AN INVESTIGATION OF SEDIMENT TRANSPORT BEHIND THE TEXAS CITY DIKE

A Senior Scholars Thesis

by

APRIL LYNNE TAYLOR

Submitted to the Office of Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

April 2007

Major: Marine Sciences

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Approved by:

Research Advisor: Timothy Dellapenna
Associate Dean for Undergraduate Research: Robert C. Webb

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ABSTRACT

An Investigation of Sediment Transport Behind the Texas City Dike (April 2007)

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In 1915, the Texas City Dike was built to block the sediment from migrating into the Texas City ship channel. The Texas City Dike is proximal to the flood tidal delta of the Bolivar Roads entrance, and it appears that the Texas City Dike has the potential of trapping a large quantity of sand. For this study, it is hypothesized that the Texas City Dike is trapping significant volumes of sand. To test this hypothesis, we collected a series of short vibracores in January of 2005 along the north side of the dike, conducted a grain size analysis, and have analyzed the historical dredging records. In fact, this study confirmed the null hypothesis the Texas City Dike does not contain significant sand because the accommodation space where sand would be trapped has been used as a placement area for dredge spoils.

ACKNOWLEDGMENTS

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I would like to especially thank the members of the Coastal Geology Lab. Thank you Robert Webster, Bryan Fielder, Christian Noll, Julie Manuel, Jeffery Berg, and Dr. Ernest Estes for their help with data collection, analysis of data, and their extensive support throughout this project. Finally, thank you Dr. Timothy Dellapenna for all your support, patience and for providing me with many opportunities.

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CHAPTER I

INTRODUCTION

Galveston Bay is a bar built estuary located on the upper Texas coastline. Its two main river inflows include the San Jacinto and the Trinity Rivers. With a total area of 1360 square kilometers (600 square miles), Galveston bay has four sub-bays—West Bay, East Bay, Trinity Bay, and Upper Galveston Bay, which equals 373 kilometers (232 miles) of bay shoreline (GBEP, 2002; Allison Et al., 2006).

As a main asset of the bay, the shipping industry has an ongoing relationship with Galveston Bay. The three ports in Galveston Bay are the Port of Galveston, the Port of Texas City, and the Port of Houston. The Port of Texas City is 8^{th} largest port in the U.S. and 3^{rd} in the state of Texas, and the Port of Houston ranks first in metric tons of cargo in the U.S. (GBEP, 2002; Allison Et al., 2006). As a result of this growing industry, navigational dredging has become an issue in transportation aesthetics, economic benefits, and in the environmental affects to the bay. Interrelated, the possible use of the dredge spoil material and placement area locations have become an issue. In 1990, the Interagency Coordination Team (ICT) created the Beneficial Uses Group (BUG) to reduce open bay disposal of dredge material and to find other uses for the material including use for creating marsh and various habitats (GBEP, 2002). Furthermore, in search for possible uses for the material, the General Land Office of

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This thesis follows the style and format of Estuarine, Coastal, and Shelf Science.

Texas has proposed the Galveston Sand Source Study—to locate potential sand sources in the bay for future beach nourishment of Galveston Island.

The natural Galveston Island beach sand is 0.11-0.15 mm (3.0 -3.5 phi) in mean grain size. Placement of coarser material than this size would result in a steeper beach slope, and the use of finer material would create a shallower beach slope and the sand would move offshore and require larger volumes of sand.

The Texas City Dike was chosen as one of the first sites in Galveston Bay to be investigated for a sand source. In January of 2005, 13 vibracores were collected, and core analyses conducted, including lithologic core logs, core photographs, water content, and a grain size analysis. A grain size analysis was used to determine whether a sand deposit exists along the Texas City Dike and a dredging record was documented. For the grain size analysis, a Malvern particle size analyzer was used to determine the grain size distribution. Grain size parameters were compared to the natural beach to determine if this site was a viable sand source.

Texas City Dike Study Area

As shown in Figure 1, the Texas City Dike is located on the upper Texas coast in the southern part of Galveston Bay and extends from the mainland toward Pelican Island. It is currently 8.4 kilometers (5.2 miles) long and parallels the Texas City Ship Channel (GBEP, 2002).

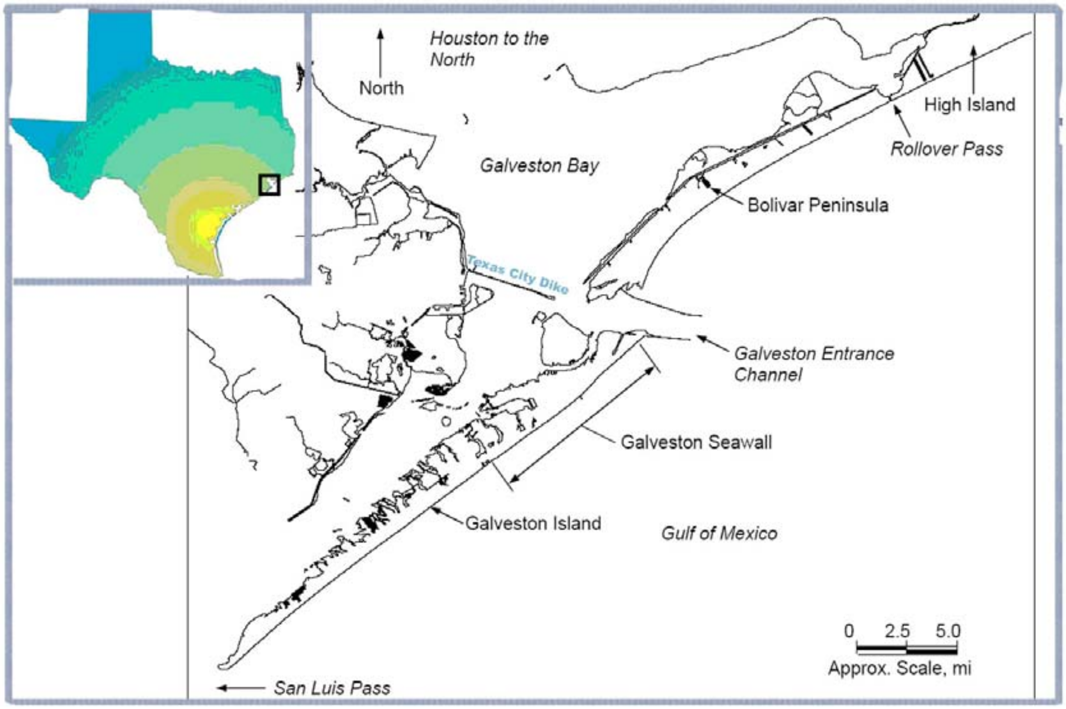

Fig. 1. Map of Texas City Dike in relation to Galveston Bay.

The Texas City Dike was built in 1915 to protect the Texas City Ship Channel. As a result, it greatly restricted sediment exchange between Galveston Bay and West Galveston Bay (GBEP, 2002; Ward, 1993).

In January of 2005, a crew from Texas A&M University at Galveston collected thirteen vibracores in five shore-normal transects along the entire length of the 8.4-kilometer dike. The transects were numbered sequentially starting at the northeast end (see Figure 2). A summary of core sites, water depths, and core lengths can be found in Appendix A.

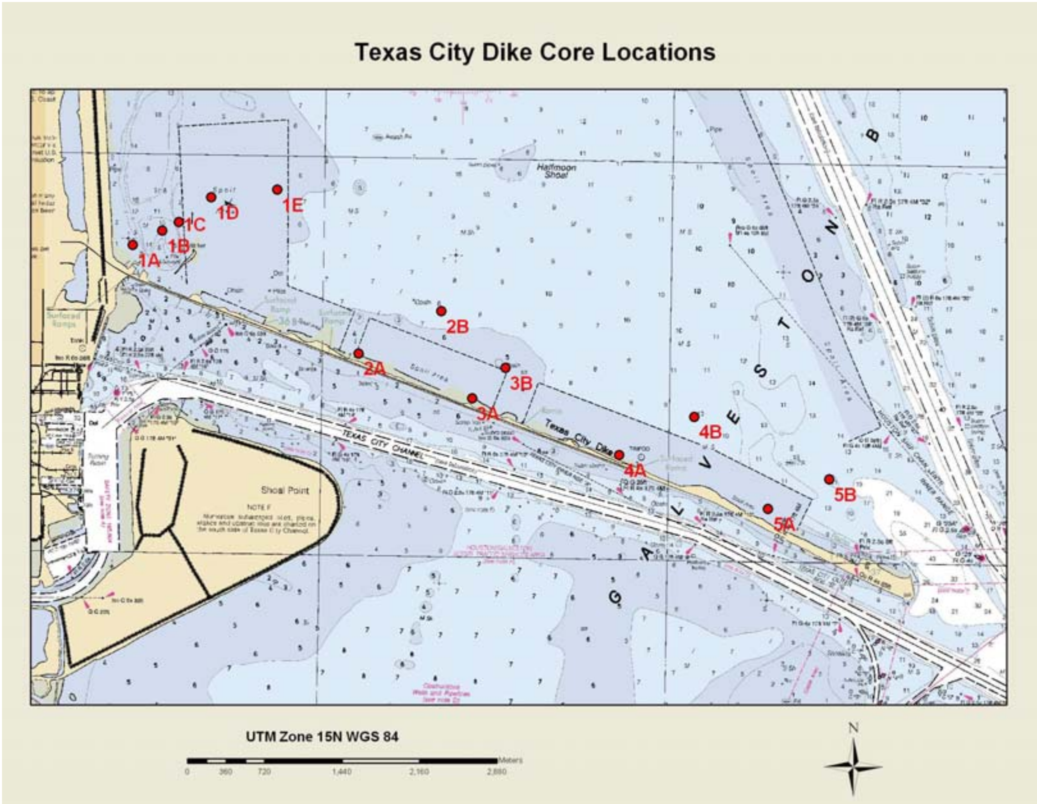

Fig. 2. Core location map

History of Texas City Dike Area (1855 to the present)

The history of the Texas City Dike area was documented from 1855 to the present. The primary source of research material was from the Corp of Engineers Library's dredging records.

Several surveys made in the mid-1800s demonstrated the dynamic morphology of the estuary, before dike construction, showing the shifting shoals, channels, and tidal deltas present in the region (see Figure 3).

1855 1898

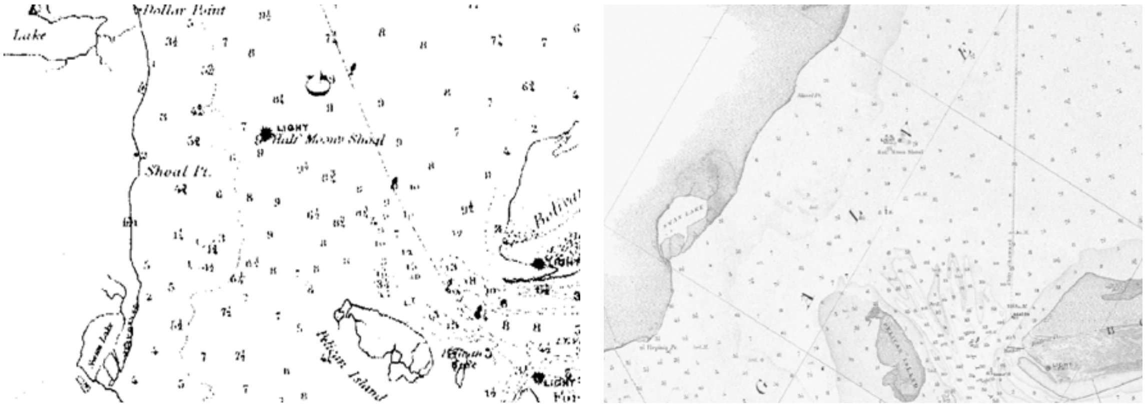

Fig. 3. Historic charts from 1855 and 1898 showing the presence of Half Moon Shoal and Pelican Island ("Historical," 2004).

In 1893, dredging of the Texas City Ship Channel began; however, dredging was delayed due to Pleistocene fossils being found and palentological excavation of mammoths sparking an interest in the area (see Figure 4). As the dredge material was searched through, the spoil was placed parallel to the channel creating a berm or elongated mound of sediment and for years as erosion occurred along the berm fossils emerged (GBEP, 2002).

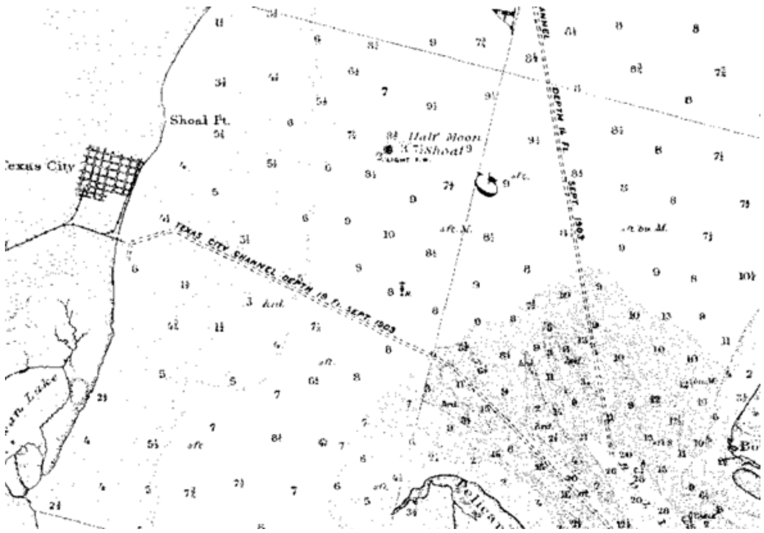

Fig. 4. Historic chart from 1901 showing the first presence of the Texas City Ship Channel (“Historical,” 2004).

The Texas City Dike was built in 1915 when dike construction was common and thought of as beneficial. The Dike was completed within two years and was considered a great achievement as a landmark for being the longest dike in the Galveston Bay area. The building began a relationship between the physical environment and the possibilities for the Port of Texas City (GBEP, 2002; Handbook, 2005; U.S. Army, 1957).

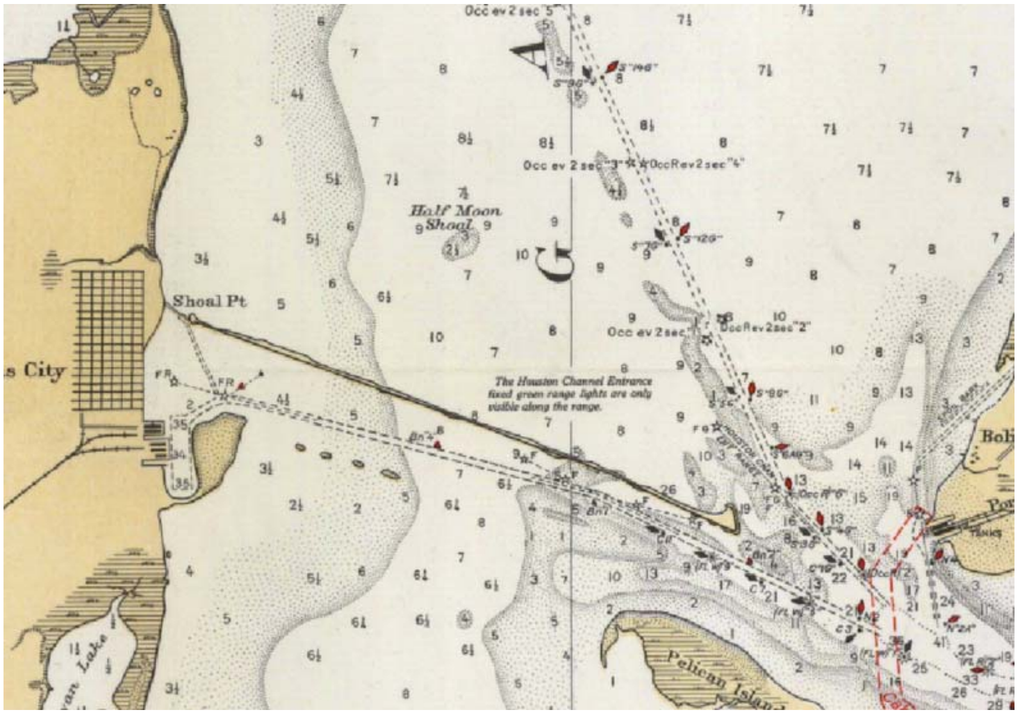

Fig. 5. Historic chart from 1933 showing the presence of the Texas City Dike and altered bathymetry ("Historical," 2004).

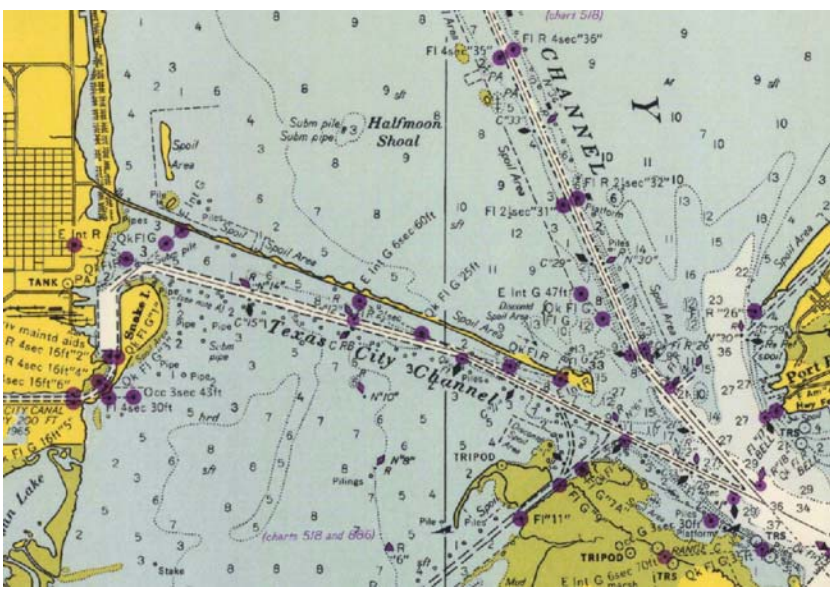

Fig. 6. Historic chart from 1967 showing the altered bay ("Historical," 2004).

As time progressed and dredging continued, Pelican Island became much larger and the flood levee along the west bank on the north side of dike was built due to the placement of dredged material (see Figures 5, 6, and 7) (U.S. Army, 1957).

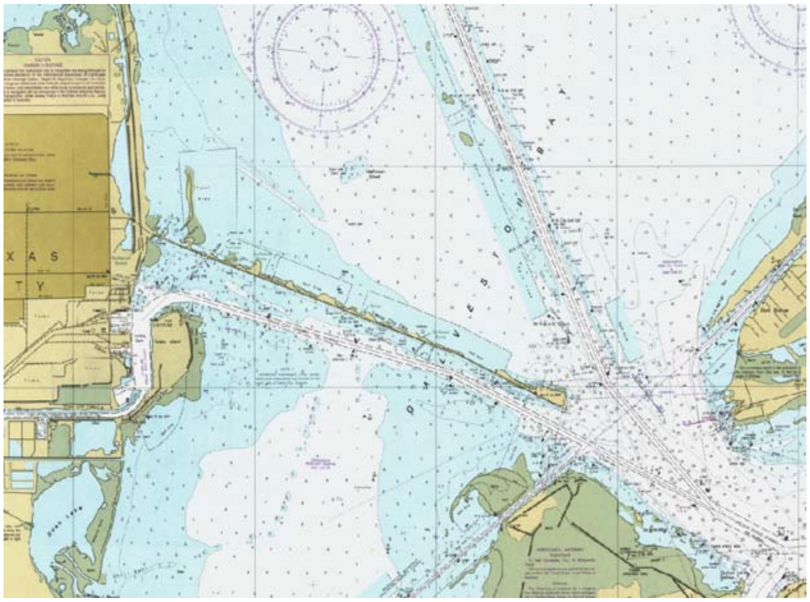

Fig. 7. Historic chart from 1985 showing the widening of the dike and the proposed spoil areas blocked along the north side of the dike ("Historical," 2004).

In 1986, a proposal was written addressing the possibility of deepening the Texas City Ship Channel to 50 feet by 600 feet wide. In this proposal, the first layouts for the recreational area along the north side of the dike were planned showing the 90 acres of spoil was to be placed to create "a beach (U.S. Army, 1989)."(see Figure 8).

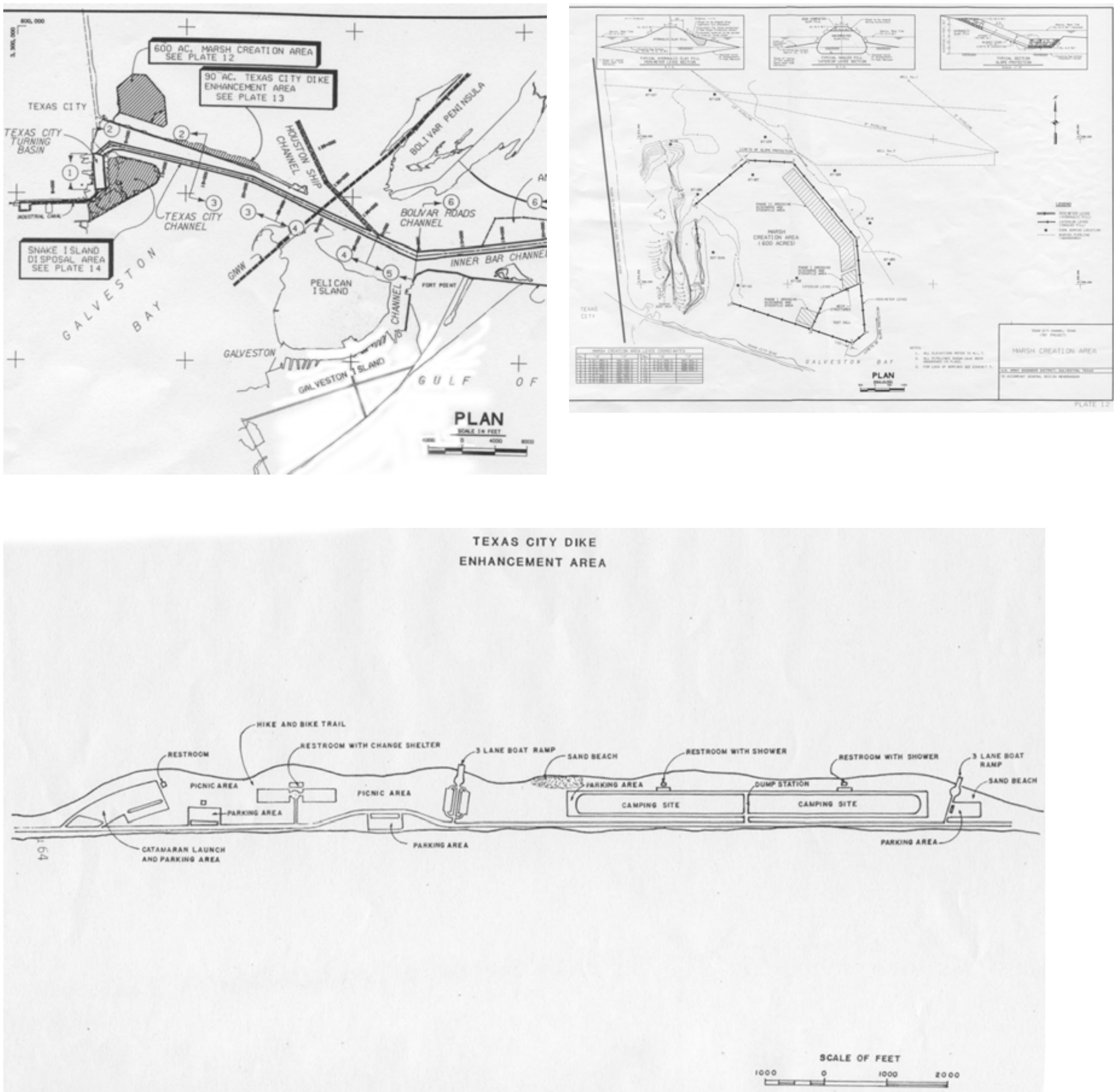

Fig. 8. COE report images showing the beach enhancement plans and placement (U.S. Army, 1989).

Since the late 1980's, the COE has been creating this "Beach" with clay levees offset parallel along the dike in the proposed spoil areas to help contain the dredge spoil (U.S. Army, 1981).

In January of 2007, the COE issued a permit to deepen the Texas City Ship Channel from 40 feet to 45 feet to further extend its ship draft capabilities. The report proposes that 2.4 million cubic yards (mcy) be placed in three 75-acre placement areas along the north side of the dike named 2A, 2B, and 2C. In addition, the report estimates that approximately 1 mcy will be dredged every 2 years and about 22.3 mcy be placed in this 225 acre site in the next 50 years. In addition to the permit for deepening, this report includes two rock groins to be placed along the north side of the dike to slow sedimentation into the ship channel (see Figures 9 and 10) (U.S. Army, 2007).

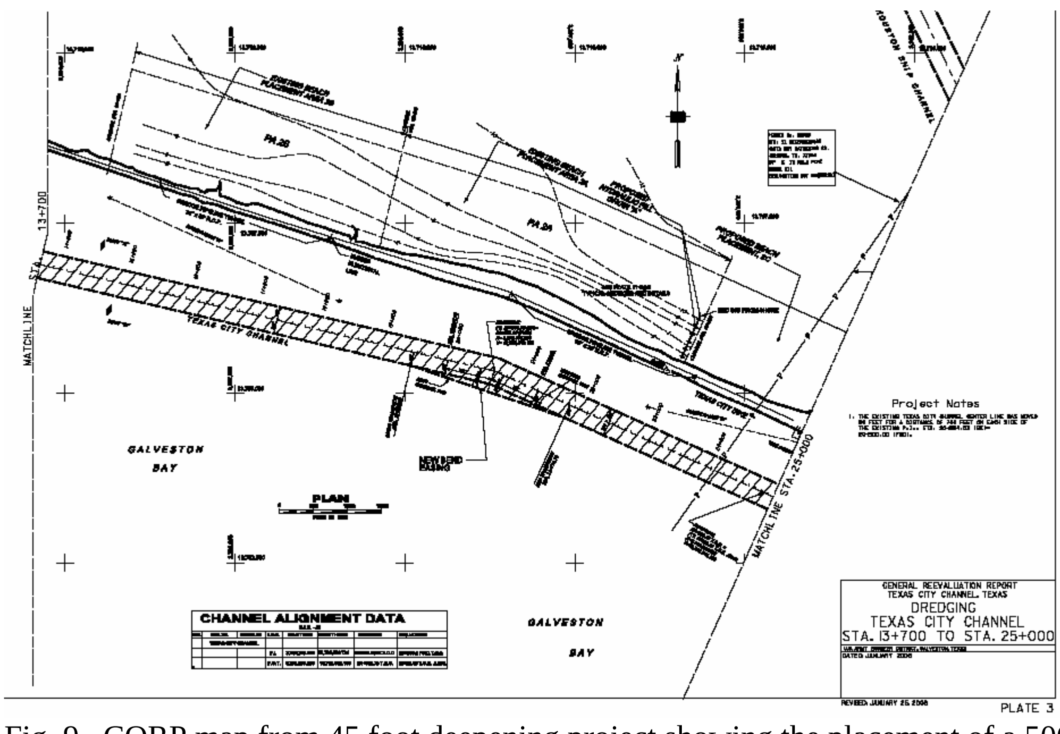

Fig. 9. CORP map from 45 foot deepening project showing the placement of a 500 foot groin placement along the Texas City Dike on both sides of placement area 2C (U.S. Army, 2007).

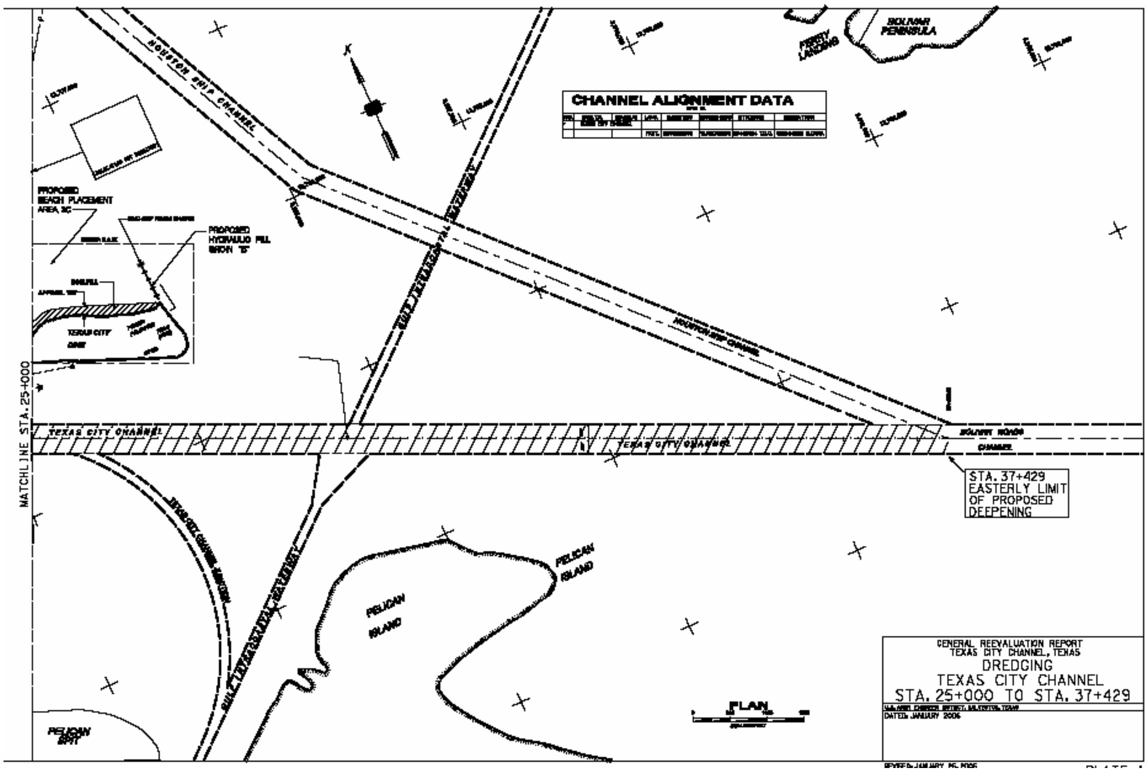

Fig. 10. CORP map from 45 feet deepening project showing the placement of a 500 foot groin placement along the end of the Texas City Dike (U.S. Army, 2007)

Table 1
Timeline providing the historical chronology of the dredging events that have shaped the Texas City Dike area.

Date		**Activity**
1855		First Historic Chart of Galveston Bay
1870		Dredge Equipment purchased and began to be used in the bay.
		(U.S. Army, 1957)
1893		Meyer Brothers of Duluth Minnesota dredged an 8 ft ship channel and dispose of the spoil as a berm north of the channel
1895		Texas City Terminal Company deepens the ship channel to 16 feet (GBEP, 2002)

Table 1 Continued

Date		Activity
1899-1900		Corp of Engineers deepens the Texas City Ship channel to 25 feet. (GBEP, 2002)
1900		Hurricane hits Galveston Bay and large amounts of spoil washed ashore (GBEP, 2002)
1909		Corp of Engineers reported that shoaling had filled the ship channel (U.S. Army, 1947)
1910		Corp of Engineers deepened the Texas City Ship Channel to 27 feet by 200 feet wide (U.S. Army, 1957)
1913		62nd Congress authorized a 30 feet by 300 feet ship channel and an adjacent pile dike (U.S. Army, 1957)
1915		Texas City Dike was completed as a 5.3 mile pile dike costing a total of $1.4 million (GBEP, 2002; U.S. Army, 1957)
1930		71st Congress authorized the Dike to be reinforced with rubble or granite boulders and patented ownership of 1000 feet wide dike to the city of Texas City (GBEP, 2002)
1932		73rd Congress authorized the Texas City Ship Channel deepened to 32 feet (U.S. Army, 1957)
1936		74th Congress authorized the Texas City Ship Channel deepened to 34 feet (U.S. Army 1957)
1948		80th Congress authorized the Texas City Ship Channel deepened to 36 feet by 400 feet wide(U.S. Army, 1957)
1961		Texas City claims the Texas City Dike as a recreational area (U.S. Army, 1989)
1963		Texas City Dike patented the East tip to 2,000 feet wide (U.S. Army, 1989).

Table 1 Continued

Date		Activity
1967		Texas City Ship Channel deepened to 40 feet by 400 feet wide (U.S. Army, 1989)
1972		92nd Congress authorized the Texas City Ship Channel to be deepened to 40 feet (U.S. Army, 1974)
1979		Marsh grass planted in north west wetland area but was destroyed due to the 31 mph winds that struck the area the following day (U.S. Army, 1989).
1986		Proposal for 50 feet by 600 ft with 90 acres along north side of the dike for beach enhancement and 600 acres toward wetland creation but there was insufficient funding (U.S. Army, 1989)
1998		Galveston Bay Foundation proposed a marsh restoration area on the north side of the dike (GBEP, 2002)
1999		Corp of Engineers reported 30,000 cubic yards dredged from outside permits(GBEP, 2002)
2007		Texas City Ship Channel deepening from 40 ft to 45 feet project with approximately 2.4 mcy to be placed on the north side of the dike and 2 Rock groins to be placed along the north side of the dike and 1000 acres of march to be mitigated (U.S. Army, 2007)

This historical timeline (see Table 1) reveals that the large morphological changes along the north side of the Texas City Dike have been caused by navigational improvements including dredged channels. Dredging records indicate however, that large volumes of material were handled and re-handled due to recycling of the same material. Therefore, dredging volume bears little relation to the volume of material that has accumulated.

In summary, during the last 150 years, Galveston Bay area has experienced major changes including the dumping of large volumes of dredge and spoil material (GBEP, 2002). The results of this historic background illustrate how the Dike has had a significant impact on maintaining and holding the large volumes of sediment. Understanding this history provides an analogue to help understand the sediment transport and budget in Galveston Bay and thus sand transport over time. While this is a comprehensive dredging history, it is incomplete because the sediment budget is still uncertain.

CHAPTER II

METHODS

A total of 13 cores were collected along the north side of the Texas City Dike in Galveston Bay in water depths ranging from 0.61 m to 3.96 m using an Oztec BP-50 vibracorer.

In the lab, cores were split in half lengthwise, photographed, and visual descriptions of the sediment lithology and Munsell color were recorded. One-half of each core was archived for future reference and one-half processed for water content and grain size analysis. Grain size samples were collected at the top and bottom of each lithologic interval. A total of 194 samples were processed for grain size analyses.

The samples were prepared for analyses by sonicating the sample with deionized water and a dispersant solution, then wet sieved through a #10/2 mm screen into a graduated cylinder. Wet sieving is used to separate the shell that is larger than 2 mm because the Malvern instrument has a limited size range (0-2000 um). The shell fraction in the sieve was placed into a pre-weighed aluminum tin and dried in the oven for twenty-four hours. Once dried, the shell fraction (> 2 mm) was weighed. The sample in the graduated cylinder was rinsed back into the jar and the jar was then filled with deionized water to 250 mLs.

A Malvern Particle Size Analyzer is a laser instrument used to analyze the sediment between 0.2 to 2000 um- in a liquid medium. Jars were placed on a magnetic mixer and a 2-30 mL sample was pipetted into the instrument until the obscuration was in “green” range on the instrument display. Obscuration is the measure of the range of laser light lost due to the introduction of the sample itself (ideally 3-30%). The instrument runs three, 12-second measurements and then takes an average. The left over sample in the jar was poured into pre-weighed aluminum tins and dried in the oven for twenty-four hours. After drying, the samples were weighed and weights were recorded.

Upon completion of grain size analysis, the Malvern software reports the percent shell (250-2000 um), sand, silt, clay, mean, standard deviation, skewness, and kurtosis for each sample. Please note that the Malvern cannot analyze sediment larger than 2 mm. To calculate total percent shell in the sample, the percent of the sample used in the Malvern was calculated and then used to calculate the weight of the volume used. The total sample weight was calculated by adding the weight used, the dried left over weight, and the sieve weight. The weight of the Malvern shell percent (250-2000 um) was calculated by multiplying it by the total sample weight. Thus, the total percent shell equaling the Malvern shell percent weight and the sieve shell weight.

Data was graphed with depth and grain size profiles. Core photographs were assembled using Adobe Photoshop. Computerized core logs showing the visual descriptions were assembled using the LOGPLOT software program. The appendix contains the Texas City Dike core data.

CHAPTER III

RESULTS

We determined the grain size distribution of sediment along the north side of the dike. Upon visual description and grain size analyses of the sediment cores, it was found that sand layers were difficult to identify and trace.

From the core data, an estimated upper sand layer thickness was determined, which is the top interval of sand present. The gross sand interval was determined as the maximum depth within the core that a > 50 % sand was present, and the net sand interval is the number of centimeters within the core that sand was present (see Table 2).

Table 2
Estimated core upper sand layers, gross intervals, and net sand intervals

Core ID	Core Length (cm)	Estimated Upper Sand Layer Thickness (cm) > 75% Sand	Estimated Upper Silty Sand Layer Thickness (cm) > 50 %	Gross Sand Interval (cm)	Net Sand Interval (cm)
1A	229	15	45	95	55
1B	61	0	0	15	10
1C	175	35	35	75	125
1D	104	25	45	96	55
1E	158	9	88	88	88
2A	122	21	26	118	108
2B	175	0	0	95	30
3A	69	0	3	29	20
3B	145	0	0	25	10
4A	137	5	5	105	95
4B	175	47	156	156	156

Table 2 Continued

Core ID	Core Length (cm)	Estimated Upper Sand Layer Thickness (cm) > 75% Sand	Estimated Upper Silty Sand Layer Thickness (cm) > 50 %	Gross Sand Interval (cm)	Net Sand Interval (cm)
5A	74	5.5	21	67	57
5B	168	0	0	95	30

For example core 1A, % sand, silt, and clay graph and the % table shows that the upper 15 cm is greater than %75 sand. However, the % sand does decrease below 50 % sand until after a depth of 45 cm. At 95 cm, the last % sand number of > 50% sand occurs as a 10 cm interval, so this core has a net sand of 55 cm (45+10= 55) within a 229 cm long core (see Table 3 and Figure 11).

Table 3
% Clay, silt, sand, shell, and mean grain size for core 1A

Texas City Dike Core TXD-1A							
Sample ID	Midpoint	% Clay	% Silt	% Sand	Total % Shell	Mean (um)	Mean (mm)
0-10	5.0	1.54	4.981	91.556	2.657	125.324	0.1253
10-20	15.0	2.04	10.632	82.093	5.909	127.771	0.1278
20-23	21.5	4.18	22.364	70.633	4.536	109.235	0.1092
23-30	26.5	4.87	26.37	67.685	1.067	93.287	0.0933
30-34	32.0	3.69	23.087	72.923	0.641	93.86	0.0939
34-40	37.0	5.25	24.145	70.318	0.286	90.848	0.0908
41-50	45.5	4.63	26.711	68.403	0.247	89.156	0.0892
51-60	55.5	7.93	68.168	23.902	0.000	44.282	0.0443
61-70	65.5	6.63	68.49	24.874	0.000	45.361	0.0454

Table 3 Continued

Sample ID	Midpoint	% Clay	% Silt	% Sand	Total % Shell	Mean (um)	Mean (mm)
71-77	74.0	10.37	76.694	12.669	0.267	34.242	0.0342
77-80	78.5	28.01	53.817	16.476	1.690	41.712	0.0417
80-86	83.0	14.79	51.112	34.098	0.000	49.903	0.0499
81-90	85.5	5.39	45.059	49.55	0.000	66.856	0.0669
91-100	95.5	4.97	41.91	53.114	0.000	70.366	0.0704
101-110	105.5	9.07	58.744	32.177	0.000	50.075	0.0501
111-120	115.5	5.21	44.382	50.401	0.000	67.423	0.0674
121-130	125.5	12.07	61.987	25.94	0.000	43.39	0.0434
131-140	135.5	9.43	48.032	42.531	0.000	59.255	0.0593
141-150	145.5	2.11	12.736	28.046	57.1	598.206	0.5982
151-160	155.5	13.24	54.569	31.736	0.447	52.169	0.0522
161-170	165.5	5.69	48.483	45.821	0.000	62.704	0.0627
181-190	185.5	8.69	58.311	32.992	0.000	50.525	0.0505
191-200	195.5	9.90	60.726	29.373	0.000	46.672	0.0467
201-210	205.5	14.60	66.892	18.501	0.000	35.824	0.0358
221-227	224.0	15.76	63.579	20.653	0.000	36.939	0.0369

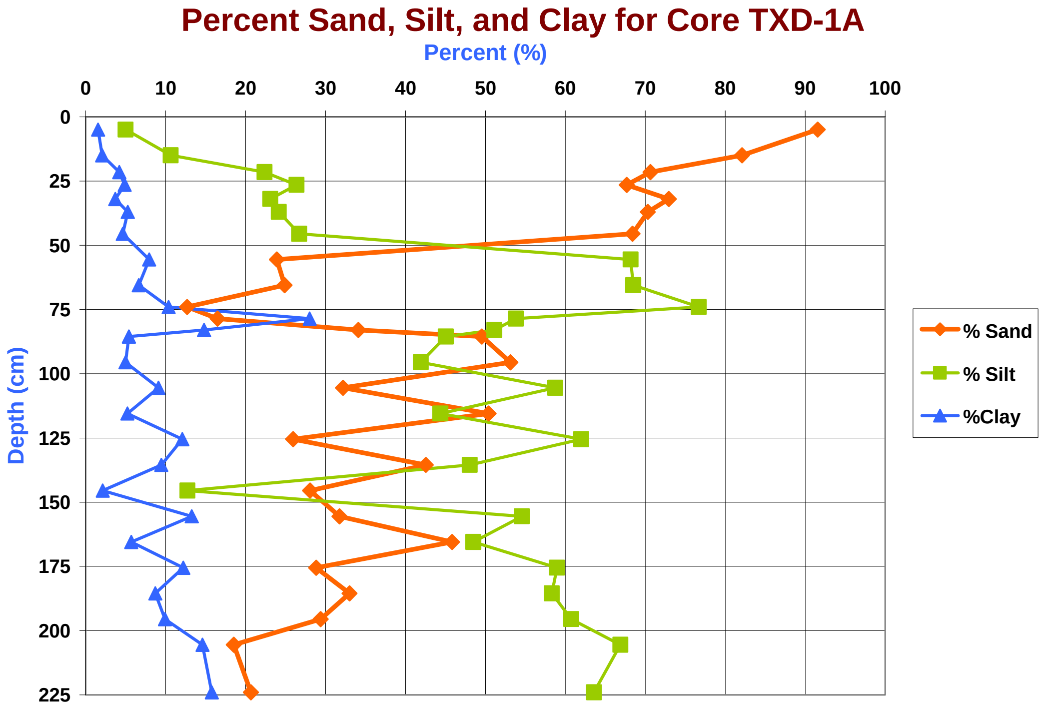

Fig. 11. Percent sand, silt, and clay graph for core 1A

In observing the data represented, most cores were determined to be poor sites for consideration. For example, cores 1B, 2B, 3A, and 3B were poor due to high variability in grain size distribution and too low of a mean grain size (< 0.11 mm). This variability could be due to dredge spoils, but there is also a variation in site location or distribution of these cores along the dike. As an example, the percent sand, silt, and clay graph for core 2B shows the variability and the mean grain size graph shows the size to be too low (see Figures 12 and 13).

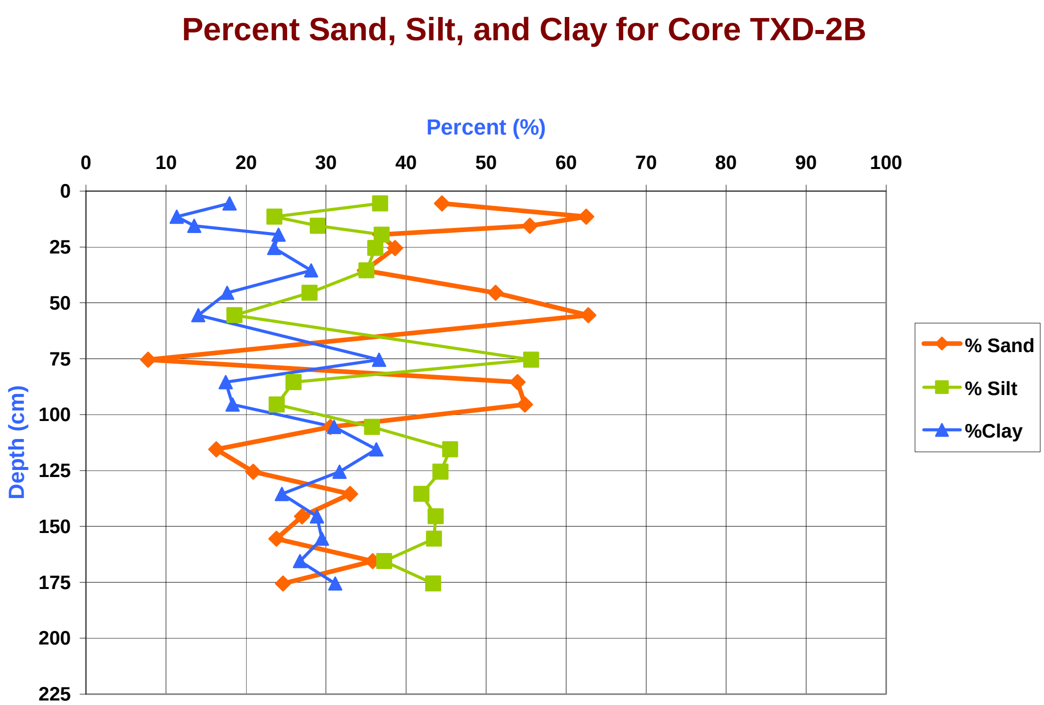

Fig. 12. Percent sand, silt, and clay graph for core 2B

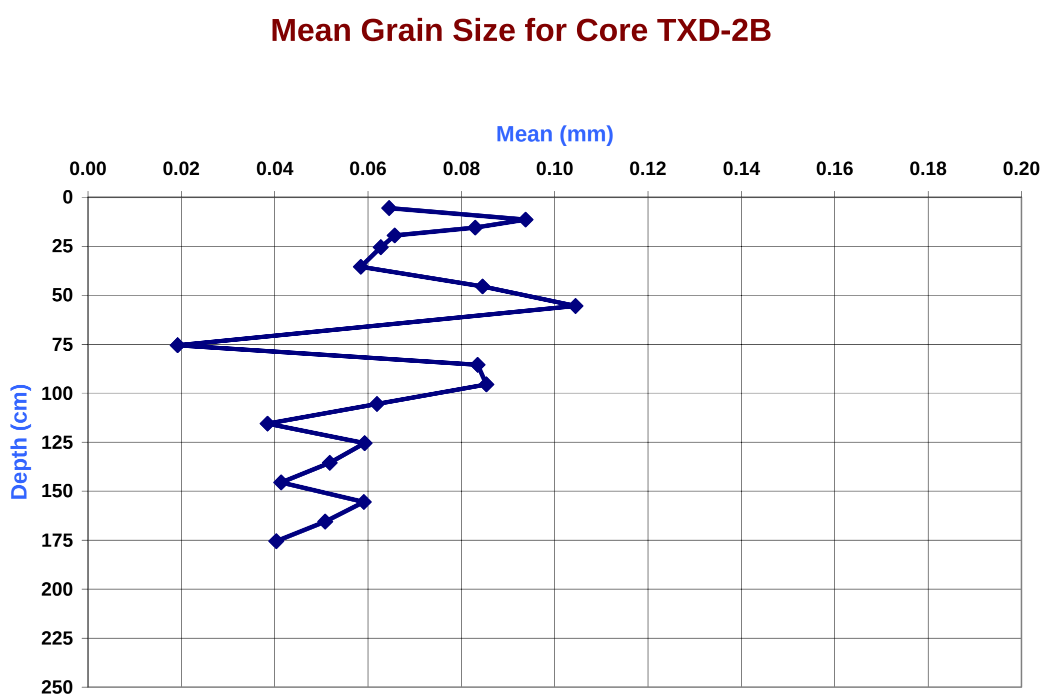

Fig. 13. Mean grain size graph for core 2B

Four of the cores (1D, 2A, 4A, and 5A) revealed small layers of mud present For example core 4A revealed a silt layer of > 45 % at 13 cm (see Table 4).

Table 4
% Clay, silt, sand, shell, and mean grain size table for core 4A

Texas City Dike Core TXD-4A							
Sample ID	Midpoint	% Clay	% Silt	% Sand	Total % Shell	Mean (um)	Mean (mm)
1-9	5	0.000	0.134	98.373	4.499	140.740	0.1407
11-16	13.5	14.439	45.512	39.685	1.236	58.391	0.0584
16-20	18	13.543	26.395	56.703	3.738	90.756	0.0908
24-30	27	1.842	3.351	90.487	8.184	144.909	0.1449
35-40	37.5	8.224	22.062	66.003	15.886	105.687	0.1057
Sample ID	Midpoint	% Clay	% Silt	% Sand	Total % Shell	Mean (um)	Mean (mm)
41-50	45.5	0.000	0.212	95.464	4.552	150.179	0.1502
51-55	53	0.000	0.000	87.920	17.264	178.443	0.1784
61-69	65	4.008	16.491	77.280	2.326	110.632	0.1106
81-84	82.5	4.118	6.863	87.100	1.919	123.933	0.1239
84-90	86.5	9.440	18.708	69.426	2.642	102.077	0.1021
101-109	105	2.408	3.379	88.049	6.164	149.580	0.1496

While two of the cores (3B and 5B) revealed only small layers of sand present. For example, core 3B had a sand layer present at 25 cm of only 77 % sand (see Figure 14).

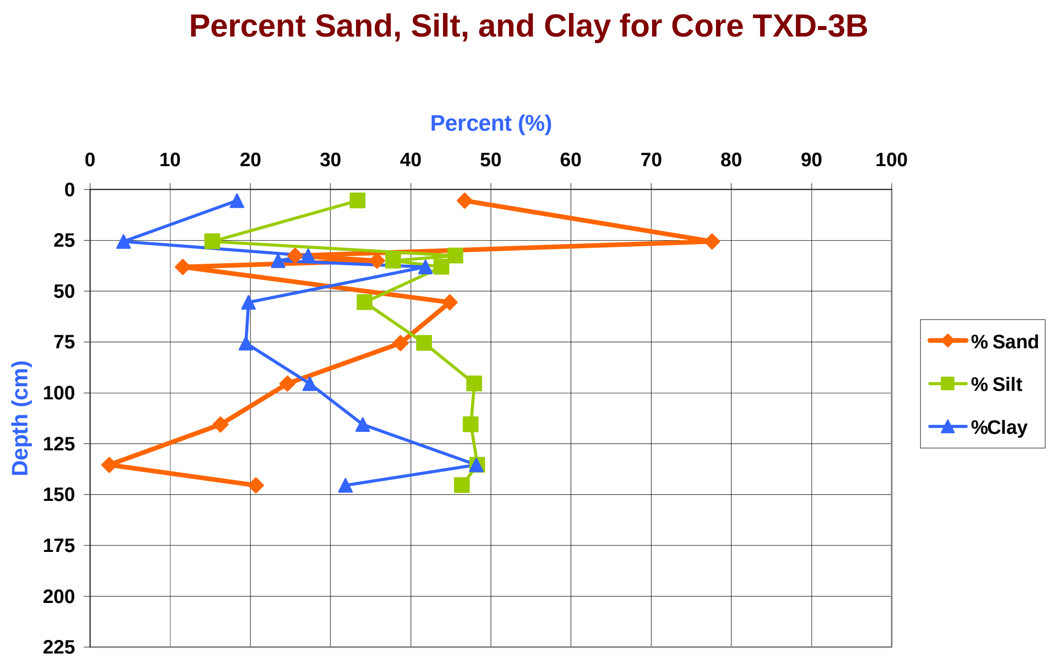

Fig. 14. Percent sand, silt, and clay graph for core 3B

Furthermore, two of the cores (1E and 5B) had layers of > 50 % shells (see Table 5).

Table 5
% Clay, silt, sand, and shell and mean grain size table for core 5B

Texas City Dike Core TXD-5B							
Sample ID	Midpoint	% Clay	% Silt	% Sand	Total % Shell	Mean (um)	Mean (mm)
1-10	5.5	9.982	15.979	47.478	67.451	177.186	0.1772
21-30	25.5	17.878	24.337	43.008	49.308	123.044	0.1230
31-40	35.5	8.280	11.797	64.797	54.479	153.212	0.1532
51-60	55.5	4.502	6.733	74.005	20.255	168.338	0.1683
81-90	85.5	6.042	10.076	67.890	19.953	161.360	0.1614
91-100	95.5	0.000	2.190	81.877	18.955	184.505	0.1845
111-120	115.5	14.032	37.392	44.081	9.142	82.702	0.0827

Out of the 13 cores taken, three (1A, 1C, and 4B) cores revealed small upper sand layers. However, the spacing of these three cores is variable and indicates patchiness of sand. For example, the % sand, silt, and clay graph and mean grain size graph for core 4B reveals a sand layer of 47 cm (see Figures 15 and 16).

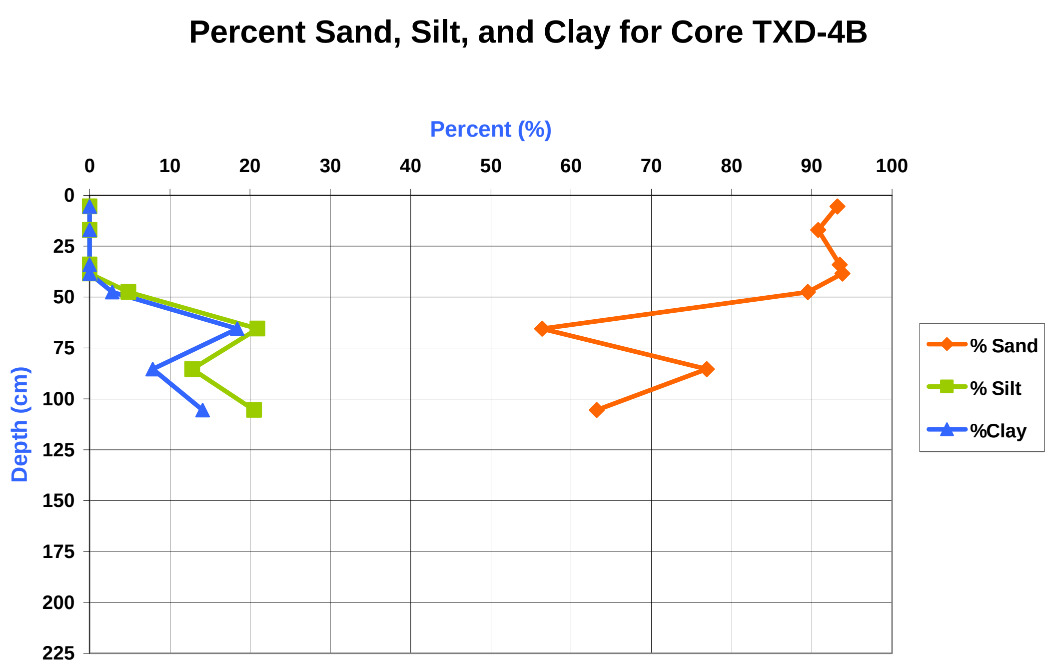

Fig. 15. Percent sand, silt, and clay graph for core 4B showing the 47 cm of sand.

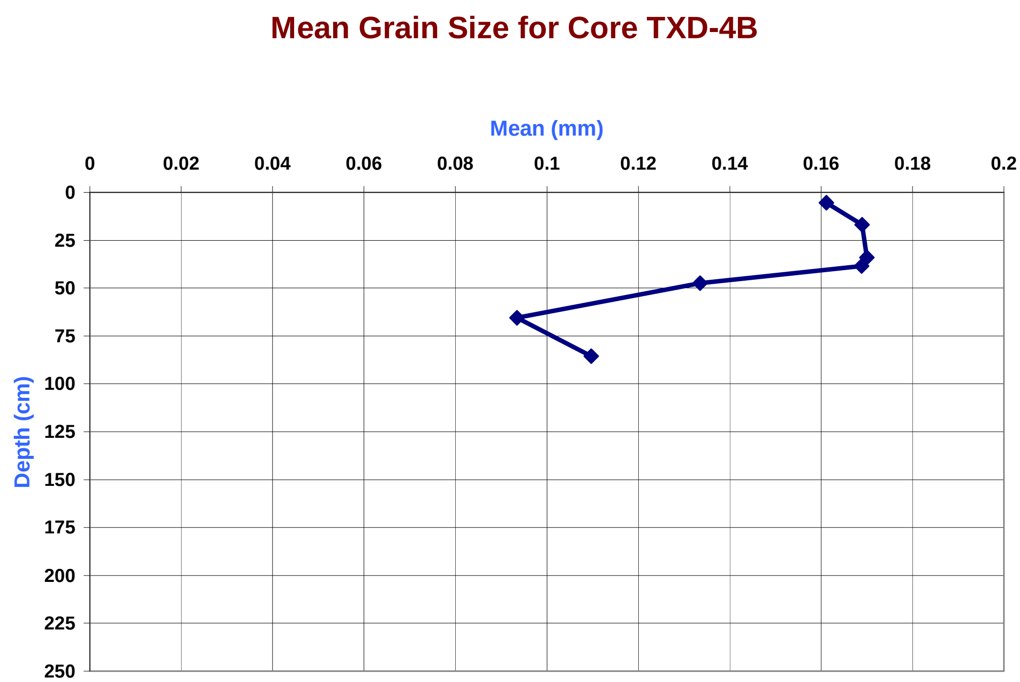

Fig. 16. Mean grain size graph for core 4B

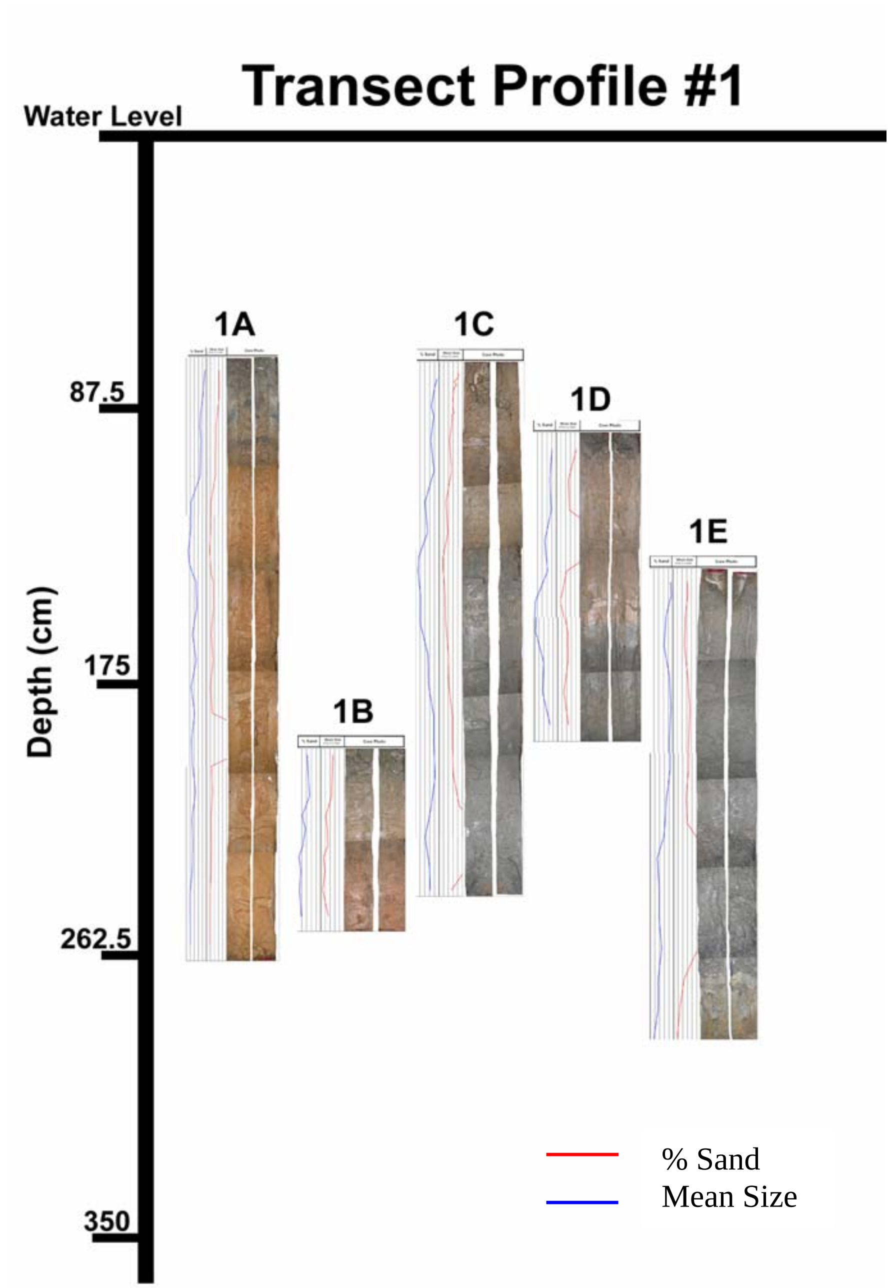

Fig. 17. Stratigraphic transect profile #1.

In transect #1 in the north west section of the study area; the data reveals significant units of orange oxidized silty clay (see Figure 17). Tracing these units throughout the transect was not possible.

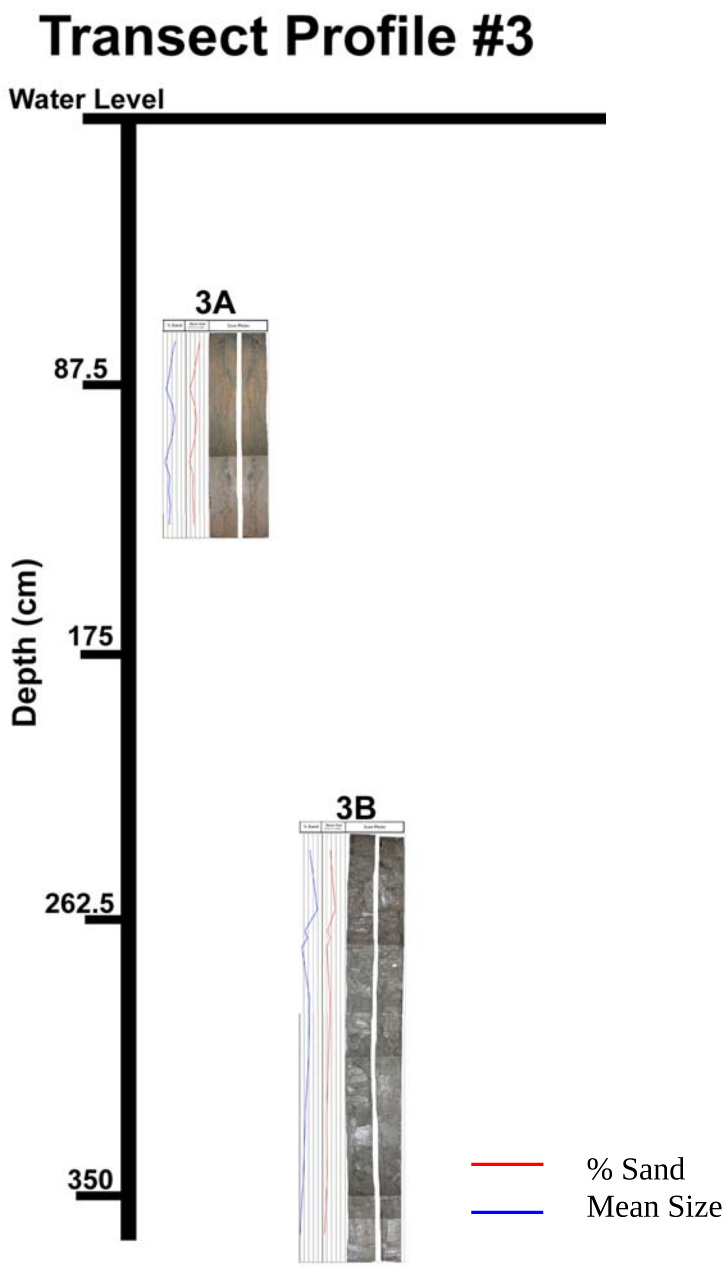

Fig. 18. Stratigraphic transect profile #3

About half way down the dike (4.2 kilometers), transect #3 revealed that in about 2-3 ft of water silty sand is present; however, 3B contains dark silty clay (see Figure 18).

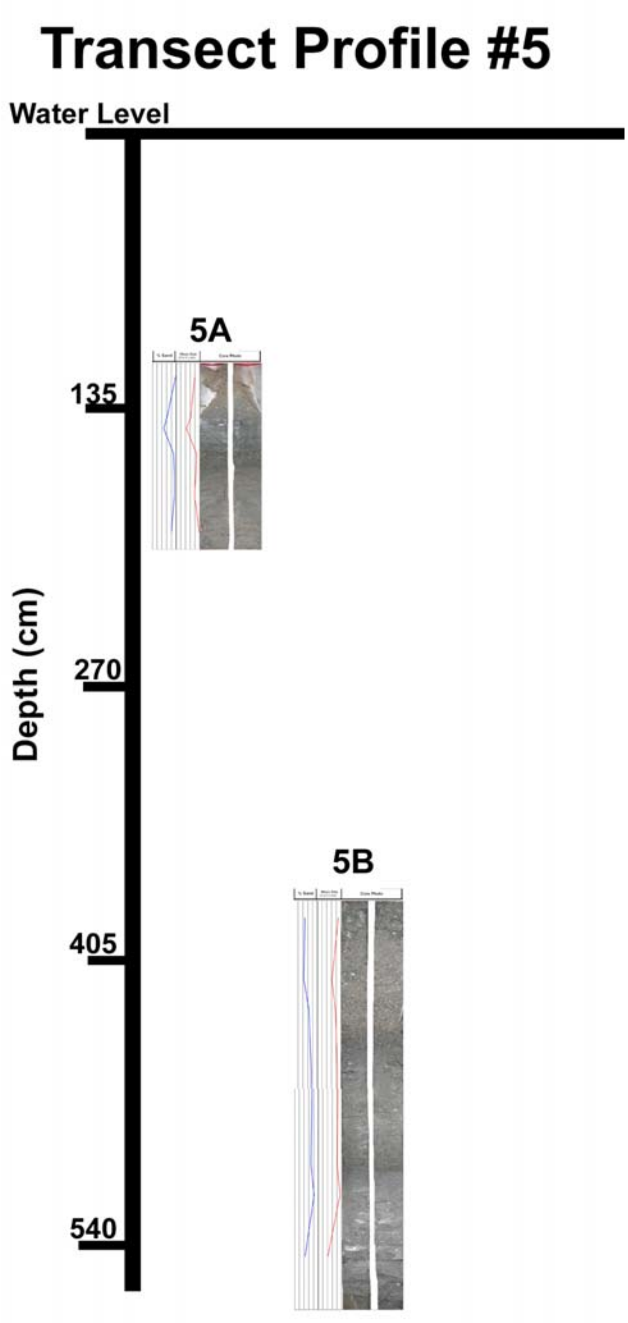

Fig. 19. Stratigraphic transect profile #5.

At the east end of the dike, transect #5 reveals that, close to the dike at core 5A, sand is present with a significant silty mud layer at about a depth of 25 cm and off of the dike at core 5B a shelly silty sand (see Figure 19). However, the mean grain size varies widely which could signify a homogenized dredge spoil.

CHAPTER IV

DISCUSSION AND CONCLUSIONS

In January 2005, 13 sediment cores were taken along the north side of the Texas City Dike. The sediment cores were determined to be poor sites for consideration for beach nourishment and revealed instead a significant dredge spoil deposit. The cores consisted of too fine of sediment (average < 0.11 mm) and sand patches that were primarily present within a 500 meters (1500 ft) proximity to the dike, thus the volume of sand is limited. The core data shows a significant presence of dredge spoil and homogenized sediment, which confirms the dredging record.

From this investigation, some possible scenarios can be generated. Before the Texas City Dike was constructed, sand may have been deposited into both Galveston Bay and into West Galveston Bay. The dredge history suggests that the sand is either being covered by dredge spoil or is being transported elsewhere

Although the Texas City Dike may trap significant volumes of sediment, the placement of silt rich dredge spoils in our study site restricted our ability to make this determination. If we cored further east, we may have found evidence of the depositions of this material.

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APPENDIX
TEXAS CITY DIKE CORE DATA

The appendix–Texas City Dike core data is attached as a separate file. It contains a detailed description of the grain size analysis for the 13 cores located on the north side of the Texas City Dike.

The appendix is designed with five types of figures and a table for each core. The first figure is a computerized core log which includes the associated core site information and identity in the top portion of each core log, visual patterns and descriptions of lithologic units, grain size samples in relation to the units, percent sand (0-100%) graph down the core, mean grain size (0-0.2 mm) graph down the core, and a core photo to aid in visual interpretation. The second figure is the Malvern particle distribution graphs that were extracted for every 6-10 samples. (These graphs are in microns not milli-microns.) Next, the percent clay, silt, sand, and total shell table shows the actual numbers obtained. This table has a column of sample identity, a midpoint of the sample interval (Ex: 1-10 cm = 5.5 cm), percent clay, silt and sand columns which were taken directly from the <2 mm Malvern sub-samples, and a percent total shell column which was calculated from total sample weight taking the shell percent from the Malvern (< 2 mm) and the sieve weight (> 2 mm). For example, a sample could be 20% shell of a total sample within sediment that is 90 % sand. This table is important in that the number is where the upper sand layer thickness is determined and the percent sand graph in the computerized core log is extracted. An additional column is the mean grain size showing the mean in microns and milli-microns taken from the Malvern statistics of < 2 mm. Note that the size range between 250-2000 microns is assumed to be shell. The third figure is a percent sand, silt, and clay graph (0-100%) with depth (cm). This graph is represented with sand in orange, silt in green, and clay in blue. The fourth figure shows only the percent sand graph and the fifth figure is the mean grain size graph (0-0.2 mm). Note that the mean grain size can be > 0.2 mm due to heavy shells present.

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