0	16.0	0.88	23.75	0.160	1.032	0.36	1.91	BDL	2.78

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Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
15-1P R	0.0	16.0	0.88	23.66		1.062				
15-2P	16.0	30.0	1.01	25.73	0.063	1.956	BDL	2.16	BDL	BDL
15-3P	30.0	44.0	0.90	23.19	0.064	2.618	BDL	2.75	1.17	2.01
15-3P R	30.0	44.0	1.23	34.55		2.554				
16-1	0.0	13.0	0.14	2.06	0.024	0.381	BDL	2.69	BDL	2.18
16-1 R	0.0	13.0			0.024		BDL	2.71	BDL	BDL
16-2	13.0	25.0	0.12	1.65	0.026	0.439	BDL	2.99	BDL	BDL
16-3	25.0	40.0	0.20	2.39	0.045	1.034	BDL	11.21	1.98	BDL
16-4	40.0	52.0	0.33	4.74	0.043	1.589	0.38	3.80	1.42	BDL
17-1	0.0	18.5	0.26	3.55	0.044	0.617	BDL	7.38	1.58	BDL
17-1 R	0.0	18.5	0.26	3.51		0.596				
17-2	18.5	33.0	0.32	5.00	0.037	1.248	0.44	3.34	1.00	BDL
17-3	33.0	45.0	0.32	5.74	0.032	1.425	0.34	2.85	1.07	BDL
17-4	45.0	62.5	0.02	0.21	0.008	0.217	BDL	1.73	BDL	BDL
17-1P	0.0	18.5	1.07	34.15	0.063	1.388	0.44	1.57	BDL	BDL
17-1P R	0.0	18.5	1.06	33.02		1.424				
17-2P	18.5	33.0	1.08	34.01	0.055	2.317	BDL	1.52	BDL	5.09
17-3P	33.0	45.0	0.88	35.41	0.067	2.931	BDL	1.72	BDL	BDL
18A-1	top		0.01	0.12	0.003	BDL	BDL	0.43	BDL	BDL

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Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
18A-2	middle		BDL	0.08	0.007	BDL	BDL	0.43	BDL	BDL
18A-2 R	middle				0.003		BDL	0.44	BDL	BDL
18A-3	bottom		0.01	0.21	0.003	BDL	BDL	0.26	BDL	BDL
18A-3 R	bottom		0.01	0.20		BDL				
18B-1	0.0	10.5	0.27	3.88	0.040	0.631	0.36	7.18	1.32	BDL
18B-1 R	0.0	10.5			0.043		0.46	3.77	1.16	3.39
18B-2	10.5	21.0	0.25	3.66	0.044	0.542	0.31	2.86	BDL	BDL
18B-3	21.0	32.0	0.02	0.20	0.005	0.071	BDL	0.54	BDL	BDL
18B-4	32.0	44.5	BDL	0.06	0.004	0.048	BDL	0.50	BDL	BDL
18B-4 R	32.0	44.5	BDL	0.06		0.048				
18B-5	44.5	56.0	0.01	0.08	0.004	0.102	BDL	1.18	BDL	BDL
19-1	0.0	14.0	0.24	4.21	0.026	0.349	0.71	2.00	BDL	3.80
19-1 R	0.0	14.0	0.24	4.05		0.355				
19-2	14.0	29.0	0.45	8.30	0.040	1.123	BDL	7.97	1.25	BDL
19-3	29.0	44.0	0.30	5.99	0.028	1.903	BDL	2.71	BDL	BDL
19-3 R	29.0	44.0			0.028		0.50	3.01	BDL	BDL
19-4	44.0	55.5	0.02	0.44	0.008	0.312	0.56	0.89	BDL	BDL
20-1	0.0	14.0	0.28	4.04	0.041	0.487	0.46	2.64	BDL	4.01
20-2	14.0	27.0	0.46	7.81	0.038	1.338	0.37	2.54	BDL	BDL

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
20-2 R	14.0	27.0	0.47	8.01		1.374				
20-3	27.0	45.0	0.02	0.45	0.004	0.106	BDL	0.68	BDL	BDL
20-4	45.0	60.5	0.04	0.75	0.009	0.299	BDL	1.40	BDL	BDL

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Sample ID	Upper interval (cm)	Lower interval (cm)	Elements							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
1-1	0.0	15.0	0.881	0.323	5.2	17.64	1.85	2.08	0.74	253
1-1 R	0.0	15.0	0.920	0.315	5.3	16.09	1.79	2.04	0.73	240
1-2	15.0	29.0	1.219	0.735	2.2	15.92	2.48	2.15	0.82	275
1-3	29.0	44.0	0.710	2.236	5.6	14.90	2.57	1.98	0.87	236
1-4	44.0	60.5	0.713	0.854	4.6	12.99	1.86	2.00	0.86	207
1-5	60.5	67.0	0.781	BDL	11.3	13.06	3.23	2.13	0.90	267
2-1	0.0	16.0	1.290	BDL	6.7	39.56	2.01	1.93	0.68	268
2-2	16.0	35.0	0.835	0.620	5.9	17.80	2.77	2.13	0.97	267
2-3	35.0	55.0	1.395	BDL	6.9	18.85	2.59	2.28	1.08	250

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Sample ID	Upper interval (cm)	Lower interval (cm)	Elements							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
2-4	55.0	71.0	1.097	1.434	1.5	23.56	2.95	2.55	1.10	259
2-4 R	55.0	71.0								
2-5	71.0	92.0	0.677	0.691	9.1	19.76	3.09	1.62	0.99	102
2-5 R	71.0	92.0	0.705	1.424	10.6	19.80	3.15	1.66	1.00	121
2-6	92.0	103.0	0.944	BDL	2.6	9.31	2.23	1.93	1.04	111
3-1	0.0	21.0	0.708	0.651	7.5	29.83	2.36	1.92	0.83	219
3-2	21.0	37.0	0.977	BDL	5.2	17.67	2.01	1.92	0.94	166
3-3	37.0	52.0	1.448	0.953	5.8	22.45	2.86	2.31	0.96	269
3-4	52.0	67.5	1.085	1.056	4.1	26.38	3.21	2.29	1.08	255
3-4 R	52.0	67.5								
3-1P	0.0	21.0	0.388	0.832	9.2	26.60	1.54	0.92	0.51	98
3-1P R	0.0	21.0	0.390	0.391	8.5	26.92	1.50	0.89	0.49	109
3-2P	21.0	37.0	0.296	0.569	7.5	28.00	1.31	0.40	0.36	42
3-3P	37.0	52.0	0.394	BDL	13.5	21.68	2.11	1.06	0.52	70
3-3P R	37.0	52.0								
3-4P	52.0	67.5								
4-1	Top		0.267	BDL	4.9	9.48	1.85	1.49	0.34	232
4-2	Middle		0.224	0.457	3.6	8.75	2.02	1.61	0.32	192
4-3	Bottom		0.279	BDL	4.9	9.68	1.99	1.58	0.38	219

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
4-3 R	Bottom		0.280	1.191	5.8	9.12	2.00	1.52	0.38	222
5-1	0.0	6.0	0.091	1.043	7.3	13.20	2.11	0.20	0.10	289
5-2	6.0	17.5	0.215	BDL	6.7	14.39	1.34	1.10	0.21	137
5-3	17.5	27.0	0.655	BDL	2.9	14.33	2.61	2.12	0.64	262
5-4	27.0	33.0	0.560	0.753	1.9	15.90	2.46	1.96	0.57	225
7-1	0.0	13.5	1.039	0.495	6.0	45.49	1.95	1.73	0.84	207
7-1 R	0.0	13.5	1.099	BDL	6.7	45.60	1.94	1.79	0.84	210
7-2	13.5	24.0	0.705	0.433	7.2	18.11	2.14	1.67	0.90	230
7-3	24.0	40.0	0.606	0.634	12.1	13.03	2.19	1.50	0.99	136
7-3 R	24.0	40.0								
7-4	40.0	49.5	0.814	BDL	8.3	8.85	1.75	1.62	0.99	226
8-1	0.0	15.0	0.087	BDL	19.7	1.18	0.14	0.19	0.11	69
8-2	15.0	32.5	0.046	BDL	8.4	BDL	0.16	0.12	0.04	55
8-3	32.5	37.5	0.310	BDL	8.1	5.10	1.44	1.31	0.31	311
9A-1	0.0	10.5	0.390	BDL	4.1	6.27	1.33	1.21	0.42	174
9A-2	10.5	21.0	0.462	BDL	7.0	9.03	2.05	1.55	0.62	207
9A-3	21.0	34.0	0.536	0.532	9.1	12.19	3.01	1.64	0.92	221
9A-3 R	21.0	34.0								
9B-1	0.0	11.5	0.371	BDL	5.5	6.66	1.39	1.24	0.43	155

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
9B-1 R	0.0	11.5	0.362	BDL	4.6	7.23	1.36	1.21	0.43	152
9B-2	11.5	18.5	0.448	BDL	9.1	9.33	1.89	1.53	0.55	201
9B-2 R	11.5	18.5	0.478	BDL	6.0	9.48	1.90	1.55	0.59	203
9B-3	18.5	33.0	0.443	0.735	10.4	12.91	2.11	1.47	0.72	214
9B-4	33.0	48.0	0.436	BDL	8.1	12.41	2.11	1.67	0.79	211
9B-5	48.0	63.0	0.503	BDL	11.0	10.66	2.52	1.65	0.95	228
9B-6	63.0	73.0	0.062	0.474	11.1	BDL	0.18	0.30	0.07	18
10-1	0.0	13.0	0.623	0.388	7.5	14.36	1.45	1.61	0.54	181
10-1 R	0.0	13.0								
10-2	13.0	27.0	0.579	BDL	6.9	7.16	1.52	1.64	0.47	189
10-3	27.0	47.3	0.712	0.359	8.2	13.41	2.72	1.82	0.89	317
10-4	47.3	71.0	0.718	BDL	7.0	11.77	2.46	1.82	0.99	296
10-5	71.0	86.5	0.777	0.703	6.0	21.08	1.86	1.80	0.94	290
11-1	4.0	16.3	0.823	0.302	9.7	25.12	2.86	1.81	0.89	325
11-2	16.3	35.0	0.709	BDL	12.8	19.94	2.79	1.70	0.81	304
11-2 R	16.3	35.0	0.757	BDL	10.0	19.36	2.91	1.81	0.88	317
11-3	35.0	51.0	0.745	BDL	8.5	8.89	3.39	1.65	0.87	328
11-3 R	35.0	51.0								
11-4	51.0	65.0	0.752	BDL	8.8	9.01	2.60	1.77	1.00	299

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
12-1	0.0	13.5	1.591	BDL	3.4	3.93	0.73	1.56	0.27	132
12-2	13.5	25.5	0.488	BDL	5.1	5.31	1.12	1.38	0.40	174
12-3	25.5	43.0	0.699	BDL	7.3	10.28	2.33	1.68	0.84	265
12-4	43.0	58.0	0.747	BDL	7.3	9.73	2.13	1.84	1.06	261
12-5	58.0	63.5	0.843	0.317	7.6	8.11	2.29	1.99	0.99	286
12-6	63.5	76.0	0.570	BDL	5.0	4.91	1.28	1.34	0.58	191
12-6 R	63.5	76.0	0.557	0.590	5.6	9.70	1.31	1.33	0.53	215
13-1	1.5	12.0	0.513	BDL	4.3	15.45	1.20	1.41	0.35	133
13-2	12.0	27.0	0.633	BDL	7.1	14.89	2.02	1.62	0.62	224
13-3	27.0	42.0	0.793	BDL	7.2	16.53	3.40	2.02	1.18	289
13-4	42.0	57.0	0.730	BDL	4.3	14.04	4.06	2.16	1.32	307
13-5	57.0	76.0	0.664	BDL	8.7	12.00	2.97	1.59	0.86	284
13-6	76.0	96.5	0.790	0.634	5.5	11.16	2.58	1.77	0.79	300
14-1	0.0	9.0	0.584	1.745	6.4	8.45	1.15	1.78	0.37	170
14-1 R	0.0	9.0								
14-2	9.0	18.0	0.534	1.517	4.9	9.13	1.58	1.66	0.43	192
14-3	18.0	32.0	0.609	BDL	4.3	8.74	1.62	1.57	0.53	202
14-3 R	18.0	32.0	0.625	BDL	3.6	10.41	1.66	1.63	0.56	204
14-4	32.0	50.0	0.806	BDL	4.3	8.50	1.58	1.66	0.98	228

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
14-4 R	32.0	50.0	0.782	BDL	5.7	8.46	1.60	1.59	0.98	229
14-5	50.0	62.0	0.470	BDL	1.5	5.72	0.89	1.18	0.38	121
14-6	62.0	79.0	0.319	BDL	4.0	5.91	0.53	1.15	0.18	90
14-7	79.0	95.5	0.239	BDL	BDL	3.02	0.31	1.08	0.09	56
15-1	0.0	16.0	0.529	1.152	4.2	10.89	1.52	1.59	0.46	245
15-1 R	0.0	16.0								
15-2	16.0	30.0	0.625	BDL	7.5	12.01	1.88	1.84	0.55	189
15-3	30.0	44.0	0.720	BDL	3.1	15.69	2.74	2.05	1.09	275
15-4	44.0	58.5	0.649	BDL	8.3	15.45	2.86	1.81	0.89	303
15-1P	0.0	16.0	0.798	BDL	15.3	17.36	2.98	0.82	0.39	1034
15-1P R	0.0	16.0								
15-2P	16.0	30.0	0.337	BDL	10.0	15.18	1.92	0.98	0.39	121
15-3P	30.0	44.0	0.376	2.187	8.8	20.25	3.22	1.07	0.49	176
15-3P R	30.0	44.0								
16-1	0.0	13.0	0.455	BDL	3.1	9.74	0.87	1.50	0.29	100
16-1 R	0.0	13.0	0.472	BDL	1.7	9.40	0.91	1.52	0.31	99
16-2	13.0	25.0	0.493	1.250	3.8	10.67	1.17	1.62	0.37	118
16-3	25.0	40.0	0.877	BDL	6.9	18.69	3.38	2.54	1.39	297
16-4	40.0	52.0	0.637	BDL	7.9	16.31	3.12	1.74	0.90	331

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
17-1	0.0	18.5	0.810	BDL	6.9	19.23	2.50	2.01	0.98	268
17-1 R	0.0	18.5								
17-2	18.5	33.0	0.630	BDL	6.9	13.80	1.88	1.44	0.62	207
17-3	33.0	45.0	0.578	2.152	8.0	15.21	1.93	1.38	0.70	202
17-4	45.0	62.5	0.376	BDL	122.8	5.36	0.66	0.89	0.18	142
17-1P	0.0	18.5	0.276	1.215	15.0	38.16	2.21	0.52	0.37	110
17-1P R	0.0	18.5								
17-2P	18.5	33.0	0.267	1.641	9.6	23.51	1.77	0.49	0.30	75
17-3P	33.0	45.0	0.231	BDL	3414.0	20.93	1.80	0.49	0.29	95
18A-1	top		0.064	0.785	134.4	6.10	0.10	0.26	0.02	31
18A-2	middle		0.065	BDL	228.6	10.75	0.12	0.25	0.02	39
18A-2 R	middle		0.065	0.953	219.0	11.28	0.12	0.24	0.02	40
18A-3	bottom		0.032	BDL	138.3	3.60	0.07	0.17	0.01	24
18A-3 R	bottom									
18B-1	0.0	10.5	0.735	0.396	10.1	16.51	2.01	1.63	0.92	251
18B-1 R	0.0	10.5	0.626	BDL	8.8	18.49	1.91	1.38	0.71	249
18B-2	10.5	21.0	0.491	1.095	5.5	11.93	1.42	1.08	0.58	182
18B-3	21.0	32.0	0.069	BDL	47.6	3.97	0.15	0.27	0.05	28
18B-4	32.0	44.5	0.078	BDL	104.3	8.01	0.16	0.29	0.05	36

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Sample ID	Upper interval (cm)	Lower interval (cm)	Elements							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
18B-4 R	32.0	44.5								
18B-5	44.5	56.0	0.202	BDL	47.6	2.93	0.30	0.66	0.08	52
19-1	0.0	14.0	0.375	BDL	43.0	12.35	0.84	0.89	0.36	173
19-1 R	0.0	14.0								
19-2	14.0	29.0	0.782	BDL	4.9	26.47	2.05	1.87	1.03	206
19-3	29.0	44.0	0.543	1.243	6.6	11.93	1.96	1.28	0.63	128
19-3 R	29.0	44.0	0.588	BDL	9.1	12.30	1.97	1.31	0.62	159
19-4	44.0	55.5	0.151	BDL	1.7	3.23	0.57	0.39	0.11	114
20-1	0.0	14.0	0.480	BDL	4.4	14.82	1.38	1.04	0.58	244
20-2	14.0	27.0	0.514	BDL	5.4	11.72	1.51	1.01	0.71	170
20-2 R	14.0	27.0								
20-3	27.0	45.0	0.115	BDL	86.2	2.61	0.18	0.30	0.07	44
20-4	45.0	60.5	0.276	BDL	2.4	6.03	0.72	0.52	0.22	130

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
1-1	0.0	15.0	7.5	2.64	30.0	40.0	201.0	0.40	74.0	16.5	69.8
1-1 R	0.0	15.0	4.1	2.55	31.2	27.5	203.0	0.38	72.4	18.5	67.5
1-2	15.0	29.0	6.6	2.49	30.3	51.5	241.6	0.44	80.1	28.6	79.1
1-3	29.0	44.0	4.7	3.15	26.0	38.8	172.1	0.35	83.8	19.2	81.5
1-4	44.0	60.5	5.1	3.16	28.5	20.2	174.9	0.37	83.9	19.1	59.4
1-5	60.5	67.0	6.4	2.34	37.5	19.1	184.6	0.43	91.3	23.5	82.6
2-1	0.0	16.0	4.6	2.53	61.7	32.1	160.6	0.39	72.1	13.3	83.7
2-2	16.0	35.0	3.6	3.08	28.9	114.5	214.9	0.41	91.8	23.9	74.7
2-3	35.0	55.0	2.6	3.22	27.3	118.4	217.0	0.43	93.7	35.4	61.2
2-4	55.0	71.0	8.1	2.89	29.0	22.1	246.6	0.44	102.1	35.7	72.4
2-4 R	55.0	71.0									
2-5	71.0	92.0	14.3	4.60	34.8	15.9	150.6	0.29	77.9	15.7	68.3
2-5 R	71.0	92.0	13.4	4.72	34.4	16.3	158.2	0.29	77.6	17.4	72.0
2-6	92.0	103.0	6.8	4.67	18.6	15.9	192.1	0.34	83.3	21.4	41.4
3-1	0.0	21.0	6.3	2.88	51.0	46.0	163.1	0.37	79.6	17.8	87.0
3-2	21.0	37.0	5.7	4.41	17.5	12.6	175.9	0.41	79.9	23.7	50.5
3-3	37.0	52.0	4.1	2.98	34.6	30.5	295.4	0.45	83.8	51.2	72.6
3-4	52.0	67.5	11.1	3.16	29.3	19.1	222.6	0.42	91.4	38.8	73.3

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
3-4 R	52.0	67.5									
3-1P	0.0	21.0	5.5	1.09	19.3	52.5	89.5	0.24	73.9	14.0	115.1
3-1P R	0.0	21.0	11.5	1.07	20.6	53.5	87.7	0.23	72.4	13.4	119.6
3-2P	21.0	37.0	17.4	0.61	9.3	38.8	56.5	0.13	63.7	15.3	56.2
3-3P	37.0	52.0	17.6	1.17	33.2	36.2	95.0	0.20	83.7	27.4	105.9
3-3P R	37.0	52.0									
3-4P	52.0	67.5									
4-1	Top		1.5	0.69	17.7	13.9	86.8	0.42	49.9	10.0	42.6
4-2	Middle		BDL	0.65	17.1	24.9	88.8	0.27	42.8	10.3	37.8
4-3	Bottom		1.5	0.74	24.5	-3.0	93.0	0.32	43.7	11.7	40.8
4-3 R	Bottom		BDL	0.70	17.5	8.3	99.3	0.40	50.7	11.5	38.6
5-1	0.0	6.0	BDL	0.23	4.3	12.8	31.9	0.39	15.0	10.5	20.4
5-2	6.0	17.5	3.7	0.64	26.1	9.5	83.7	0.42	37.9	10.5	24.9
5-3	17.5	27.0	2.3	1.24	27.4	19.6	179.6	0.61	72.0	44.0	46.6
5-4	27.0	33.0	3.8	1.20	33.3	29.1	154.4	0.54	74.2	32.9	45.6
7-1	0.0	13.5	10.3	3.48	83.3	18.9	153.7	0.30	82.1	14.9	68.5
7-1 R	0.0	13.5	5.0	3.64	85.1	26.9	143.3	0.31	84.9	13.6	70.2
7-2	13.5	24.0	9.0	3.08	33.3	47.7	164.0	0.35	83.8	14.1	76.7
7-3	24.0	40.0	12.1	4.33	34.5	25.5	147.8	0.29	70.2	12.2	70.7

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Sample ID	Upper interval (cm)	Lower interval (cm)	Elements								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
7-3 R	24.0	40.0									
7-4	40.0	49.5	5.0	3.37	23.8	13.7	170.4	0.29	71.5	17.5	55.0
8-1	0.0	15.0	1.8	0.24	BDL	BDL	27.9	0.03	4.6	1.5	6.8
8-2	15.0	32.5	BDL	0.11	BDL	BDL	12.5	0.08	4.1	1.1	8.6
8-3	32.5	37.5	1.2	0.75	13.4	13.3	103.5	0.35	38.7	15.6	33.9
9A-1	0.0	10.5	2.8	1.22	25.7	24.7	111.7	0.30	43.0	10.7	42.3
9A-2	10.5	21.0	4.7	1.88	28.8	18.7	126.7	0.42	66.0	15.7	50.0
9A-3	21.0	34.0	4.3	2.81	37.2	36.7	142.8	0.39	85.7	18.4	78.6
9A-3 R	21.0	34.0									
9B-1	0.0	11.5	3.4	1.30	25.7	24.3	110.5	0.32	46.7	9.5	41.9
9B-1 R	0.0	11.5	4.2	1.28	26.5	21.1	109.0	0.32	45.1	9.2	40.3
9B-2	11.5	18.5	4.2	1.72	48.6	22.0	135.7	0.37	66.9	11.9	53.6
9B-2 R	11.5	18.5	2.4	1.68	45.1	29.8	135.0	0.36	66.5	14.7	54.6
9B-3	18.5	33.0	6.5	2.22	47.6	41.4	122.6	0.22	68.9	14.6	72.3
9B-4	33.0	48.0	2.5	2.63	28.6	23.0	124.4	0.30	79.3	12.4	61.0
9B-5	48.0	63.0	6.3	2.69	37.8	24.4	124.5	0.37	84.0	17.6	63.2
9B-6	63.0	73.0	1.2	0.38	BDL	3.8	27.3	0.03	3.9	1.3	2.8
10-1	0.0	13.0	5.8	1.89	53.7	15.7	169.6	0.26	45.4	11.4	44.6
10-1 R	0.0	13.0									

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
10-2	13.0	27.0	3.3	1.75	51.4	18.8	169.8	0.25	42.6	9.3	42.6
10-3	27.0	47.3	5.3	2.23	29.4	27.0	168.9	0.38	81.2	17.5	78.9
10-4	47.3	71.0	6.2	2.85	25.3	6.6	170.7	0.36	81.5	16.4	68.6
10-5	71.0	86.5	3.0	3.19	29.5	8.9	176.2	0.31	83.1	16.0	56.1
11-1	4.0	16.3	BDL	2.04	40.0	47.1	165.6	0.38	86.8	18.2	84.8
11-2	16.3	35.0	BDL	2.01	28.5	38.4	138.5	0.37	80.1	15.2	77.1
11-2 R	16.3	35.0	BDL	2.03	28.1	30.8	168.8	0.38	82.5	19.0	77.5
11-3	35.0	51.0	1.1	2.36	23.7	14.8	167.3	0.33	75.9	18.0	63.8
11-3 R	35.0	51.0									
11-4	51.0	65.0	1.9	2.63	28.2	10.6	163.5	0.35	86.6	19.0	67.0
12-1	0.0	13.5	4.6	1.62	23.5	20.6	217.9	0.20	23.7	4.3	29.1
12-2	13.5	25.5	6.8	1.59	34.7	14.3	153.2	0.30	38.4	6.5	35.7
12-3	25.5	43.0	2.6	2.67	30.5	23.6	119.0	0.38	85.3	9.7	63.8
12-4	43.0	58.0	1.1	3.15	19.6	20.0	160.6	0.34	84.5	17.6	59.9
12-5	58.0	63.5	BDL	2.43	26.9	14.0	188.3	0.40	84.8	18.5	59.0
12-6	63.5	76.0	2.2	1.82	19.1	12.7	156.5	0.32	51.5	35.8	35.8
12-6 R	63.5	76.0	5.6	1.87	24.7	19.1	148.6	0.35	53.5	35.3	36.2
13-1	1.5	12.0	4.7	1.64	72.9	17.2	147.9	0.16	33.7	7.4	37.7
13-2	12.0	27.0	2.8	1.92	44.2	30.5	168.6	0.28	64.5	14.5	65.9

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
13-3	27.0	42.0	BDL	2.16	32.4	30.3	164.3	0.38	82.9	41.4	94.4
13-4	42.0	57.0	1.8	2.42	30.4	35.6	185.1	0.38	94.5	44.1	90.1
13-5	57.0	76.0	7.6	2.47	24.7	25.0	124.7	0.38	89.3	13.2	66.4
13-6	76.0	96.5	3.6	2.25	27.7	17.3	155.0	0.43	87.5	13.6	58.2
14-1	0.0	9.0	4.7	1.66	26.5	12.8	189.0	0.24	37.0	7.9	36.3
14-1 R	0.0	9.0									
14-2	9.0	18.0	4.9	1.50	26.9	27.0	168.0	0.30	46.7	9.3	48.1
14-3	18.0	32.0	2.0	1.92	32.1	21.2	171.1	0.29	49.5	10.6	42.4
14-3 R	18.0	32.0	5.4	1.95	28.8	22.2	177.9	0.30	50.4	12.2	43.5
14-4	32.0	50.0	2.3	2.75	29.8	25.3	166.2	0.34	64.7	25.6	45.9
14-4 R	32.0	50.0	BDL	2.67	28.4	13.6	161.3	0.32	63.2	24.2	45.8
14-5	50.0	62.0	4.5	1.39	25.1	9.5	132.1	0.21	29.9	7.6	23.1
14-6	62.0	79.0	BDL	0.94	37.2	4.3	123.5	0.21	15.7	5.2	19.3
14-7	79.0	95.5	2.8	0.68	4.7	BDL	114.9	0.17	10.4	3.2	9.4
15-1	0.0	16.0	5.3	1.98	41.9	18.7	161.5	0.18	40.2	9.0	48.3
15-1 R	0.0	16.0									
15-2	16.0	30.0	2.8	1.94	36.8	34.8	187.0	0.24	53.9	12.6	61.9
15-3	30.0	44.0	2.2	1.94	34.7	27.4	202.5	0.34	75.7	33.7	76.6
15-4	44.0	58.5	BDL	2.16	29.6	37.2	156.1	0.38	89.4	18.9	81.1

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
15-1P	0.0	16.0	7.0	1.11	20.0	36.4	119.2	0.12	45.7	14.3	61.3
15-1P R	0.0	16.0									
15-2P	16.0	30.0	5.2	1.04	14.6	16.1	93.5	0.17	53.9	11.6	51.8
15-3P	30.0	44.0	8.1	0.80	20.2	33.8	101.6	0.24	87.8	18.2	66.3
15-3P R	30.0	44.0									
16-1	0.0	13.0	6.7	1.36	28.9	12.7	155.5	0.15	28.6	6.7	31.4
16-1 R	0.0	13.0	2.3	1.38	34.5	22.9	157.7	0.15	29.6	7.0	31.1
16-2	13.0	25.0	3.3	1.49	42.0	17.9	173.2	0.19	38.6	8.2	40.9
16-3	25.0	40.0	2.4	2.12	26.7	37.7	220.1	0.42	90.2	47.0	89.6
16-4	40.0	52.0	4.4	2.69	36.4	32.4	135.5	0.38	94.5	12.8	74.9
17-1	0.0	18.5	1.5	1.99	31.2	37.8	216.8	0.40	86.8	29.5	85.4
17-1 R	0.0	18.5									
17-2	18.5	33.0	6.3	2.14	34.7	14.6	135.3	0.33	62.4	10.5	52.0
17-3	33.0	45.0	4.9	2.78	33.0	12.1	121.7	0.36	65.2	10.9	50.1
17-4	45.0	62.5	2.6	0.97	8.4	9.8	99.6	0.27	18.9	4.6	17.2
17-1P	0.0	18.5	10.1	0.70	17.9	51.8	58.4	0.14	88.4	12.3	75.0
17-1P R	0.0	18.5									
17-2P	18.5	33.0	13.4	0.48	16.5	41.0	56.9	0.14	58.9	14.0	65.1
17-3P	33.0	45.0	16.9	0.42	41.6	9.2	48.8	0.14	81.3	14.3	57.9

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
18A-1	top		BDL	0.12	5.1	BDL	30.9	0.03	3.5	1.2	3.9
18A-2	middle		2.3	0.11	15.0	BDL	28.5	0.02	3.1	1.4	33.4
18A-2 R	middle		2.3	0.11	13.9	BDL	29.0	0.05	5.1	1.3	32.8
18A-3	bottom		1.6	0.06	4.1	BDL	17.2	0.02	3.2	1.1	3.2
18A-3 R	bottom										
18B-1	0.0	10.5	3.3	1.83	48.6	19.7	157.8	0.40	68.1	26.8	71.0
18B-1 R	0.0	10.5	2.7	1.80	50.5	29.7	136.4	0.39	71.1	14.5	72.7
18B-2	10.5	21.0	1.6	1.51	51.7	23.3	111.2	0.27	58.4	10.9	49.0
18B-3	21.0	32.0	BDL	0.23	5.5	BDL	28.6	0.04	4.8	1.5	7.6
18B-4	32.0	44.5	2.3	0.27	6.4	BDL	33.1	0.08	5.9	1.3	7.5
18B-4 R	32.0	44.5									
18B-5	44.5	56.0	BDL	0.56	1.1	3.9	73.8	0.10	8.5	2.2	8.9
19-1	0.0	14.0	5.5	1.53	59.3	-3.0	101.5	0.39	38.6	6.3	22.0
19-1 R	0.0	14.0									
19-2	14.0	29.0	3.9	2.73	31.9	36.0	233.5	0.35	78.7	27.2	71.8
19-3	29.0	44.0	7.3	2.69	51.7	16.4	118.6	0.30	52.9	9.2	48.0
19-3 R	29.0	44.0	3.9	2.80	55.1	19.9	139.2	0.29	54.7	10.5	49.6
19-4	44.0	55.5	BDL	0.50	5.8	4.1	45.2	0.29	13.0	3.3	10.0
20-1	0.0	14.0	3.5	2.06	50.7	23.2	110.2	0.42	56.6	9.3	51.3

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples: **R** = Replicate sample (QA/QC): **T** = triplicate sample (QA/Q). Bank/bluff samples were collected at sites 4 and 18; samples collected from top, middle and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
20-2	14.0	27.0	1.4	2.85	34.8	16.3	116.8	0.33	55.2	10.4	44.7
20-2 R	14.0	27.0									
20-3	27.0	45.0	BDL	0.39	1.7	BDL	40.4	0.07	5.6	1.7	4.5
20-4	45.0	60.5	2.3	0.80	5.7	4.9	62.4	0.33	20.3	4.4	18.3

APPENDIX D
Land loss and loading calculations

Calculating Land Loss (Area and Volume)

For each land loss polygon, the area (m^2) covered by water is recorded for the years 1942 and 1989. Likewise, the total length (m) of the 1989 shoreline is recorded. Land loss over the 47-year period is determined by subtracting water area in 1989 from water area in 1942. The difference in water area is equivalent to the area of land lost by erosion. Table D-1 is a tabulation of water area, land loss, and shoreline length for each polygon and basin. Land loss is indicated by a negative (-) sign, which is dropped in subsequent calculations.

For any given land loss polygon, the associated rate of shoreline retreat is calculated by dividing area lost by the length of the reach:

$$R = \frac{A_{(1989-1942)} / SL_{(1989)}}{47\,yr} \qquad \textbf{Eq. D-1}$$

where: R is the annual rate of shoreline retreat (m/yr),

$A_{(1989\text{-}1942)}$ is the area of land (m^2) lost to erosion within the land loss polygon between 1942 and 1989 (47-year period), and

$SL_{(1989)}$ is the length (m) of the shoreline within the polygon.

Table D-1. Area (m^2) and volume (m^3) of land lost during the 47-year period between 1942 and 1989 and linear rates (m/yr) of shoreline erosion, by shoreline reach (land loss polygon).

Polygon	1942 Water area (m^2)	1989 Water area (m^2)	1989 Shoreline length (m)	Change in land area (m^2)	Change per meter of shoreline	Annual change (m/yr)	Bank height (m)	Volume loss (m^3)	Annual volume (m^3/yr)
P1	581,017.4	648,248.0	4,461.0	-67,230.6	-15.07	-0.32	0.48	32,270.7	686.6
P2	650,990.2	730,948.1	5,783.2	-79,957.9	-13.83	-0.29	0.78	62,367.1	1,327.0
P3	1,054,321.9	1,123,874.2	4,513.6	-69,552.3	-15.41	-0.33	0.76	52,859.7	1,124.7
P4	692,115.3	729,004.5	1,392.9	-36,889.3	-26.48	-0.56	1.18	43,529.4	926.2
P5	1,748,837.0	1,795,336.3	4,694.1	-46,499.3	-9.91	-0.21	0.60	27,899.6	593.6
P6	1,108,681.0	1,153,603.6	7,797.8	-44,922.5	-5.76	-0.12	0.60	26,953.5	573.5
P7	1,183,332.5	1,253,236.8	3,642.9	-69,904.4	-19.19	-0.41	0.42	29,359.8	624.7
P8	528,630.5	537,583.0	1,231.9	-8,952.5	-7.27	-0.15	0.45	4,028.6	85.7
P9	880,887.7	922,150.5	3,148.6	-41,262.8	-13.11	-0.28	0.44	18,155.6	386.3
P10	1,908,098.3	2,005,925.3	20,850.6	-97,827.0	-4.69	-0.10	0.83	81,196.4	1,727.6
P11	950,650.0	1,115,269.1	20,671.5	-164,619.1	-7.96	-0.17	0.83	136,633.9	2,907.1
P12	499,646.7	518,223.7	3,401.6	-18,577.0	-5.46	-0.12	0.68	12,632.3	268.8
P13	1,413,280.0	1,440,944.0	4,528.9	-27,664.0	-6.11	-0.13	0.64	17,704.9	376.7
P14	563,055.8	604,999.3	6,270.2	-41,943.5	-6.69	-0.14	0.75	31,457.6	669.3
P15	789,555.5	830,338.3	7,124.4	-40,782.8	-5.72	-0.12	0.83	33,849.7	720.2
P16	970,729.4	1,019,003.3	12,656.8	-48,273.9	-3.81	-0.08	0.45	21,723.3	462.2
P17	2,611,668.0	2,652,782.5	4,729.4	-41,114.5	-8.69	-0.18	0.62	25,491.0	542.4
P18	6,438,191.7	6,504,264.1	67,398.3	-66,072.4	-0.98	-0.02	0.37	24,446.8	520.1
P19	1,127,834.5	1,239,148.0	7,029.0	-111,313.5	-15.84	-0.34	0.37	41,186.0	876.3
P20	2,030,608.3	2,058,063.0	6,069.0	-27,454.7	-4.52	-0.10	0.38	10,432.8	222.0
P21	124,142.9	132,164.7	1,092.1	-8,021.8	-7.35	-0.16	0.58	4,652.6	99.0
P22	296,531.7	309,080.0	1,774.6	-12,548.3	-7.07	-0.15	0.58	7,278.0	154.9
P23	51,811.1	58,039.8	1,883.6	-6,228.6	-3.31	-0.07	0.37	2,304.6	49.0
Total	**28,204,617.5**	**29,382,230.1**	**202,146.0**	**-1,177,612.6**	**Mean = -9.31**	**Mean = -0.20**	**Mean = 0.61**	**748,414.1**	**15,923.7**

Calculating mean component concentrations for each site

The mean bulk concentration of each nutrient (total carbon, nitrogen, and phosphorus) was calculated for each core or bank/bluff site by averaging the concentrations of the individual core samples using equation D-2.

$$\overline{C}_{N(site)} = \frac{\sum_i \left(r_{adj(i)} * 1000 * \frac{[N]_{(i)}}{100} * l_{(i)} \right)}{l_{(t)}} \qquad \textbf{Eq. D-2}$$

where:	$\overline{C}_{N(site)}$	is the mean bulk concentration (Kg/m^3)of the component of interest (N) (e.g., carbon, nitrogen, phosphorus, etc.) for core/site,
	$r_{adj(i)}$	is the adjusted dry bulk density (g/cm^3) of the sample section *(i),* corrected to account for any core compaction,
	1000	factor to convert g/cm^3 to Kg/m^3
	$[N]_{(i)}$	is the nutrient concentration (% dry weight) measured for sample section (*i*),
	$l_{(i)}$	is the length, in meters, of the sample section *(i)*, and
	$l_{(t)}$	is the total core length, in meters, truncated to measured bank height or, in the case of a bluff sample, bluff height.

Mean bulk concentrations of sand, silt, and clay components for each site were calculated using a slightly different equation (Eq. D-3). The sand, silt, and clay percentages obtained from the textural analysis applied the abiotic or mineral portion of the sediment sample only, not the whole sample. Therefore, textural component percentages were multiplied by the fraction representing the mineral portion of whole sediment:

$$\overline{C}_{S(site)} = \frac{\sum_i \left(r_{adj(i)} * 1000 * \frac{[S]_{(i)}}{100} * \frac{[M]_{(i)}}{100} * l_{(i)} \right)}{l_{(t)}} \qquad \textbf{Eq. D-3}$$

where:	$\overline{C}_{S(site)}$	is the mean bulk concentration (Kg/m^3)of the textural component of interest (S) (*e.g.*, sand, silt, clay-size particles, etc.) for core/site;
	$r_{adj(i)}$	is the adjusted bulk density (g/cm^3) of the sample section *(i),* corrected to account for any core compaction;
	1000	factor to convert g/cm^3 to Kg/m^3

$[S]_{(i)}$	is the textural component (% dry weight sand, silt, or clay) measured for sample section (*i*);
$[M]_{(i)}$	is the abiotic or mineral portion (%dry weight) of the sample section;
$l_{(i)}$	is the length, in meters, of the sample section *(i);*
$l_{(t)}$	is the total core length, in meters, truncated to measured bank height; or, in the case of a bluff sample, height of the bluff.

Table D-2. Mean textural and nutrient concentrations calculated for each site using equations D-2 and D-3. **All values listed are Kg/m^3.** These site values are assigned to specific land loss polygons (see Table **4-2**) to calculate the sediment and nutrient contribution rates for the polygon using equation D-4.

Site	Total Solids	Nutrients				Metals		Textural component			
		Total Organics (biotic component)	Carbon	Nitrogen	Phosphorus	Pb	Zn	Total Clastics (abiotic component)	Sand	Silt	Clay
1	488.1	108.1	24.90	1.41	0.181	0.019	0.036	380.0	96.14	172.65	111.20
2	461.1	125.4	28.95	1.65	0.185	0.031	0.034	335.7	57.11	149.75	128.89
3	437.2	92.1	30.57	1.78	0.181	0.013	0.032	345.0	24.39	182.95	137.68
4	1679.6	46.3	1.89	0.28	0.320	0.034	0.066	1633.2	726.35	671.71	234.16
5	1299.0	77.5	16.13	1.00	0.317	0.020	0.042	1221.5	726.07	360.70	134.73
7	280.7	110.4	28.73	1.45	0.124	0.009	0.020	170.3	28.02	81.40	60.84
8	1333.2	7.5	5.89	0.40	0.091	0.003	0.017	1325.7	1177.11	120.21	28.06
9	706.8	113.9	22.93	1.36	0.249	0.019	0.038	592.9	182.18	276.97	133.74
10	574.1	91.5	23.04	1.35	0.181	0.009	0.034	482.6	142.02	226.06	114.52
11	573.4	117.6	26.68	1.69	0.244	0.016	0.042	455.8	30.39	300.98	124.40
12	649.4	121.1	25.89	1.37	0.177	0.012	0.029	528.3	289.40	139.22	92.94
13	533.2	109.1	29.35	1.78	0.196	0.015	0.037	424.1	124.54	173.53	126.03
14	945.9	116.1	27.47	1.71	0.387	0.012	0.029	829.8	582.85	161.10	85.84
15	655.8	62.7	30.89	1.89	0.355	0.017	0.040	593.1	343.29	138.56	111.29
16	684.3	94.9	16.04	1.18	0.224	0.017	0.038	589.4	293.52	177.91	117.96
17	576.2	124.9	24.59	1.65	0.233	0.016	0.040	451.3	132.94	175.79	142.57
18	1304.0	53.3	8.66	0.57	0.125	0.004	0.024	1250.7	1148.75	64.59	37.40
19	514.6	95.8	29.66	1.62	0.157	0.007	0.022	418.9	248.25	100.25	70.35
20	861.6	108.3	28.35	1.70	0.196	0.010	0.025	753.3	586.93	94.95	71.39

Calculating component loadings (Kg/yr)

The mean site concentration values were then assigned to specific polygons to calculate the nutrient loading for the polygon using the following equation:

$$L_{(N),(S)} = \overline{C}_{N,S(site)} * \left(\frac{A_{(1989-1942)} * \overline{H}}{47yr} \right) \qquad \textbf{Eq. D-4}$$

where: $L_{(N),(S)}$ is the annual loading (Kg/yr) of the component of interest (Nutrients, *N*: e.g., carbon, nitrogen or phosphorus; or Sediments, *S*: e.g., sand, silt, clay) for the land loss polygon;

$\overline{C}_{N,S(site)}$ is the mean loading concentration (Kg/m^3)of the component of interest (N) (*e.g.*, carbon, nitrogen, phosphorus, etc.) for core/site assigned to the land loss polygon;

$A_{(1989\text{-}1942)}$ is the area of land (m^2) lost to erosion within the land loss polygon between 1942 and 1989 (47 year period);

$\overline{H}$ is the mean bank height assigned to the land loss polygon.

Table D-3. Annual component loadings (Kg/yr) for each land loss polygon. Loadings (except total volume eroded) were calculated using Equation D-4. Area eroded ($A_{(1989\text{-}1942)}$) and mean bank height ($\overline{H}$) are listed in Table D-1.													
Polygon	**Annual volume (m^3/yr)**	**Total Solids (Kg/yr)**	**Total Organics (Kg/yr)**	**Carbon (Kg/yr)**	**Nitrogen (Kg/yr)**	**Phosphorus (Kg/yr)**	**Lead (Pb) (Kg/yr)**	**Zinc (Kg/yr)**	**Total Sediments (clastics) (Kg/yr)**	**Gravel (Kg/yr)**	**Sand (Kg/yr)**	**Silt (Kg/yr)**	**Clay (Kg/yr)**
P1	687	335,156	74,249	17,098	969	124.22	13.304	24.910	260,907		66,014	118,544	76,349
P2	1,327	611,862	166,341	38,416	2,193	245.19	41.525	44.942	445,522		75,777	198,716	171,029
P3	1,125	491,656	103,619	34,377	2,002	203.19	14.830	36.448	388,038		27,434	205,757	154,846
P4	926	1,555,545	42,926	1,748	257	296.56	31.216	60.798	1,512,619	923	672,714	622,109	216,873
P5	594	771,076	45,981	9,573	594	188.14	12.063	24.794	725,095		430,998	214,117	79,979
P6	573	744,929	44,421	9,248	574	181.76	11.654	23.953	700,507		416,383	206,857	77,267
P7	625	175,344	68,985	17,946	904	77.69	5.338	12.477	106,359		17,506	50,849	38,004
P8	86	114,277	642	504	34	7.79	0.275	1.450	113,635		100,897	10,304	2,405
P9	386	273,036	44,008	8,856	525	96.19	7.335	14.825	229,028		70,375	106,990	51,663
P10	1,728	991,891	158,152	39,810	2,340	312.19	15.666	58.648	833,740		245,350	390,544	197,846
P11	2,907	1,669,112	266,131	66,990	3,938	525.34	26.362	98.690	1,402,982		412,864	657,190	332,927
P12	269	154,118	31,620	7,171	455	65.53	4.179	11.282	122,498		8,168	80,895	33,435
P13	377	244,616	45,613	9,754	516	66.73	4.685	10.775	199,003	2,533	109,017	52,444	35,009
P14	669	356,880	73,025	19,644	1,193	131.00	9.784	24.848	283,855		83,356	116,144	84,355
P15	720	681,250	83,630	19,787	1,231	278.92	8.441	20.865	597,620		419,774	116,026	61,820
P16	462	303,123	28,979	14,277	874	164.09	7.940	18.289	274,144		158,667	64,041	51,436
P17	542	371,119	51,454	8,700	640	121.35	9.349	20.605	319,665		159,195	96,494	63,976
P18	520	267,672	49,808	15,429	845	81.88	3.781	11.209	217,865		129,128	52,146	36,590
P19	876	754,989	94,902	24,839	1,489	171.89	8.510	22.089	660,087		514,323	83,207	62,557
P20	222	127,897	27,719	5,458	367	51.65	3.471	8.977	100,178		29,510	39,022	31,646
P21	99	129,089	5,274	858	57	12.36	0.444	2.424	123,815		113,718	6,394	3,703
P22	155	201,929	8,250	1,341	89	19.33	0.694	3.792	193,679		177,885	10,001	5,792
P23	49	25,233	4,695	1,454	80	7.72	0.356	1.057	20,538		12,173	4,916	3,449