I. SEDIMENT ANALYSIS

A. EAST OCEAN VIEW BEACH SEDIMENT ANALYSIS

Sediment samples were collected along the East Ocean View Beach project area at every fifth survey transect (~500 ft) used for the beach surveys, beginning with the transect closest to the Little Creek Inlet Jetty (See **Figure 1-1**). There were a total of 11 transects at which sediment samples were collected. For each of these transects, sand samples were collected at 1) top of dune, 2) toe of dune, 3) mid-beach (halfway between toe of dune and water line), 4) high water line, and 5) elevation = -6' NAVD88, and 6) elevation = -15' NAVD88. A standard sieve analysis (following ASTM C136 standards) was performed for each sample using the following sieve sizes: #4, #10, #16, #30, #40, #50, #60, #80, #100, #140, and #200.

1. *Grain Size Distributions*

Based on methodologies presented in the U.S. Army Corps of Engineers (COE) Coastal Engineering Manual (CEM), a composite native beach grain size distribution was computed from the available sediment data. Sediment data (grain size distributions) were averaged alongshore for all 11 sample locations at 1) dune toe, 2) mid beach, and 3)-6 ft. Next, an overall average distribution was computed from the average dune toe, mid beach, and -6 ft distributions, yielding the composite grain size distribution for the project area. **Figure 1-2** shows the average distributions computed for the dune toe, mid beach, and -6 ft samples, and the resulting composite distribution.

2. *Median Grain Size*

Median grain sizes were computed for each station and sample location and averaged along each transect (between the dune toe and -6 ft) and along the shoreline. As shown in **Table 1-1**, the median grain sizes generally increased in moving from east to west along the project area.

Table 1-1 Median Grain Sizes for East Ocean View Beach Sediment Samples

Station	d50 – dune toe (mm)	d50 – mid beach (mm)	d50 - -6 ft (mm)	d50 - avg of dune toe, mid beach, -6 ft (mm)
1+00	NA	NA	0.16	0.16
6+00	NA	NA	0.14	0.14
11+00	0.22	0.23	0.14	0.20
16+00	0.23	0.19	0.13	0.18
21+00	0.23	0.19	0.30	0.24
26+00	0.26	0.25	0.17	0.23
31+00	0.23	0.25	0.29	0.26
36+00	0.23	0.23	0.19	0.22
41+00	0.25	0.32	0.18	0.25
46+00	0.34	0.35	0.33	0.34
51+00	0.32	0.32	0.21	0.28
AVG	**0.26**	**0.26**	**0.20**	**0.23**
MIN	**0.22**	**0.19**	**0.13**	**0.14**
MAX	**0.34**	**0.35**	**0.33**	**0.34**

3. Characteristics for Calculation of Overfill Factor

The CEM defines the overfill factor (R_A) as "*the volume of borrow material required to produce a stable unit of usable fill material with the same grain size characteristics as the native beach sand*." The closer the overfill ratio is to 1.0, the better the sand source. The methodology for computing the overfill factor was taken from the CEM and consists of calculating relationships between the means and standard deviations between the potential borrow site and the native beach. The means and standard deviations are calculated using characteristics of the phi scale grain size distribution of the native and borrow materials. These relationships can then be plotted on a nomograph in the CEM to determine the overfill factor, R_A.

Characteristics of the native beach sand were determined from the composite grain size distribution (avg of distributions between dune toe and -6 ft for entire study area). While there is some variability in these distributions along shore, an overall average was used since it was fairly certain that the borrow site and construction scheduling and costs would not allow specialized dredging and placement programs. The required input for computing the overfill factors were determined from the phi-scale grain size distribution. The phi scale distribution for the native beach and the resulting characteristics used for computing the overfill factor for the native beach are shown on **Figure 1-3**. The Thimble Shoal Channel was then identified as a possible borrow source and the following data was collected for the borrow site.

B. THIMBLE SHOAL CHANNEL SEDIMENT ANALYSIS

Two data sources were available for analyzing the compatibility of the Thimble Shoal Channel dredge material with the native beach. These sources were:

- VIMS study (Hobbs et al, 1984) of sand resources in the lower Chesapeake Bay and their suitability as beach fill for several nearby sites, including Norfolk Beaches. This study included boring data and grain size distributions for 6 borings taken near or in the potential dredge area for the COE project.

- COE plans and specs for Thimble Shoal Channel dredging, including borings near the proposed dredging project area. The boring are dated 1984-1985 and include general characteristics such as median grain size (d50), percentage of fines, description of material, and evaluation of material (good or bad for beach fill). Unfortunately, detailed grain size distributions were not available for these borings.

Figure 1-4 shows the location of the VIMS and COE borings. The COE borings are contained mainly in and adjacent to the channel while most of the VIMS borings are located on the banks surrounding the channel. It should be noted that all of this boring data was collected in the early 1980's, and thereby subject to have changed.

1. Summary of Thimble Shoal Boring Analysis (VIMS Data)

Of the 6 borings near the COE channel dredge project extent, one boring (WB097) was located close enough to the COE borings to allow comparison of the grain size distribution with the native beach. Boring WB097 consisted of three sample depths 1)-52 to -57 ft, 2)-57 to -62 ft, and 3)-62 to -67 ft. Each of these grain size distributions were plotted against the composite native beach grain size distribution (See **Figure 1-5**). As one can see from the figure, the grain size distribution from -52 to -57 ft is more well-graded than the native beach and the lower elevations in the channel. While the distributions for the lower elevations have shapes which are more similar to the native beach, using these materials is not allowed since these elevations are lower than the current Congressionally Authorized depth for Thimble Shoal Channel of -58 ft.

As part of the VIMS 1984 study, the overfill factors were computed for all borings (at numerous depths) against the native beach sand for a composite "Norfolk Beach" (i.e. complete 7 mile extent). The overfill factor for the 6 borings surrounding the Thimble Shoal channel dredging project extent were typically 1.0 or not significantly greater, indicating a highly compatible borrow source.

To validate this data, overfill factors were calculated for the VIMS boring WB097 against the native beach material using the available data collected in this study. As was done for the native beach sediment, the grain size distributions were plotted on a phi scale, and the required characteristics were estimated from the curves. **Figure 1-6** shows the phi-scale distributions from which the characteristics used in computing the overfill factor were obtained. The overfill factors were computed using ACES (Automated Coastal Engineering System) software. For computing these factors, ACES requires the user to input the mean sediment diameters (M_f) and the standard deviations (s_f) for the native and borrow materials. The following equations from the CEM were used for computing these parameters:

$$M_\varphi = \left(\frac{\varphi_{16} + \varphi_{50} + \varphi_{84}}{3}\right)$$

$$\sigma_\varphi = \left[\left(\frac{\varphi_{84} - \varphi_{16}}{4}\right) + \left(\frac{\varphi_{95} - \varphi_{5}}{6}\right)\right]$$

The overfill factors (R_A) were computed for each of the 3 depths of the borrow source boring WB097 as well as for an average of the three depths. The results of this analysis are presented in **Table 1-2**. As one can see from the table, the calculated overfill factors were mostly all close to 1.0 confirming the VIMS report. A likely explanation for the factors that were above 1.0 is the fact that the old sediment equations in the previous edition of the CEM (SPM) did not include as many parameters to describe the overall sediment distribution (namely, the 95% and 5% retained values). This better definition of the curve (accounting for more of the fines and coarser fractions) allows for a more accurate calculation of the overfill factor.

Table 1-2 Overfill Factors Based on VIMS Boring WB097

		NATIVE BEACH		**BORROW SOURCE**		
Boring	**Depth of Sample**	M_{fn}	s_{fn}	M_{fb}	s_{fb}	R_A
WB097	-52 to -57 ft	2.097	0.728	1.425	1.425	1.12
	-57 to -62 ft	2.097	0.728	1.067	1.067	1.00
	-62 to -68 ft	2.097	0.728	0.744	0.744	1.00
AVG		2.097	0.728	1.079	1.079	1.01

2. *Summary of Thimble Shoal Boring Analysis (COE Data)*

In addition to the VIMS data, the information on sediment borings available from the COE plans and specifications for the dredging of Thimble Shoal Channel was used to develop a summary of the available borrow material by station along the project area. This summary allowed for narrowing down the potential borrow areas and focusing on specific locations at which to evaluate sediment compatibility. A summary of the sediment near and within the project site by station is presented below with average d50s and percentage of fines (corresponding to the percentage passing the 0.075 mm or the percentage retained for the 3.74 phi-size particle), where available. Note that the project stationing on the dredging plans began at Station 734+00, on the west end of the channel and extended to Station 1328+00 on the east end of the channel.

St 734+00 - 1090+00	▪ Material not compatible based on boring logs.- high percentage of fines
St 1090+70.17	▪ Chesapeake Bay Bridge Tunnel Crossing
St 1091+00 – 1106+00	▪ No information available
St 1106+00 – 1141+00	▪ Natural Ground (NG) to -53 ft - mostly clay/fine sand ▪ -53 ft to -58 ft – d50 = 0.21mm, 12% fines
St 1141+00 – 1159+00	▪ Material not compatible based on boring logs – mostly clay
St 1159+00 – 1188+00	▪ NG to -53 ft – d50 = 0.33 mm, 9% fines ▪ -53 to -56 ft – d50 = 0.4 mm, 7% fines ▪ One questionable boring to south of dredging extent
St 1188+00 – 1204+00	▪ NG to -51 ft – d50 = 0.11mm, 26% fines ▪ -51 to -56 ft – d50 = 0.15 mm, 30% fines
St 1204+00 – 1218+00	▪ NG to -56 ft – d50 = 0.22mm, 15% fines ▪ -56 to -62 ft – d50 = 0.24 mm, 10% fines
St 1218+00 – 1300+00	▪ NG to -62 ft – d50 = 0.35 mm, 5% fines
St 1300+00 – 1328+00	▪ Material not compatible based on boring logs – high percentage of fines

To compare the compatibility of this material with the native beach, the d50s and percentage fines (passing the #200 sieve) for the borings between stations 1106+00 to 1300+00, with the exception of the section between stations 1141+00 to 1159+00 were plotted against the native beach sand distributions (See **Figure 1-7**).

However, to compute the overfill factors at these locations, it was necessary to develop a grain size distribution from the available data presented in **Figure 1-7**. Two methodologies were used to approximate grain size distributions for each of the locations. For both methodologies the shape of the grain size distribution was approximated from the VIMS Boring WB097 grain size distribution for the depth of -52 to -57 ft (See **Figure 1-6**). This distribution was selected because most of the COE samples were within this depth range and this is the range of depths within which dredging would most likely occur. The methodologies used for creating distributions from the COE sample point data are as follows.

- Method 1: The differences between the phi-size of the particle corresponding to the 50% retained and the % fines retained for a given COE sample and the VIMS WB097 distribution were computed. The differences (in phi units) were then interpolated for intermediate points (between the % fines and d50) and extrapolated for points along the curve beyond the known points at the % fines and the d50 to yield a shifted distribution. This shifted distribution became the phi-scale distribution for a given COE sample. The characteristics required for calculating the overfill factors were estimated from each shifted sample curve. The results of the analysis based on Method 1 are presented in **Table 1-3**.

Table 1-3 Overfill Factors Based on COE Borings – Method 1

		NATIVE BEACH		BORROW SOURCE		
Station Range	**Depth of Sample**	M_{fn}	s_{fn}	M_{fb}	s_{fb}	R_A
1106+00 – 1141+00	-53 to -58	2.10	0.73	2.12	1.53	1.37
1159+00 - 1188+00	NG to -53	2.10	0.73	1.48	2.02	1.26
	-53 to -56	2.10	0.73	1.20	2.12	1.22
1188+00 – 1204+00	NG to -51	2.10	0.73	3.06	0.94	4.34
	-51 to -56	2.10	0.73	2.61	1.80	1.73
1204+00 – 1218+00	NG to -56	2.10	0.73	2.06	1.73	1.39
	-56 to -62	2.10	0.73	1.94	1.69	1.33
1218+00 – 1300+00	NG to -62	2.10	0.73	1.39	1.81	1.20

- Method 2: As done for Method 1, the differences between the phi-size of the particle corresponding to the 50% retained and the % fines retained for a given COE sample and the VIMS WB097 distribution were computed. The average of these differences (50% retained and corresponding % fines) was computed, and the intact VIMS WB097 curve was shifted by this average difference. By this methodology, the resulting distribution maintained the same shape as the VIMS WB097 distribution. This shifted distribution became the phi-scale distribution for a given COE sample. The characteristics required for calculating the overfill factors were estimated from each shifted sample curve. The results of the analysis based on Method 2 are presented in **Table 1-4.**

Table 1-4 Overfill Factors Based on COE Borings – Method 2

		NATIVE BEACH		BORROW SOURCE		
Station Range	**Depth of Sample**	M_{fn}	s_{fn}	M_{fb}	s_{fb}	R_A
1106+00 – 1141+00	-53 to -58	2.10	0.73	2.23	1.29	1.36
1159+00 - 1188+00	NG to -53	2.10	0.73	1.88	1.12	1.12
	-53 to -56	2.10	0.73	1.67	1.12	1.07
1188+00 – 1204+00	NG to -51	2.10	0.73	2.83	1.28	1.99
	-51 to -56	2.10	0.73	2.77	1.29	1.88
1204+00 – 1218+00	NG to -56	2.10	0.73	2.25	1.31	1.37
	-56 to -62	2.10	0.73	2.08	1.23	1.25
1218+00 – 1300+00	NG to -62	2.10	0.73	1.65	1.12	1.06

C. SELECTION OF SUITABLE BORROW MATERIAL FROM THIMBLE SHOAL CHANNEL DREDGING PROJECT EXTENTS

Given the results of the compatibility analysis between the potential borrow site at Thimble Shoal Channel and the native beach material on East Ocean View Beach, a decision on the location of the most suitable borrow material within the COE dredging project extent could now be made. The COE CEM gives the following guidelines for selecting suitable borrow material for beach fill:

> "*As a general recommendation, a nourishment project should use fill material with a composite mean grain diameter equal to that of the native beach material, and with an overfill factor within the range of 1.00 to 1.05. This is the optimal level of sediment compatibility. However, obtaining this level of compatibility is not always possible due to limitations in available borrow sites…Borrow material that is coarser than the native material will produce a beach which is at least as stable as a fill comprised of native beach material.*"*(*EM1110-2-1100 (Part V), PGS. V-4-24-25)

As shown in **Table 1-2**, the overfill factors computed using the sediment data from the VIMS boring WB097, are equal to 1.00, with the exception of the boring between -52 to -57 ft, which has an overfill factor of 1.12. The overfill factors computed from the COE boring data (approximated grain size distributions) using both Methods 1 and 2, are generally greater than the optimal range as defined by the COE. The main reason that the overfill factors are higher is due to the larger percentage of fines found in the COE borings. This is not surprising, as a higher percentage of fines are usually found in channels in comparison to their neighboring banks. It is likely that these fines will be carried offshore quickly, but the coarser d50s should provide somewhat of an armouring effect during future storm events.

Given the resulting overfill factors shown in **Tables 1-3** and **1-4**, the range of stations and depths selected as the most suitable for borrow material are the following:

1159+00 – 1188+00 Natural Ground to -56 ft
1204+00 – 1218+00 Natural Ground to -62 ft

1218+00 – 1300+00 Natural Ground to -62 ft

The section of borrow material between Station 1106+00 to 1141+00 was not selected because of a top layer of fines/clays to elev -53 ft and spotty material below that.

As shown on the permit drawings, the required fill quantity for this project is approximately 370,000 yd^3. To finalize the dredging depths for these locations of suitable borrow material, the latest survey of the channel was placed in the AutoCad LDD software package. Using this survey, various channel depths were tested to determine available quantities. **Table 1-5** shows the resulting available quantities for the tested depths.

Table 1-5 Dredging Quantities Available at Various Channel Depths

Station	CUMULATIVE DREDGE QUANTITIES (CU YDS)							
	-51	**-52**	**-53**	**-54**	**-55**	**-56**	**-57**	**-58**
1106+00 - 1141+00	26,853	55,588	99,605	147,331	196,323	246,173	296,840	348,304
1141+00 - 1158+00	36,782	57,469	81,205	105,367	129,936	154,914	180,299	206,087
1159+00 - 1188+00	89,228	127,538	168,748	211,208	254,357	298,185	342,695	387,893
1188+00 - 1204+00	29,873	40,370	52,137	64,948	78,455	92,447	106,799	121,502
1204+00 - 1218+00	12,615	18,774	25,851	33,965	42,922	52,275	61,950	71,943
1218+00 - 1300+00	12,862	26,914	48,492	77,283	112,229	151,273	192,637	235,862
TOTAL	208,214	326,653	476,039	640,102	814,223	995,267	1,181,219	1,371,591
TOTAL (1159+00-1188+00 & 1204+00-1300+00)	114,706	173,226	243,092	322,457	409,508	501,733	597,282	695,698

In conclusion, it would appear that in utilizing the preferred sections between station 1159+00 to 1188+00 and station 1204+00 to 1300+00, the required project quantity should be met by dredging these areas to -55 ft. Using the normal 1 ft allowable overdredge, the project quantity should be easily met and would also allow for a factor of safety if some unforeseen pockets of silts/muds or shell hash are encountered. The dredge could then be directed to move to a different area if needed. In fact, given the age of these borings and the concern of % fines shown in the COE borings, the most prudent course of action would be to identify the preferred channel sections as primary borrow areas while denoting the remaining sections of the channel as secondary borrow areas. The contractor could then concentrate in the primary borrow areas and only move to the secondary areas if unforeseen pockets of material are found in the primary areas. These areas are shown in detail on the separately submitted dredging drawings as part of this package.

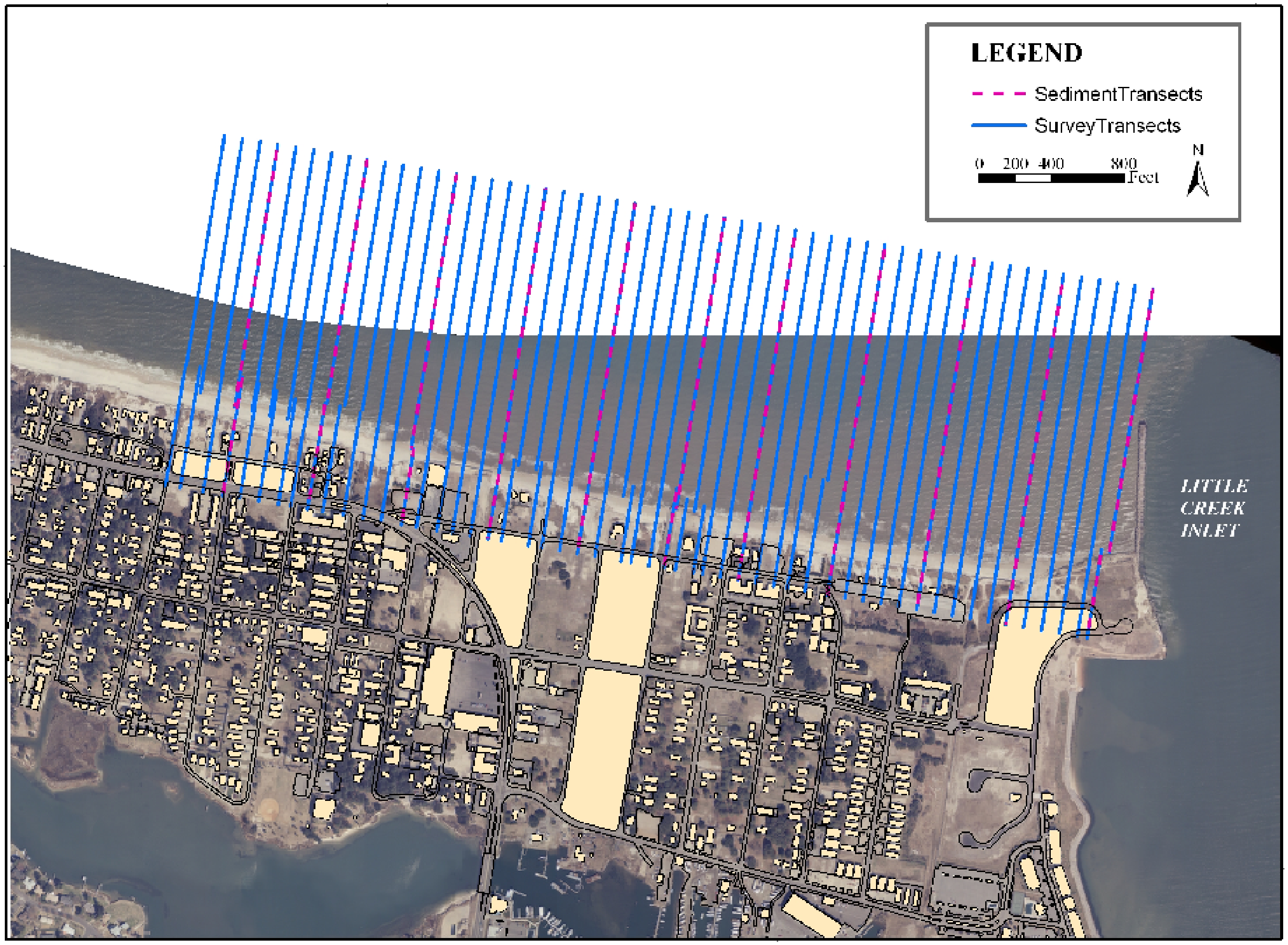

Figure 1-1 Location of Sediment Sample Transects

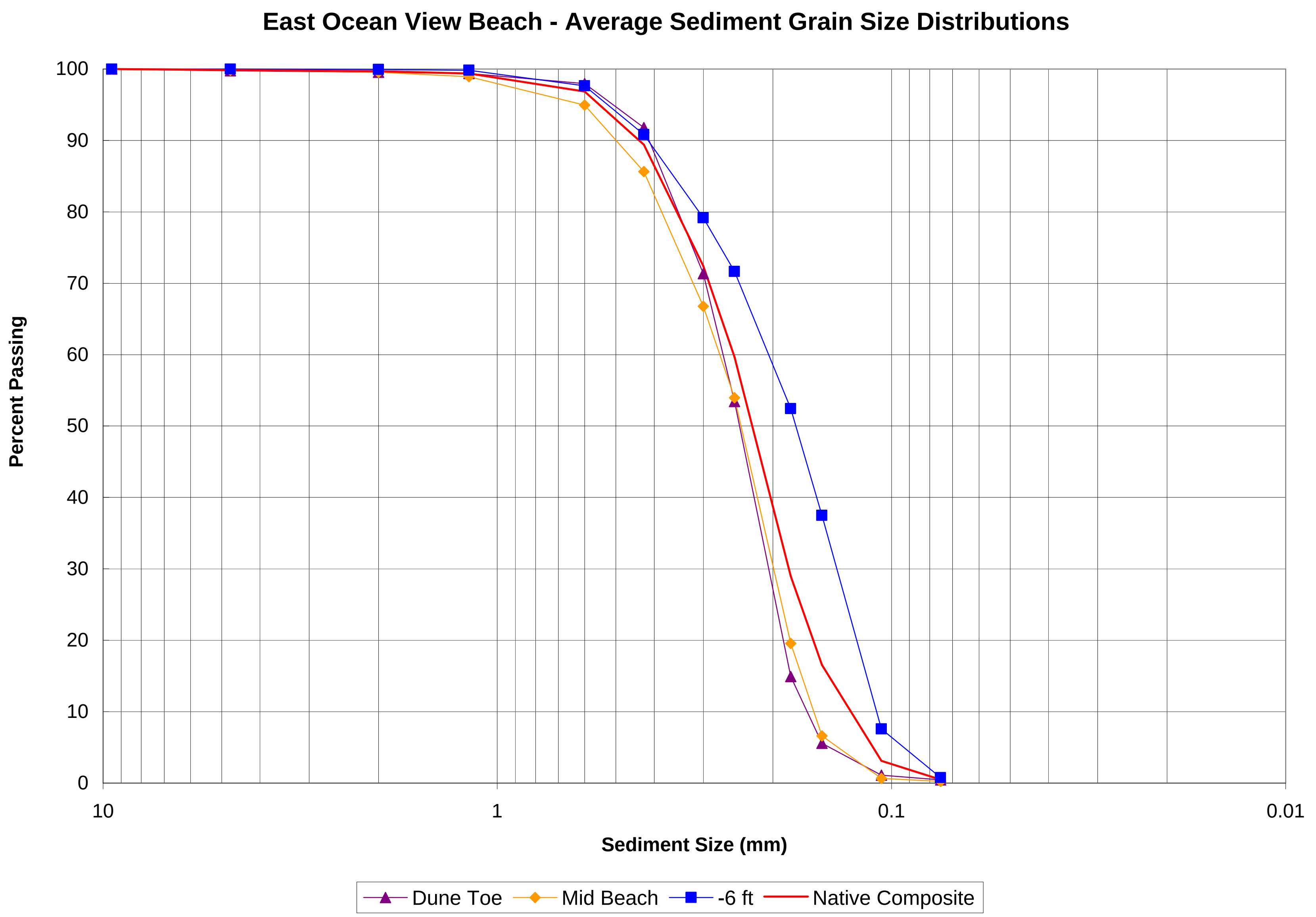

Figure 1-2 Average Sediment Grain Size Distributions and Resulting Composite Distribution for East Ocean View Beach

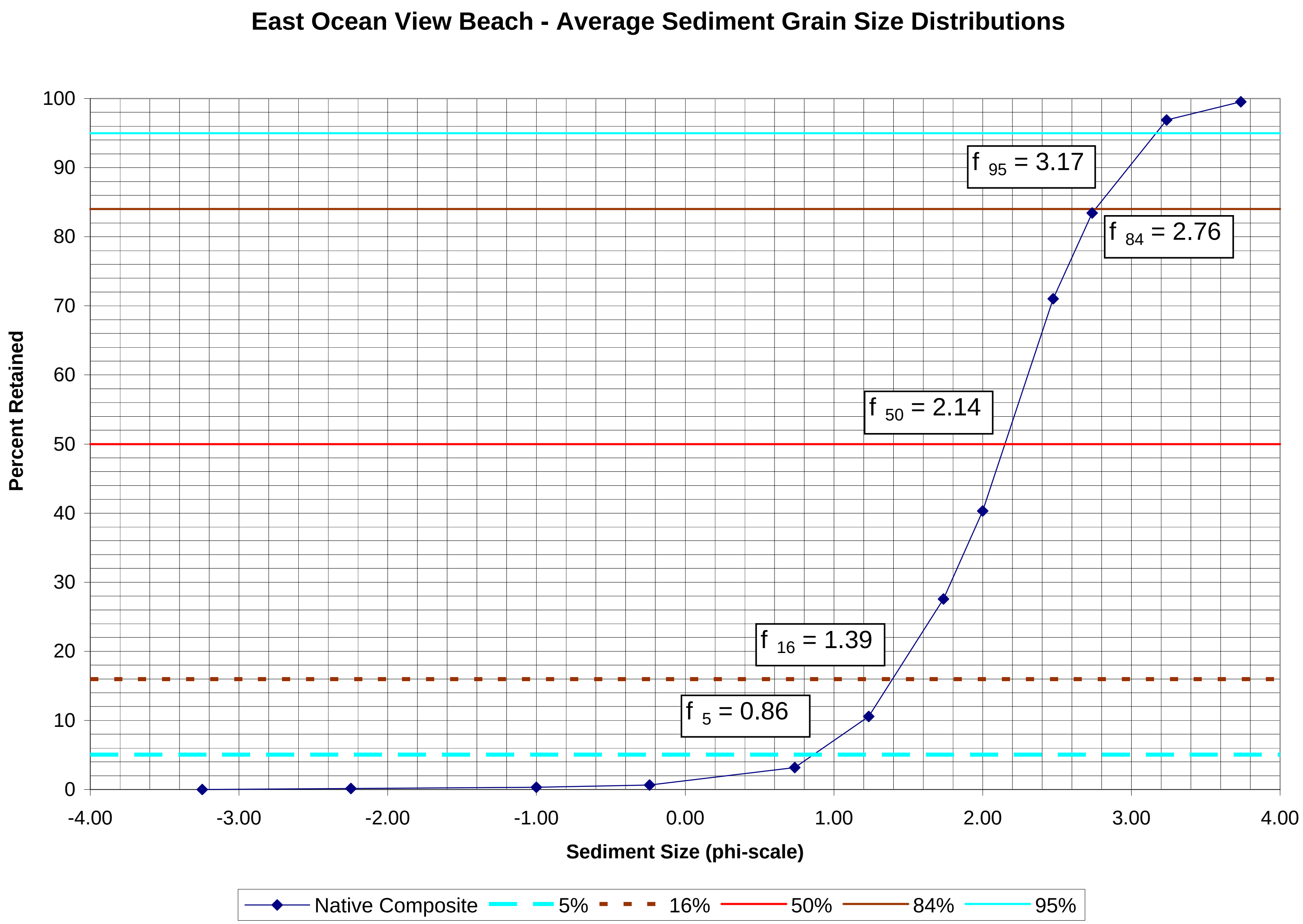

Figure 1-3 Phi-Scale Composite Grain Size Distribution for East Ocean View Beach

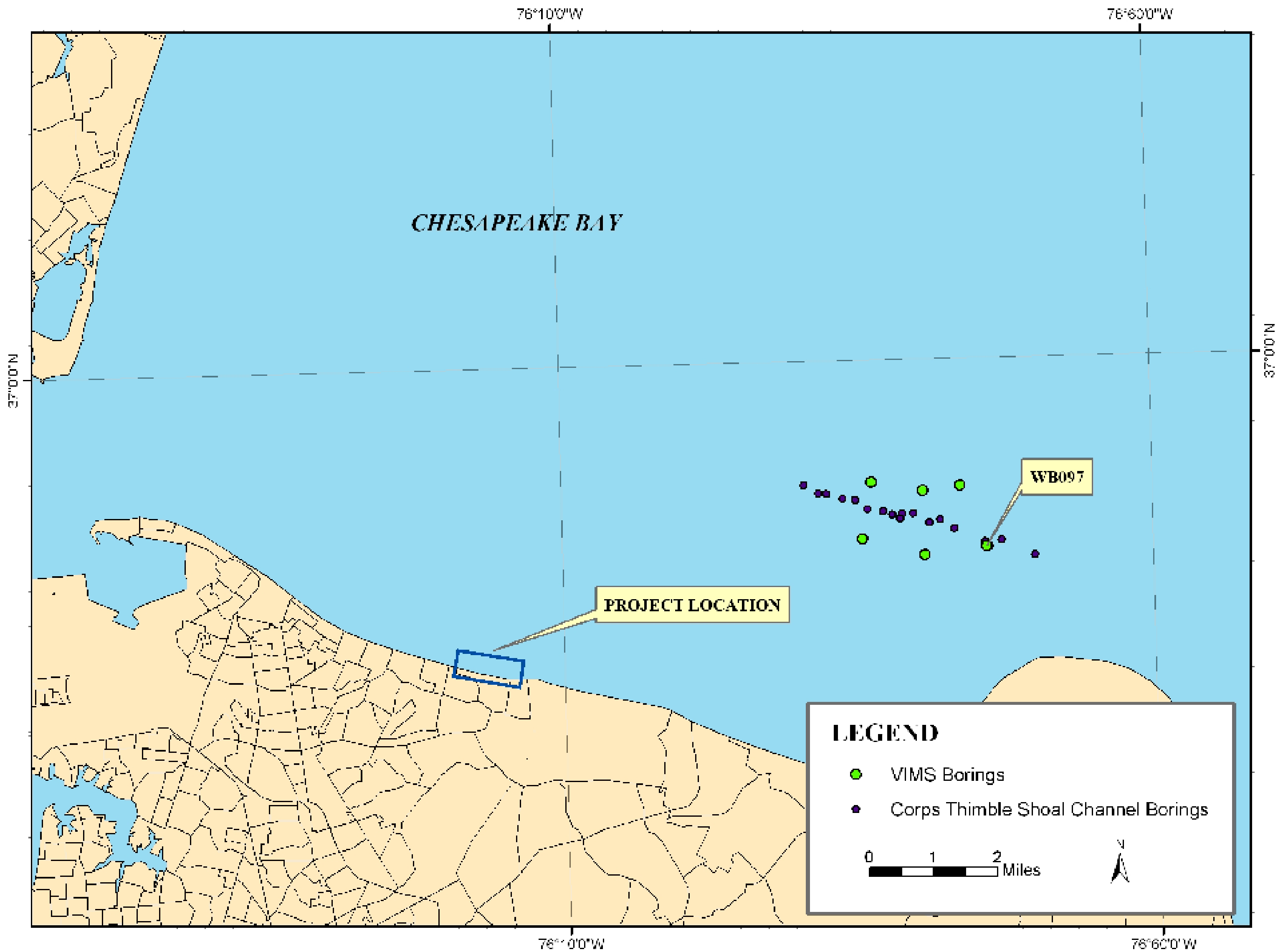

Figure 1-4 Location of VIMS and COE Sediment Borings near Thimble Shoal Channel

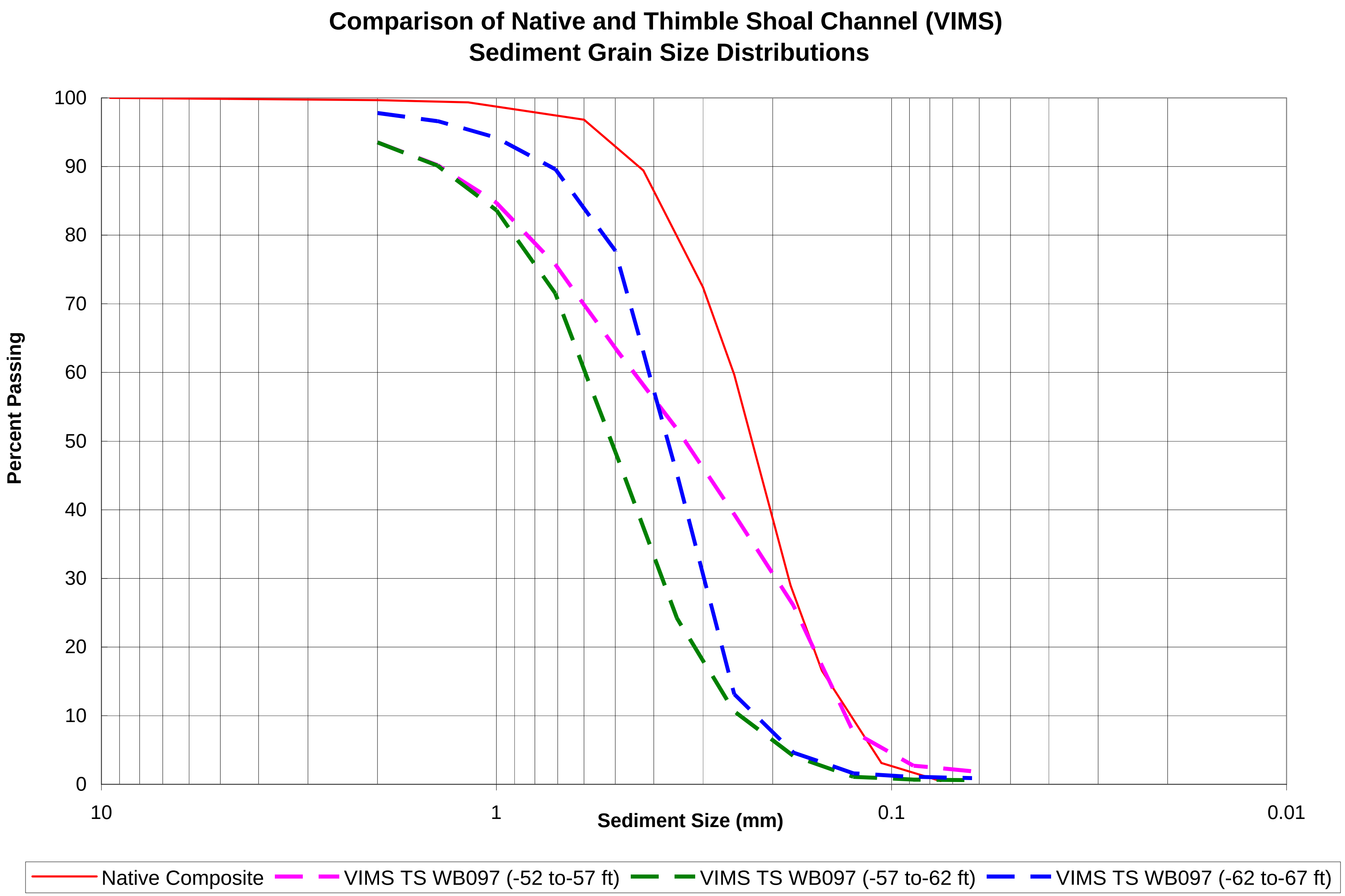

Figure 1-5 Comparison of Native Composite and VIMS WB097 Sediment Grain Size Distributions

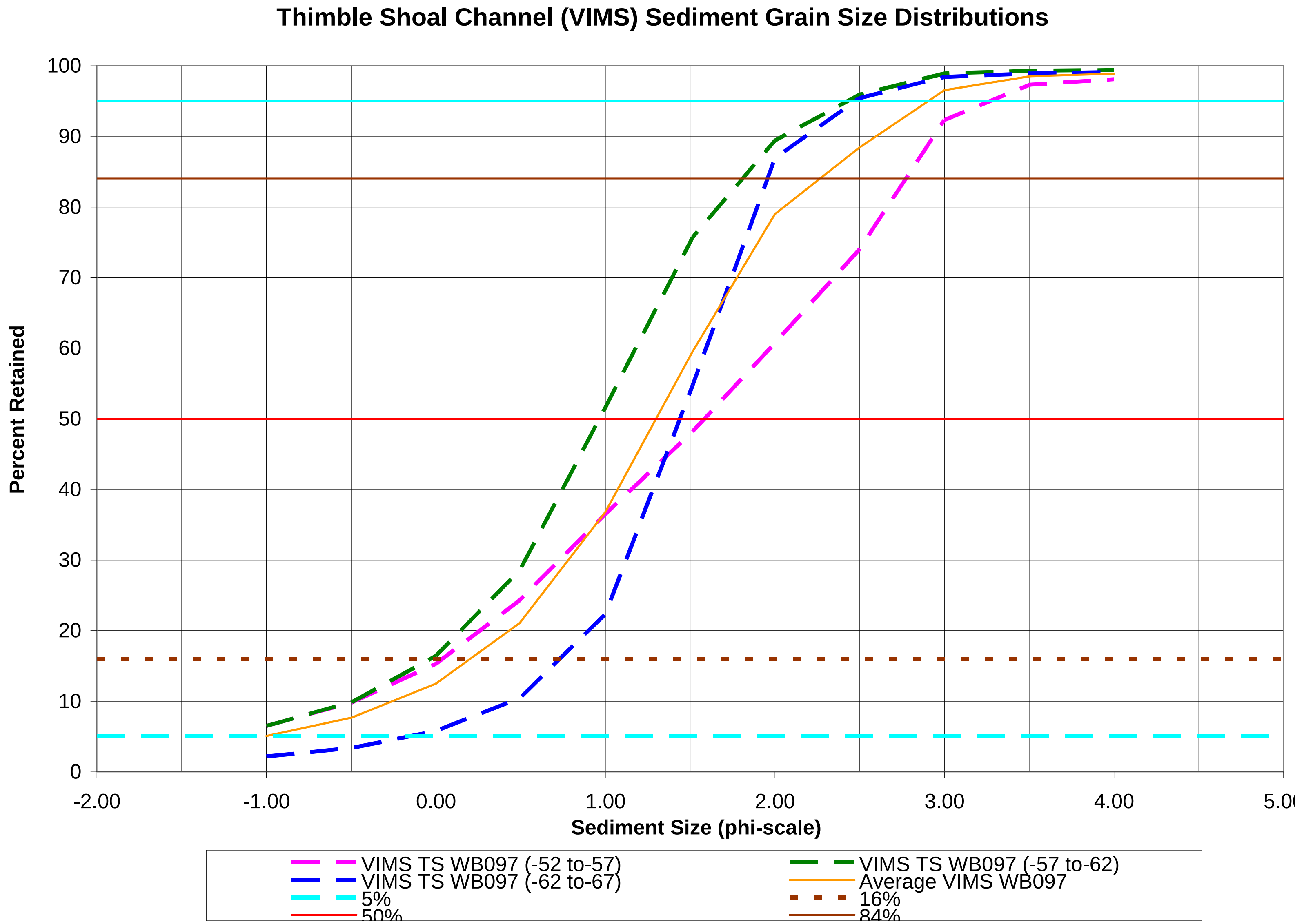

Figure 1-6 Phi-Scale Sediment Grain Size Distributions for VIMS WB097 Borings

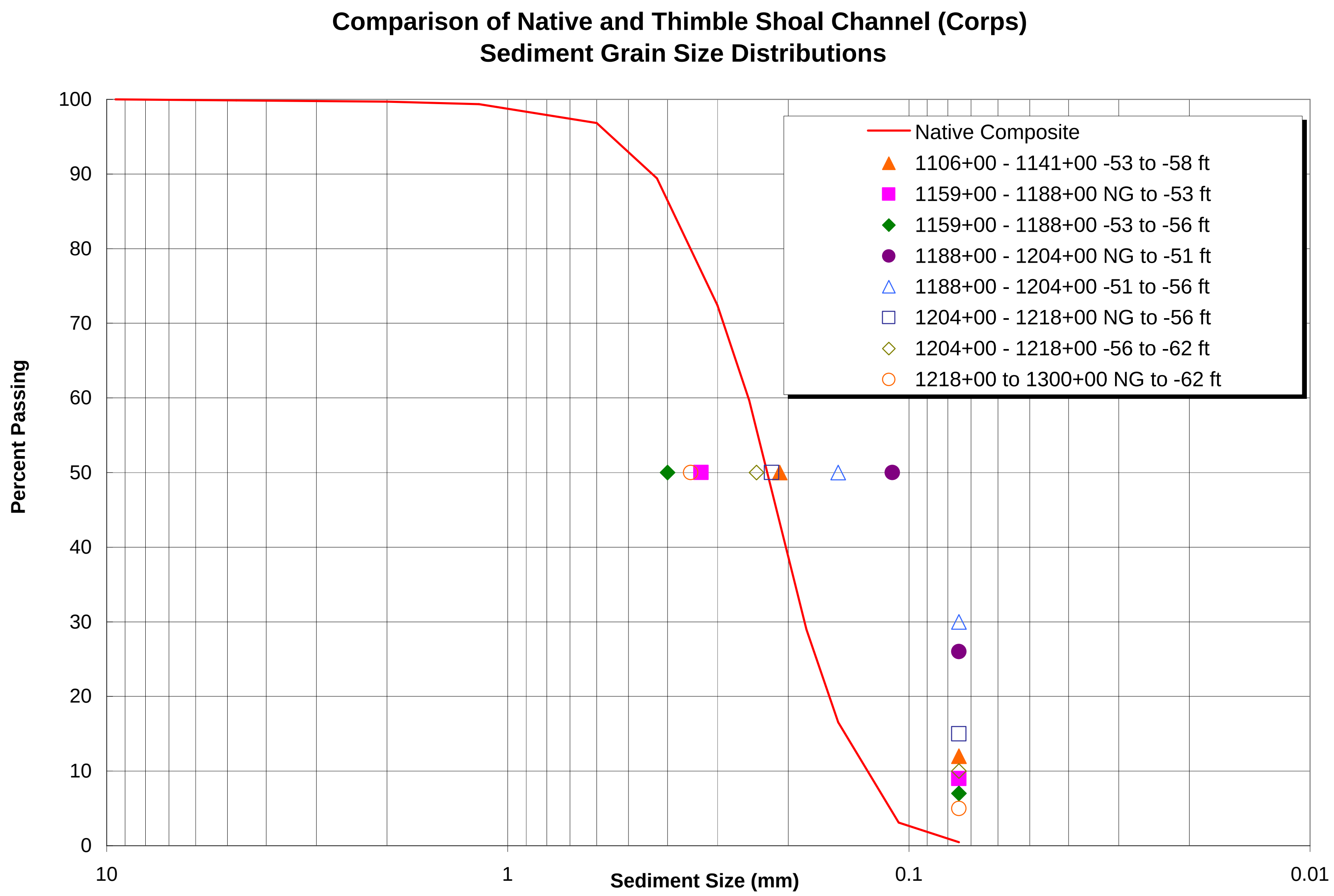

Figure 1-7 Comparison of Native Composite and COE Sediment Data