Using Vibracore and Profile Data to Quantify Volumes of Renourished Sediments, Holocene Thickness, and Sedimentation Patterns: Hancock County, Mississippi

Keil Schmid

Mississippi Department of Environmental Quality
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Open-File Report 131

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Table of Contents

Abstract 1

Introduction 2

Previous Works 3

  Study Site 4

Methods 8

Data and Interpretations 11

  Profiles 11

  Sediment Data 12

    Subaerial Beach Samples 12

    Nearshore Units 14

  Facies F or H? 16

    Unit A Sub-units 17

    Profile Data 19

    Combined Data 20

Results 22

  1994 Renourishment 22

  Facies F and H 23

Discussion 25

  Renourished Sediments (Facies F) 26

  Natural Sediments (Holocene and Pleistocene) 27

Conclusion 28

References Cited 29

Abstract

The recreational, aesthetic, and cost benefits of sand beaches have made renourishment an attractive protection option in Mississippi Sound. Thus, nearshore sediment volumes and projected beach life spans are important information to local and state planners. Quantifying volumetric change and shoreline retreat values is an important first step; however, the unique aspects of fill deposition also provide an opportunity to clarify long-term sediment transport. Naturally, this is made easier by the use of "unique" fill sediment; or, alternately, with highly accurate bathymetry prior to and following renourishment. Unfortunately, use of both fill sediment and bathymetry in Hancock County were limited by sediment source and time, respectively. Although the fill sediments were not unique, sedimentary structures, composition and faint contacts helped distinguish discret sedimentary sequences. However, the differences were subtle enough in some cases to raise questions about the origins of the sediment, be it fill or natural sedimentation. To increase confidence in the elevation of Fill/Holocene contacts an 'if then' logic, using both profile and sediment data, was employed. Short-term depositional patterns determined from profiles were used to validate or reject individual sedimentary sequence contacts as the Fill/Holocene boundary based on a set of logical rules. This technique, while taking some purity out of the interpretation, helped increase confidence and repeatability in determining the Fill/ Holocene boundary.

Long-term volumetric and spatial results agree well with documented renourishment projects and suggest that much of the renourished sediment is being moved from the subaerial beach to the broad nearshore platform. The nearshore platform appears to have grown vertically by an average of more than 0.4 m and nearly 1,000,000 cubic yards of renourished sediment has been deposited here. Use of a nearshore sediment source for the latest renourishment appears to have caused the onset of erosion landward of the borrow pit. Previously, this area was dominated by deposition. Taken in total, however, vertical aggradation of the nearshore platform may act to stabilize or buffer high-erosion shoreline areas. The width of the nearshore platform, an important factor in limiting wave energy reaching the beach, is controlled largely by the lithology and morphology of underlying Pleistocene units.

Introduction

Cost and esthetic benefits of a pumped-in beach as opposed to riprap or offshore breakwaters has made beach renourishment in conjunction with previously constructed seawalls an attractive protection option in Mississippi. Recently, with the introduction of legalized gaming and the associated increase in tourist visits, the beaches have also become a recreational asset. As a result, an increasing number of people live and vacation on or near the coastline, which further emphasizes the protective role of artificial beaches. In light of this perception, each of the three coastal counties has recently, within the last five years, completed or started renourishment projects. Unfortunately, the paucity of sandy sediment in Mississippi Sound makes the search for suitable renourishment sources progressively more difficult. Many of the larger projects target nearshore sources that are, themselves, part of the eroding system.

Mississippi Sound and the mainland beaches are in a microtidal, low-energy, riverine-influenced system and, correspondingly, sediments are dominantly muddy (Otvos, 1985), although localized sandy sediments do occur on the periphery of the basin (nearshore) and in areas adjacent to eroding sandy Pleistocene units (Otvos, 1976; Upshaw et al., 1966). Sediment volume and beach morphology changes measured by cross shore beach profiles, GPS (Global Positioning System) surveys and more recently using LIDAR (Light Detection and Ranging) elevations (Schmid, 2000c) show that, in general, most of the Mississippi mainland beaches are experiencing both shoreline retreat and sediment loss (Schmid, 2000a; 2000b).

In light of the eroding conditions, the absolute volume of sediment remaining on the renourished beaches and projected lifespan are especially important information to local and state planners. For example, lifespan estimates can be used to appropriate funds for future renourishments; yearly volume reports can document rapid loss of sediment during intense storms, thus helping in the pursuit of disaster funding. On renourished beaches, volumetric change and shoreline retreat values can adequately quantify beach erosion; however, given the unique nature of deposition there is also an opportunity to clarify sediment transport pathways, be it offshore, alongshore, or onshore. Where nearshore sand sources are targeted as a resource it is even more important to determine transport pathways as changes to the system may alter the expected outcome. In many cases following renourishment of the subaerial beach a portion of sand moves offshore to re-establish a state of semi-equilibrium. In this process the nearshore platform may be enhanced; if so, it helps build a base for future renourishments, thus reducing costs and possibly increasing the capacity to buffer highly localized erosion trends. If, on the other hand, the sediment bypasses the system and is lost offshore, the beach renourishment process will become increasingly more expensive. Determining the degree to which both processes are occurring is made easier if either profiles or detailed bathymetry are performed regularly over the history of renourishment. In this way cross shore profiles can provide information about geomorphic changes and document the absolute volume of renourished sediment remaining on the beach. The obvious problem is the difficulty in gathering or locating continuous, long-term, systematic data beginning with the earliest renourishment. To overcome this common problem we explored the use of sediment core transects along a renourished beach as an alternate solution.

In light of the advantages of understanding sediment transport on renourished beaches, the goals of this paper are to reconstruct the 'natural' Holocene surface offshore of a continuously renourished beach, track the fate of renourished sediments, and contour and describe the Pleistocene framework. In so doing, the results may 1) better quantify the coastal sediment budget, 2) document potential nearshore sediment sources, 3) describe sedimentation adjacent to a nearshore borrow site, and 4) define a relationship, if present, between Holocene sediments and erosion rates to the underlying Pleistocene framework.

Previous Works

The introduction of renourished sands can be seen as a sort of tracer experiment (Thieler et al., 1994; Thieler et al., 1999) if either the composition varies from the natural sediment or there is enough sediment to reverse local trends, e.g., truncation of a muddy or upward fining sequence with a sandy sequence. This idea has been used along the US Atlantic Coast by Pearson and Riggs (1981), Thieler et al. (1994; 1998; 1999), and Reed and Wells (2000) in North Carolina and by Pabich (1995) in Massachusetts. In these studies textural and grain characteristic techniques were used to map and describe nearshore shelf sands following renourishments. The North Carolina studies found that the character of thin sand bodies overlying Holocene mud and Tertiary and Pleistocene units was traceable to the lagoonal sediments used in the renourishments. From these data they were able to define the transport paths of both coarse and fine fractions of the introduced sediment.

These works using renourished sediments as tracers were ultimately aimed towards resolving local sediment budgets and providing insight on the relative success or failure of particular projects. The North Carolina studies also showed that the sediment transport patterns had definite links to antecedent nearshore geology. This then creates an obvious problem for traditional models based on beach profiles and wave parameters. Saddled with such a problem when a disparity between longshore drift calculations on Eastern Long Island arose, Schwab et al. (1999a; 1999b) used high-resolution seafloor mapping to describe the interplay of geologic framework and physiography to erosion rates.

Understanding the importance of the geologic framework in coastal change has prompted several studies on the nearshore geologic framework of the Mississippi Sound and Northern Gulf of Mexico. Otvos (1985; 1976) described and named Pleistocene units along with their potential for use in renourishment in Mississippi, Alabama and western Florida. Hummel (1995) documented the Pleistocene/Holocene framework in eastern Mississippi Sound and quantified local sediment sources for renourishment offshore of Morgan Peninsula, Alabama following Hurricane Georges (Hummel, 1999). Significant work has been and continues to be done to the southwest of the study site in Louisiana; see for example (Kindinger et al., 1989a; Kindinger et al., 1991; Kindinger et al., 1989b).

Any study using renourished sediment as a tracer is aided by in-depth renourishment histories; however, determining specifics on early projects is hampered by variable record keeping practices and highly variable sources (Dixon and Pilkey, 1991; Trembanis and Pilkey, 1998). Some of the parameters necessary for reconstruction of a historical database at the Hancock County study site were documented by a county task force (Sand Beach Planning Team, 1986), who also noted that offshore transport might be the most significant component of erosion in the area.

Study Site

The Hancock Beach System is in southwestern Mississippi; it is the second largest renourished beach in the state and encompasses two towns, Bay St. Louis and Waveland

(Figure 1). Hancock County has a southwest – northeast trending shoreline that stretches from the town of Bay St. Louis in the northeast to the Pearl River, which forms the boundary between Mississippi and Louisiana, in the southwest. The southwestern two thirds of the shoreline are dominated by natural marsh, with a few small pockets of sandy beach that are fed by remnant and locally eroding Holocene dune/beach ridges (Otvos, 1985) stranded within the marsh. A seawall, which is fronted along its northern two-thirds by an artificial beach, armors the northeastern third of the county's shoreline.

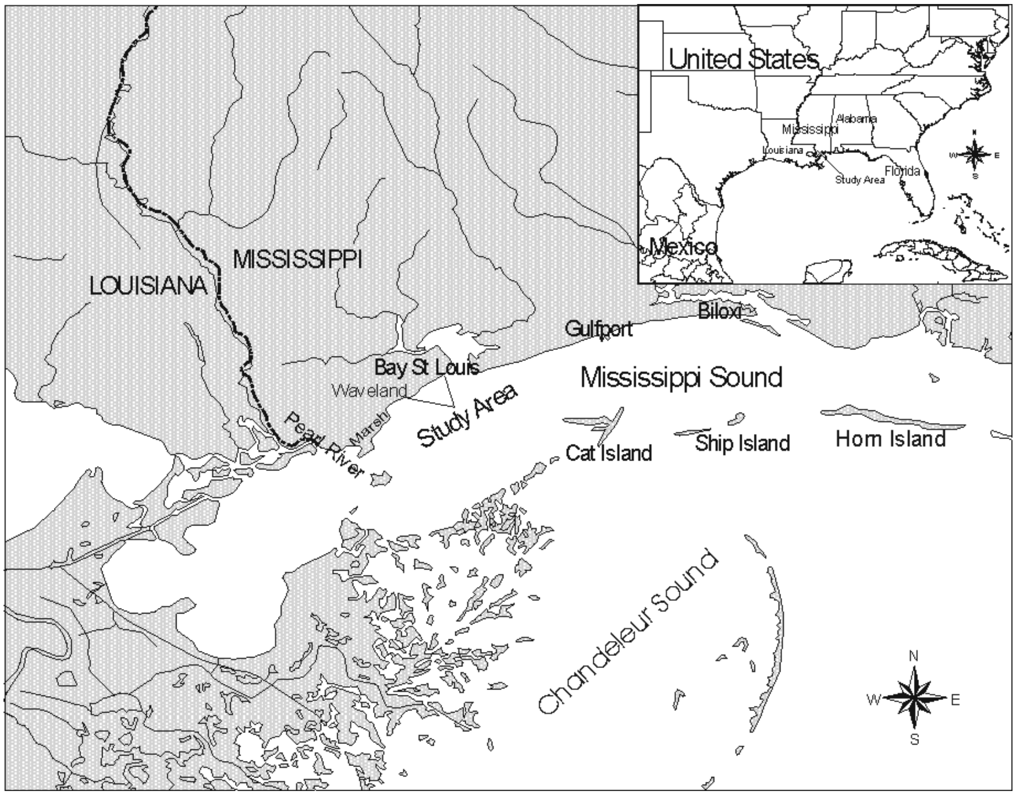


Figure 1. Map of general study area within the Northeast Gulf of Mexico.

Once the seawall was constructed in 1928 (Meyer-Arendt, 1991) a line in the sand was effectively drawn; sediment supply from eroding headlands was cut off and an immovable yardstick, to which erosion could be easily measured, had been constructed. The general lack of a sediment source, rising sea level, and construction of a seawall created a situation prone to erosion. The seawall, originally built to protect upland infrastructure and the adjacent coastal road, has been an effective backbone in the coastal defense scheme during severe storms (Sullivan et al., 1985). However, its continuing effectiveness is dependent on a constant replenishment of sand to help buffer the impact of moderate to large storms through time. At present, along the Hancock County Beach, the seawall crest is at or near beach level on the northern 8000 m portion where renourishment has recently been undertaken. Along the southern 4000 m, where there are only small pockets of beach trapped by groins, the seawall rises 1 to 1.5 meters above the mean water level. Along this stretch, even short duration sea breeze conditions create splash over onto the adjoining road. In general, the elevation of the developed upland adjacent to the shoreline is only slightly above the level of the seawall crest.

The entire Mississippi mainland lies behind a discontinuous string of barrier islands situated 12-18 km offshore that, along with the mainland coast, form the boundaries of the Mississippi Sound (Figure 1). Mississippi Sound is a shallow (average 3 m depth), long (131 km), and narrow (average of 15 km) east – west trending body of water (Higgins and Eleuterius, 1978). Winds typically blow from the north in the winter months and from the southeast to southwest the remaining portion of the year (Eleuterius, 1998). The strongest winds come from hurricanes that have historically affected the coast, either as a direct hit or in close proximity, about three times per decade and from winter cold fronts (Lana, 1998). The high return rate of hurricanes is among the reasons for the initial construction of seawalls in Mississippi. Tides in Mississippi Sound are microtidal and diurnal with a range of 0.5 meters (US Department of Commerce et al., 1977). As the Sound is relatively shallow and has a surface area of over 2 billion square meters, wind tides can have a more pronounced effect than the gravitational tides. Given the shallow slopes of the Mississippi beaches this can either expose several hundred meters of normally submerged nearshore or cause water to encroach on the seawall. Despite a relatively low-energy regime in Hancock County, the nearshore exhibits a well-developed and extensive nearshore bar pattern that shows little chronological change (Oivanki, 1994b) and may be associated with standing waves (Nummedal et al., 1980).

The Holocene history of the western portion of Mississippi Sound is directly influenced by the formation and abandonment of the Saint Bernard lobe of the Mississippi River Delta (Otvos, 1985). The prograding Saint Bernard created a large subaerial subdelta that almost completely shielded the shoreline from the Gulf of Mexico, although deltaic sediments did not bury the shoreline itself. Subsequent abandonment and erosion of the Saint Bernard delta about 1200 years ago (Frazier, 1967) returned the shoreline to its present conditions. Nearshore Holocene sediments are underlain by Pleistocene units, including the Prairie, Biloxi, and Gulfport formations that represent alluvial/fluvial, brackish/marine, and nearshore/beach deposits, respectively (Otvos, 1985).

The 10 km renourished Hancock County Beach system is significantly smaller than the 40 km long artificial Harrison County Beach system to the east. The combined Hancock Beach System is at present about 8000 meters long and has undergone several renourishments (Dixon and Pilkey, 1991; Sand Beach Planning Team, 1986; Trembanis and Pilkey, 1998) since the construction of the seawall in 1928. The most recent county project was completed in 1994 (Oivanki, 1997); a smaller project was completed in 1996 on the beach fronting the downtown section of Bay St. Louis to the north of the study area. The two most volumetrically important renourishments in the study area were in 1967 and 1994; the 1967 renourishment created a 45 to 60 m (150-200 ft) wide beach from the bare seawall, the 1994 renourishment a 60 to 68 m (200-225 ft) wide beach.

Picture 1. View towards shore from vessel anchored over borrow pit; piling is several meters shoreward of the actual borrow pit.

Sand for the latest renourishment (1994) came from an offshore borrow site less than 700 m from shore (Picture 1, Figure 2); sand for the 1967 renourishment was also pumped in. Offshore Holocene sediments in the area are not typically suitable as a source for renourishment; they are dominantly muddy fine sands to sandy mud (Otvos, 1985). However, a broad, shallow (<1.5 m deep) nearshore sand platform extends from the shoreline up to 700 m offshore; it has been and continues to be used as a sediment source.

Methods

To define fill volumes, interpret the Holocene sediments and describe the underlying Pleistocene units, a series of vibracores and hand augers was taken on regularly surveyed (Oivanki, 1997) cross shore profiles (Figures 2 and 3). Each profile was surveyed using a total station, and every other cored (see Figures 2 and 3); each core location was also surveyed-in to establish accurate elevations. Hand augers were used to core the subaerial beach at two or more locations along the profile; samples were recovered at every half a foot (0.15 m). Hand auguring in unconsolidated and saturated soils was accomplished by inserting a section of aluminum pipe into the borehole to act as a well casing. Total auger depths ranged from 2 to 4 meters. Hand auger data were recorded in the field and sampled for later analysis. Vibracores were taken at elevations of between -0.75 and -1.25 m, corresponding to locations about 250 to 450 m seaward of the shoreline (Figure 3). Vibracores ranged from 1.8 to 4.3 m in length. Vibracores were capped in the field and then later sectioned, described, and sampled in the lab.

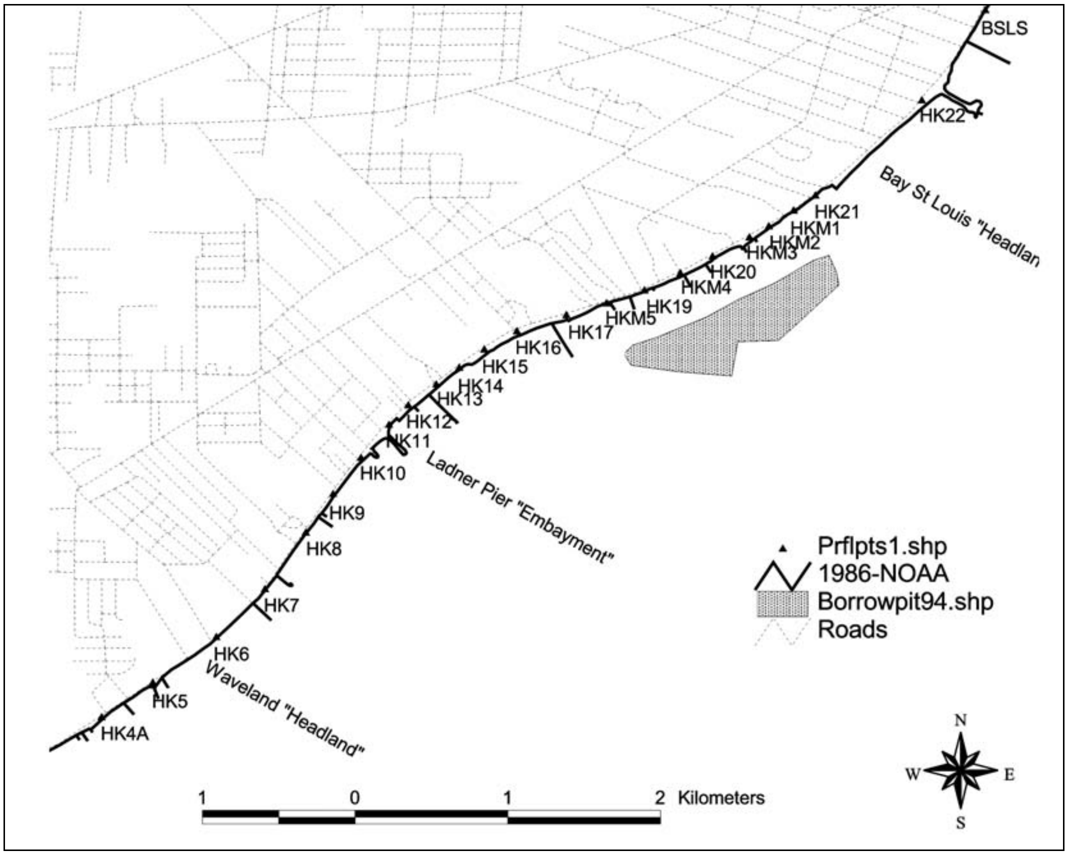


Figure 2. Profile locations along Hancock County Beach.

Several representative sample splits were taken from the Holocene section. Granulometric analysis of the samples was performed using methodology outlined by Folk (1968). Sediments with noticeable amounts of mud were washed using a 4 Phi sieve; the mud component was captured and pipetted to determine its weight percent. Median grain size and sorting coefficients were determined by the method of moments. Based on settling characteristics of the mud, the pan/mud fraction was assigned a medium silt value. Composition of units was also visually estimated in samples and whole cores.

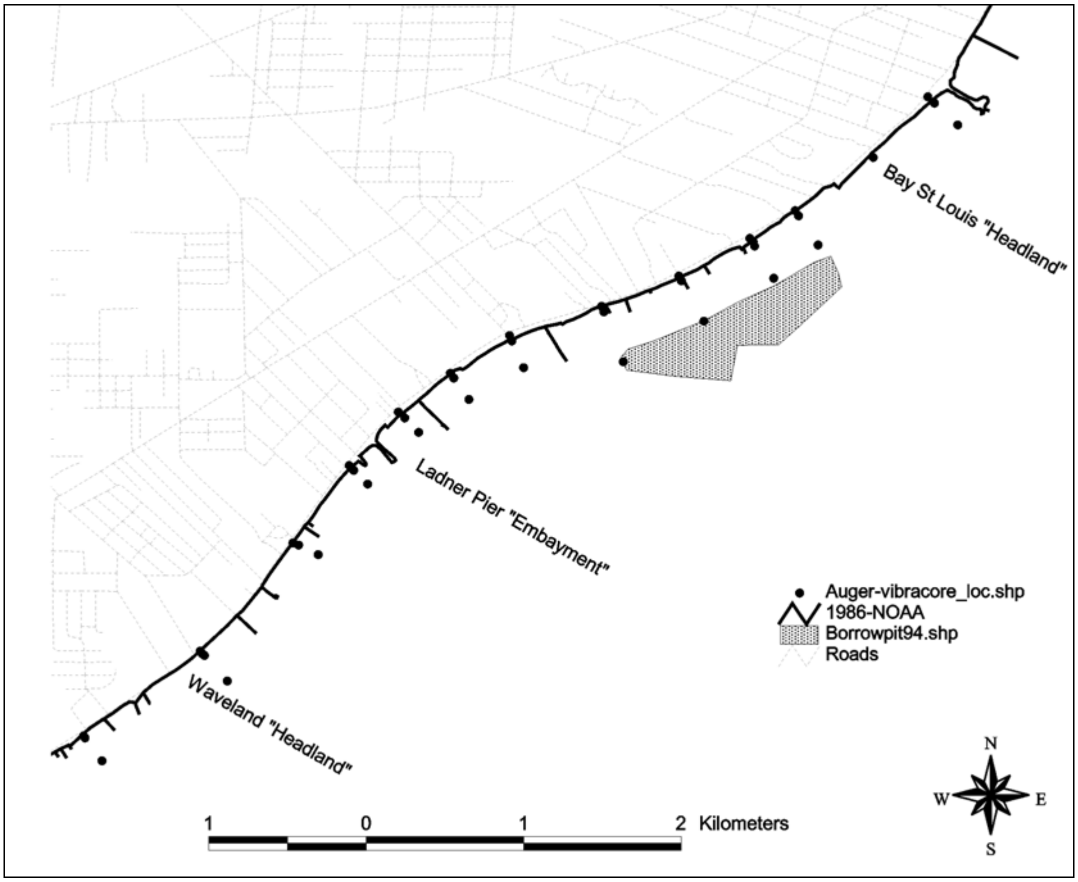


Figure 3. Auger and vibracore sample locations at the study site; sample locations represent control points for subsurface interpretations.

Previously established profiles (Figure 2) had been surveyed annually to semi-annually since 1991; they extended from the seawall to an elevation of about -1.25 meters, where, typically, the depth increases rapidly and sediments turn muddy. The shallow nature of the nearshore platform and low-energy setting significantly aid in profiling. The present mean high tide shoreline position has been surveyed annually using kinematic Global Positioning System (GPS) technique since 1993 by Oivanki (1997) on the shoreline position and further analyzed by Schmid (2000a).

Surveyed profiles from 1993, 1994, and 1999 were entered into a spreadsheet, converted to a Transverse Mercator based coordinate system and loaded into AUTOCAD MAP (AutoDesk, 1998). GPS data were post processed and imported into a Geographic Information System (GIS) along with vibracore, auger, and profile locations and elevations. Elevations of different units based on profile, core and sample analysis were determined and later exported to AUTOCAD MAP.

Once location and elevation data were determined, surfaces were produced using QUICKSURF (Schreiber Instruments, 1998). A Triangulated-Grid technique and a 15 x 15 grid were used to produce surfaces using profile, vibracore and auger data. Several methods of gridding were tried before settling on a grid with no surface curvature that had the least overshoots between distantly spaced points, but also showed the least precision with closely spaced points. Higher order surfaces produced highly detailed surfaces where points were closely spaced but where spacing between points or profiles became large (>200 m) the surfaces became highly suspect without "ghost points" added by the author. Because the data were not originally set up for use as a DTM (Digital Terrain Model), it was decided to use the lowest power grid method (Hicks and Hume, 1997).

Data and Interpretations

Profiles

Beach profiles were used to quantify the 1994 renourishment and document the volume of sediment flux and general sediment deposition/erosion trends following renourishment. Comparison of pre-renourishment and 1994 beach elevations interpolated from profiles shows a net addition of roughly 800,000 cubic yards (c.yds.) (Table 1) of sediment across the entire study area. The value is broken down by town to compare with the literature; Trembanis and Pilkey (1998) reported that 600,000 c.yds were used in the Waveland portion of the renourishment. The computed Waveland volume is within about 5% of the reported value.

Table 1. Profile volumes in cubic yards; 1994 volumes for total renourishment, 1994 to 1999 volumes of change during period.

	Waveland	Bay St. Louis	Total
1994 Renourishment	560,000	250,000	810,000
	Onshore	Nearshore	Net Change
1994 to 1999 volume change (entire beach)	-76,000	156,000	80,000

The total sediment volume change from 1994 to 1999 was computed using surfaces generated by profiles surveyed in 1994 and 1999 (Table 1). It is clear that there is an offshore loss component; however, there is roughly an additional 80,000 c.yds. of sediment on the nearshore that cannot be accounted for. Although some natural longshore transport may have occurred from sources to the southwest and/or northeast, it is unlikely that this would reach 80,000 c.yds. Therefore, this value is taken to represent the error in computing surfaces with profiles and roughly equates to a 2.5 cm (1 inch) elevation error over the entire study area. The error notwithstanding, the relationship between onshore loss and offshore gain is an important finding as it strongly suggests that much, if not all, of the earlier renourished sediment (fill) resides on the broad nearshore platform.

Sediment Data

Sediment data were used to map the Pleistocene lithology, Holocene thickness and lithology, and fill thickness along the study site. Two approaches were taken to establish the elevation of fill–Holocene contact along the beach. Samples taken on the subaerial (dry) beach with hand augers were analyzed to look at a change from subaqueous deposition to subaerial deposition; the nearshore (below sea-level) samples taken with vibracores were analyzed to determine changes in sedimentation rates. The two approaches to determine whether the sediments were fill or natural are treated in separate sections. Geologic units from each approach are denoted differently; onshore (hand augers) units are given numeric prefixes (1, 2, 3) and nearshore units (vibracores) are given alphabetical prefixes (A, B, C). The units are further defined as Facies F (fill) for units associated with fill deposition or Facies H (Holocene) if they were deposited before the fill events or are associated with natural sedimentation.

Subaerial Beach Samples

In augers taken on the subaerial beach, eight basic lithologies were described on the basis of texture, color, and macroscopic composition; no sedimentary structures were preserved in the coring process. The eight lithologies were further refined to four major units.

Unit 1 consists of two lithologies: yellow medium sand (1A) and light gray, medium to fine sand (1B). Units 1A and 1B had very similar median and sorting values with less than 0.5% finer than 63 μm (Table 2). They were nearly devoid of shell material larger than 2 mm, contained small pockets of black-stained organics, and composed dominantly of quartz sand. Organics were more abundant in 1B than 1A. The contact between 1A and 1B normally corresponded to the elevation of the water table except when sampling after heavy rains. Better preservation of organic material and gray color in 1B is attributed to less oxidation below the water table. Total thicknesses of 1A and 1B together ranged from 1 to 2 m and typically decreased in thickness towards the shoreline. Based on sediment descriptions, stratigraphic position and elevation, these two backshore to foreshore units are interpreted as fill (Facies F) used in renourishment.

Table 2. Subaerial beach auger sediment data – Holocene units.

Unit	n	Mean (phi)	Sorting (std dev)	Mud%
1A	3	2.01	0.58	0.08
1B	3	2.11	0.60	0.30
2	4	2.48	1.05	5.76
3	3	3.20	1.79	21.36

Unit 2, a light greenish-gray, slightly organic, silty medium to fine sand differed in color and texture from the above units; its darker gray to greenish color is indicative of an increase in mud-sized sediment (Table 2). Organic and shell fragments were more abundant than in Unit 1. Shells were abraded and highly weathered; the organic particles were black stained and dominantly carbonized wood and bark fragments. Gravel sized clasts, mostly weathered and well rounded stream gravels, are present in trace concentrations. As a consequence of the sampling technique, the bedding characteristics of the gravels could not be determined. Man-made artifacts were also found in this unit. At several locations the contact between Unit 2 and Unit 1 corresponded to organic rich layers that were less than 0.15 m (one sample interval) and consisted mainly of small carbonized wood fragments. The thickness of Unit 2 varies from 0.5 to 1.5 m; it is interpreted as the natural inshore beach sediment and/or subaqueously reworked fill sediment from the earliest renourishments. The high energy, low preservation potential of this facies combined with the sampling method makes distinction between natural and fill sediment (Facies F) difficult to impossible. However, for the practical purpose of this report Unit 2 is, based on texture, color, and composition, defined as the natural Holocene inshore to foreshore facies (Facies H) and, thus, marks the elevation of the natural beach surface.

Unit 2 typically overlies Unit 3. Unit 3 is a dark gray to brownish green, silty to muddy fine sand (Table 2) that commonly contained more organic detritus and semi-intact shell fragments. The coring process was significantly easier once reaching Unit 3 as the increased mud content and poorer sorting reduced the amount of porewater flow into the borehole. The thickness of Unit 3 varied considerably from 0 to 1.3 m and typically increased basinward (seaward). No distinct upward or downward fining trends were noticed. Unit 3 is also defined as the Holocene inshore to foreshore facies (Facies H). During the period of deposition, which is interpreted as middle to late Holocene based on stratigraphic position and elevation, there may have been pulses of higher mud content entering the system from the adjacent Saint Bernard Delta (Otvos, 1985). Therefore, in this case, a fining upward sequence, which would normally be expected from a rise in sea level, is absent. The limited thickness of Unit 3, even as significant sediment was entering the basin, is partly a result of the basin edge location.

The lower contact of Unit 3 is associated with a distinct change in lithology that defines Unit 4; the contact is abrupt with some oxidation in the upper sandy clay samples, and is tentatively described as an unconformity surface. Unit 4 consists of two subtypes, a tight, light gray-yellow to blue-green to occasionally red sandy clay (4A) and a white to humate-stained silty sand (4B). Both of these subtypes have been previously recognized and described as Pleistocene in age by Otvos (1985). Specifically, the clay unit is interpreted to be part of the Prairie Formation, which is an alluvial/fluvial unit deposited during the previous highstand (Otvos, 1985; Otvos, 1976). The humate-stained silty sand is interpreted as the Gulfport Formation, which is described as relict barrier or shoreline beach ridges that were deposited nearly contemporaneously with the Prairie Formation. Unit 4 elevations, therefore, mark the basement of Holocene deposition.

Nearshore Units

The nearshore sediments were sampled with vibracores, enabling the use of depositional structures along with texture, color, and composition for interpretation of depositional environment. Using these characteristics, three major units were differentiated. From shallowest to deepest they are: 1) Unit A, tan medium sand to greenish-gray fine sandy mud; 2) Unit B, brown to black sandy organic mud; and 3) Unit C1, tight reddish gray to bluish gray sandy clay or Unit C2, humate-stained slightly silty sand.

Units C1 and C2 are directly correlated to Units 4A and 4B in the onshore samples. The contacts between Units C and A (no cores penetrated both B and C units) are typified by a disconformity with numerous rip-up clasts, oxidation of clay minerals in the upper 0.25 m, dark humate stained organics and extensive bioturbation. These characteristics of unit C(1 and 2) are consistent with the Pleistocene age adopted by Otvos (1985) and will, along with Units 4A and 4B, be referenced as the Prairie (clayey unit – C1) and the Gulfport (sand unit – C2) formations.

Unit B consists of dark brown to black sandy organic mud with abundant wood fragments and only occurred in the bottom of two cores. In one core the top contact was marked with a layer of gravel. This unit was exceedingly tight and only small portions were cored before refusal. The elevation of Unit B's upper contact was between –2.5 and –3.0 m, which is deeper than the two adjacent cores that hit the Prairie Formation. The texture, stratigraphic position and organic content indicate that this unit represents a Pleistocene/Holocene marsh or drainage channel, which occupied a small erosional depression. Because this unit has a limited areal extent and is lower than the surrounding Pleistocene, its bottom depth (depth of refusal) is used to approximate the Pleistocene elevation at the two locations it was sampled.

Unit A consists of several lithologies, from tan well sorted sands to gray-green poorly sorted sandy mud, that occur from the sediment-water interface to the Pleistocene and represents the bulk of the cored sediments. Cores easily penetrated Unit A, which in some cases was thicker than 4 m. The unit is typified by medium to fine quartz sand. Organic staining in the upper portion is common; bioturbation is found throughout, although at different densities and with different burrow geometry. Whole and abraded shell and small wood fragments occur in trace quantities. Mud contents generally range from 1 to 15 % (Table 3) with locally higher concentrations. There is an overall coarsening upward trend; however, within individual lithologic sequences both fining and coarsening upwards sequences are present but relatively subtle. Based on the nature of the sediments, stratigraphic position, and elevations the lower portion of Unit A is interpreted to represent natural Holocene sedimentation and correlates with Units 2 and 3 (Facies H) in the auger samples. In many cores, however, the upper portion, based on profile data, correlates to Unit 1 (Facies F). The distinction in Unit A between Facies F and H is critically important to the end result and as such will be discussed in greater detail.

Table 3. Nearshore vibracore sediment data – Holocene units.

Unit	n	Mean (phi)	Sorting (std. dev)	Mud%
A1	4	2.88	0.90	10.79
A1(TYP)*	3	2.60	0.65	1.66
A2	3	2.72	0.96	5.76
A3	3	3.11	1.25	14.37

* excluding 1 sample of fine grained A1 sediment

Facies F or H?

In the preceding section, correlation of the onshore and nearshore Pleistocene surface provided the bottom elevation of the Holocene envelope. Similarly, the onshore Unit 1 was interpreted to be Facies F based on sedimentation and elevation (profile data) and, thus, defines the upper elevation of the onshore Holocene envelope. This leaves one important but as yet unanswered elevation: the upper elevation of the nearshore Holocene envelope. The result is crucial in answering the question, ‘how much of the fill sediment is staying within the system and how much is lost’. The answer requires differentiating between fill deposits (Facies F) and naturally deposited sediments (Facies H) in the nearshore. Unfortunately, unlike earlier studies (Pearson and Riggs, 1981; Thieler et al., 1994) that used a sharp contact formed by the dissimilar character of Tertiary to Late Holocene units and overlying gray colored fine sands dredged from the adjacent estuary to determine fill thickness, the similarity of the fill sands, largely derived from the nearshore Holocene layer, limits the contrast of the Fill/Holocene contact. In short, there is no distinct erosional surface in this setting from which deposition can be measured nor is there a tracer “type” of sediment that characterizes the renourished sediment along the beach. Therefore, a hierarchal approach is used with the available data sources.

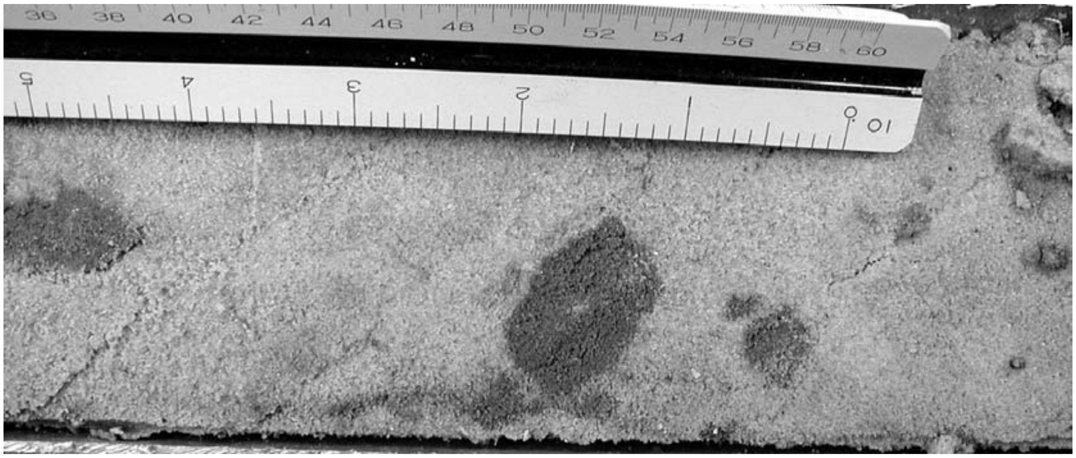
The primary data source is interpretations from vibracores. Within Unit A there are several sub-units that are distinguished by stratigraphic position, changes in texture or textural sequences, sedimentary and burrow structures, and location on the broad nearshore platform.

These individual units will be further separated into potential fill units (Facies F) and naturally deposited sediments (Facies H). Differences in depositional patterns (wave energy) within the study area and locations of cores with respect to the nearshore boundary (water depth, seaward location) limit the use of single sediment parameters, such as grain size, sorting, composition or mud content, to qualify a sediment as natural or fill. Instead, changes in sediment parameters mark horizons that compartmentalize the Holocene layer.

Along with core descriptions and grain size analysis, profile data, which encompasses the fate of the most recent (1994) renourishment sediments, is used to describe the spatial character of sedimentation along the beach, whether dominated by erosion, transport (minor erosion or deposition) or deposition. The accuracy of these data is documented by volumetric calculations shown in the previous profiles section (page 11).

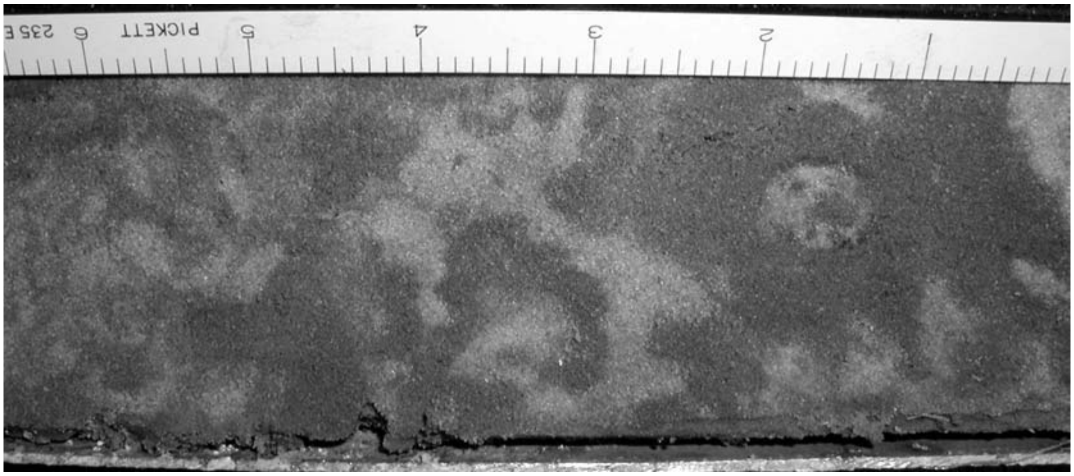
Unit A Sub-units

Upper sections of vibracores contain one to two sequences that are subtly distinguished from the bulk of the underlying sediments by changes in burrow concentrations and textural trends. Unit A1, the uppermost portion of Unit A, showed a broad range of sediment character, as would be expected on a fairly low energy shoreface. It generally consists of tan-gray sand (Table 3; A1(typ)) that is lightly bioturbated to chaotically bedded (Picture 2). There was, however, a noticeable difference in three deeper cores (> 1m water depth) near Ladner Pier. Dark gray-green muddy fine sands with significant organic staining typify unit A1 in these cores. Shells, weathered or whole, are noticeably absent in Unit A1. Burrows where present, commonly have a round, horizontal geometry and are filled with dark organic silts. Unit A1 ranges in thickness from 0.25 to 1.0 m, with the thickest deposits on the northeast and southwest ends of the study area, where cores were taken on the crest of megaripples, and the lowest thickness in the middle of study area. No characteristic fining upward or downward sequences define A1; the northeast and southwest cores show no trends, the middle cores fine upward. This unit may reflect high sedimentation rates initially following renourishment; or localized short-term mixing such that conditions are not averaged over any significant length of time and, thus, show different textural trends across the study area.

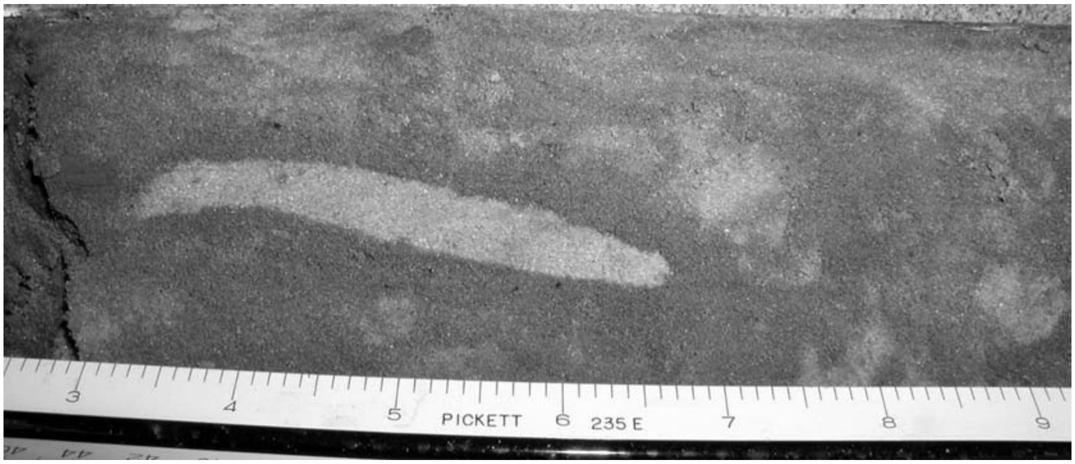

Picture 2. Unit A1 in the core barrel; note the horizontal trace fossils.

Unit A2, where present, underlies unit A1 and is a more homogenous sediment unit. It generally consists of light greenish-gray muddy sand (Table 3). Shells and organics are slightly more abundant and trace fossils are filled with both organic silts and clean sands (Picture 3). Unlike Unit A1 there is no major spatial difference along the beach. Sedimentary characteristics of this unit suggest that deposition is averaged over a longer period, but it is neither clearly a fill unit nor a natural sediment unit. The contact between A1 and A2 is gradational. It is mainly associated with a slight change in bedding or burrow characteristics and typically a slight increase in mud sized sediment (Table 3). Unit A2 is more heavily bioturbated than A1 and burrows were typically larger in size (up to 4 cm wide). Unit A2 is from 0 to 1 m thick.

Unit A3 extends from the Holocene/Pleistocene surface to the contact with either Unit A2 or A1. It is the thickest of the A units and has been interpreted to be part of Facies H. The unit differs in that it is generally finer grained (Table 3), poorly sorted, and contains higher concentrations of whole and partial shells. Trace fossils are mainly filled with clean sands (Picture 4). The lowest portions of the unit contain rip-up clasts from the underlying Pleistocene. Like the previous units its upper contact with either Unit A1 or A2 is subtle and typically gradational.



Picture 3. Unit A-2 in core barrel; note the increase in mud (dark) content and higher level of bioturbation than in Unit A-1.



Picture 4. Unit A-3 in core barrel; note the large vertical trace fossil filled with clean sand.

Profile Data

Profile data from 1994 and 1999 were used to describe the volumetric change of the 1994 fill sediment. Renourished sediments were initially placed on the backshore to foreshore portion of the beach and left to adjust themselves into a semi-equilibrium profile; subsequent maintenance operations such as bulldozing probably hastened the deflation of the beach profile. Annual profile data indicate that after two to three years the profile changes became subtle, having achieved a state of semi-equilibrium. Therefore, it is tentatively assumed that a five-year period is long enough to highlight the basic sediment transport patterns on the beach.

Profile differences from 1994 to 1999 were mapped and compared to highlight sediment deposition trends. Areas that had a clear positive elevation change were defined as depositional, areas with marginal elevation changes were defined as transport, and areas that had a negative elevation change were defined as erosional (see Figure 5).

Combined Data

To mate vibracore and profile data an "if then" logic is used. By using core and profile data together in this fashion, Holocene compartment elevations are accepted or rejected based on sedimentation patterns at each core location. The use of two data sources is necessary because of the difficulty in determining with certainty the difference between fill and natural units. The technique helps provide consistent elevations of the Fill/Holocene surface based on a set of depositional rules. The logic follows that areas: 1) associated with deposition have high accommodation space (lower Holocene elevation), 2) associated with transport have less accommodation space and higher energy, and 3) associated with erosion have a higher Holocene (Facies F) elevation (low accommodation space). These basic rules are incorporated into an "if then" logic to help reduce obvious errors. Obvious errors are those that would assign areas with notable profile accretion to low fill thicknesses, or are areas typified by erosion assigned high fill thicknesses. In all, this process is used to increase repeatability in the contact elevation between Facies F and H, yet it does so at the expense of strictly defining natural vs. artificial sediment character.

The rule-based "if then" interpretation of the Facies F-H contact combines two variables, Unit A sub-units (A1, A2, and A3) and profile change between 1994 and 1999 to produce a cross section with the onshore units (Figure 4). **If** the location of the nearshore core was within a depositional area **then** the Facies F-H contact was defined at the Unit A3 contact such that both Unit A1 and A2 are defined as fill. **If** the core is an erosional area **then** the Facies F-H contact is defined at the contact between Unit A2 and A1. In several erosional areas Unit A1 and A2 were nearly indistinguishable and thus both treated as natural sediment such that the Facies F-H contact lies at the sediment-water interface. Finally, **if** the location of the core was within a transport area **then** the Facies F-H contact was set at the Unit A2 contact, or if the A1 and A2 units were indistinguishable then at the A3 contact.

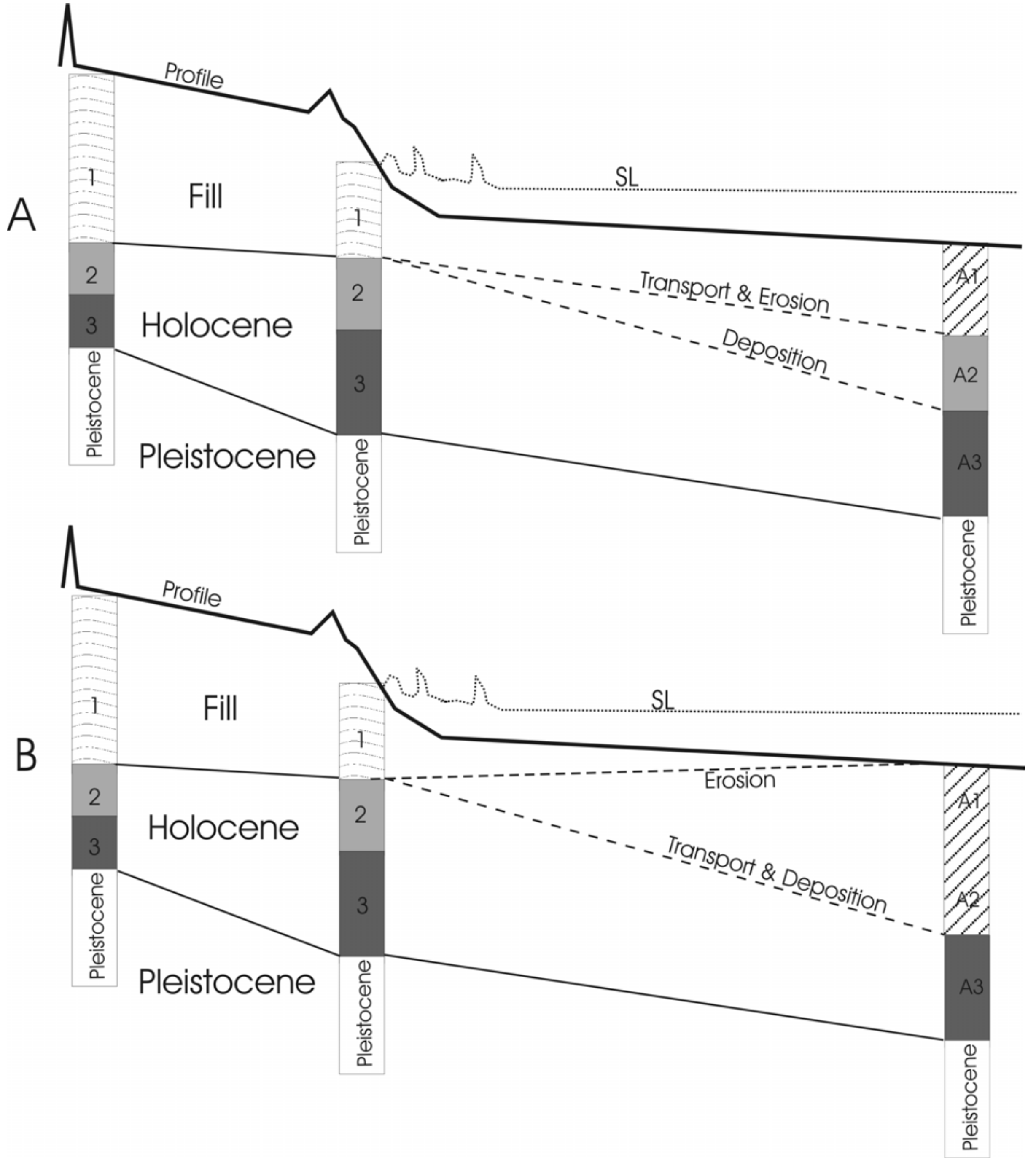


Figure 2. "If Then" logic diagram detailing facies determinations and resulting subsurface interpretations; A) "if then" cross section possibilities if the nearshore A1 and A2 units could be differentiated; B) cross section possibilities if units A1 and A2 were undifferentiable.

Results

1994 Renourishment

Elevation (profile) data used to track the recently added sediments offer a strictly measured summary of the general sediment flux occurring on the Hancock County beach. Comparison of interpolated bathymetry from profile data taken in 1994 and 1999, which encompasses the life of the present renourished beach (Table 1), suggests that it is nearly a closed system. Sediment losses would include longshore transport beyond the end of the renourished beach, sand blown inland, and sediment transported offshore beyond the nearshore platform. Likewise sediment sources would include longshore drift and mud deposition settling out from the water column.

In general the entire nearshore was elevated from 1994 to 1999, while the onshore portion was deflated (Figure 5). Therefore, build-up of the nearshore platform is, to a large degree, occurring; however, the pattern also indicates that the extreme northeastern and southwestern portions are not receiving significant sediment input from the renourished foreshore. These areas may be dominated by longshore drift as opposed to offshore sediment migration. Given that the trend is toward nearshore enhancement, the nearshore area could potentially grow vertically by 0.3 m (12 inches) if the entire 1994 package of renourished sediment were transported seaward. More importantly, the trends indicate that sediment from earlier renourishments should, to a large degree, also remain on the nearshore platform and comprise a significant thickness.

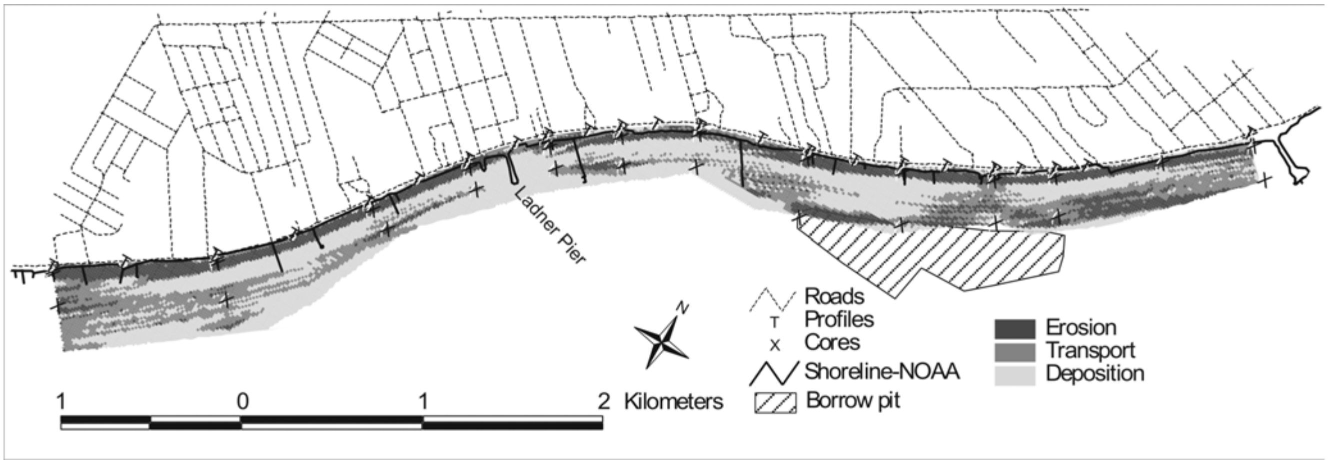


Figure 5. Sedimentation patterns from 1994 to 1999 based on changes in profile elevation.

Facies F and H

Elevations of the Facies F – H contact were determined from core data and depositional characteristics of the nearshore platform, as discussed previously. These elevations represent the natural Holocene surface. Facies F – H contact evaluations were subtracted from the measured 1999 bathymetry to arrive at Facies F thicknesses and volumes (Table 4). The thickest areas were on the dry beach, where much of the recent renourishment remains (Figure 6). On the nearshore platform, the area southwest of the borrow area has the thickest deposit; the area to the south of the Ladner pier had the thinnest Facies F deposits. These thin deposits correspond to the area where muddy surface sediments dominate and the nearshore platform is fairly narrow. It should be noted that as a result of core locations the fill thickness map area (Figure 6) is slightly less than the actual nearshore area; however, the thickness of Facies F at the extreme southern end appears to be marginal and should not significantly change the volume calculations.

Table 4. Sediment volumes for the study area.

	Onshore	Nearshore	Total
1994 to 1999 change	-76,000	156,000	80,000
Total Fill (1945-1999)	700,000	980,000	1,680,000
Total Holocene*	640,000	3,250,000	3,890,000

*Actual volume higher on the nearshore than reported because of incomplete calculation area (see Figure 7)

Calculated volumes serve two purposes; first, and most importantly, they help check the validity of the Facies F and H contact; and second, they summarize the basic nature of the beach. The total onshore volume of about 700,000 c. yds. (Table 4) agrees fairly well with the addition of roughly 800,000 c.yds. in 1994 and implies that little sediment remains from the previous renourishments in 1941, 1967, and 1972 (Sand Beach Planning Team, 1986). This volumetric consistency also suggests that the onshore contact elevations between Facies F and H are correct.

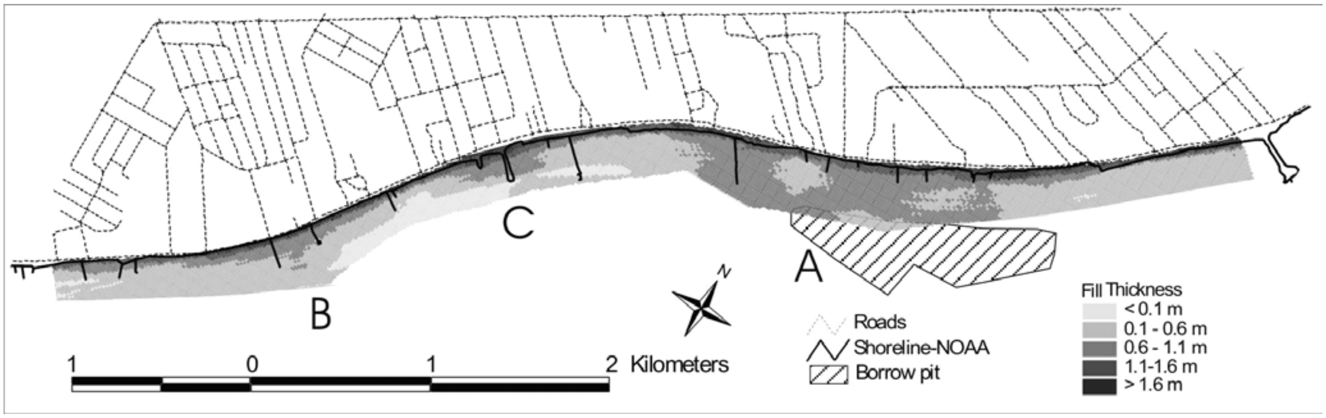


Figure 6. Fill thickness across the study area based on the Facies F-H contacts.

Assuming the two largest renourishments (1967, 1994) contained similar amounts of sediment, based on similar beach widths (Sand Beach Planning Team, 1986), over the study area then there would be the potential for a total of roughly 1,600,000 (800,000 x 2) c. yds. of renourished sediment. Some of which would have been lost, but it is possible that a certain amount of additional muddy sediment was deposited over the 33-year period. The computed total volume of the fill layer (Table 4) comes very close, about 5% difference, to the theoretical value. The fill volume on the nearshore platform represents an average thickness of 0.44 m (17 inches). The overall volumetric accuracy adds validity to the Facies F – H contact elevations and to the depositional patterns that they suggest.

As nearshore sources have been used in the past to renourish beaches, it is reasonable to look at the total amount of Holocene/Fill sediment that is resident on the nearshore platform. The contact between Facies H and the Pleistocene marks the lower boundary; the sediment-water interface marks the upper boundary. Unlike the contact between Facies F and H, the Pleistocene is easily distinguished from the overlying Holocene. The interpolated area is smaller than previous areas because several of the cores did not reach the Pleistocene. In the partial interpolated nearshore the combined Holocene/Fill volume is 4.2 million cubic yards. Holocene thickness is highest in the areas offshore of the two slight headlands (Figure 7).

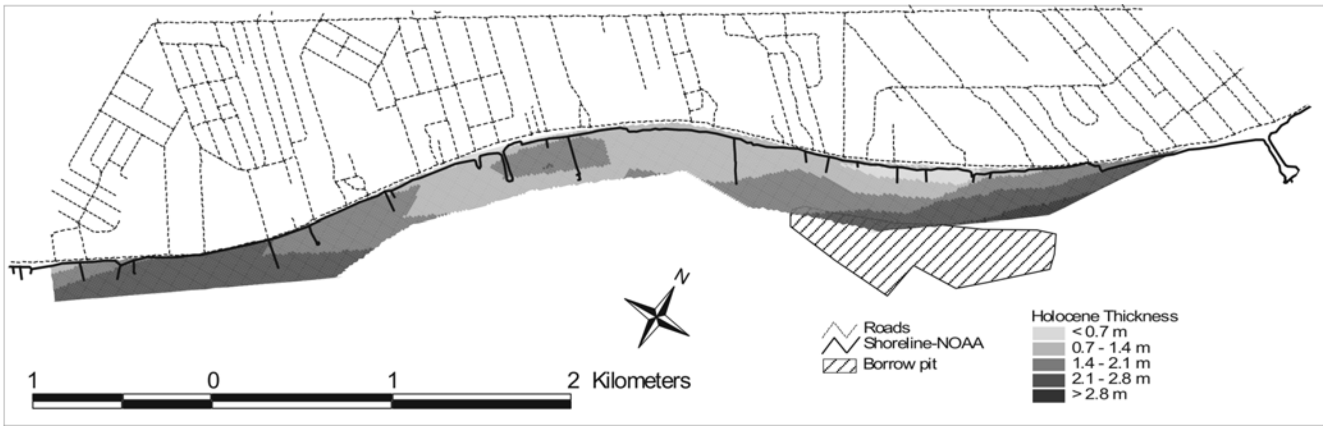


Figure 7. Holocene thickness; northeast portion is limited because several cores failed to reach the Pleistocene surface.

Discussion

Previous research has shown that sediments used for renourishment can themselves be used to document sediment patterns (Pearson and Riggs, 1981; Thieler et al., 1994). They are, in effect, used as a semi-controlled tracer experiment. This type of experiment is aided by the use of "unique" fill sediment; or, alternately, with highly accurate bathymetry prior to and following renourishment. Use of both the fill sediment and bathymetry in Hancock County were limited, either by time in the case of the bathymetry or by geology in the case of fill type. These practical aspects make using the renourishment event as a tracer experiment more difficult.

In the Hancock County beach example, the most recent renourishment was preceded and followed by accurate profile data out to the edge of the nearshore platform; however, the older renourishments lack sufficient baseline survey data for use as a tracer experiment. In addition, the sediments used as fill are themselves part of the nearshore Holocene compartment. No unequivocal textural and compositional differences exist between known fill in the uppermost layer and the bulk of the Holocene layer. However, trace fossils, the sediments filling them, small changes in shell content and faint contacts helped distinguish small sedimentary sequences. The existence of large bedforms would also seem to play a role in determining sedimentary sequences. However, the apparent stability of the features over tens of years (Oivanki, 1994b) suggests that bedform movement was slow enough to facilitate destruction of crossbeds by bioturbation. To increase confidence in the elevation of Fill – Holocene contacts an 'if then' logic using both profile and sediment data was used. This technique, while taking some of the purity out of the interpretation, helped increase the confidence of picking the Fill – Holocene boundary based on sediment deposition patterns and sedimentary sequences. With all of the facies elevations now defined it is possible to examine the Holocene evolution of the nearshore and document sedimentation patterns in response to renourishment, underlying units, and sand dredging.

Renourished Sediments (Facies F)

Recognizing renourished sediments was made difficult by the use of nearshore sediments as a source; however, the low energy, depositional nature of the study area facilitates the successful use of profile measurements out to the nearshore/offshore boundary. Core data helped extend the sediment history back to the earliest renourishment (ca. 1940's). This provides an insight into the overall sediment depositional patterns occurring on the Hancock County shoreline. Based on the findings, there are three principal nearshore areas with higher depositional trends (Figure 6); two are associated with slight shoreline headlands (A and B) and the third is in an embayment with large groins (C).

It is not surprising that one of the thickest fill areas (label A: Figure 6) is adjacent to the dredge pit used in the latest renourishment because this area also has a thick Holocene sequence (Figure 7) and, thus, a continuous history of deposition. Note, however, that following excavation of the dredge pit for sand, the sedimentation patterns adjacent to the pit appear to have switched to transport or even erosion (Figure 5). The second headland area (B) is also associated with a fairly thick Holocene deposit (Figure 7), but low fill thickness (Figure 6) and recent transport (Figure 5). These differences suggest that the northeastern headland (A) has a higher offshore component than the southwestern headland (B), such that fill sediments are moved offshore from the subaerial beach in the area adjacent to the borrow pit (A) and in doing so may be gradually filling in the pit. The embayment depositional area (C) is in the only segment in the study area with large shore-normal structures. These groins are efficient in trapping longshore movement; however, adjacent areas exhibit low fill thicknesses. Areas associated with little or no renourishment sediment are typified by thin Holocene thickness (high Pleistocene elevations) and, thus, appear to have always had a low deposition potential.

Natural Sediments (Holocene and Pleistocene)

The Holocene surface (Figure 8) is clearly related to the underlying Pleistocene formation and/or shoreline orientation. Where Gulfport sands are resident (headlands) the Holocene surface dips moderately towards the southeast. In areas underlain by the Prairie Formation, the Holocene surface dips toward the embayment axis and in the embayment the surface dips steeply toward the southeast. The result is a broad, gently dipping platform in the headland areas and a thin, steeply dipping platform in the embayment. This suggests that the Holocene sediments are largely reworked from the underlying Gulfport sands and have not shown much longshore movement and/or were preferentially deposited in the headland areas. In the likely case that the broad Holocene platform is a product of reworked Gulfport sands, it would suggest that there is minimal longshore drift – with more of an offshore-onshore transport component. It is also possible that once the broad platform was established the energy regime associated with the headland was such that deposition was enhanced (Carter et al., 1990).

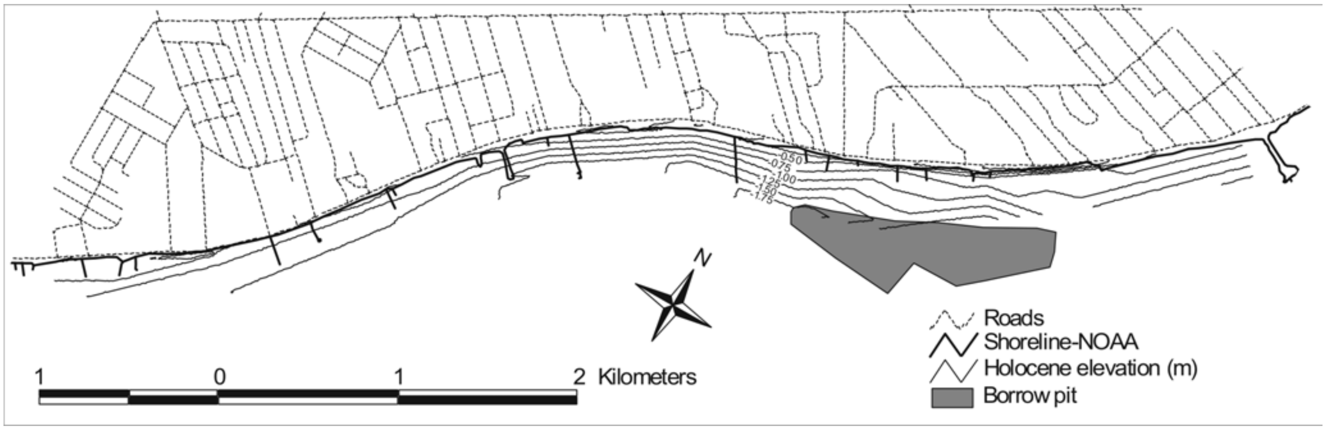


Figure 8. Holocene surface contours; control points are shown on Figure 3.

There appears to be a good correlation between thick Holocene deposits and the underlying Pleistocene units. Holocene thicknesses in locations underlain by Pleistocene Gulfport sands are greater than where Prairie mud and clays are resident (Figures 7 and 9). This relationship is partly attributed to the fact that the Gulfport Formation surface elevations tend to be lower than the Prairie Formation (Otvos, 1992). In the nearshore, the Pleistocene surface topography follows this trend, such that the elevation of the Prairie surface tends to be higher than the adjacent Gulfport. This suggests that the two units eroded equally during initial flooding (Figure 9). Lack of detailed onshore stratigraphic control limits the interpretation of the shoreline configuration, particularly for determining whether the headlands are a result of slightly elevated Gulfport ridges running semi-perpendicular to the present shore, a result of antecedent fluvial/alluvial processes, or both. This is an important question, as the headlands appear to control the overall Holocene sedimentation patterns (Oivanki, 1994a), including the fate of recent fill sediment. Given the data, one can only make the generalization that areas associated with the Prairie represent the embayment while those areas associated with the Gulfport represent headlands.

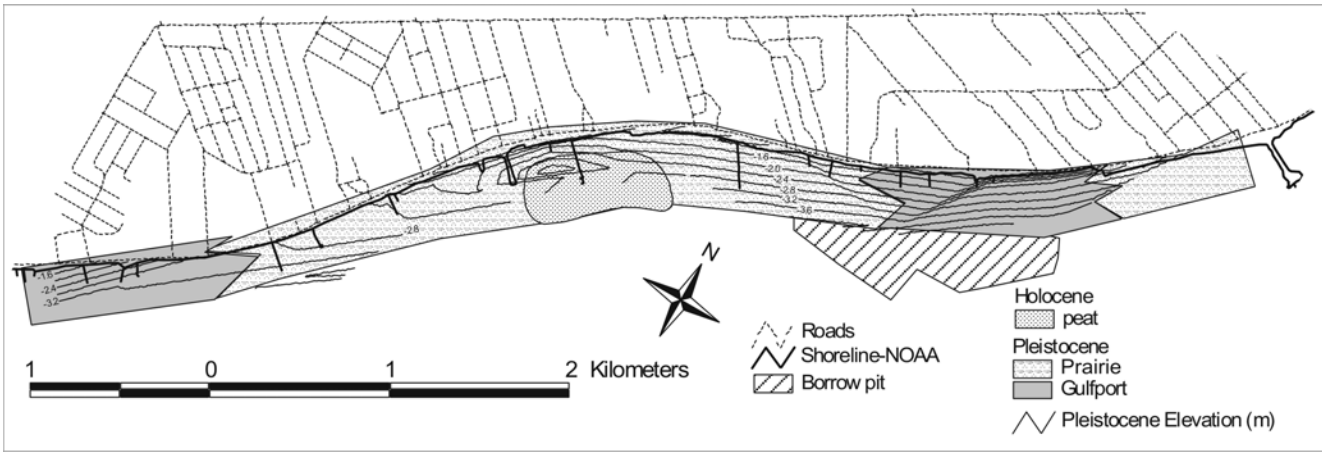


Figure 9. Pleistocene units and surface elevation (m) based on cores taken in study area.

Conclusion

To achieve the intended goals of quantifying and describing nearshore sediment movement and deposition following repeated renourishment and associated nearshore mining, a combination of survey and geological data was used. Profile data provided recent changes associated with the latest renourishment; core data, although limited in resolution, helped document long-term sedimentation. Taken in tandem the two partial datasets provide a lengthy record of sedimentation including renourishment and natural Holocene deposition. The use of profile data along with core data taken offshore of a renourished beach represents a practical approach to a difficult situation in this study area. Use of this technique highlights the wide-ranging utility of monitoring activities prior to and following renourishment.

1) In the study area, recent renourished sediments were predominantly transported off the subaerial beach and deposited on the nearshore. Volume estimates further imply that the beach is nearly a closed system.

2) Combining data sources using a basic set of rules and an ‘if then’ logic helped resolve the long-term fill-Holocene contact. Subsequent volume calculations are in line with the theoretical value from the two largest renourishment projects.

3) The location of the borrow site was in an area of high Holocene deposition and coincides with a sandy Pleistocene formation. A similar area exists at the southwest end of the study site. Following excavation, however, the area immediately adjacent to the borrow location appeared to be adversely affected by the resulting ‘hole’ in the nearshore platform.

4) The Pleistocene units control Holocene thicknesses and fill thicknesses. Muddy Pleistocene units (Prairie Formation) are topographically higher than sandy units (Gulfport Formation), and have limited Holocene thickness. Areas with low Holocene thicknesses are also associated with low fill thicknesses, possibly as a result of lower accommodation space.

5) The existence of the two headlands and the presence of the Gulfport units is likely an important component in the development of a wide nearshore platform. Continued progradation of the nearshore platform should increasingly buffer erosion at the shoreline, and should also reduce future renourishment costs.

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