US Army Corps of Engineers
Philadelphia District

New Jersey Department of
Environmental Protection

New Jersey Beneficial Use of Dredged Material for the Delaware River

Feasibility Report and Integrated Environmental Assessment
Technical Appendices

Volume III

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Appendix C1 – Hydrology & Hydraulics

Appendix C2 – Civil Design

Appendix C3 – Cost Engineering

Appendix C4 – Geotechnical Data

US Army Corps of Engineers
Philadelphia District

NEW JERSEY BENEFICIAL USE OF DREDGED MATERIAL FOR THE DELAWARE RIVER

FEASIBILITY REPORT AND INTEGRATED ENVIRONMENTAL ASSESSMENT

APPENDIX C - HYDROLOGY, HYDRAULICS, AND COASTAL

May 2019

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1.0 INTRODUCTION

1.1 OVERVIEW OF APPENDIX

This Hydrology, Hydraulics, and Coastal Appendix provides an overview of the analyses supporting the New Jersey Dredge Material Utilization (DMU) Coastal Storm Risk Management Feasibility Study. The majority of Appendix focuses on the coastal engineering analyses conducted in support of the beach restoration alternative evaluation and Beach-fx modeling effort.

1.2 STUDY AREA

The study area is located within the section of the Delaware River watershed, which lies within the State of New Jersey and the Delaware River itself. The north/south boundaries of the study area extend from Trenton, NJ to Cape May Point, NJ (Figure 1). The centerline of the Delaware River and Bay represents the western study area boundary and it extends approximately 135 miles from the Atlantic Ocean upstream to the head of tide at Trenton, New Jersey.

For the purposes of CSRM, the study area not only includes flood prone areas along the mainstem Delaware River and Delaware Bay, but also the tributaries of the Delaware which contribute to both tidal and fluvial flooding. Tributaries to the Delaware River and Bay within the study area include: Dennis Creek, Maurice River, Cohansey River, Stowe Creek, Alloway Creek, Salem River, Oldmans Creek, Raccoon Creek, Mantua Creek, Big Timber Creek, Cooper River, Pennsauken Creek, Rancocas Creek and Black Creek.

This feasibility study evaluated coastal storm-related damages in New Jersey occurring in two defined planning reaches within the Delaware River/Bay system. The "northern reach" is from the head of tide at Trenton, NJ down to the approximate river/bay boundary (around Alder Cove), while the "southern reach" extends south from the Alder Cove area (river/bay boundary) to the mouth of the Delaware Bay at Cape May Point, NJ.

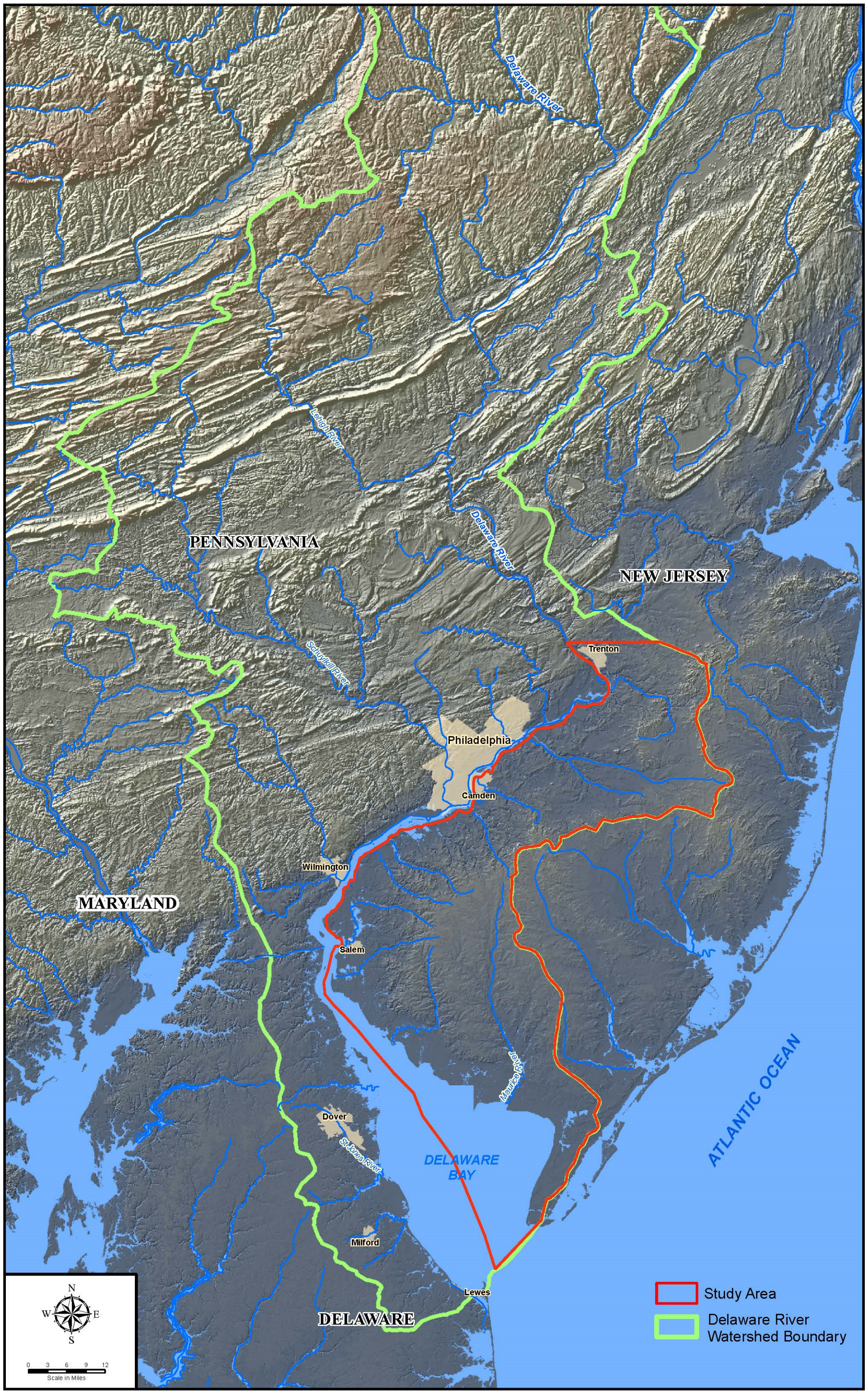


Figure 1: Study Area

2.0 SCREENING LEVEL ASSESSMENT

2.1 SCREENING LEVEL STAGE-PROBABILITY DATA

For the northern reach, stage-probability data for each of the DMU project sites were obtained directly from U.S. Army Engineer Research and Development Center (ERDC) in November 2015. These data were compiled by ERDC from the North Atlantic Coast Comprehensive Study (NACCS) results, originally finalized in January 2015, but subsequently updated to incorporate model refinements, and new data as they became available. Additional information regarding the NACCS modeling study is provided in Section 3.5.

NACCS modeling output supplied by ERDC was reported at each Save Point, which is a point in the modeled area at which results such as water surface elevation, wave height, etc., are saved, for a total of 18,977 discrete locations throughout the NACCS study area. These data were provided in both spreadsheet form, and as Google Earth KML format for use in GIS systems. As the NACCS numerical modeling utilized a coupled surge and wave model (ADCIRC + STWAVE), and for the results utilized for screening (Base+Tides conditions), reported water levels explicitly accounted for effects of storm surge, wave setup, and tides, but required incorporation of actual wave height effects (i.e. wave crest elevations). As such, two separate data sets were supplied by ERDC: one for static water level or stillwater elevation (SWEL), and one for wave height, again reported at each model node in the NACCS study area. Both data sets were supplied at various average recurrence intervals (ARI) from 1- to 10,000-yr, with the mean (average) value reported, including multiple upper confidence limits (84th, 90th, 95th percentile, etc.). For later incorporation into HEC-FDA, conversion from ARI to annual exceedance probability (AEP) was completed using the reciprocal (e.g. 2-yr ARI = 1/2, or an AEP of 0.5, or 50% annual chance exceedance (ACE)). NACCS model results were originally supplied in metric units, and were subsequently converted from meters, MSL to feet, NAVD88 through conversion values provided by ERDC.

Following data conversion, one half (0.5) the wave height was added linearly to the SWEL to account for wave effects, resulting in the wave crest elevation, or total water level (TWL), at each model save point, again across various ARI, and multiple confidence intervals. The one half (0.5) fraction is an approximation based on the simplifying assumption of linear wave theory. Wave height is the difference in elevation between the wave crest and wave trough. In linear wave theory, the total wave height (crest to trough) is vertically symmetrical about the still water level that is, the wave crest is ½ the of the wave height above the still water level. This was deemed sufficiently detailed for screening level decisions.

For each study location within the northern reach, multiple proximate save points (typically 3 to 5) were compiled. SWEL, wave height, and TWL data for compiled save points were plotted and reviewed to determine a representative save point at each study location. Additionally, as uncertainty varied spatially throughout the NACCS modeling domain, ERDC also provided estimates of epistemic uncertainty for each save point, to further qualify confidence in the model results, allowing screening of save points for use at each of the DMU study locations. In general, stage-probability data varied only slightly across each individual study location, and as such it was determined that data from a single representative save point was sufficient to describe anticipated water levels at each study location, to inform project screening. In total, two base stage-probability curves were determined for each study location: SWEL, and SWEL + ½ Wave

Height, each reported with the mean and multiple confidence limits. Figure 2 below depicts example location with NACCS Save Points used in screening assessment, with Table 1 showing all NACCS Save Points used during screening, by location. Figure 3 shows an example of output data from NACCS analysis for one location.

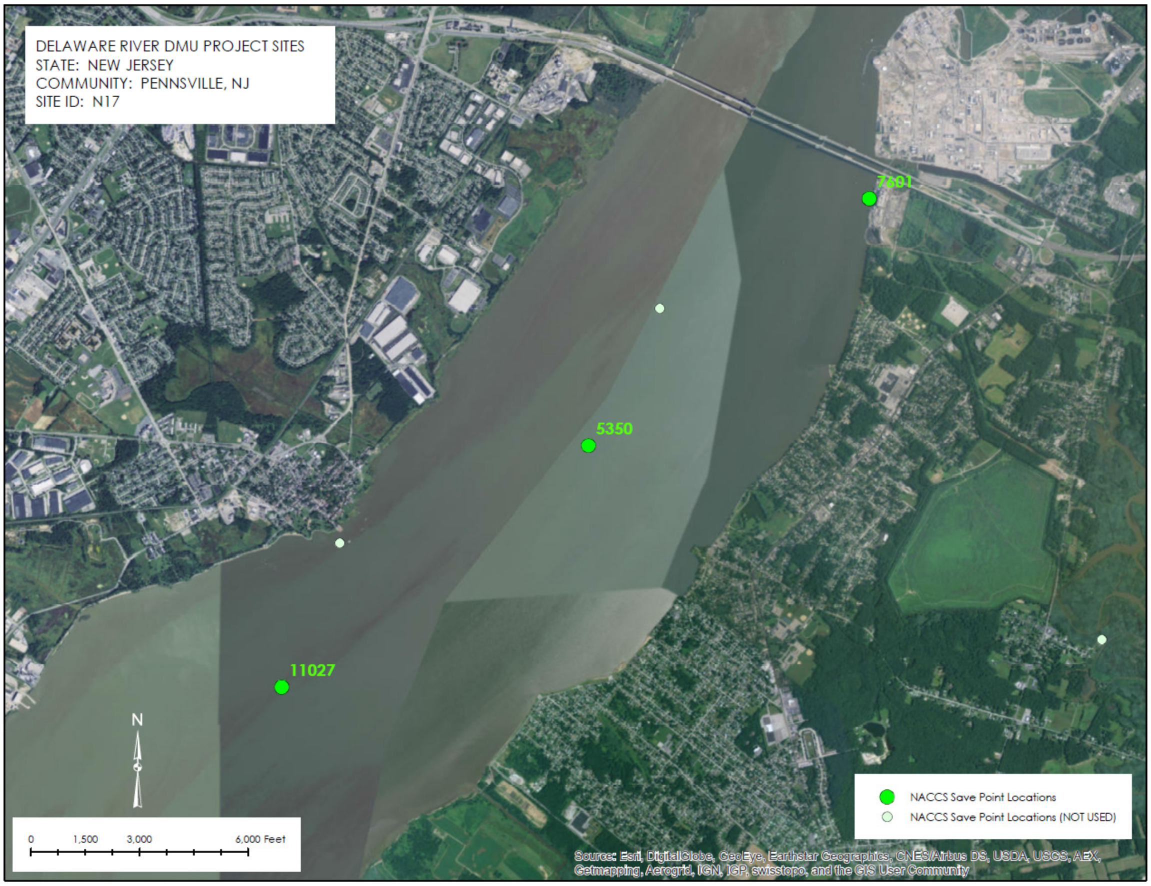


Figure 2: Example NACCS Save Point Map

Table 1: NACCS Save Points Used for Initial Screening

Site ID	N15	N17	N25	N26	N27	N28	N33
Location / Municipality	Penns Grove	Pennsville	Bivalve	Shellpile	Port Norris	Maurice River	Villas
NACCS Save Point ID	11109	13295	13403	13403	13403	11185	15258
	11030	5349	13402	13402	13402	11192	11168
	11100	11102	13404	13404	13404	11184	13425
	13322	11024	13396	13396	13396	13409	11169
	5351	7601	11191	11191	11191		15268
		11028	11185	11185	11185		11205
		5350					
		7158					
		11027					
		7600					
		7599					
		11112					

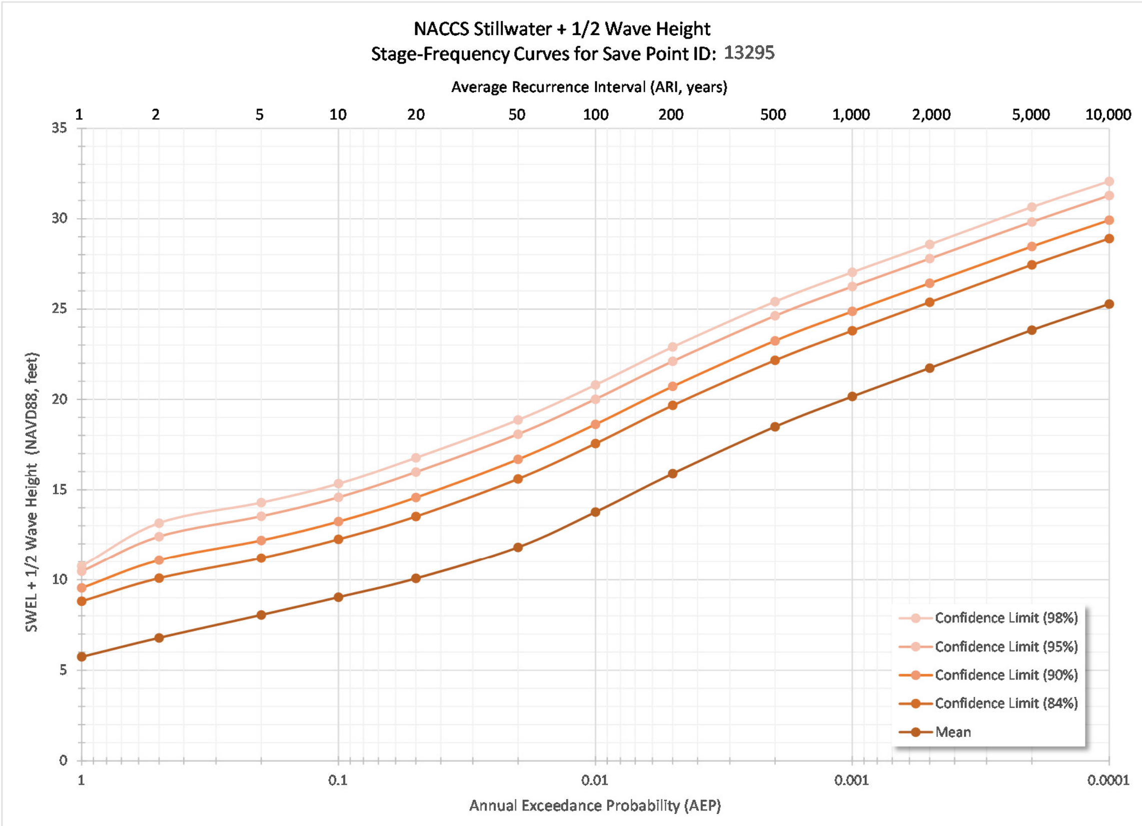


Figure 3: Example NACCS Save Point Output compiled for screening (note: confidence limits shown convey epistemic uncertainty only, not sampling uncertainty)

2.2 SCREENING LEVEL RELATIVE SEA LEVEL CHANGE (RSLC) ANALYSIS

In accordance with USACE ER 1100-2-8162, potential effects of RSLC on overall water levels were analyzed for each study location, over a 50-yr economic analysis period and a 100-yr planning horizon. Given the size and scope of potential projects, and associated anticipated timing, a base year for RSLC analysis of 2020 was used, with future years of 2070 and 2120. For each study location, the most appropriate NOAA gage (typically closest geographically) was determined, and RSLC adjustments were calculated for the future years using published RSLC rates, for the three recommended curves: USACE Low, USACE Intermediate, and USACE High. Table 2 summarizes the NOAA gage utilized for each study location. For screening purposes, these RSLC adjustments were added linearly to the base stage-probability curves discussed above, resulting in a total of eight stage probability curves compiled for each study location, again each with mean and multiple confidence limits for the economic analysis. These stage-probability curves are:

- Base year (2020) SWEL
- Future year (2070) SWEL + RSLC USACE Low
- Future year (2070) SWEL + RSLC USACE Intermediate
- Future year (2070) SWEL + RSLC USACE High

- Base year (2020) SWEL + 1/2 Wave Height
- Future year (2070) SWEL + 1/2 Wave Height + RSLC USACE Low
- Future year (2070) SWEL + 1/2 Wave Height + RSLC USACE Intermediate
- Future year (2070) SWEL + 1/2 Wave Height + RSLC USACE High

Given the anticipated size of any protection features, and negligible effects to stage of the tidal Delaware River and Bay, all stage-probability curves were utilized for both without and with-project conditions. As discussed above, at study locations where wave data was unreported, only SWEL curves were produced, for four total curves rather than eight.

Table 2: Nearest NOAA Gage used for Screening Level Sea Level Change Calculations

Site ID	Location / Municipality	Nearest NOAA Gage
N15	Penns Grove	8551910, Reedy Point, DE
N17	Pennsville	8551910, Reedy Point, DE
N25	Bivalve	8536110, Cape May, NJ
N26	Shellpile	8536110, Cape May, NJ
N27	Port Norris	8536110, Cape May, NJ
N28	Maurice River	8536110, Cape May, NJ
N33	Villas	8536110, Cape May, NJ

2.3 SCREENING LEVEL TOPOGRAPHIC REVIEW

Available topographic data and bathymetric data at each study location was compiled and reviewed in ArcGIS to further inform initial screening. Specifically, topographic-bathymetric combination (topobathy) LiDAR data from 2014 was available for the majority of the study area. This was supplemented with topographic LiDAR from 2009 where necessary for coverage of the entire floodplain for a few locations in the upper extent of the study area. All elevation data were reprojected, and converted as necessary, to horizontal datum of State Plane New Jersey, NAD83, feet, and a vertical datum of NAVD88, feet, for consistent use with the NACCS stage-probability curves.

At each study location, ArcGIS was utilized to cut profiles, laid out perpendicular to the shoreline. Multiple profiles were utilized at each location to estimate existing level of protection, continuity of protection features, as well as potential impacts of with-project features. Topography at each location was also reviewed to qualitatively assess potential incremental benefits to increasing level of protection. Further, profiles were utilized for feasibility level quantity estimates of with-project conditions at each study location. FEMA Flood Insurance Rate Maps were also utilized to inform initial screening. Figure 4 shows an example of topographic profile placement and Table 3 below summarizes estimated level of existing protection at each of the study locations.

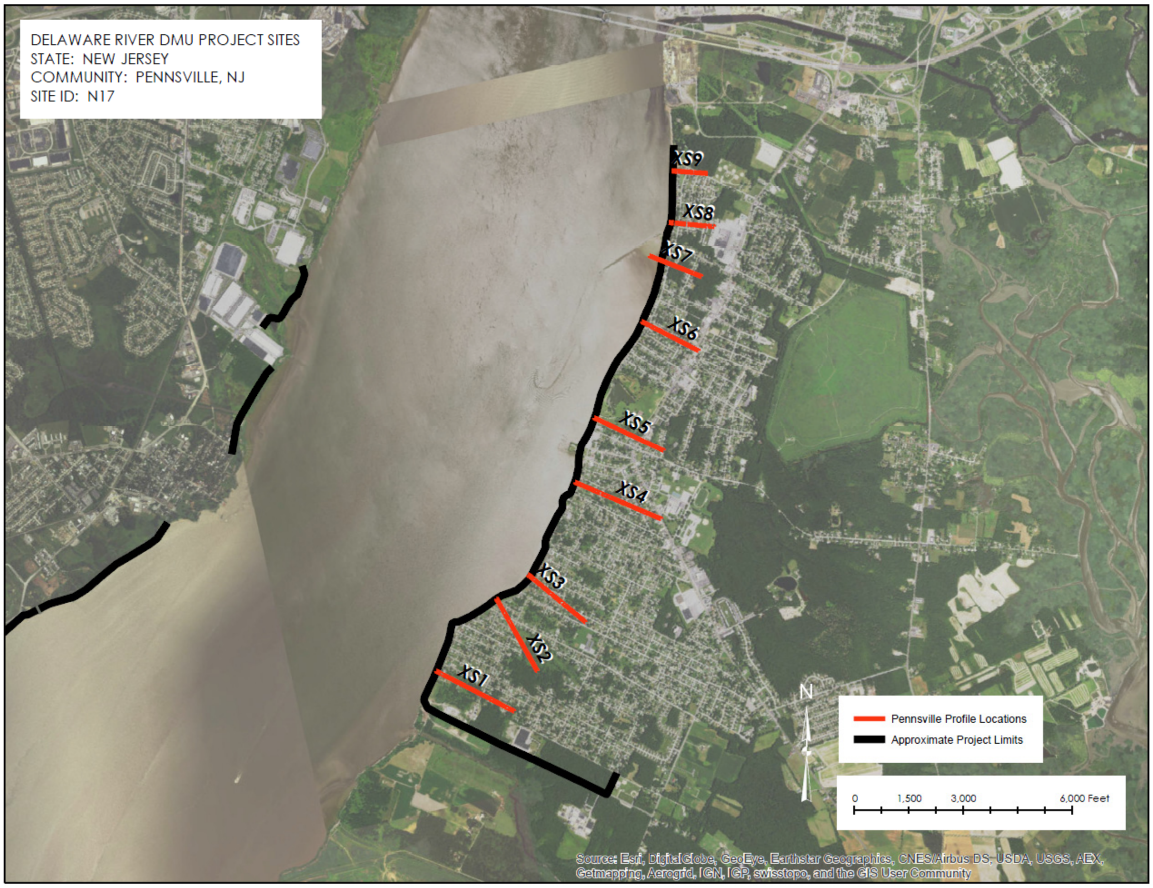


Figure 4: Example profile locations for screening

Table 3: Existing level of protection from topographic assessment

Site ID	Location / Municipality	Approx. Elevation of High Ground / Existing 'Protection' (ft, NAVD88)
N15	Penns Grove	7.0 to 8.0
N17	Pennsville	7.5 to 9.5
N25	Bivalve	6.0 to 6.5
N26	Shellpile	6.0 to 6.5
N27	Port Norris	6.0 to 6.5
N28	Maurice River	10.0 to 12.0
N33	Villas	9.0 to 12.0

2.4 SCREENING LEVEL SUMMARY

Per the screening methodologies applied in Section 2.1 through 2.3 above, the original intent was to use the two stage-probability curves generated by the NACCS numerical modeling as inputs to the HEC-FDA model to estimate the economic benefits of a beach restoration project at the CSRM problem areas. However, after further analysis, the PDT divided the study area into two planning reaches (northern reach and southern reach) based on the differing characteristics of the waterway in each reach.

In the northern reach, the width of the waterway is relatively smaller and the principal CSRM damages are due to inundation related to coastal storm surge (which includes wave radiation stresses), as occurs during tropical storms, hurricanes or nor'easters. However, in the southern reach, the width of the bay (fetch) increases and allows wind to generate greater wave energy at the shoreline, so that waves create an additional risk mechanism beyond inundation alone. Due to the additional damage mechanisms, the southern reach experiences CSRM damages from the combined effects of inundation, waves and storm erosion, analogous to the damage mechanisms experienced on the open ocean coast. Consideration of these additional damage mechanisms led to the inclusion of additional sites in the southern planning reach: Gandys Beach, Fortescue, Reeds Beach, Pierces Point, and Del Haven.

As qualitative screening, supported by a Value Engineering study, ruled out the CSRM problem areas in the northern planning reach (riverine portion of the study area), it became apparent that HEC-FDA was not the appropriate model to evaluate the sites in the southern reach. Therefore, Villas (N33) and five other sites (Gandys Beach, Fortescue, Reeds, Pierces, and Del Haven) were further analyzed with Beach-fx, as described in subsequent sections.

3.0 EXISTING CONDITIONS

This section provides a description of the hydraulic and coastal existing conditions at the six sites carried forward for to further evaluation as a beach restoration alternative. The six sites are (from north to south): Gandys Beach, Fortescue, Reeds Beach, Pierces Point, Del Haven, and Villas. Included in this section is a description of the tides, sea level change, winds, waves, NACCS model results, and historical shoreline changes. Figure 5 shows the location of the six sites as well as some of the tidal stations, wave buoy stations, and NACCS Save Points used throughout the study.

3.1 ASTRONOMICAL TIDES

Daily tidal fluctuations at the project site are semi-diurnal, with two highs and two lows per 24-hour day. Tidal ranges in Delaware Bay increase with distance above the mouth of the bay and reach a local maximum in the vicinity of Gandys Beach and Fortescue. Figure 6 shows the mean maximum tidal height in Delaware Bay. Tidal datum relationships at three NOAA stations in the study area are presented in Table 4. Fortescue Creek is used in this study to represent tidal conditions at Gandys Beach and Fortescue. Brandywine Shoal Light is used in this study to represent Reeds Beach and Pierces Point. Cape May, NJ is used to represent Del Haven and Villas.

Table 4: Tidal Datum Relationships

Datum[1]	Fortescue Creek (Feet, NAVD88)	Brandywine Shoal Light (Feet, NAVD88)	Cape May (Feet, NAVD88)
MHHW	3.20	2.60	2.43
MHW	2.80	2.16	1.99
NAVD88	0.00	0.00[2]	0.00
MSL	-0.03	-0.29	-0.45
MLW	-3.05	-2.74	-2.86
MLLW	-3.22	-2.90	-3.02

Notes: [1]Tidal datums based on 1983-2001 Tidal Epoch, [2]NAVD88 based on NOAA's VDATUM Software

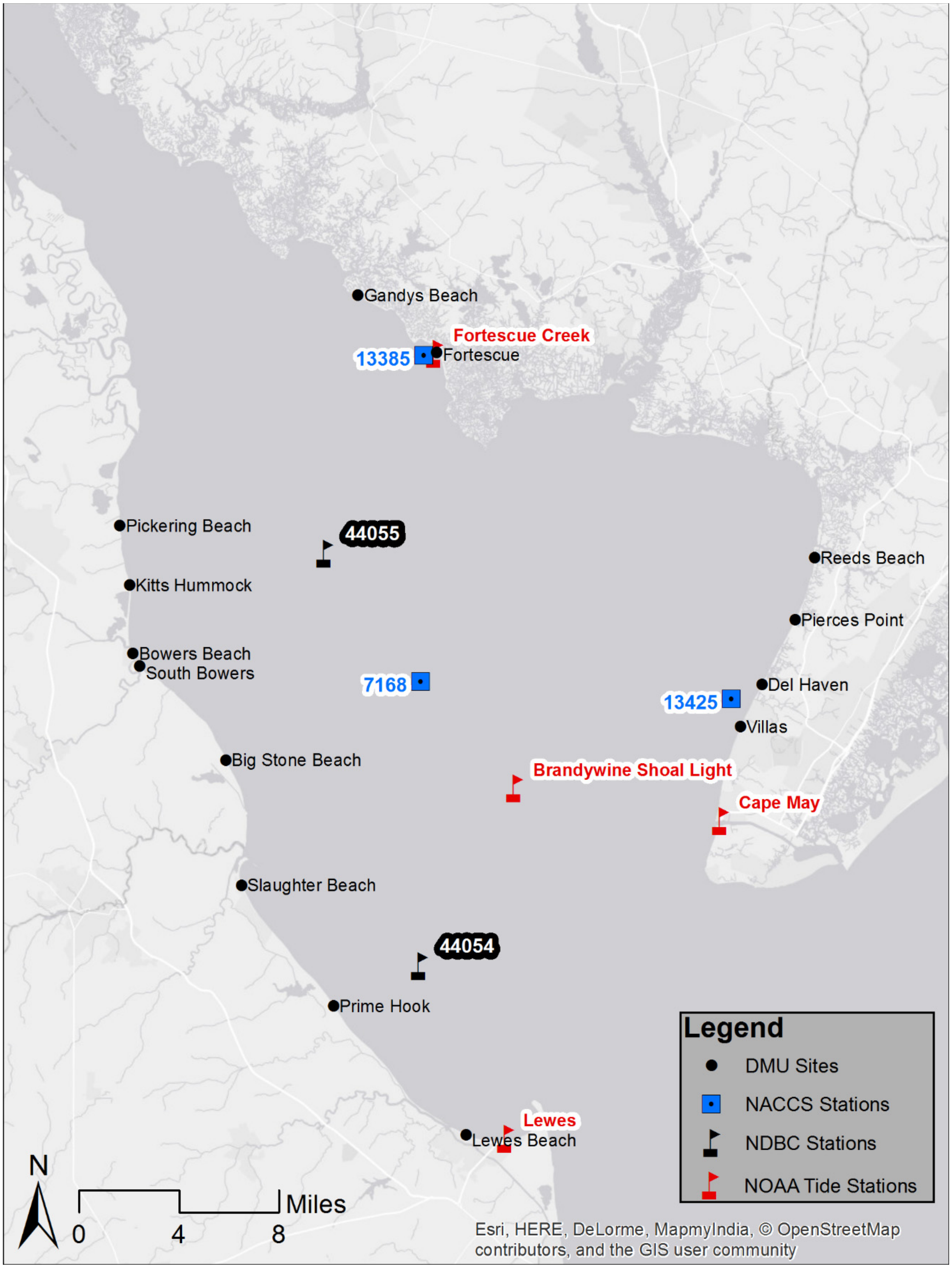


Figure 5: Existing Condition Data

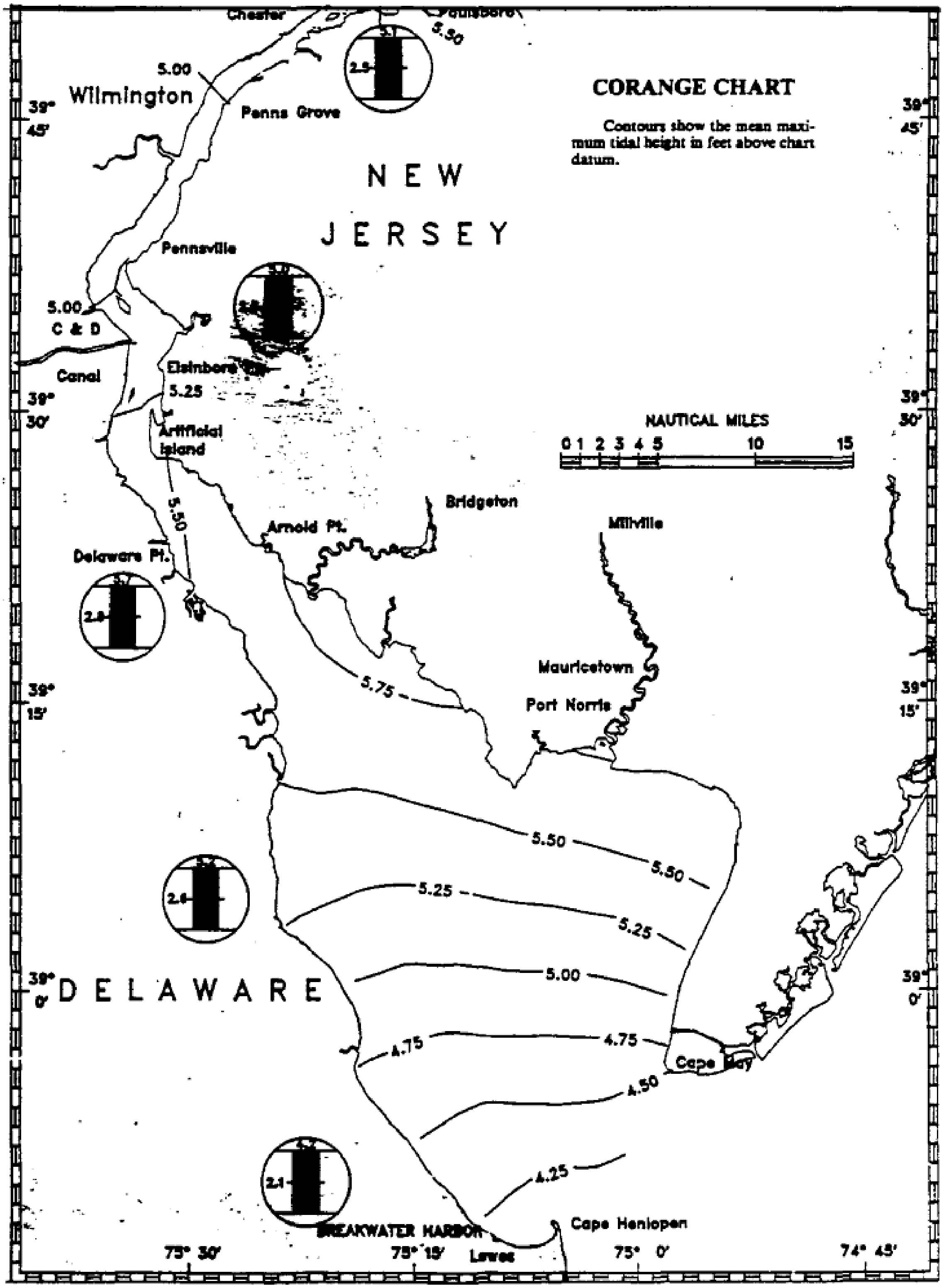


Figure 6: Maximum Tidal Range Contours (NOAA, 1988)

3.2 SEA LEVEL CHANGE

In accordance with ER 1100-2-8162, potential effects of relative sea level change (RSLC) on overall water levels were analyzed for each study location, over a 50-yr economic analysis period and a 100-yr planning horizon. A RSLC may be composed of both an absolute mean sea level change component and a vertical land movement change component. Historical sea level measurements at NOAA tide stations record the observed RSLC over time and capture the combined effect of absolute mean sea level change and vertical land movement.

Historical RSLC and USACE SLC scenarios for this study are based on NOAA tidal records at Lewes, DE (Figure 7). . Lewes, DE was selected over Cape May, NJ because the tidal record length at Lewes, DE is several decades longer than Cape May, NJ. Table 5 presents RSLC projections for the three USACE scenarios: Low/Historical, Intermediate, and High. A graphical display of the three RSLC scenarios over the 100-yr planning horizon is presented in Figure 8.

Table 5: USACE Sea Level Change Scenarios

Year	USACE - Low (ft, MSL[1])	USACE - Int (ft, MSL[1])	USACE - High (ft, MSL[1])
1992	0.0	0.0	0.0
2020	0.3	0.4	0.6
2045	0.6	0.8	1.6
2070	0.8	1.4	3.1
2095	1.1	2.0	5.0
2120	1.3	2.8	7.4

[1]Mean Sea Level based on National Tidal Datum Epoch (NTDE) of 1983-2001

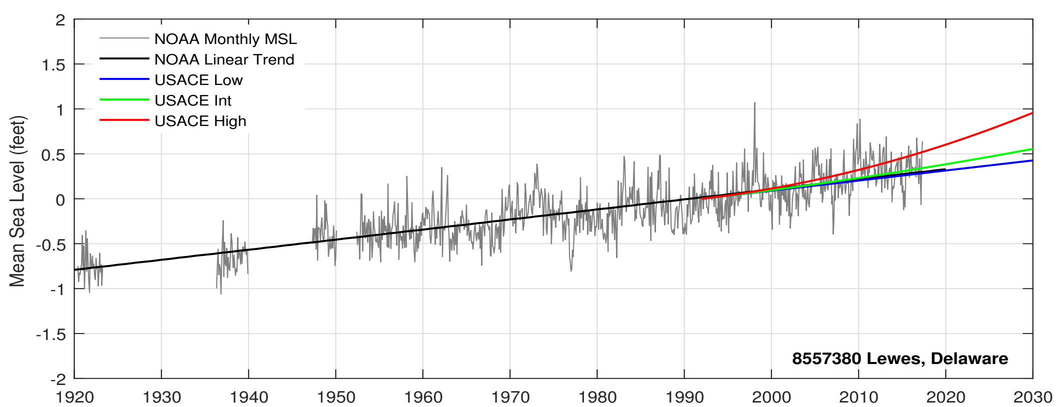


Figure 7: Historical Relative Sea Level Change at Lewes, DE

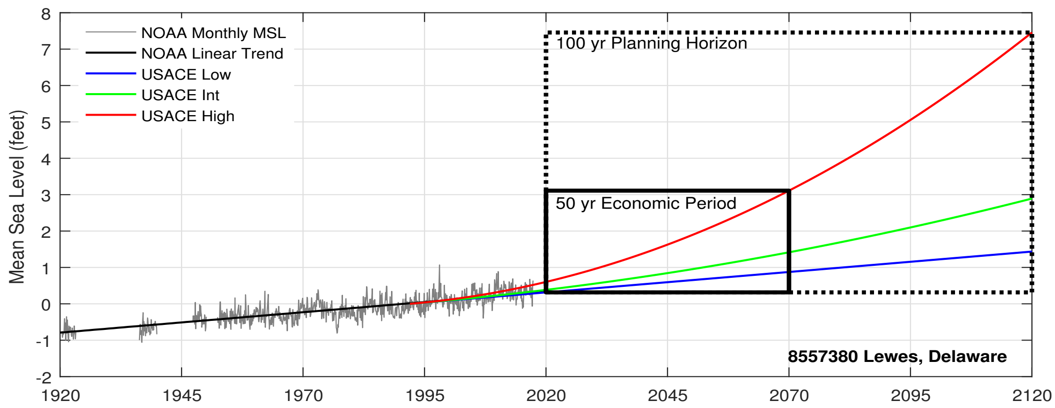


Figure 8: Relative Sea Level Change Projections at Lewes, DE

3.3 WINDS

The prevailing wind direction reported at the Brandywine Shoal Light in Lower Delaware Bay is from the northwest. The annual wind rose diagram in Figure 9 shows that the most frequent and strongest wind directions (greater than 26 knots) are from the northwest. However, relatively strong winds (greater than 18 knots) occur from all directions. Seasonal wind roses, as seen in Figure 10, show that the wind regime varies from season to season, with the stronger winter winds prevailing from the northwest and the majority of the summer winds prevailing from the south. However, some of the strongest winds (highest velocity) observed throughout the year are from the northeast (USACE 1998).

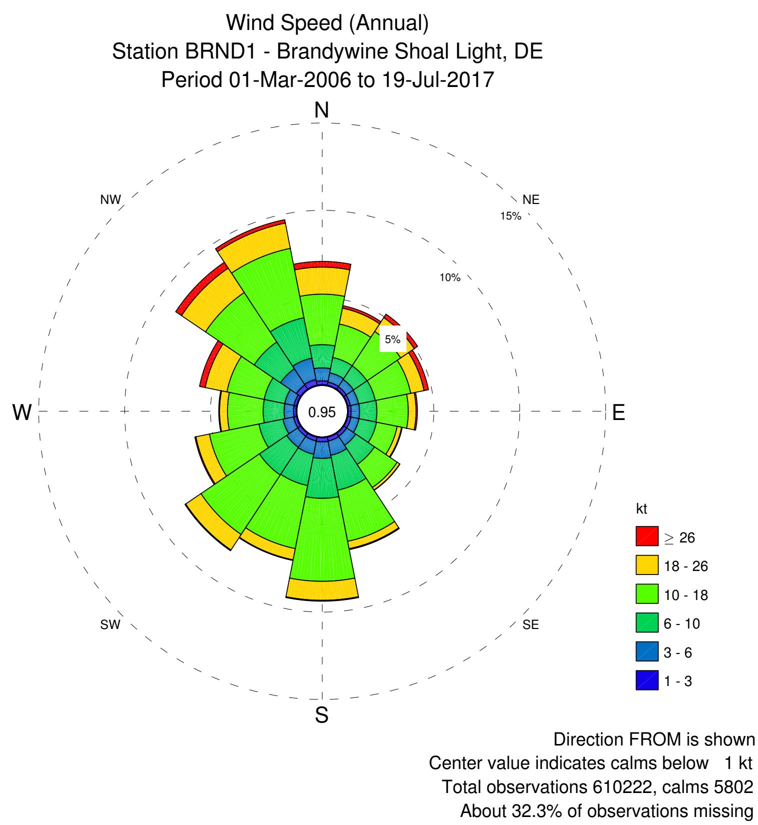
3.4 WAVES

Waves within Delaware Bay may be generated by local winds or propagate from the ocean through the mouth of the Bay. Further away from the mouth of the Bay the wave direction is associated with the wind direction and prevailing fetch. Two NOAA National Data Buoy Center (NDBC) stations are available inside Delaware Bay, 44054 and 44055. Table 6 shows the location and available record length at these two buoy stations. Station 44054 is located near the mouth of the Bay and is exposed to a combination of local winds and waves that propagate through the mouth of the Bay. Station 44055 is located farther up the Bay and is primarily exposed to locally generated waves. Wave roses for these two stations, Figure 11 and Figure 12, show that the primary difference between this two stations is that the 44054 is exposed to significant more direction from the east (i.e. propagating from ocean through the mouth of the Bay). Station 44054 is only located about 4 miles offshore of the Delaware Coastline and as a result wind generated waves from the SW quadrant don't have open water fetch to grow into significant waves.

The six sites under consideration in this study are sheltered from ocean waves propagating through the mouth of the Bay. Therefore, the general wave conditions at the sites is best characterized by station 44055. However, the wave directions at each of the 6 sites will vary based on the prevailing open water fetch direction and lengths. Wave Height probability of exceedance at Station 44055 is shown in Figure 13 and the joint probability between the wave height and peak wave period is shown in Figure 14. The joint probability figure shows that the largest wave heights at Station 44055 are short waves with peak wave periods between 2 and 6 seconds.

Table 6: NOAA NDBC Wave Data

Buoy Station	Latitude (deg. N)	Longitude (deg. W)	Water Depth (ft)	Record Length
44054	38.883	75.183	26	2017-2-6 to 2008-1-29
44055	39.122	75.256	n/a	2017-6-6 to 2008-1-29



Percentage of Occurrence

Wind Speed, kt	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Total	7.08	4.66	5.18	4.81	4.04	3.25	3.94	6.58	9.38	7.21	8.11	6.06	4.52	5.78	8.76	9.68	99.05
≥ 26	0.33	0.14	0.24	0.27										0.34	0.41	0.20	2.36
18 - 26	1.55	0.93	0.95	0.79	0.45	0.26	0.17	0.43	1.09	0.66	1.07	0.80	0.46	1.29	1.68	1.48	14.05
10 - 18	2.89	1.95	2.36	2.11	1.83	1.23	1.59	2.98	4.75	3.68	4.09	2.93	2.07	2.21	3.41	4.05	44.15
6 - 10	1.33	0.90	0.94	0.99	1.01	1.04	1.32	2.04	2.29	1.83	1.91	1.43	1.22	1.22	1.85	2.36	23.64
3 - 6	0.74	0.54	0.51	0.49	0.49	0.47	0.63	0.83	0.94	0.78	0.77	0.63	0.55	0.55	1.11	1.25	11.28
1 - 3	0.24	0.20	0.18	0.17	0.19	0.21	0.22	0.24	0.26	0.23	0.22	0.20	0.17	0.18	0.31	0.35	3.57

Figure 9: Brandywine Shoal Light Annual Wind Rose

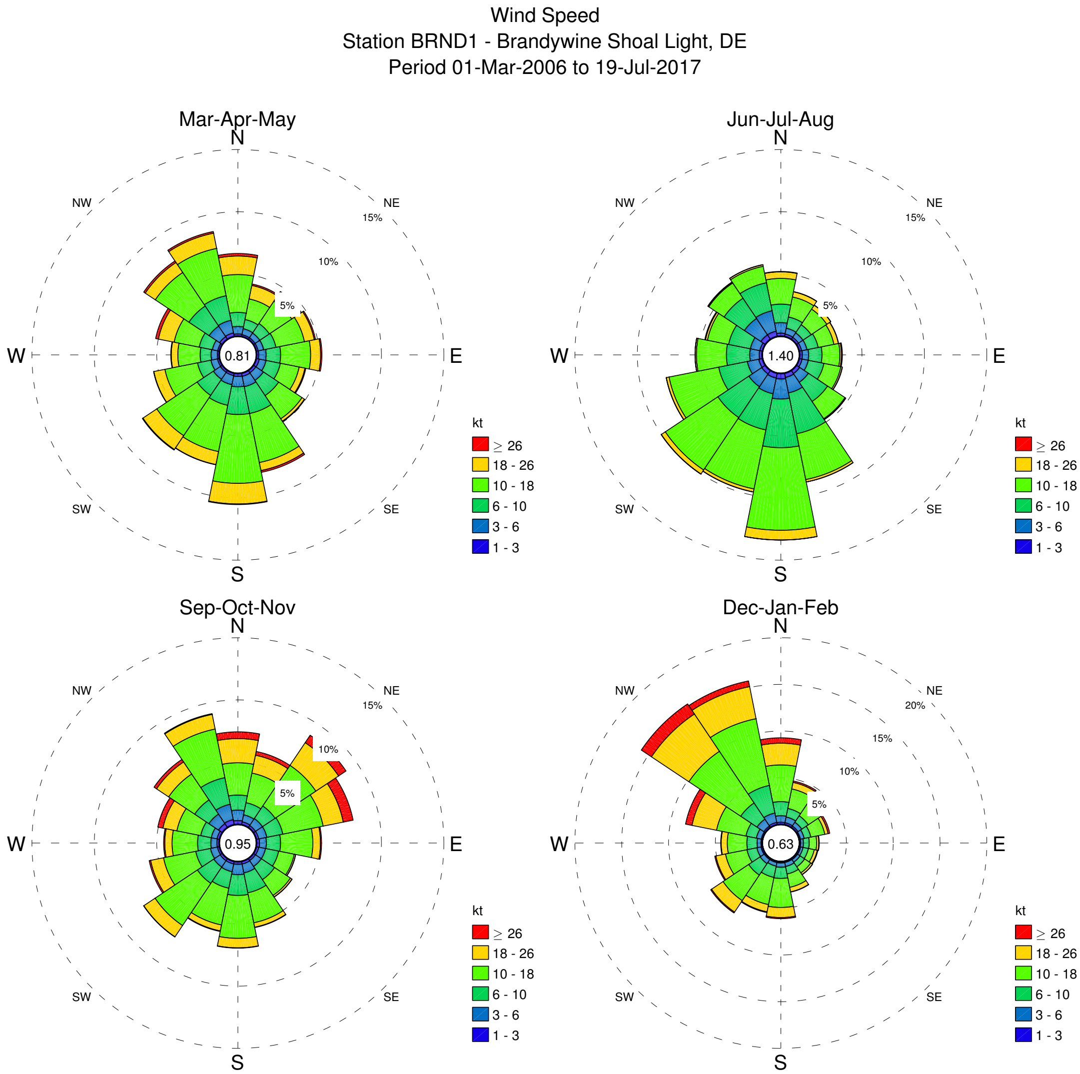
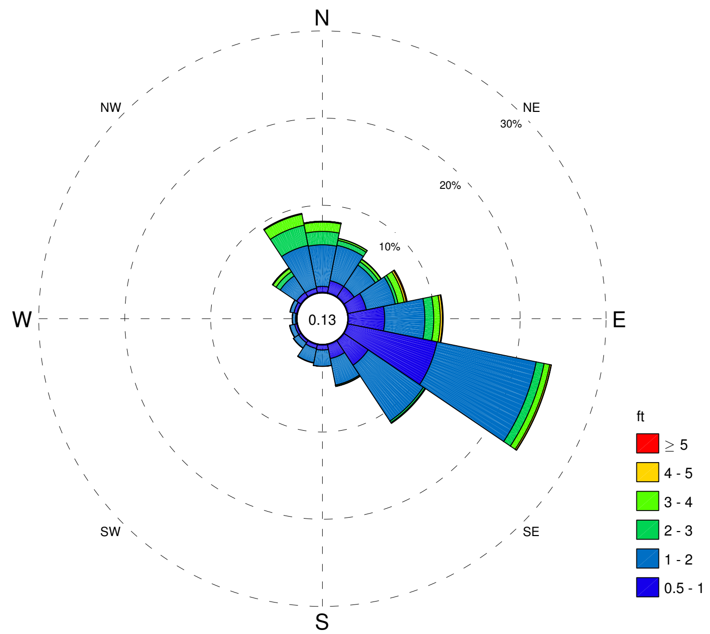


Figure 10: **Brandywine Shoal Light Seasonal Wind Roses**

Significant Wave Height (Annual)
Station 44054 - Lower Delaware Bay
Period 06-Feb-2007 to 29-Jan-2008

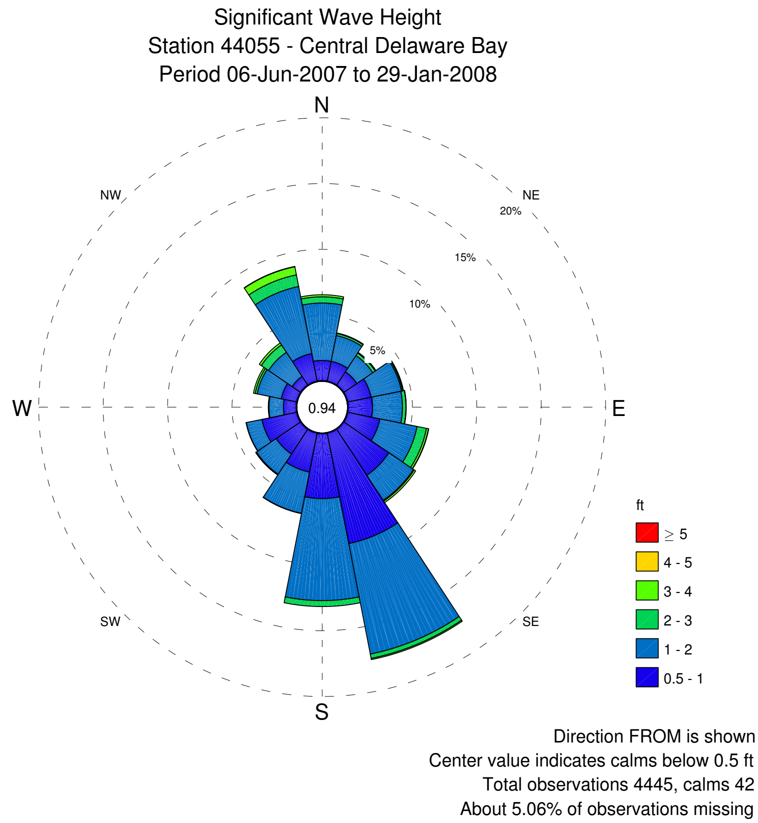


Direction FROM is shown
Center value indicates calms below 0.5 ft
Total observations 5536, calms 7
About 23.9% of observations missing

Percentage of Occurrence

Significant Wave Height, ft	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Total	8.18	6.39	5.24	7.06	11.05	24.17	11.45	4.93	2.47	2.20	1.08	0.90	0.52	0.87	4.01	9.32	99.87
≥ 5				0.13													0.31
4 - 5				0.23	0.25	0.16										0.11	1.01
3 - 4	1.07	0.22	0.33	0.74	0.76	0.67	0.11	0.13							0.43	1.28	5.73
2 - 3	1.54	0.58	0.45	0.33	1.03	0.94	0.22								0.58	2.37	8.22
1 - 2	4.77	4.14	2.96	3.43	4.68	11.76	7.71	3.11	1.86	1.66	0.72	0.58	0.38	0.45	2.29	5.00	55.51
0.5 - 1	0.70	1.45	1.45	2.20	4.24	10.60	3.41	1.66	0.60	0.49	0.33	0.29	0.13	0.38	0.61	0.56	29.10

Figure 11: Buoy 44054 Annual Wave Rose



Percentage of Occurrence

Significant Wave Height, ft	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Total	6.55	3.76	3.01	4.43	4.52	6.43	6.73	17.57	13.16	6.25	4.21	4.03	2.18	3.44	3.87	8.91	99.06
5 –																	
4 – 5																	
3 – 4	0.16					0.16	0.13							0.13	0.18	0.63	1.75
2 – 3	0.47	0.16	0.22		0.27	0.74		0.34	0.45					0.16	0.67	0.90	4.63
1 – 2	4.36	2.00	1.48	2.41	2.32	2.95	2.29	8.57	7.76	3.19	1.84	1.24	1.12	1.91	2.20	5.20	50.87
0.5 – 1	1.55	1.55	1.24	1.87	1.91	2.56	4.23	8.57	4.95	3.04	2.29	2.77	1.01	1.24	0.81	2.16	41.75

Figure 12: Buoy 44055 Annual Wave Rose

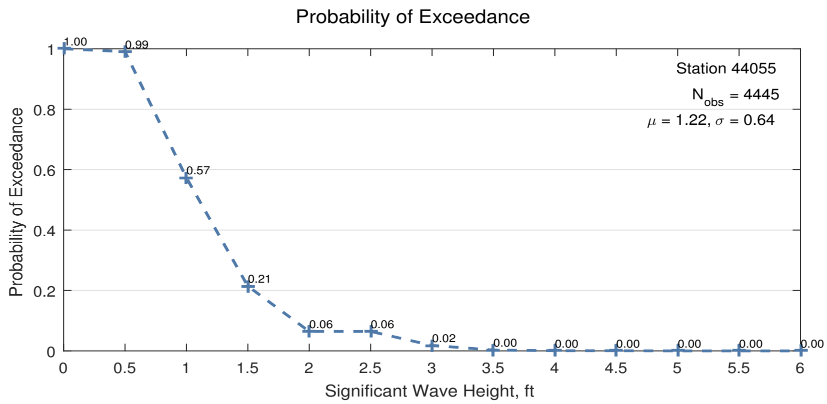


Figure 13: Buoy 44055 Probability of Exceedance

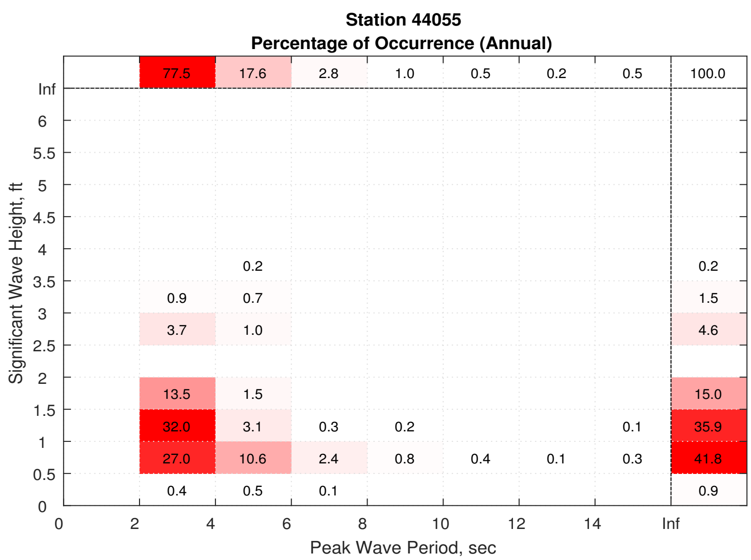


Figure 14: Buoy 44055 Joint Probability of Wave Height and Period

3.5 NORTH ATLANTIC COAST COMPREHENSIVE STUDY (NACCS)

The North Atlantic Coast Comprehensive Study (NACCS) was authorized under the Disaster Relief Appropriations Act, PL 113-2, in response to Superstorm Sandy. The Act provided the USACE up to $20 Million to conduct a study with the goal to (1) reduce flood risk to vulnerable coastal populations, and (2) promote resilient coastal communities to ensure a sustainable and robust coastal landscape system, considering future sea level change and climate change scenarios.

As part of the NACCS, the US Army Engineer Research and Development Center (ERDC) completed a coastal storm wave and water level modeling effort for the U.S. North Atlantic Coast. This modeling study provides nearshore wind, wave, and water level estimates and the associated marginal and joint probabilities critical for effective coastal storm risk management. This modeling effort involved the application of a suite of high-fidelity numerical models within the Coastal Storm Modeling System (CSTORM-MS) to 1050 synthetic tropical storms and 100 historical extra-tropical storms. Documentation of the numerical modeling effort is provided in Cialone et al. 2015 and documentation of the statistical evaluation is proved in Nadal-Caraballo et al. 2015. Products of the study are available for viewing and download on the Coastal Hazards System (CHS) website: https://chs.erdc.dren.mil/.

NACCS modeling results are applied throughout the NJ DMU study to define wave and baseline water level Annual Exceedance Probabilities (AEP) and in the development of the Beach-fx storm suite. Model results at two save points, #13425 and #13385, are used to characterize the nearshore wave and water level conditions at the 6 sites. The location of these save points in relation to the 6 sites is shown in Figure 5. Water level and wave height AEP at these two save points are presented in Table 7 and Table 8 respectively. The baseline water level AEP are taken from on the “Base + Linear superposition of 96 random tides” simulations and the mean confidence interval. The baseline water levels represent the combination and joint probability of storm surge occurring at different possible tidal amplitudes and phases. The wave height AEP are based on the “Base Conditions + 1 random tide” simulations and the mean confidence interval.

The water levels reported in Table 7 represent the peak water level observed during a storm due to the combination of storm surge and astronomical tide. Theoretically wave setup could also contribute to the peak water level, however the save points are located in relatively deep water outside the surf zone where wave setup should be small. The water level does not include individual wave crests which may increase the instantaneous water surface by approximately 0.5 times the wave height (applying linear wave theory).

Table 7: NACCS Water Level Annual Exceedance Probability

Return Period (years)	Average Annual Exceedance Probability	#13425 (ft, NAVD88)	#13385 (ft, NAVD88)
1	100.0%	4.0	4.3
2	50.0%	4.6	4.9
5	20.0%	5.3	5.7
10	10.0%	5.7	6.3
20	5.0%	6.2	6.9
50	2.0%	7.0	8.1
100	1.0%	7.9	9.5
200	0.5%	8.9	11.0
500	0.2%	10.1	12.8

Table 8: NACCS Wave Height Annual Exceedance Probability

Return Period (years)	Average Annual Exceedance Probability	#13425 Hs (ft)	#13385 Hs (ft)
1	100.0%	4.7	4.0
2	50.0%	5.4	4.7
5	20.0%	6.1	5.5
10	10.0%	6.4	6.1
20	5.0%	6.7	6.7
50	2.0%	6.9	7.2
100	1.0%	7.2	7.5
200	0.5%	7.6	7.8
500	0.2%	8.3	8.4

Note: Nominal water depths at Stations 13425 and 13385 are 15 ft and 8 ft below NAVD88, respectively

3.6 SHORELINE CHANGE

The purpose of the historic shoreline change analysis is to document the past behavior of the study area's shorelines, in order to make a reasonable estimate of the long-term shoreline change rates. Previously documented shoreline change rates along the study area were reviewed and are summarized in Table 9. The alongshore extent corresponding to each location in Table 9 is shown in Figure 15. In addition to the prior studies, a new shoreline change analysis (Attachment C) was completed at Villas and Del Haven using long profile survey data from 1995 and LiDAR data from 2014. There is considerably less information available on shoreline change rates at Gandys Beach and Fortescue. Observed shoreline changes at Fortescue were adjusted based on past beach fill activities to determine what the shoreline change rate would likely have been in the absence of these activities.

It is evident from Table 9 that there is fairly good agreement between previously reported shoreline change rates and more recent analyses by the Stockton College Coastal Research Center (2016) and USACE (2016). The greatest uncertainty appears to be at Reeds Beach, with reported values ranging between -3 ft/yr and 0 ft/yr. However, the more recent analyses show that the shoreline at Reeds Beach has been stable with shoreline change rates up to -1 ft/yr.

Recommended Future Without Project (FWOP) shoreline change rates for the NJ DMU project, Table 11, are a synthesis of all the available shoreline change data in study area with greater emphasis on newer data.

Table 9: Historical Shoreline Change Rates (ft/yr) from Prior Studies – Cape May County

<table>
<tr><th rowspan="2">Location</th><th>USACE 1960</th><th>USACE 1991</th><th>FEMA 1993</th><th>USACE 1998a</th><th>USACE 1998b</th><th>CRC 2016</th><th>USACE[2] 2016</th></tr>
<tr><th>1842 to 1957</th><th>1842 to 1957</th><th>1842 to 1986</th><th>1943 to 1995</th><th>1842 to 1994</th><th>1995 to 2016</th><th>1995 to 2014</th></tr>
<tr><td>Goshen Creek</td><td rowspan="2">-3.0[1]</td><td rowspan="2">-3</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Reeds North</td><td rowspan="3">-2</td><td></td><td>0</td><td>0</td><td></td></tr>
<tr><td>Reeds South</td><td rowspan="2">-0.2</td><td rowspan="2">0</td><td></td><td>-1</td><td></td><td></td></tr>
<tr><td>Pierces Point</td><td></td><td>-1</td><td></td><td></td></tr>
<tr><td>Del Haven</td><td rowspan="2">+1.0</td><td rowspan="2">+1</td><td rowspan="2">0</td><td>-0.6</td><td></td><td></td><td>-0.1</td></tr>
<tr><td>Villas North</td><td>-0.2</td><td></td><td>+1.5</td><td>+1.5</td></tr>
<tr><td>Villas South</td><td rowspan="2">-2.3</td><td rowspan="2">-2</td><td>-2</td><td>-1.4</td><td></td><td></td><td>-0.9</td></tr>
<tr><td>North Cape May</td><td>+3</td><td>+1</td><td></td><td>0</td><td>+0.1</td></tr>
</table>

[1]Shoreline change reported for Reeds Beach to Goshen Creek
[2]Analysis conducted by Philadelphia District in support of this study, Attachment A

Table 10: Historical Shoreline Change Rates (ft/yr) from Prior Studies – Downe Township

Location	USACE 1991	HMM 2016	USACE[2] 2017
	1943 to 1995	1930 to 2013	1943 to 1995
Gandys Beach		-2.5	
Fortescue	-1		-2.5[1]

[1]Shoreline change rate in absence of past beach fill activities
[2]Analysis conducted by Philadelphia District in support of this study, Attachment A

Table 11: Recommended FWOP Shoreline Change Rates (ft/yr)

Location	Characterization	Shoreline Change (ft/yr)
Gandys Beach	Moderate Erosion	-2.5
Fortescue	Moderate Erosion	-2.5
Reeds Beach	Stable to Low Erosion	-1
Pierces Point	Stable to Low Erosion	-1
Del Haven	Stable	0
Villas North	Stable to Accretion	+0.5
Villas South	Moderate Erosion	-1.5

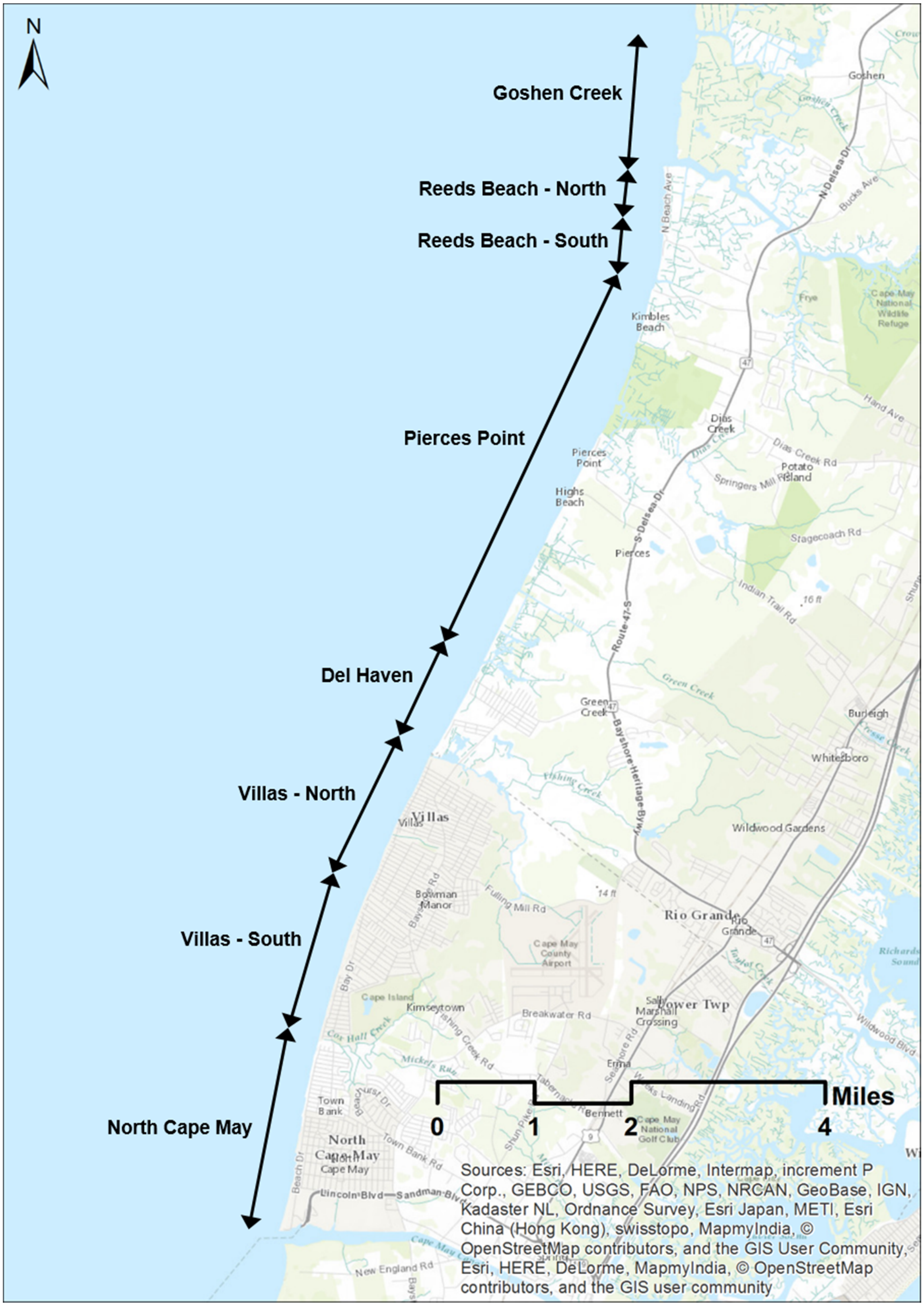


Figure 15: Shoreline Change Analysis Locations – Cape May County

3.7 LONGSHORE SEDIMENT TRANSPORT

Longshore sediment transport (LST) is the process by which incident waves, and to a lesser degree, tidal currents, mobilize sandy sediment in the swash zone and transport it in the alongshore direction, which by convention is considered either to the right or to the left of an observer facing open water. Delaware Bay shorelines experience LST in either alongshore direction at different times, depending on the incident wave direction at any given time. Over long periods transport in one direction will usually dominate transport in the other direction, with the dominant direction referred to as the direction of “net” transport.

There are two recent investigations of longshore transport in the study area that the USACE NJ DMU study team considered in project development. The engineering firm Hatch Mott MacDonald (HMM, later “Mott MacDonald”) performed an investigation in 2015-2016 titled “Gandy’s Beach Beachfront Sustainability Project”. This study utilized numerical models of relevant physical processes (wind, waves, and currents) to estimate the potential LST rate and direction along Gandys Beach and the adjacent TNC Preserve. It is emphasized that this modeling approach computes “potential” transport based on the directional distribution of wave and current energy. However, this approach does not predict “actual” sediment transport, as the method assumes an ample sandy sediment supply available for transport. This assumption is not valid for existing conditions at Gandys Beach, because of the absence of an adequate nearshore supply of sand. Nevertheless, the investigation computed that there is net northwestward potential transport at the northwest “corner” of Gandys Beach, toward the TNC Preserve.

The second investigation is the “Delaware Bay Sediment Transport Analysis Tool” (DBSTAT) developed by Stockton University for portions of the Delaware Bay shoreline in Cape May and Cumberland Counties. Unlike the HMM modeling approach, the DBSTAT effort is based on actual in situ measurements and observations, either with human observers or with electronic instruments. Although the DBSTAT data are observed and not modeled, the DBSTAT data are from much shorter periods of time compared to the several-decade numerical model simulation performed by HMM.

Considering the resources required to conduct sediment transport analysis and low accuracy and high uncertainty, the USACE chose base future without project conditions and periodic nourishment needs on historical shoreline change observations and end losses calculated from analytical shoreline change modeling. The analytical shoreline change modeling captures the additional sediment transport and losses associated with a perturbation (i.e. wide beach) along the natural shoreline, which under wave action, will spread out along the shoreline.

4.0 BEACH-FX INPUT DATA

4.1 REPRESENTATIVE PROFILES

BEACH-FX SIMPLIFIED PROFILE

Due to the complexity of natural beach profiles, Beach-fx employs a simplified or idealized beach profile, representing key morphological features defined by points as shown in Figure 16 (Gravens et al. 2007). The simplified profile represents a single trapezoidal dune with a horizontal berm and a horizontal upland landward of the dune feature. The submerged portion of the profile is represented by a detailed series of distance-elevation points or as an equilibrium profile (Gravens et al. 2007). Some of the features of the simplified profile are taken as constant, not varying with storm response or management measures to reduce the number of profile permutations in the Storm Response Database (SRD) and improve computational efficiency. The beach profile variables that may be changed by storms are: dune width, dune height, berm width, and upland width. The constant values are: upland elevation, dune slope, berm elevation, foreshore slope, and the shape of the submerged profile. Thus, in response to a storm, the berm can erode or accrete (change in berm width), the dune can change height and/or width, and can translate landward resulting in an upland width change (Gravens et al. 2007).

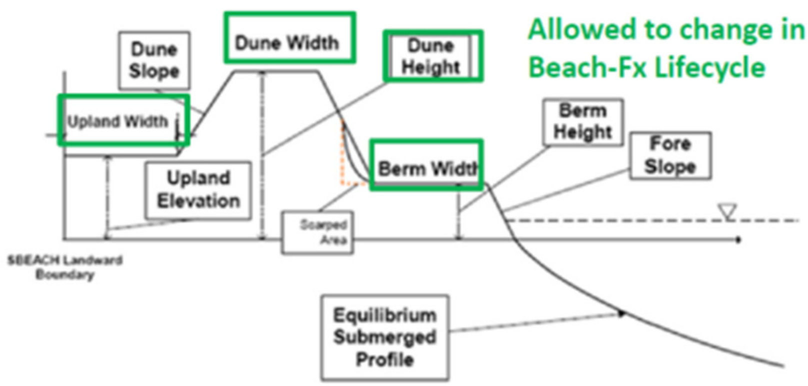


Figure 16: Beach-fx Simplified Profile

BEACH-FX MORPHOLOGY TYPES

Beach-fx supports three different morphology types as shown in Figure 17 and described below:

- Low Upland (LU): upland elevation < dune/berm elevation
- Low Berm (LB): berm elevation < upland/dune elevation
- High Upland (HU): upland elevation >= dune elevation

The most prevalent morphology types in the study area are LU and LB. However, the HU does occur in some portions of Villas where the upland elevations can exceed 14 feet NAVD88. The HU morphology type does not allow a dune that is lower than the upland elevation (invalid type shown in Figure 17. During the development of the representative profiles in Villas, it was important to understand the valid morphology types in Beach-fx.

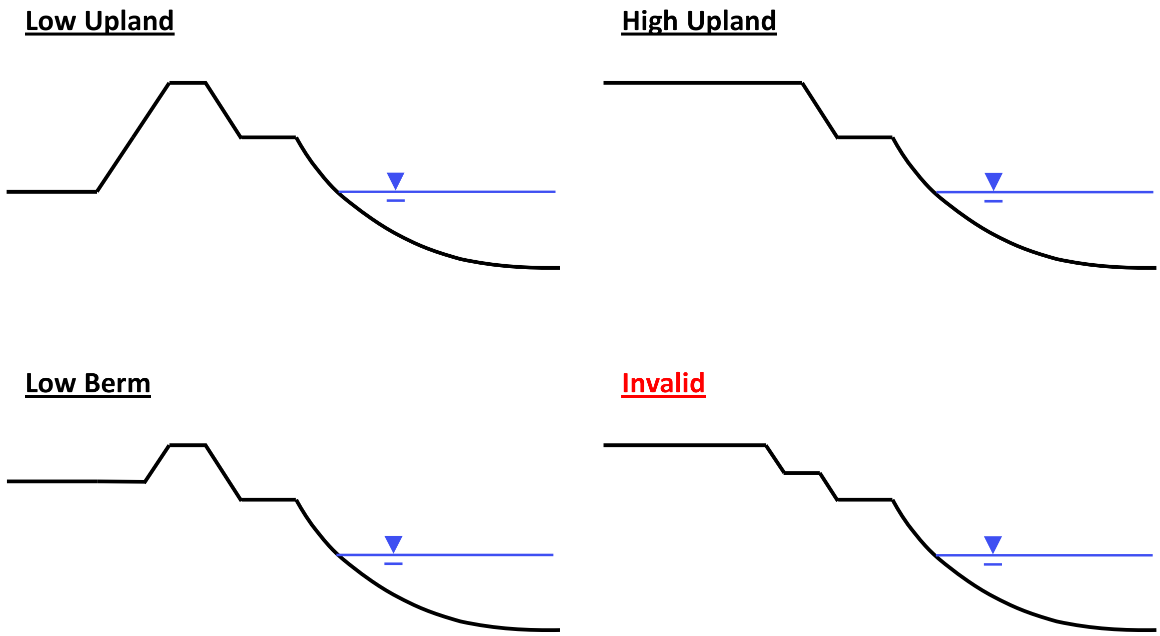


Figure 17: Beach-fx Morphology Types

Representation of the With-Project alternatives presents another challenge in Beach-fx. Many of the project sites are LB morphology type characterized with a relatively low and wide dune with houses located on the dune. With-Project alternatives at these sites include higher dunes, which would be constructed in front of the existing dune and houses (top left panel of Figure 18). These alternatives could actually have two dunes: (1) lower existing dune and (2) higher design dune. However, double dunes are not a valid morphology type in Beach-fx, so a modified representation of the alternatives is required. Figure 18 shows an example of two With-Project alternatives encountered in the project area and the approach to representing them within the allowable Beach-fx morphology types.

Another constraint within the Beach-fx framework is that the landward dune toe for all With-Project alternatives is the same as the Existing Conditions. The top right panel of Figure 18 shows an example of how the Existing and Design profile must share the same landward dune toe. With this constraint in mind, a conscious effort was made during the development of the representative profiles and existing conditions to place the landward dune toe seaward of houses where possible.

Developing representative profiles for Beach-fx is part science and part art, and the developer must balance the tradeoffs between more representative profiles and a better characterization of the existing conditions versus the resources required to model the additional representative profiles in SBEACH and Beach-fx. The developer must also balance the tradeoffs of accurately capturing the existing conditions versus accurately capturing potential With-Project alternatives.

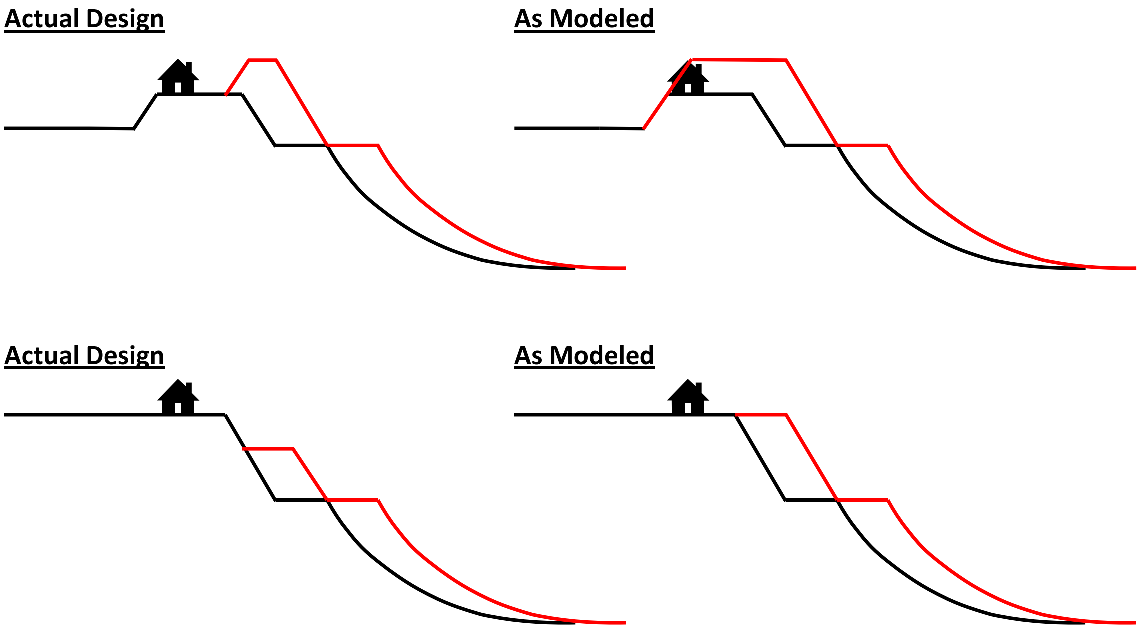


Figure 18: Beach-fx With-Project Constraints

DATA SOURCES

Three data sources were used to characterize the representative beach profiles:

- 2014 NOAA Post-Sandy Topobathymetric LiDAR
- 2015 NAP Beach Profile Survey of Gandys Beach and Fortescue
- 2017 NAP Beach Profile Survey of Reeds Beach, Pierces Point, Del Haven, and Villas

The 2014 LiDAR data was generally used to characterize the subaerial portion (dune & berm) of the profile, especially in Cape May County where survey data wasn't available until later in the study. To facilitate beach profile analyses, profiles were "cut" every 1,000 feet along the shoreline. The 2015 and 2017 NAP survey data were used to define the submerged profiles.

SUBMERGED PROFILES

The mean submerged profiles at each site were determined by first aligning all the profiles for a given site at +2 ft NAVD88, and then by calculating the mean of all the aligned submerged profiles. Figure 19 shows an example of the mean submerged profile at Del Haven. Conditions were similar enough along all of the sites except Villas to only have one submerged profile per site represent the entire site. Three submerged profiles were required at Villas to adequately capture the variability in the submerged profile conditions. The conditions at Gandys Beach and Fortescue were similar enough, both subaerial and submerged, that a single representative profile was adequate to represent both sites. A sensitivity analysis was performed at Gandys Beach and Fortescue to Superstorm Sandy to verify that a single submerged profile was adequate. Figure 20 shows the modeled dune and berm changes, which are morphological responses tracked in

Beach-fx, are very similar for both submerged profiles; hence, it was determined that a single submerged profile was adequate for Gandys Beach and Fortescue.

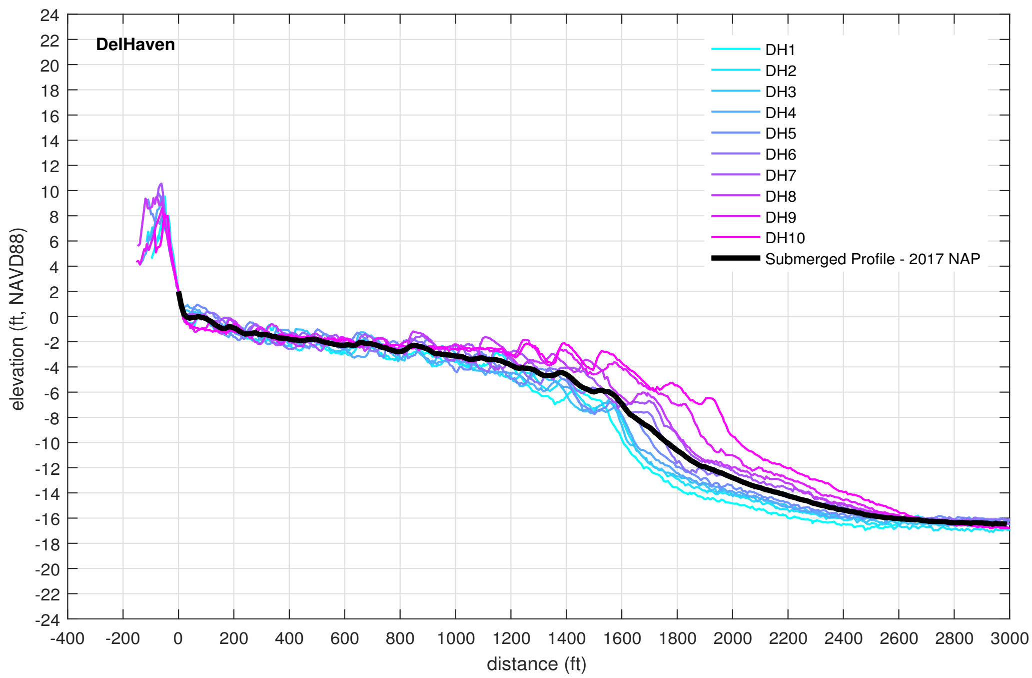


Figure 19: Submerged Profile at Del Haven

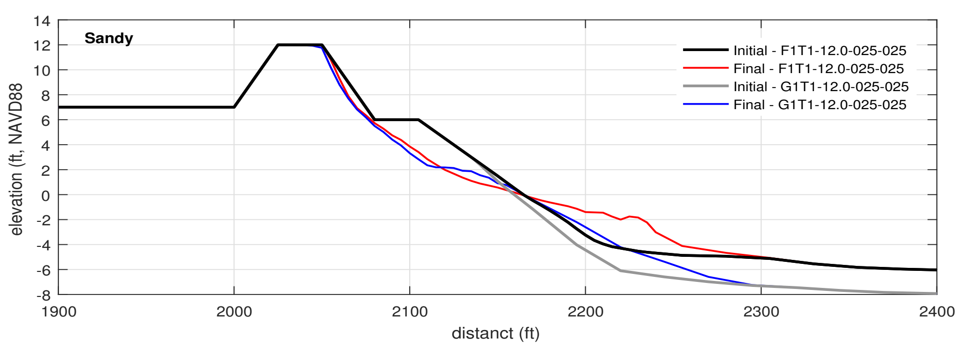


Figure 20: SBEACH Sensitivity to Submerged Profile at Gandys Beach and Fortescue

SUBAERIAL

The subaerial simplified profile parameters (Figure 16) were characterized at each site using a Matlab algorithm developed by ERDC-CHL that groups together similar profiles based on dune height and centers the profiles along the dune. The algorithm determines the representative upland elevation, dune elevation, berm elevation, berm width, dune slope, and foreshore slope.

An example of the algorithm for the "high" dune profiles at Del Haven is shown in Figure 21. The results of this analysis were primarily used to determine the characteristic foreshore slopes and dune slopes.

During the subaerial analysis, it became apparent that it was difficult to identify a berm elevation because none of the profiles exhibited a flat berm or gently sloping berm. A review of the 1999 Feasibility Reports for the study area (USACE 1999a, USACE 1999b) found that the proposed plan for Reeds Beach and Pierces Point had a berm elevation of +5.5 ft and the proposed plan for Villas and Del Haven had a berm elevation of +4.7 ft NAVD88. A review of the original LiDAR surface data revealed that in areas where the beach is the widest, there is a relatively flat berm around the +5 to +6 ft NAVD88. Based on these two data sources, a representative berm elevation of +5 ft NAVD88 was selected for Reeds Beach, Pierces Point, Del Haven, and Villas. The LiDAR data at Gandys Beach and Fortescue indicated that there was a relatively flat berm at +6 ft NAVD88 in the only area with a wide beach (adjacent to the jetty at Fortescue Creek).

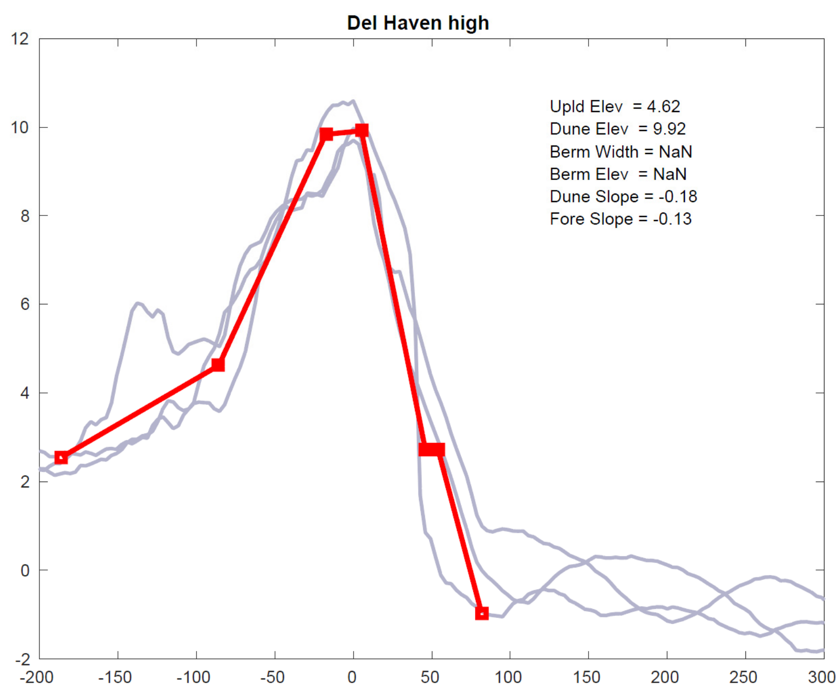


Figure 21: Example of Subaerial Profile Characterization at Del Haven

The remaining subaerial profile characteristics, upland elevation, dune height, dune width, and berm width were determined manually through trial and error by plotting the representative profile against existing profile data at each Beach-fx Reach. This trial and error process also took into consideration the cross-shore alignment of the representative profile, location of existing houses, and potential With-Project alternatives. Figure 22, Figure 23, and Figure 24 show an example of the final Beach-fx Alignment and representative profiles at Reaches 4 and 5 in Del Haven.

A complete overview of the representative subaerial profiles and envelope of existing profile data is shown in Figure 25 to Figure 34. The selected representative profiles strike a balance between accurately capturing the existing conditions and With-Project alternatives, as well as limiting the number of unique profiles and SBEACH model simulations.

EXISTING CONDITION REPRESENTATIVE PROFILES

The complete set of representative profiles is provided below in Table 12. Gandys Beach and Fortescue actually use the same representative profile and set of SBEACH simulations. All of the sites except Villas only required one representative profile. Due to distinct differences in the submerged profiles and high variability in dune and upland conditions at Villas, several representative profiles were required.

Table 12: Representative Profiles

Site	Profile Name	Submerged Profile	Upland Elv. (ft*)	Berm Elv. (ft*)	Dune Slope	Foreshore Slope	Dune Elv. (ft*)	Dune Width (ft)	Berm Width (ft)	Upland Width (ft)
Gandys	F1	Fortescue_Avg	6.5	6	0.20	0.1	6.5	0	0	1,000
Fortescue	F1	Fortescue_Avg	6.5	6	0.20	0.1	6.5	0	0	1,000
Reeds Beach	RB1	Reeds_02	5.5	5	0.10	0.1	5.5	0	0	800
Pierces Point	PP1	Pierces_Point	4.5	5	0.15	0.1	6	10	0	800
Del Haven	DH1	DelHaven	6	5	0.20	0.1	8	25	0	800
Villas North	VN1	Villas_North1	8	5	0.15	0.1	10	40	20	800
Villas North	VN2	Villas_North2	10	5	0.15	0.1	11	40	20	800
Villas North	VN3	Villas_North1	8	5	0.15	0.1	8	0	0	800
Villas South	VS1	Villas_South	10	5	0.20	0.1	12	25	0	800
Villas South	VS2	Villas_South	14	5	0.20	0.1	16	25	0	800

*All elevations are in feet NAVD88

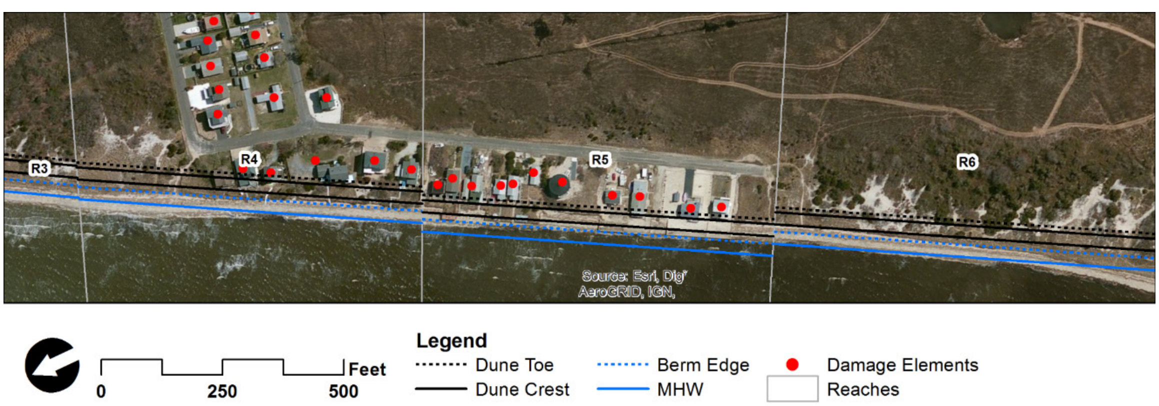


Figure 22: Beach-fx Alignment – Del Haven

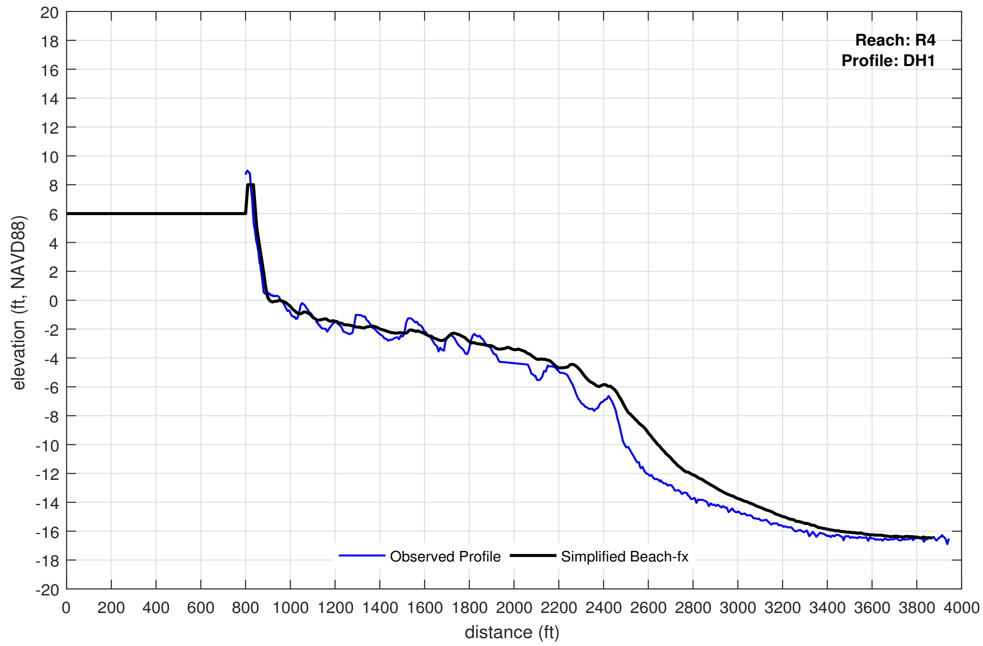


Figure 23: Trial and Error at Del Haven, Beach-fx Reach 4

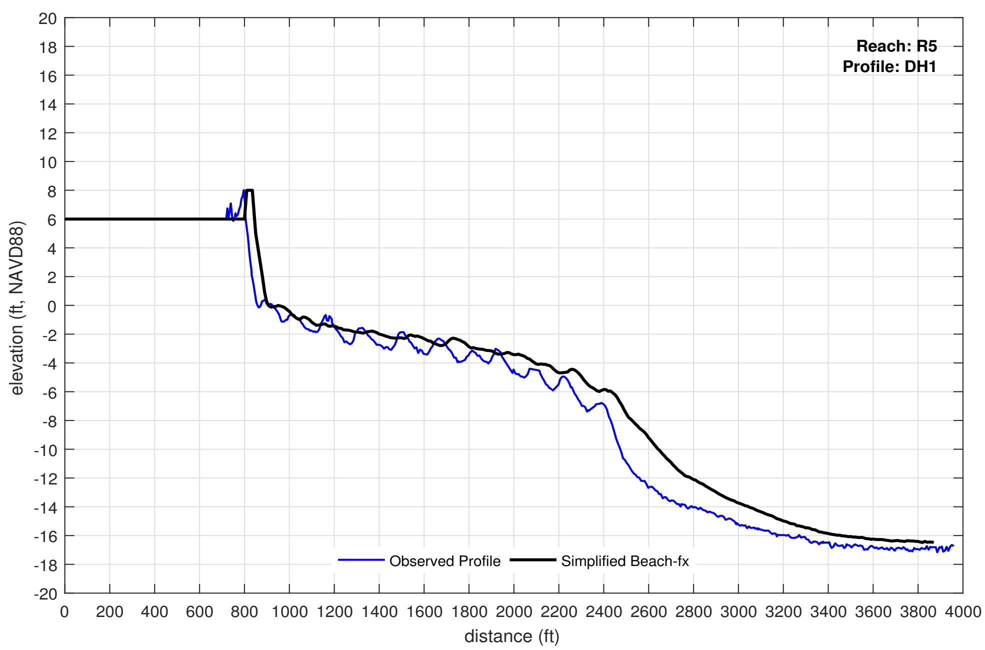


Figure 24: Trial and Error at Del Haven, Beach-fx Reach 5

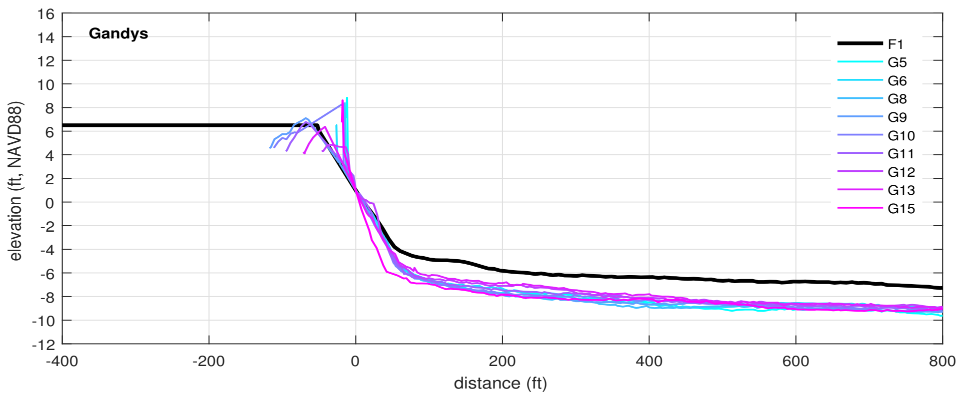


Figure 25: Representative Profile F1 – Gandys Beach

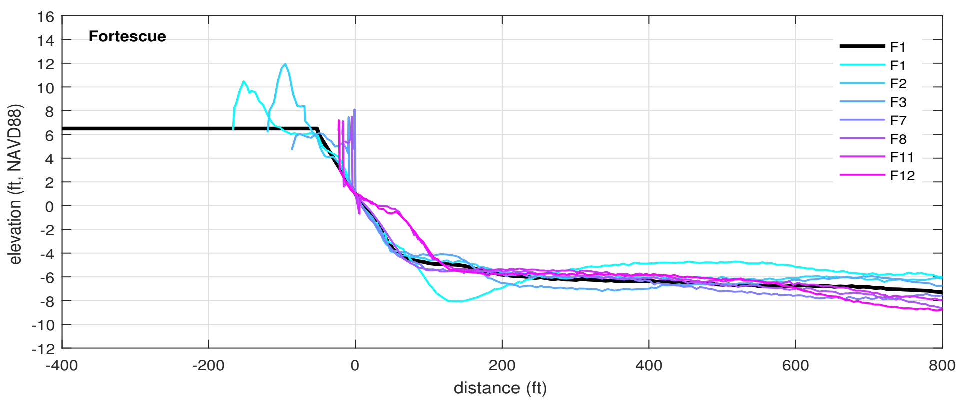


Figure 26: Representative Profile F1 – Fortescue

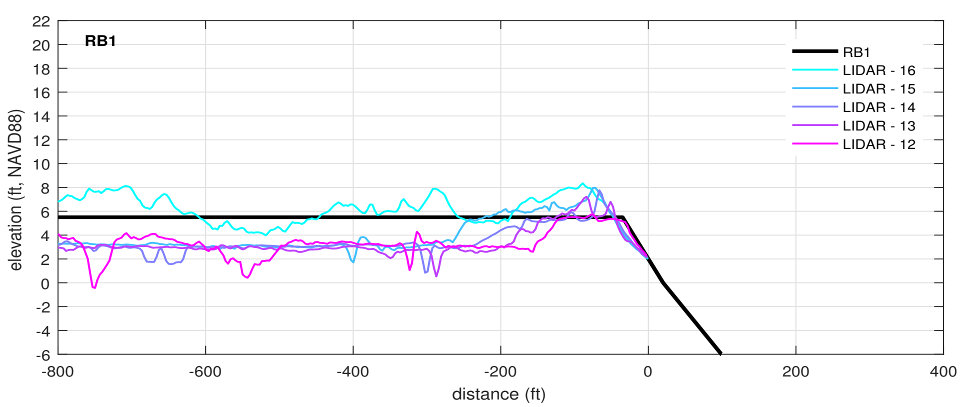


Figure 27: Representative Profile RB1 – Reeds Beach

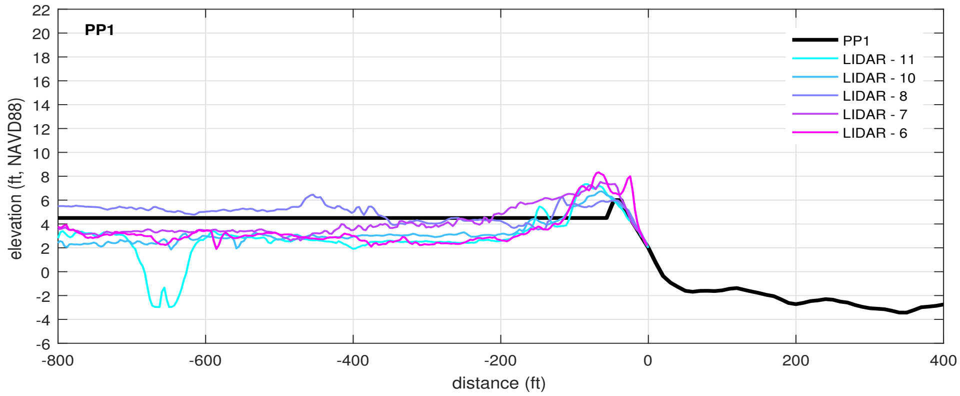


Figure 28: Representative Profile PP1 – Pierces Point

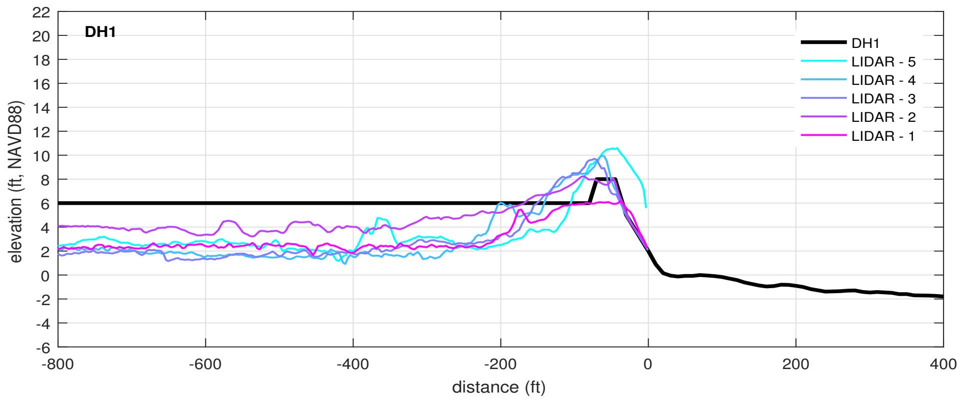


Figure 29: Representative Profile DH1 – Del Haven

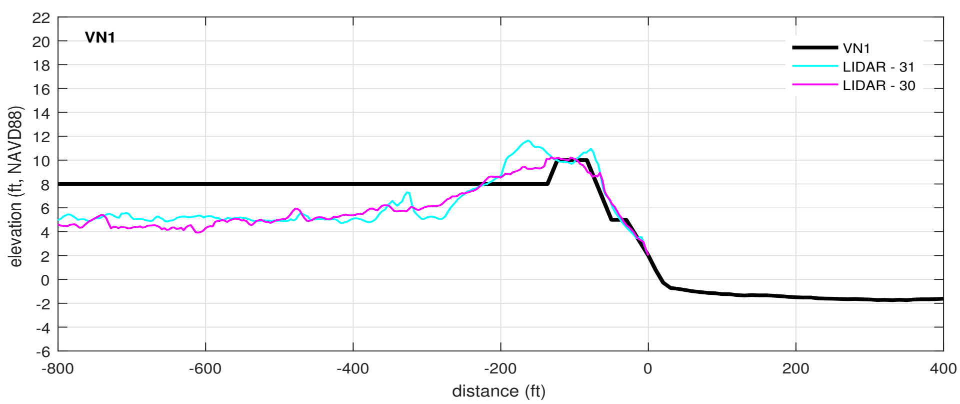


Figure 30: Representative Profile VN1 – Villas North

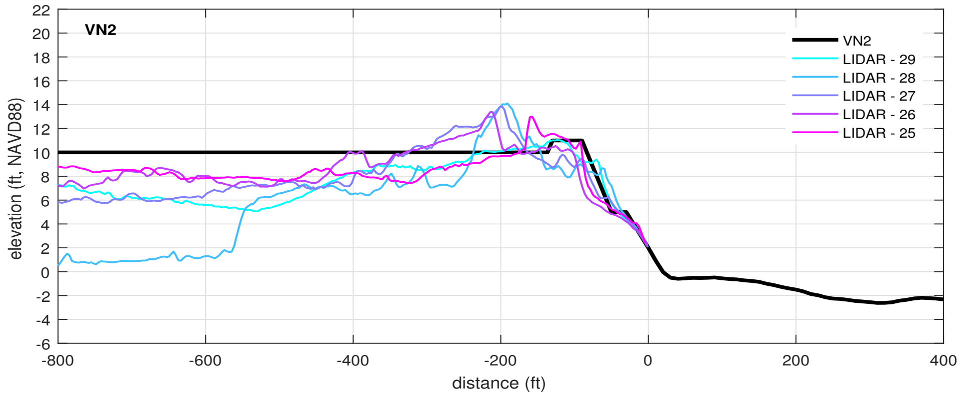


Figure 31: Representative Profile VN2 – Villas North

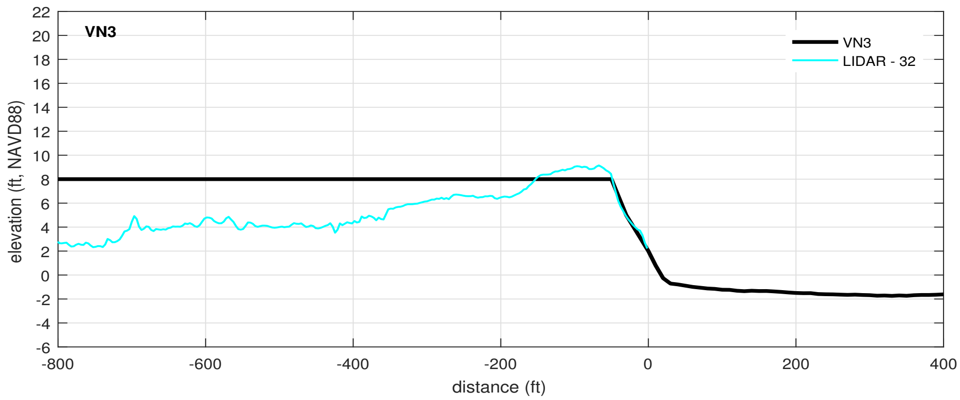


Figure 32: Representative Profile VN3 – Villas North

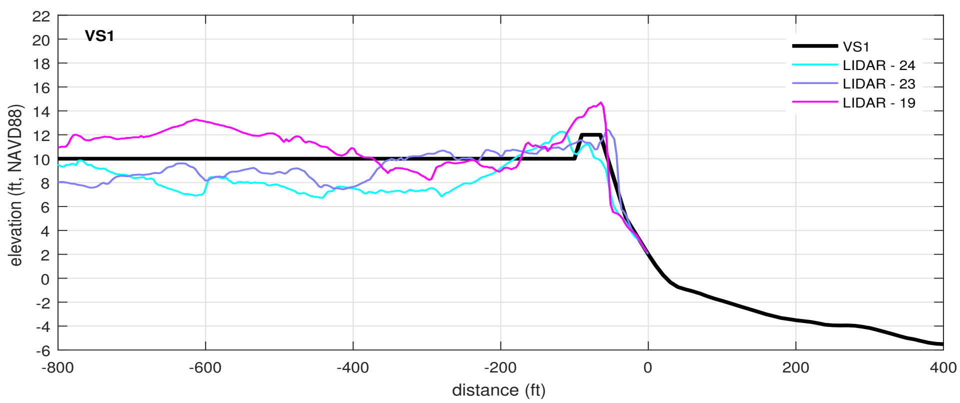


Figure 33: Representative Profile VS1 – Villas South

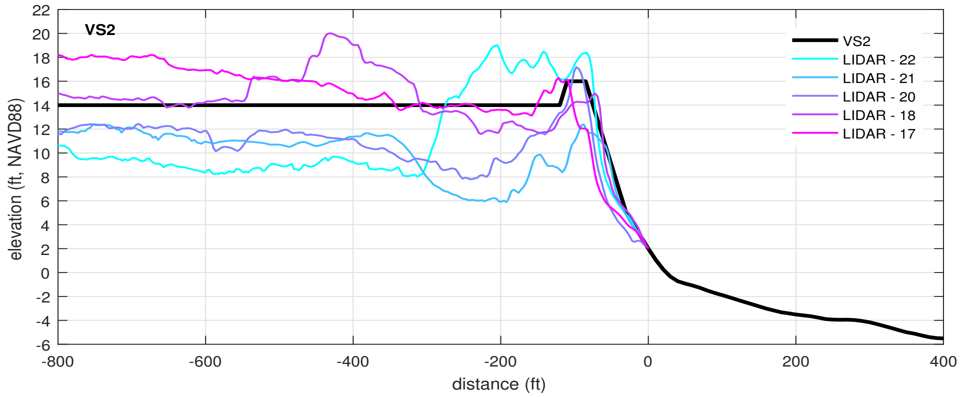


Figure 34: Representative Profile VS2 – Villas South

DEPTH OF CLOSURE

Dean and Dalrymple (2002) define the depth of closure as the "*offshore depth beyond which beach profiles taken over time at a given site coincide."* Seaward of this depth, although the waves can move sediment, the net sediment transport does not result in significant changes in mean water depth." The depth of closure is generally either determined from repeated cross-shore profile surveys or estimated using formulas based on wave statistics. Fortunately, repeated cross-shore profile surveys are available at two locations in project area from the New Jersey Beach Profile Network (NJBPN) collected by the Richard Stockton College of NJ Coastal Research Center (2013). Section 4.3 provides additional detail about the NJBPN.

Repeated profile surveys from 1995 to 2016 are available at Reeds Beach and Villas North. The survey data at Reeds Beach (Figure 35) clearly indicates a depth of closure of -6 ft NAVD88, whereas the survey data at Villas North (Figure 36) indicates a depth of -1 ft NAVD88. At both of these sites the depth of closure appears to coincide with the transition from the steep foreshore to the gentle sloping offshore portion of the profile. The wave conditions at the two sites are fairly similar and underscore the difficulty of trying to use wave statistics to estimate the depth of closure in Delaware Bay. Based on the observations at these two sites it is believed that the inflection point between the steep foreshore and more gentle offshore profile is a better indicator of the depth of closure. For simplicity, two depth of closure values were selected for the NJ DMU study, -3 ft and -6 ft NAVD88. Gandys Beach, Fortescue, Reeds Beach, and Villas South have deeper nearshore profiles and are best characterized by a depth of closure of -6 ft NAVD88. Pierces Point, Del Haven, and Villas North have shallower nearshore profiles and are characterized by a depth of closure of -3 ft NAVD88.

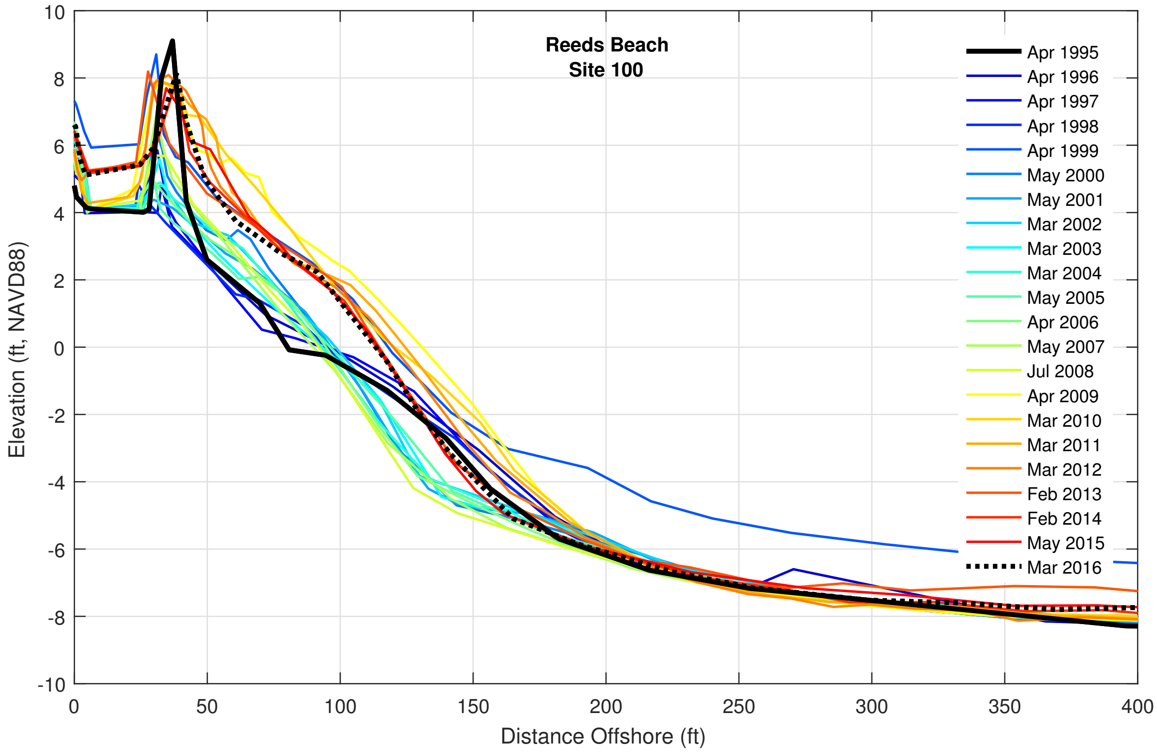


Figure 35: NJBPN – Reeds Beach (1995-2016)

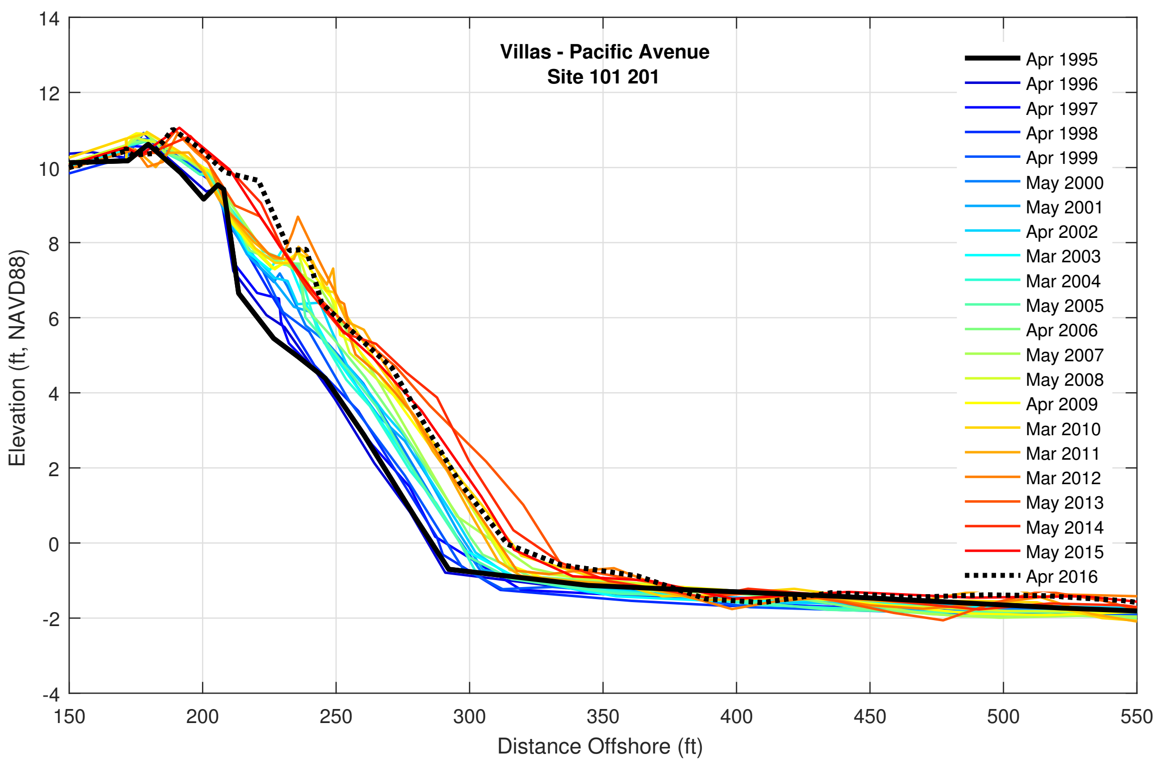


Figure 36: NJBPN – Villas North (1995-2016)

4.2 STORM SUITE

GANDYS BEACH AND FORTESCUE

This section summarizes the procedure used to develop a representative storm suite for Gandys Beach & Fortescue, NJ. Fifteen (15) tropical and 10 extratropical storms were identified as representative events characterizing the 1050 probabilistic tropical storms and 100 historical extratropical storms available for the study area in the Coastal Hazards System (CHS). Relative probabilities of the selected storms were computed by summing the individual relative probabilities of the storms each selected storm represents. The tidal analysis consisted of generating three idealized cosine tides (high, medium and low amplitude) and combining a high tide, mid-tide falling, low tide, and mid-tide rising at the peak surge of the water elevation time series. The 12 tidal combinations for each storm resulted in the generation of a total of 300 unique plausible storm events. NACCS Save Point 13385 was used in the analysis.

Identification of Representative Storms and Estimation of Relative Probabilities

Of the 1050 synthetic tropical storms available in the Coastal Hazards System (CHS), 389 storms have a storm track that pass within a 200km radius of the project site location (Figure 37). Because storms with a peak surge below 0.5m (~1.64 ft.) are assumed not to be damage producing, a peaks over threshold analysis was performed to eliminate these storms. Through this analysis, the tropical storms were further reduced from 389 to 321, and the extra-tropical storms were reduced from 100 to 77.

The storms were then placed into bins based on the peak surge elevation. By performing a K-means clustering analysis on the tropical storm peaks, the lower and upper surge limits of each bin were defined. K-means clustering is a method used to groups points together that are more similar to each other than to the points in another cluster. In this particular method, the user selects the number of clusters, *K*, and the algorithm places *K* arbitrary "centroids" in the data set. The nearest neighbor to each "centroid" is determined, thus defining the initial clusters. A new, actual centroid of each cluster is calculated, and the nearest neighbor search is performed again. This process is repeated until the centroids no longer move. By performing this analysis in one-dimensional space on the peak surge each cluster is representative of a storm bin. The lower and upper limits of each bin are calculated as the average of the peak surge where one bin ends and the next begins. For example, the limit between bins 2 and 3 is defined as the average of the highest peak in bin 2, and the lowest peak in bin 3.

Because there are significantly fewer extra-tropical storms, these bins were set up manually. Table 13 and Table 14 summarize the tropical and extra-tropical bins, respectively.

Table 13: Tropical Storm Bin Ranges and Number of Storms in Each Bin

Bin Number	Peak Surge Limits (ft. MSL)	Storms in Bin
1	1.64-2.11	31
2	2.11-2.71	42
3	2.71-3.05	30
4	3.05-3.66	38
5	3.66-4.30	36
6	4.30-5.00	36
7	5.00-5.88	28
8	5.88-6.65	18
9	6.65-7.48	16
10	7.48-8.59	20
11	8.59-9.71	11
12	9.71-10.56	7
13	>10.56	8

Table 14: Extra-Tropical Storm Bin Ranges and Number of Storms in Each Bin

Bin Number	Peak Surge Limits (ft. MSL)	Storms in Bin
1	1.64-2.13	9
2	2.13-2.46	15
3	2.46-2.79	11
4	2.79-3.12	11
5	3.12-3.45	9
6	3.45-4.10	13
7	4.10-4.59	5
8	>4.593	4

After the storms were placed into their bins, the hydrographs were shifted along the time axis to align the peak surge. Bins 3 and 4 of the tropical storms and bins 2 and 6 of the extra-tropical storms were further divided into short and long duration storms within these storm bins. One storm was selected from each bin that represents all storms in that bin (Figure 38).

The relative probability of the selected storm is calculated as the sum of the relative probabilities of the storms that it represents. CHS provides a relative probability of occurrence for each of the synthetic tropical storms ensuring that large storm events do not occur at the same rate as smaller events. Conversely, because the extra-tropical storms are based on historical observations each storm possesses the same probability of occurrence. Table 15 and Table 16 show the selected representative storms and their relative probabilities. The tropical storm probabilities were normalized by the relative probability of the storms in bin 13.

Table 15: Tropical Selected Storms and Probabilities

Bin Number	Number of storms in Bin	Number of rep. storms	Selected Storms	Normalized Relative Probability
1	31	1	165	6.72
2	42	1	145	10.65
3	19	2	179	4.05
	11		236	1.36
4	23	2	190	10.02
	15		1008	1.80
5	36	1	530	7.32
6	36	1	139	6.40
7	28	1	297	3.62
8	18	1	526	2.49
9	16	1	143	1.45
10	20	1	623	2.55
11	11	1	123	1.25
12	7	1	93	0.30
13	8	1	36	1.00

Table 16: Extra-Tropical Storms and Probabilities

Bin Number	Number of storms in Bin	Number of rep. storms	Selected Storms	Relative Probability
1	9	1	1984-02-29	9
2	7	2	1978-12-25	7
	8		1978-04-26	8
3	11	1	1987-01-02	11
4	11	1	1982-10-25	11
5	9	1	1998-01-28	9
6	8	2	1980-10-25	8
	5		1983-12-12	5
7	5	1	1968-11-12	5
8	4	1	1974-12-02	4

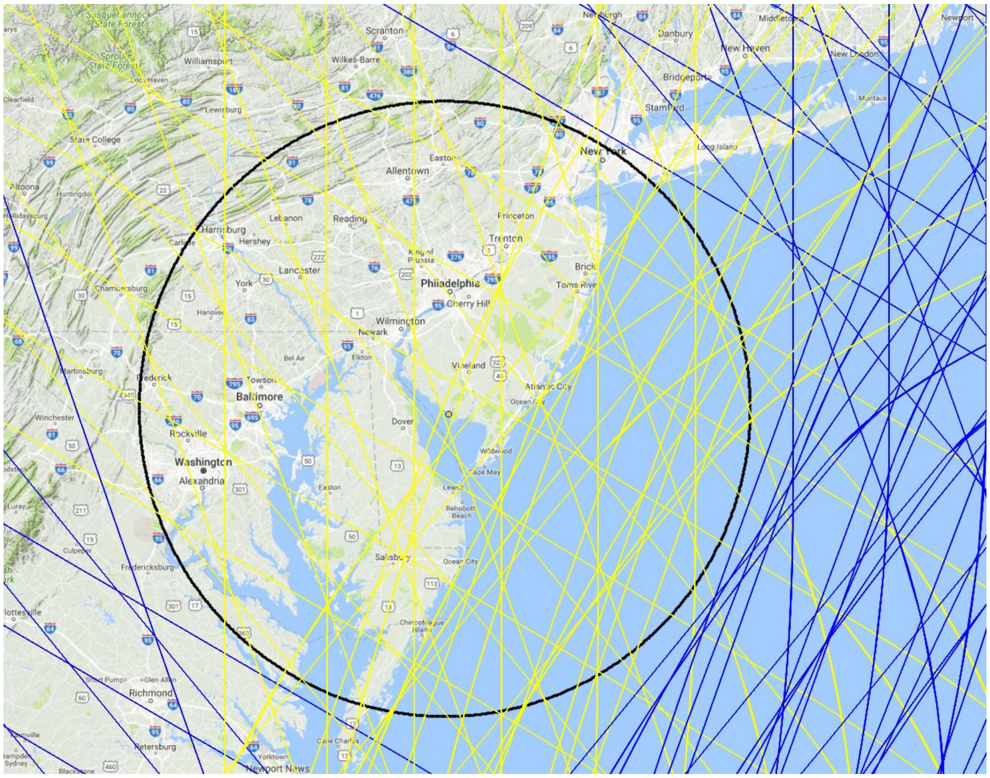


Figure 37: Storms within 200 km radius of site location

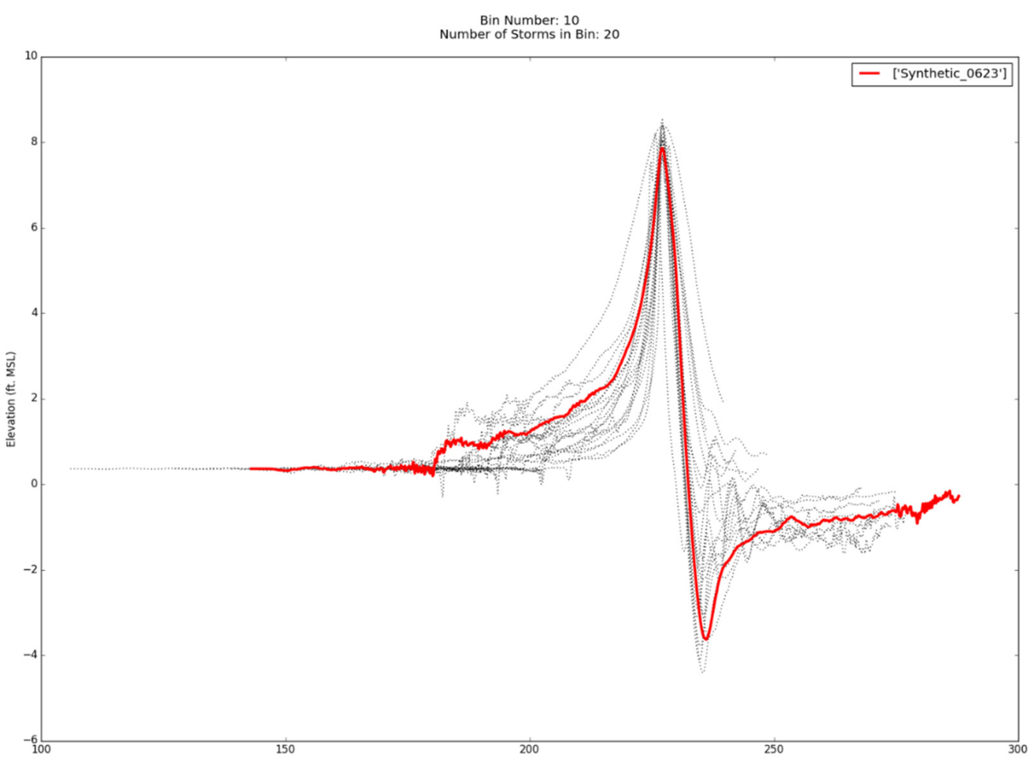


Figure 38: Selected Representative Storm for Bin 10

Wave Time Series

The wave, surge, and peak period time series of the representative storms were plotted together and were trimmed to start and end at the same time (Figure 39). There were three cases (tropical storms 143, 145, and 165) where the wave and peak period time series ended at a point that would result in the surge being trimmed immediately after the peak. In these cases, the waves were reflected across the peak value, and the peak period was increased step wise from the point of being cut off to a value of 8 seconds (Figure 40).

Tidal Analysis

The tidal analysis estimates the high, medium, and low tidal ranges for the site location, and are combined with the surge hydrograph to develop water elevation time series. A 20-year tide was created for this site location, and the probability density and cumulative distribution functions of tide elevation (CDF shown in Figure 41) were developed. From the tidal CDF, the statistically weighted idealized tide values associated with the lowest 1/16th, next 1/8th, next 1/16th, central 1/2, next 1/16th, next 1/8th, and highest 1/16th were computed. The difference between the high, medium and low idealized tide elevations are the idealized tidal ranges. Table 17 shows the CDF range values, the associated tidal elevations, and cosine approximations.

Table 17: Idealized tidal elevation associated with CDF values

Tide	CDF Range	CDF Average	Elevation (ft.)	Cos. Approx. (ft.)
HL	0-0.0625	0.03125	-3.30	-3.44
ML	0.0625-0.1875	0.125	-2.61	-2.65
LL	0.1875-0.25	0.21875	-2.10	-2.08
M	0.25-0.75	0.5	0.00	0.00
LH	0.75-0.8125	0.78125	2.07	2.08
MH	0.8125-0.9375	0.875	2.69	2.65
HH	0.9375-1	0.96875	3.58	3.44

Three semidiurnal cosine tides were created using the computed representative tidal amplitudes. The tides were then added to the surge elevation time series such that peak surge aligned with high-tide, mid-tide falling, low tide, and mid-tide rising. The combination of the three tides at the four tidal phases resulted in 12 plausible total water elevation time series for each representative storm. Figure 42 shows the storm surge hydrograph for storm 623 (black line) and the plausible total water level hydrographs corresponding to the three estimated tidal amplitudes when peak surge occurs at high tide.

Specification of Storm Seasons

The North Atlantic Coastal Comprehensive Study (NACCS) reports that the tropical storm season spans 6 months from June-November, with the distribution of storms as follows: June-0.04, July-0.04, August-0.26, September-0.48, October-0.12, and November-0.06. The probability of a storm occurring in a given month is defined as the storm distribution multiplied by the storm occurrence rate. The storm occurrence rate is provided by CHS as an attribute of the CHS Save Point.

The extra-tropical storm season spans October-March and a uniform distribution of storm occurrence across the six month season is assumed. The extratropical storm occurrence rate or average number of storms per year is calculated as the number of storms above the threshold divided by the number of years spanned (1938-2012). The probability of a storm occurring in a given month is the rate of storm occurrence divided by the number of months in the extratropical storm season (6). The tropical and extratropical storm seasons are summarized in Table 18.

Table 18: Summary of tropical and extra-tropical storm seasons

Month	Probability of Tropical	Probability of Extra-Tropical
January	0	0.171111111
February	0	0.171111111
March	0	0.171111111
April	0	0
May	0	0
June	0.007008	0
July	0.007008	0
August	0.045552	0
September	0.084096	0
October	0.021024	0.171111111
November	0.010512	0.171111111
December	0	0.171111111

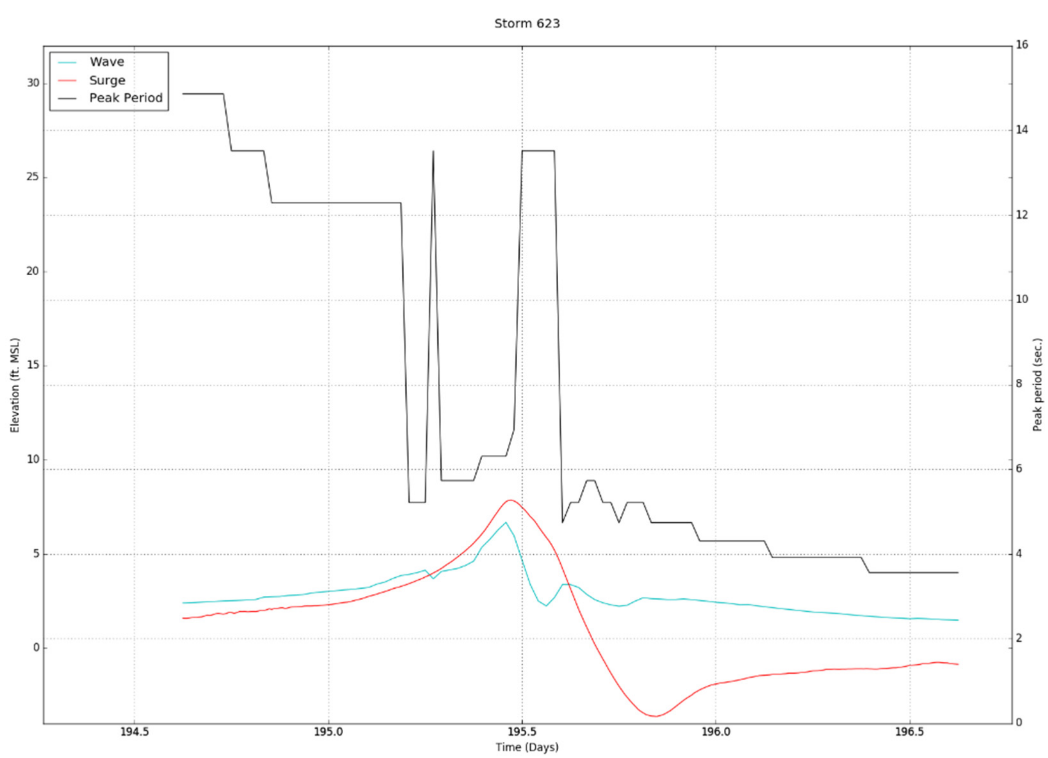


Figure 39: Plot of Surge, Wave and Peak Period Time Series

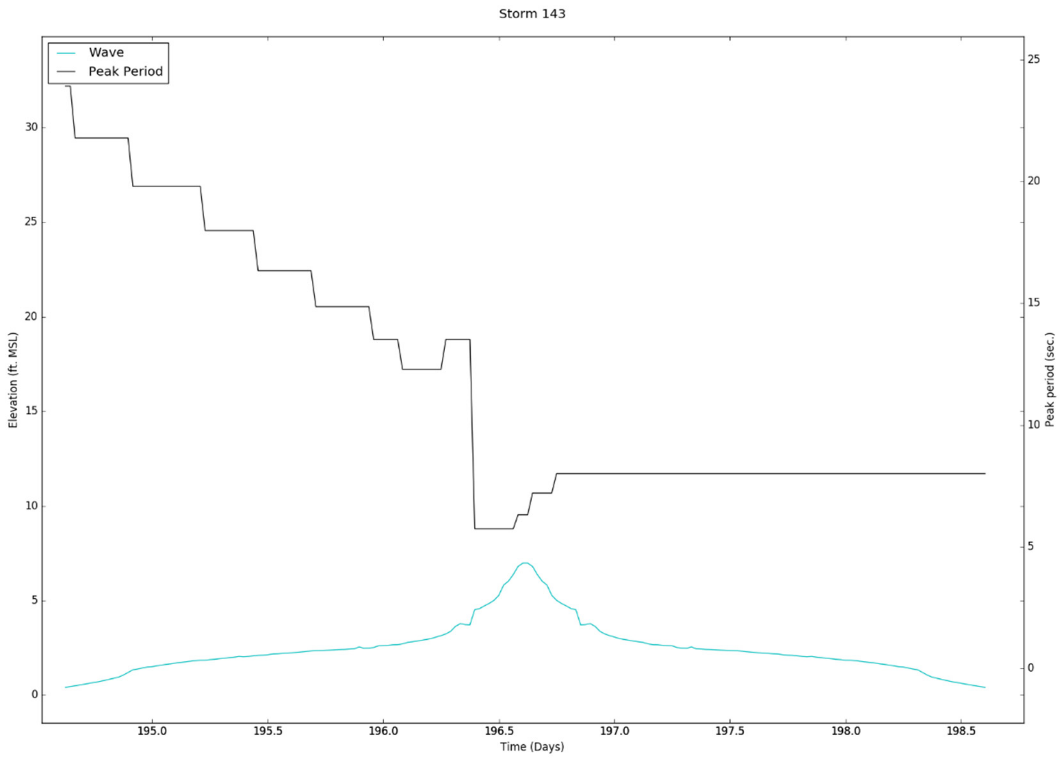


Figure 40: Plot of reflected wave time series and peak period at 8 seconds

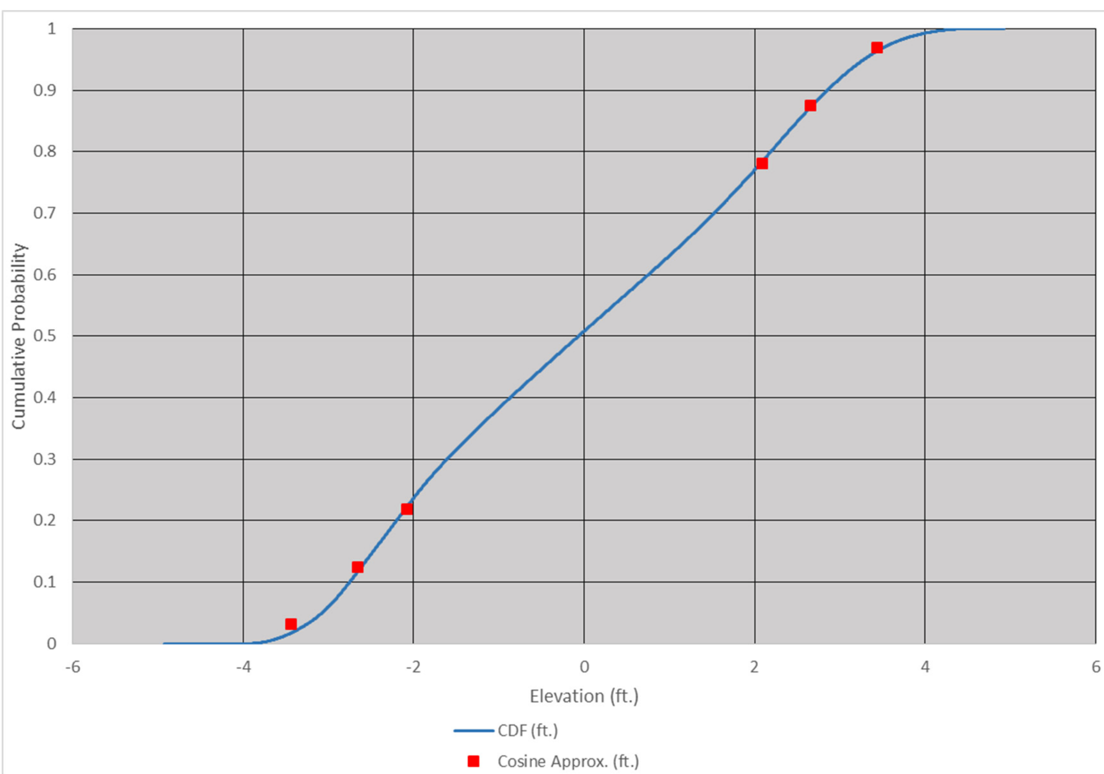


Figure 41: CDF and Cosine Approximation of Tides

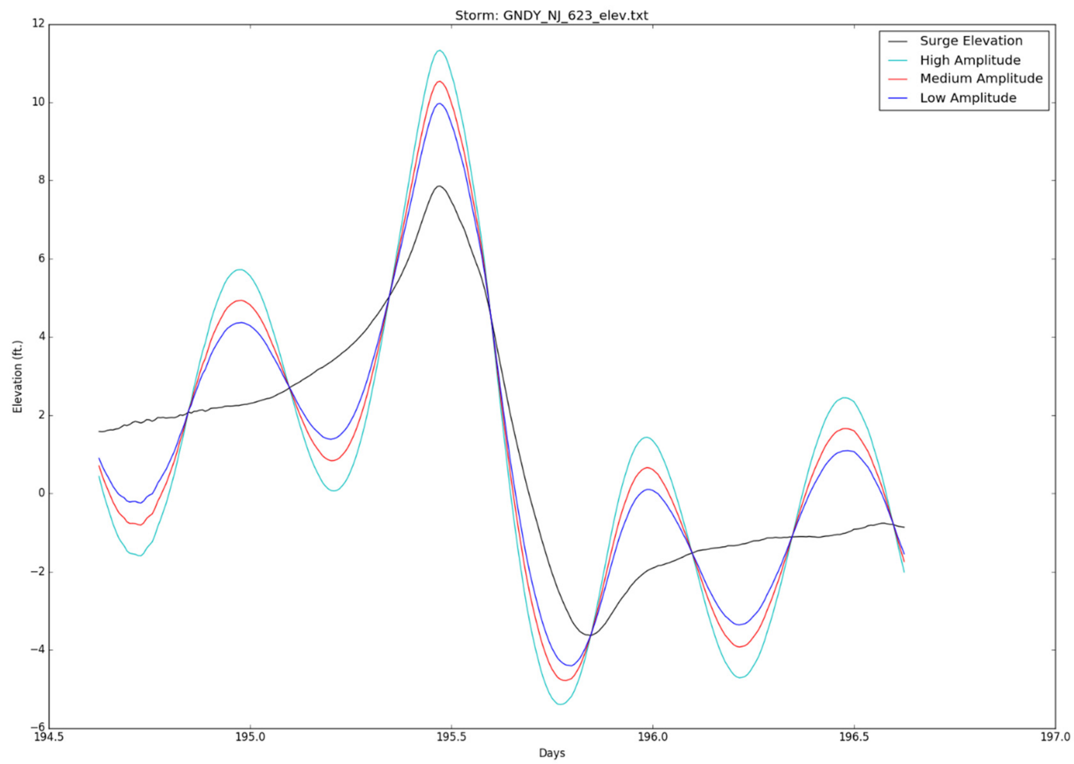


Figure 42: Three tidal amplitudes combined with surge at high tide

CAPE MAY COUNTY

A separate storm suite was developed for the Cape May County sites (Reeds Beach, Pierces Point, Del Haven, and Villas) using ADCIRC Save Point 13425. The approach applied for Cape May is similar to the approach described above for Gandys Beach and Fortescue. The primary difference is that the storm bins and selection of representative storms was completed manually. After clustering the storms based on peak storm surge, time series of storm surge values for storms within each cluster were aligned at the peak and examined to select representative storms for each cluster. The first 6 tropical storm surge bins were divided into short and long duration storms. Figure 43 shows the aligned storm surge hydrographs for the 100-Yr return period cluster with the red bold lines depicting the representative storms.

The final storm suite, shown in Table 19 and Table 20, includes 10 extratropical storms and 19 tropical storms. Relative storm probabilities were calculated using the same approach as Downe Township and the storm seasons (Table 18) are also the same for Cape May County.

The high medium and low tidal amplitudes (3.0, 2.23 and 1.74 ft) were obtained from 20-year-long equilibrium tide at National Oceanic and Atmospheric Administration (NOAA) station 855889, Brandywine Shoal Light, DE. CHS provided conversion factor from MSL to NAVD88 of -0.354 at ADCIRC Save Point 13425.

Table 19: Extra-Tropical Storms and Probabilities – Cape May

Storm Surge (ft)	Wave Height (ft)	No. of Storms	Representative Storms ID	Storm Name	Relative Probability
> 4	> 4	2	7	1950-11-25	1.0
	< 4	3	17	1962-03-07	1.5
3.5-4	> 4	2	27	1972-02-19	1.0
	< 4	7	76	1998-01-28	3.5
3-3.5	> 5	1	26	1972-02-04	0.5
	< 5	16	11	1953-11-07	8.0
2.5-3	> 5	1	34	1977-10-14	0.5
	< 5	19	53	1987-01-02	9.5
2-2.5	> 4	8	6	1947-03-02	4.0
	< 4	10	67	1994-12-24	5.0

Table 20: Tropical Storms and Probabilities – Cape May

Return Period (yr)	Storm Surge (ft)	No. of Storms	Representative Storms ID	Relative Probability
2	3.35	62	360	33.719
			243	33.719
5	4.20	81	362	31.559
			545	31.559
10	4.66	46	399	18.077
			530	18.077
20	5.09	79	300	24.496
			549	24.496
50	6.14	62	209	23.156
			222	23.156
100	7.28	48	170	10.194
			528	10.194
200	8.23	17	38	2.279
			193	2.279
500	9.22	15	45	7.535
1,000	9.84	9	196	2.869
2,000	10.43	6	168	1.000
5,000	11.12	1	36	0.058
10,000	11.65	3	43	0.264

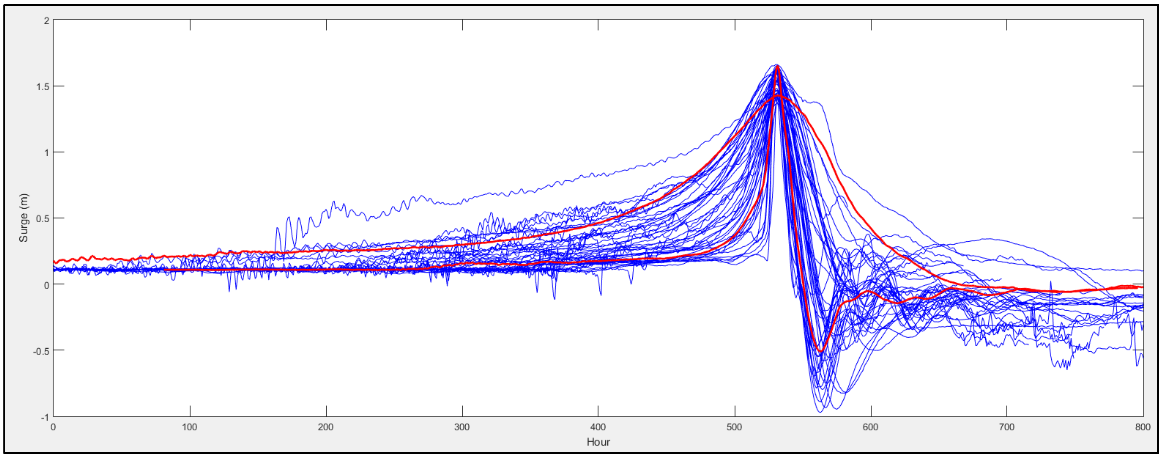


Figure 43: Hydrographs for the 100-Yr return period cluster (selected storms in red)

4.3 SBEACH MODELING

SBEACH OVERVIEW

Storm-Induced BEAch CHange Model, SBEACH, is a one-dimensional model, developed by the United States Army Corps of Engineers (Larson and Kraus 1989, Larson et al. 1989), which simulates cross-shore erosion of beaches, berms, and dunes under storm water levels and waves. SBEACH calculates beach profile change using an empirical morphologic approach with emphasis on beach and dune erosion. In model simulations, the beach profile progresses to an equilibrium state based on the initial profile, median grain size, and storm conditions (wave height, wave period, wave condition, wind speed and direction, and water level). The model also simulates overwash and dune lowering.

SBEACH is primarily used in this study to build the Beach-fx Storm Response Database (SRD). The SRD is a lookup table that stores the morphological profile responses (i.e. change in berm width and dune width/height) and damage driving parameters (i.e. wave height, water level, and vertical erosion). The SRD is based on approximately over a million SBEACH simulations for a range or possible beach profile configurations and storm conditions.

SBEACH MODEL SETTINGS

SBEACH model settings, Table 21, are the same as used in the Delaware Dredge Material Utilization (DE DMU) Study and are based on ERDC-CHL past applications and experiences. Model settings were validated based on Hurricane Sandy observations as described in the section below.

Table 21: SBEACH Model Settings

SBEACH Parameter	Value
Landward surf zone depth (ft)	1
Effective grain size (mm)	0.33
Maximum slope prior to avalanching (deg)	30
Transport rate coefficient (m^4/N)	$1.5e^{-6}$
Overwash transport parameter (K_B)	0.001
Coefficient for slope-dependent term (m^2/s)	0.002
Transport rate decay coefficient multiplier	0.5
Water temperature (°C)	20

SBEACH simulations were performed on using variable grid spacing that generally uses 2 ft grid cells from the landward boundary to the 0 ft contour, 5 ft grid cells from the 0 ft contour to about the -4 ft contour, 10 ft grid cells from the -4 ft contour to about the -6 ft contour, and then 20 ft grid cells to the seaward end of the profile. Simulations were conducted with a time step of 1-minute and wave height randomization activated with 10% variability.

The only parameter that is different from the DE DMU is the effective grain size (0.33 mm). Geotechnical analysis of beach samples collected in 1995 and subsequent compositing determined that the native mean grain size was 0.31 mm at Villas/Del Haven and 0.33 mm at Reeds Beach/Pierces Point.

An effective grain size of 0.33 mm is applied at Gandys Beach and Fortescue even though sediment samples collected by the Philadelphia District in September 2016 indicate that the existing grain size at these two sites is coarser (D50 of 0.5 mm). Modeling coarse grain sizes in SBEACH (greater than about 0.4 mm) is not recommended unless there is measured data to calibrate the model, which there is not at Gandys Beach and Fortescue. Sediment transport in SBEACH is based on an equilibrium energy dissipation determined from the input grain size, and simulations with coarse sediments could result in concrete-like profile responses, unrealistic for the current study.

HURRICANE SANDY MODEL VALIDATION

SBEACH model validation was completed using available pre- and post-Superstorm Sandy beach profile surveys at three locations in the project area. Superstorm Sandy survey data and observations are available from the New Jersey Beach Profile Network (NJBPN) collected by the Richard Stockton College of NJ Coastal Research Center (2013). Unfortunately, there are not any NJBPN or other profile data available at Gandys Beach or Fortescue suitable for model validation.

Wave and water level boundary conditions for the Superstorm Sandy model simulations were obtained from the NACCS modeling results at stations 13421 (Reeds Beach) and 13425 (Villas and North Cape May). Figure 44 and Figure 45 show the nearshore wave and water level conditions at NACCS station 13421 and 13425 during Superstorm Sandy. While Sandy's storm track and wind orientation may have spared Delaware Bay from the relatively high storm surges observed north of Atlantic City, Sandy generated very large waves in Delaware Bay that were directed at the bay shore of Cape May County.

On November 9th of 2012, the Richard Stockton College of NJ Coastal Research Center collected photographs and surveys to wading depths at profiles #100, #101/#201, and #102 in the project area (Figure 46). Figure 47, Figure 49, and Figure 51 present the pre- and post-sandy photographs and profile surveys at Reeds Beach, Villas, and North Cape May, respectively. NAP was unable to obtain digital records of the November 9th surveys, but digital records for long profile surveys from November 19th and 21st are available and are plotted against the SBEACH model results in Figure 48, Figure 50, and Figure 52.

The reason why the earlier beach profile surveys from November 8th and 9th are included here is to try and best capture the conditions at sites before any major recovery or cleanup efforts were undertaken. However, even by the time of the November 9th survey at Reeds Beach, Figure 47, sand on the roadway had been transferred back to the beach in the form of a series of dune-like piles. By the time of the November 19th survey the piles of sand are even larger and could lead to false conclusion that the dune survived Superstorm Sandy.

Overall, the SBEACH settings previously used in the DE DMU study produced acceptable results. Model results are in very good agreement with observations at Villas, with a slight over-prediction of erosion at Reeds Beach and under-prediction of erosion at North Cape May.

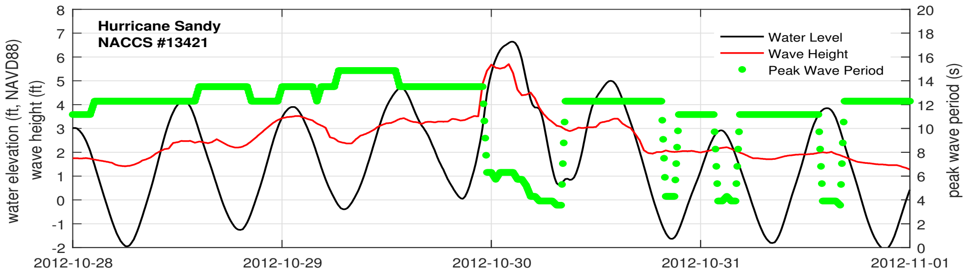


Figure 44: Superstorm Sandy Boundary Conditions at Reeds Beach

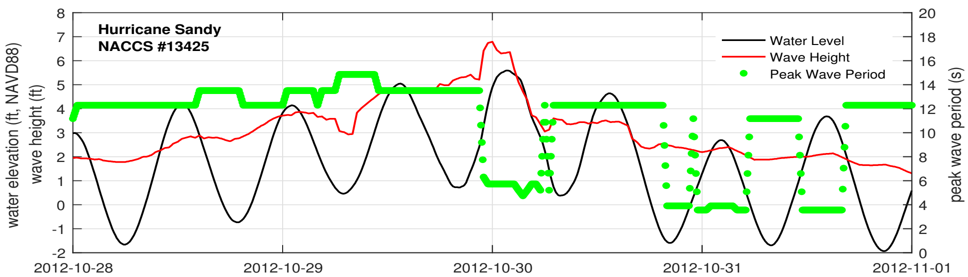


Figure 45: Superstorm Sandy Boundary Conditions at Villas

MATRIX OF SIMULATIONS

Over 1 million SBEACH simulations were performed to create the Storm Response Database (SRD) for Beach-fx. The SRD is a pre-generated set of beach profile responses to storms for the storm suite, and for a range of profile configurations that are expected to exist under different scenarios of storm events and management actions, such as beach nourishment (Gravens et al. 2007). The complete matrix of SBEACH simulations is shown in Attachment C.4. Beach-fx supports non-uniform increments in dune height, dune width, and berm width; however, it was more efficient in this case to setup the model simulations using uniform increments, 5 ft in dune width and 10 ft for berm width. Dune heights range from as low as the upland elevation to as high as + 18 ft NAVD88.

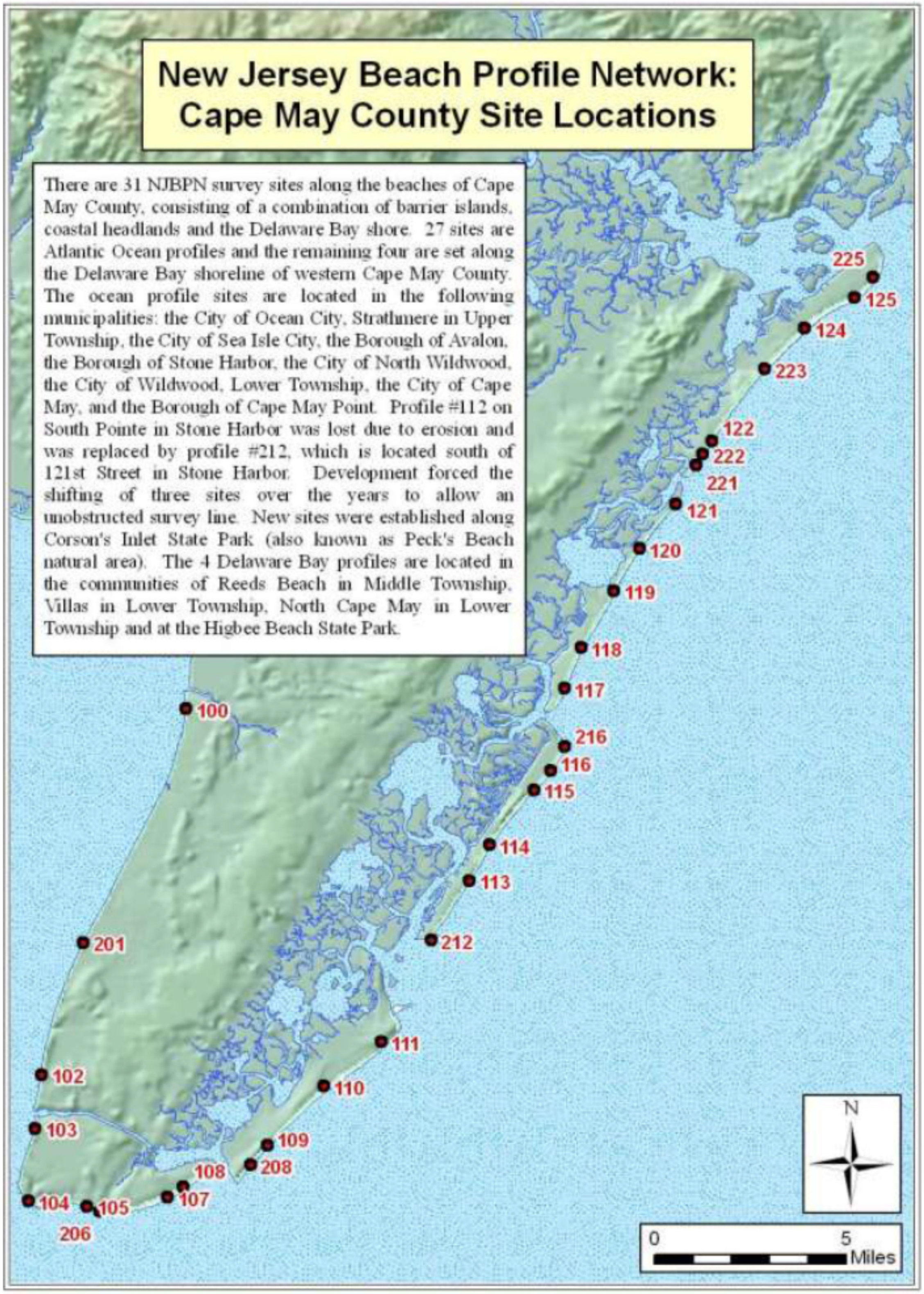


Figure 46: New Jersey Beach Profile Network: Cape May County Locations

The left photograph was taken March 5, 2012 looking south. The dune was vegetated and the beach was higher in elevation compared to the post-Sandy picture on the right taken November 9, 2012. The sand in the center of the right photo has been transferred from the roadway back to the beach as a series of piles.

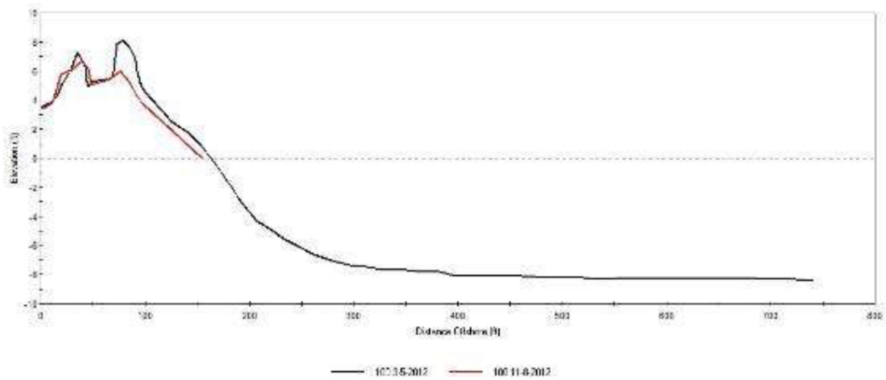


Figure 2. Reeds Beach, Cape May County is located on the western shoreline facing into Delaware Bay. This beach was nourished using dredge material from Bidwell Creek to the north in 2010. The "dune" between the road and the bay was removed and the sand pushed across the road into the salt marsh. The shoreline retreated 8 feet as well. The lost material will not return to the beach except for the material excavated from the roadway.

Figure 47: Reeds Beach (100) NJBPN Superstorm Sandy Observations

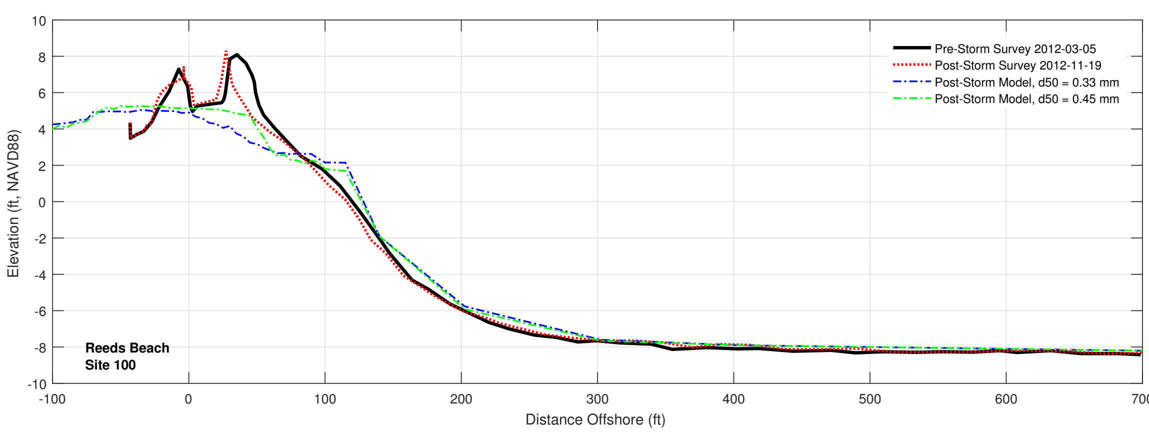


Figure 48: Reeds Beach Superstorm Sandy SBEACH Model Results

The left view was taken March 7, 2012 looking south along the beachfront. By November 9th the storm impact was found to have eroded the beach into the toe of the dune reducing the beach elevation and creating a minor scarp. The height of the uplands bluff prevented local wave or tidal flooding.

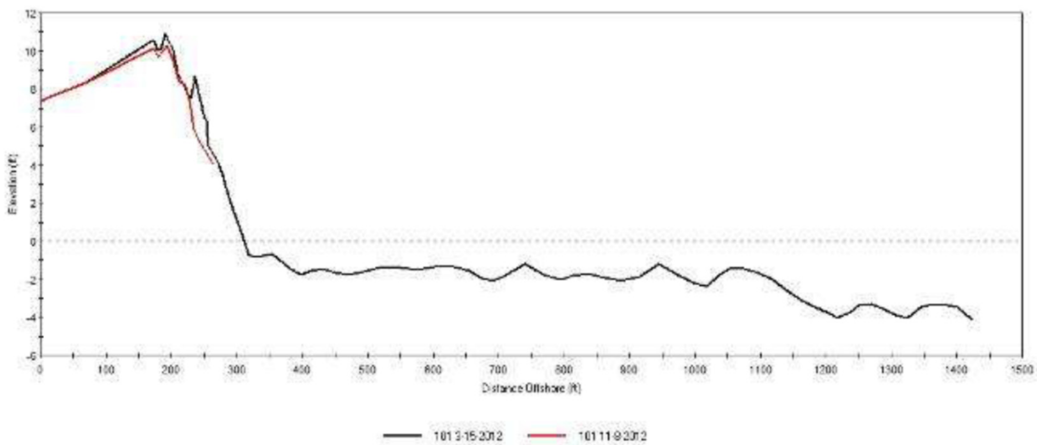


Figure 3. The wide shelf terrace likely saw sediment shifted around, but little erosion vertically appeared to have drastically changed the situation. The small foredune was removed and waves lowered the beach elevation, likely moving sand onto the nearshore terrace segment.

Figure 49: Villas (101) NJBPN Superstorm Sandy Observations

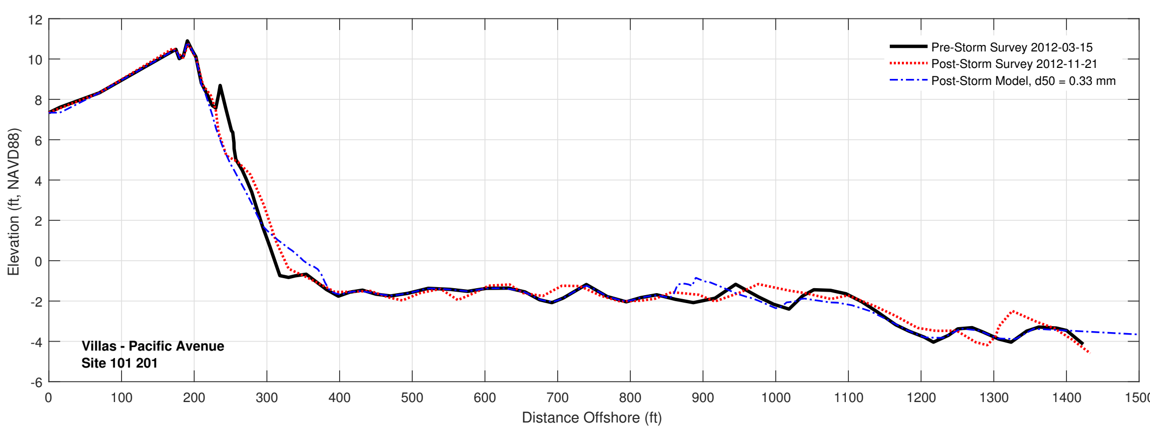


Figure 50: Villas Superstorm Sandy SBEACH Model Results

At Whitter Avenue the drainage line shows the extent of beach erosion between March 15, 2012 and after Sandy on November 9th. Sand was moved offshore onto the terrace, but the dune withstood the majority of the Delaware Bay wave assault on this shoreline.

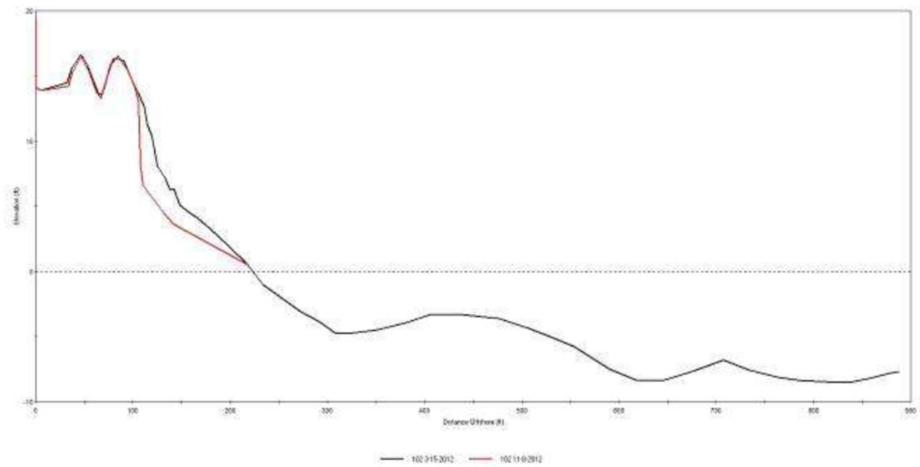


Figure 4. The cross section shows the erosion into the seaward toe of the dune with the post-storm beach slope meeting the pre-storm line at a much lower slope angle. Sand was transported offshore at the expense of the existing beach and dune.

Figure 51: North Cape May (102) NJBPN Superstorm Sandy Observations

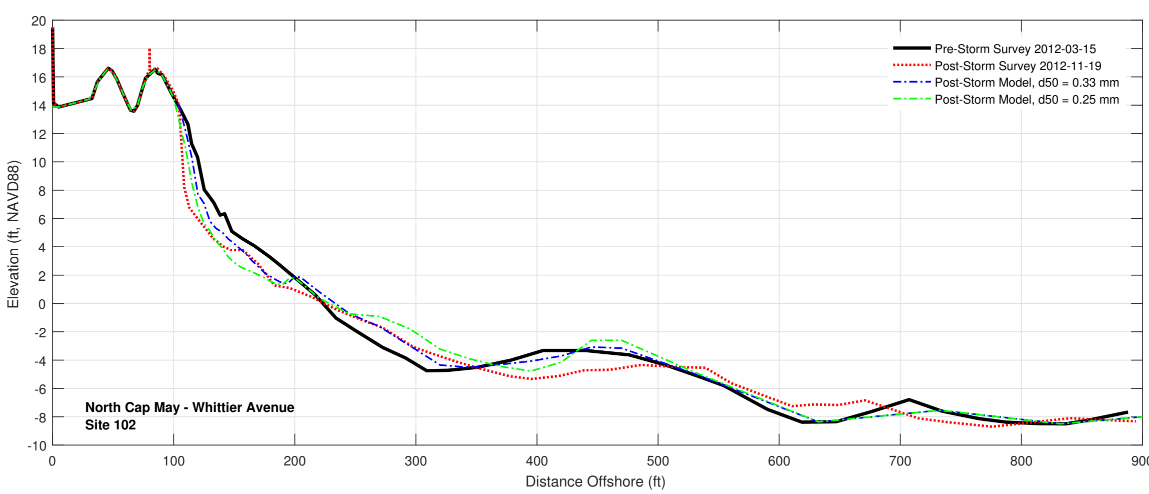


Figure 52: North Cape May (102) Superstorm Sandy SBEACH Model Results

SBEACH MODEL RESULTS

SBEACH modeling results, Figure 53, are presented for the existing conditions at 3 sites: Reeds Beach, Villas North, and Villas South. Hurricane Sandy was selected to show sample SBEACH results even though it is not part of the storm suite because it provides a good frame of reference for evaluating the SBEACH results. The results shown in Figure 53 are all displayed at the same scale to facilitate comparison between sites. The most striking observation is that at Reeds Beach the horizontal erosion is greatest and the entire profile is inundated during the peak of the storm. The existing condition dunes at Villas North and South are high and wide enough to prevent the profile from being inundated. The second observation is that there is considerably more dune erosion at Villas South than Villas North. This is likely due to two factors: (1) Villas North has a 20 ft wide berm that provides a buffer for the dune, and (2) Villas South has a deeper submerged profile allowing larger waves to attack the dune.

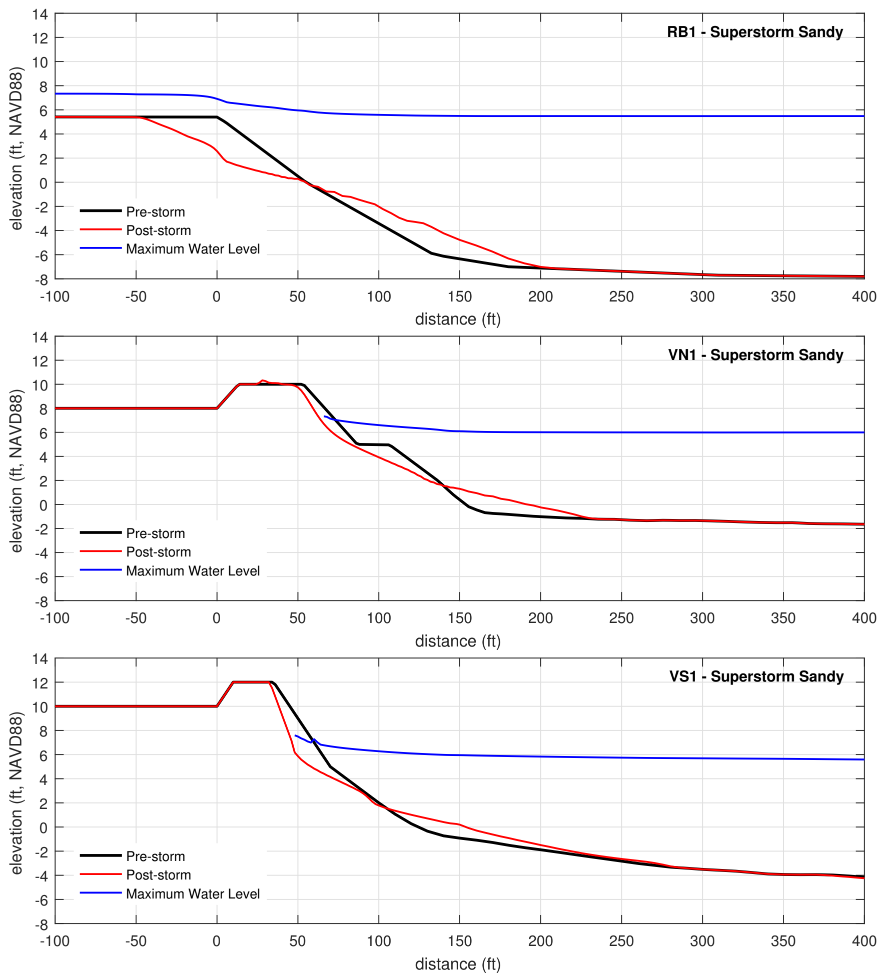


Figure 53: SBEACH Model Results for Superstorm Sandy at Reeds, Villas North, and Villas South

BACK BAY FLOODING

All of the communities evaluated in Beach-fx are also exposed to "back bay flooding," a term used to described flooding occurring from the landward side or marsh side of the communities. Figure 54 shows an aerial image of Reeds Beach, highlighting the flow of water from Delaware Bay into the marshes that border the landward side of the beach sites. Beach restoration alternatives at these sites may reduce erosion damages, wave damages, and even block the flow of water from the seaward side of beach, but they will do nothing to stop back bay flooding. Beach-fx is able to capture back bay flooding by applying single peak water level for each storm event and using the greater value of the two values: (1) seaward water level from SBEACH, and (2) back bay flooding elevation. Peak water elevations for each storm at the nearshore NACCS stations are used to define the back bay flooding elevations in the model.

Figure 54: Conceptualization of Back Bay Flooding at Reeds Beach

4.4 DIFFUSION LOSSES

OVERVIEW

Beach nourishment projects constructed on a long beach represent a perturbation or planform anomaly, which under wave action, will spread out along the shoreline (Dean, 2002). This process is illustrated in Figure 55, which shows waves interacting with the beach nourishment causing sediment transport away from the anomaly and smoothing or spreading out of the sediment (Dean & Grant 1989). The term "spreading out" losses actually refers to a redistribution of the sediment and not a total loss to the system but rather a loss from the region in which the sediment is placed (Dean & Grant 1989). This process is referred to as "beachfill diffusion" since the process is modeled analytically using the one-dimensional diffusion equation, first utilized by Pelnard-Considere (1956). Diffusion losses within the study area could be significant at many of sites and be several times greater than the background erosion rates, thus having an outsized effect on periodic nourishment quantities.

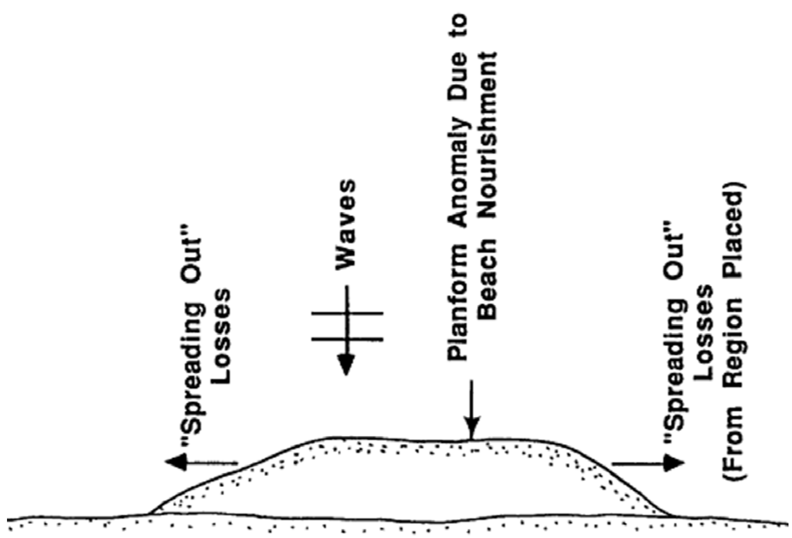


Figure 55: "Spreading Out" losses occurring from diffusion

Beachfill diffusion is modeled analytically in this study using solutions to the Pelnard-Considere equation for a rectangular planform anomaly on an infinitely long shoreline. Losses are primarily a function of the wave energy, alongshore length of beach nourishment, and cross-shore width of planform anomaly. The non-dimensional solution to the equation is shown in Figure 56, where t' is a non-dimensional representation of time based on the ratio of the alongshore length (l) of beach nourishment anomaly, time (t) after construction, and longshore diffusivity (G). The longshore diffusivity is a function of how energetic the wave environment. Figure 56 shows how the planform anomaly spreads out over time. The non-dimensional form of time indicates that rate at which diffusion occurs is a function of the diffusivity and alongshore length. Locations with more wave energy will have a larger longshore diffusivity and t' will increase. Similarly, as the alongshore length decreases, t' increases. An example solution to the Pelnard-Considere equation for a 4,000 foot-long beach nourishment project is shown in Figure 57. The bottom panel of Figure

57 shows the fraction of sand volume remaining and the impact of background erosion, which is linearly added to diffusion losses.

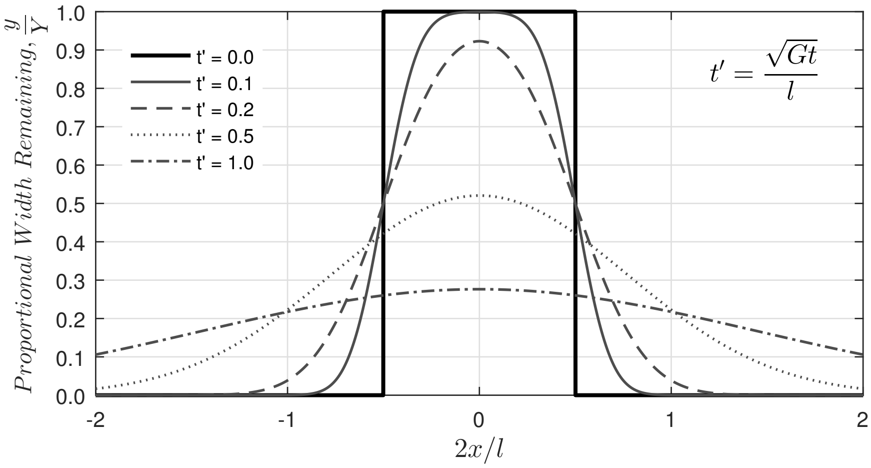


Figure 56: Non-dimensional Shoreline Evolution

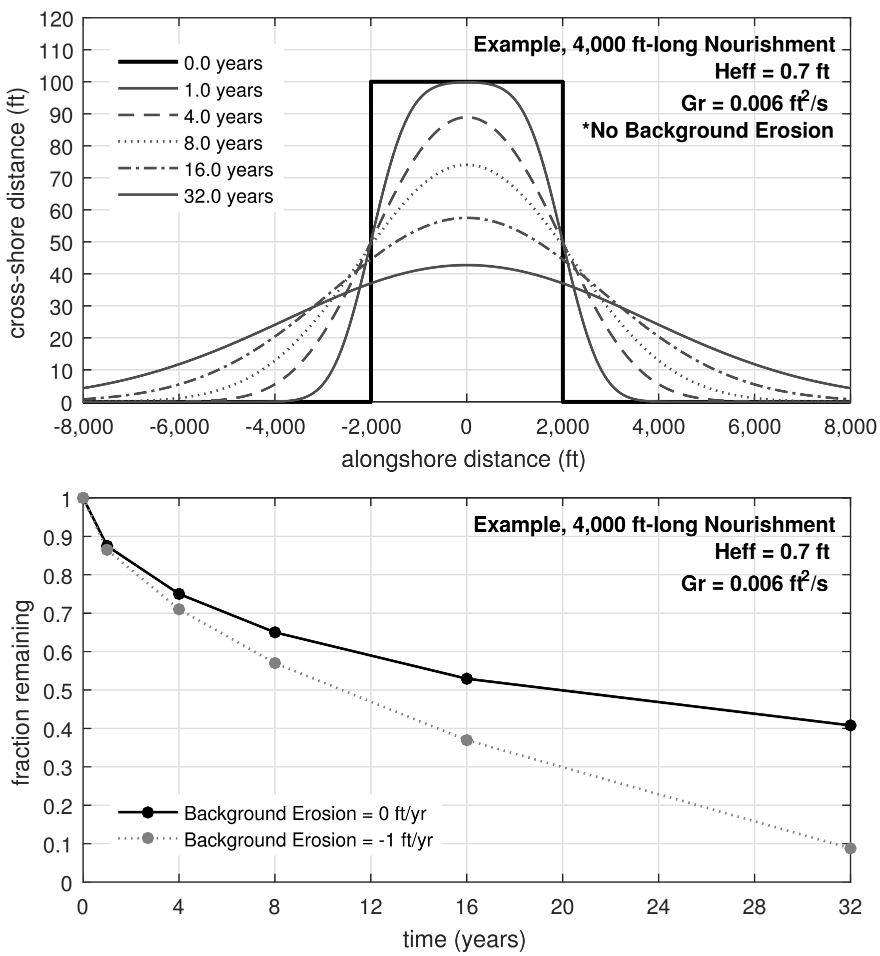


Figure 57: Example of Diffusion Losses at 4,000 foot-long Nourishment Project

EFFECTIVE WAVE HEIGHT

Wave conditions at NOAA NDBC Buoy 44055 located in the middle of Delaware Bay are used to calculate the effective wave height and longshore diffusivity, G. The formula for calculating the effective wave height, H_{eff}, is provided below from Dean and Grant (1989):

$$H_{eff} = \left[\frac{1}{N}\sum_{n=1}^{N}\left(K_s H_{s,n}\right)^{2.4}\right]^{\frac{1}{2.4}}$$

where Hs is the significant wave height, and Ks is the shoaling coefficient and equal to 0.735. An effective wave height of 0.7 feet and representative wave period of 3.4 seconds was calculated for Buoy 44055.

The formula for the longshore diffusivity, G, is also provided below from Dean (2005) including the effects of wave refraction around the planform:

$$G = \frac{K H_b^{\frac{5}{2}} \sqrt{g/\kappa}}{8(s-1)(1-p)(h_* + B)} \frac{C_b}{C_*}$$

Where K is the sediment transport factor (0.78), H_b is the breaking wave height taking here as the effective wave height, g is the acceleration of gravity, κ is the wave breaking index (0.78), s is the sediment specific gravity (2.65), p is the in-place sediment porosity (0.35), h_* is the depth of closure, B is the berm height, C_b is the wave celerity at breaking, and C_* is the wave celerity at the depth of closure. The longshore diffusivity is 0.0143 ft^2/s and 0.0061 ft^2/s at sites with a depth of closure of -6 ft and -3 ft NAVD88 respectively.

TERMINAL GROINS

There are two existing terminal groins or jetties in the study area: (1) northern end of Reeds Beach, and (2) northern end of Fortescue Creek. A third terminal groin is proposed at the northern end of Gandys Beach, the justification for this groin is provided in Section 5.3. These three terminal groins would significantly reduce diffusion losses. Dean & Grant (1989) describe a simple approach to incorporate terminal groins in the diffusion analysis. The recommended approach for a single terminal groin is to increase the effective length of the nourishment to twice the physical length of the project and apply background erosion rates that account for the influence of the terminal groin. By doubling the effective length of the nourishment, diffusion losses are cut in half. The same approach, doubling the effective length of the project, was also applied at the southern end of Del Haven where the nourishment project would tie-into the adjacent nourishment project at Villas.

APPLICATION TO PROJECT AREA

Diffusion calculations were first performed at the sites based on the planform anomaly length (i.e. alongshore length of nourishment) and a range of possible planform anomaly widths (ΔY). This analysis resulted in a site-specific lookup table relating planform anomaly widths to diffusion rates, where the diffusion rate represents the average loss over the entire nourished beach after 4 years. At the time the diffusion analysis was completed, the anticipated periodic nourishment cycle was 4 years.

After generating the lookup table of diffusion rates, the next step was to determine the planform anomaly width for different With-Project alternatives. The planform anomaly width is measured as the cross-shore difference between the existing condition shoreline position and With-Project shoreline position. To simplify the analysis, the representative profile from Beach-fx was used to represent the existing conditions. Figure 58 and Figure 59 show an example of the process used to determine the planform anomaly width for various With-Project alternatives at Gandys Beach, Fortescue and Villas South.

The results of the diffusion analysis for the tentatively optimized With-Project alternative is presented in Table 22.

Table 22: Diffusion Results

Site	Design	Length (ft)	ΔY (ft)	Diffusion (ft/yr)
Gandys	WP6.5B50	2,890[1]	100	-4.4
Fortescue	WP6.5B50	4,400[1]	100	-2.8
Reeds	WP5.5B50	5,300[1]	50	-1.2
Pierces	WP6B50	3,000	50	-5.9
Del Haven	WP8B50	5,600[1]	50	-1.7
Villas North	WP8B50	16,400[2]	45	-1.0
Villas South	WP12B50a	16,400[2]	50	-1.2

[1]Effective Length is twice as long due to terminal groins and adjacent projects
[2]Entire length of Villas was used in calculations with design specific planform anomalies (ΔY).

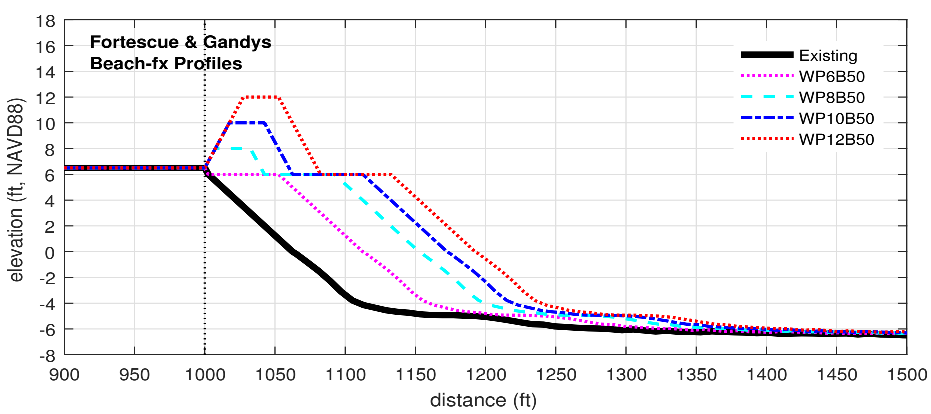


Figure 58: Beach Nourishment Alternatives at Gandys Beach and Fortescue

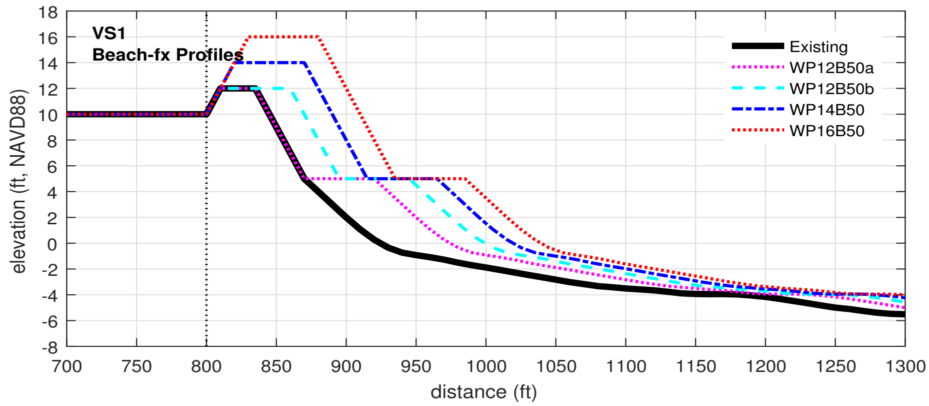


Figure 59: Beach Nourishment Alternatives at Villas South

4.5 SEA LEVEL CHANGE IMPLEMENTATION IN BEACH-FX

Mark Gravens (2011) provides a detailed description of how sea level change (SLC) is implemented in Beach-fx. A brief overview of this paper is provided here as well as a discussion of the site specific inputs for the NJ DMU.

SLC is implemented in Beach-fx based on four assumptions:

1. Natural berm elevation will rise in concert with rising sea surface (supports #2);
2. Pre-computed beach profile responses in Shore Response Database are equally valid at the end of the project life cycle as they are at the beginning of the project life cycle;
3. Water surface and wave elevations may be incrementally increased by an amount equal to the estimate amount of SLC;
4. Bruun Rule (1962) may be used to estimate additional shoreline recession associated with SLC.

Based on these assumptions, Beach-fx only requires two additional site specific inputs to evaluate the effect of sea level change, historic rate of SLC, and average profile slope over active beach. A third parameter, G_a, may also be included in the Bruun Rule calculation to account for the loss of fines from an eroding upland. Beach-fx has its own internal sea level change calculator, consistent with ER 1100-2-8162, and is able to calculate the mean sea level at any point in time for all three SLC scenarios (Low, Intermediate, and High). The historic rate of SLC in the study area is +0.0105 ft/yr (Lewes, DE). The average profile slope over the active beach profile, ϑ, was estimated to be 1V:30H based on profile surveys in the project area. G_a was set to the default value of 1.0 for this study.

Shoreline recession associated with SLC is modeled in Beach-fx after Bruun (1962).

$$R = \frac{S}{\theta} G_a$$

S = change in sea level

θ = average profile slope over active beach profile

R = horizontal recession of beach

G_a = factor relating volume of eroded material required to yield a unit volume of compatible beach sand, accounting for the loss of fines from eroding upland

Application of the Bruun Rule to the study area, Table 23, reveals that historic rate of sea level change is responsible for 0.3 feet of background shoreline erosion per year. The 0.3 feet of shoreline erosion associated with the historic rate of SLC is a component of historical background erosion rate. Therefore, the potential impact of SLC in the Intermediate and High SLC scenarios is the net increase in shoreline change relative to the historic rate (Δ Shoreline Change). Table 23 shows that the Intermediate and High SLC scenarios could increase shoreline erosion by 0.3 ft/yr and 1.3 ft/yr, respectively.

Table 23: Bruun Rule Results

SLC Scenario	SLC[1] (ft)	Shoreline Recession (ft)	Shoreline Change (ft/yr)	Δ Shoreline Change[2] (ft/yr)
Low/Historic	0.53	-16	-0.3	0.0
Int.	1.00	-30	-0.6	-0.3
High	2.48	-74	-1.5	-1.3

[1]Projected sea level change from 2020 to 2070.

[2]Increase in shoreline change relative to historical background erosion.

4.6 MORPHOLOGICAL EVOLUTION

Morphological results from the Future Without Project (FWOP) Beach-fx model simulations are presented in this section. A detailed discussion of Beach-fx and the economic results are presented in the Main Report and Economics Appendix. The focus of this section is to verify that the morphological evolution simulation in Beach-fx is consistent with the inputs described in the previous section.

Beach-fx simulates profile morphology changes through five mechanisms:

1. Storm-induced morphology change based on SBEACH model results stored in SRD
2. Post-storm berm width recovery
3. SLC-induced shoreline change (Bruun Rule)
4. Applied shoreline change rate
5. Project-induced shoreline change (e.g. diffusion losses)

Together, the first four factors make up the long-term background erosion rate. For this study, the applied shoreline change rate was used as a calibration parameter to ensure that Beach-fx is reproducing the long-term background erosion rates (Table 11). It is noted that model calibration is performed under the Low SLC scenario. A berm width recovery factor of 95%, which is fairly standard value, was applied in this study. The 5th factor, project-induced shoreline change, was applied in the With-Project simulations and set equal to the diffusion losses (Table 22).

The FWOP Beach-fx model results for all 300 lifecycle simulations are presented here for the Intermediate SLC scenario. Each lifecycle simulation is performed over a 55-year period from 2017 to 2072. Figure 60 to Figure 69 show the existing condition profile in 2017 and FWOP profile at the end of the simulation in 2072. The light red lines represent the FWOP profile at the end of each iteration. The thick red line represents the average profile in 2072. Not surprisingly, the greatest erosion is observed at the sites with the highest background erosion rates: Gandys Beach, Fortescue, and Villas South. Reeds Beach and Pierces Point also experience significant erosion. Since the background erosion rates at Del Haven and Villas North are stable, it is not surprising the Beach-fx simulations show fairly stable conditions. Figure 60 to Figure 69 do not capture the post-storm conditions, so it is possible that the profiles eroded back even further during a storm event before recovering (i.e. 95% berm width recovery factor).

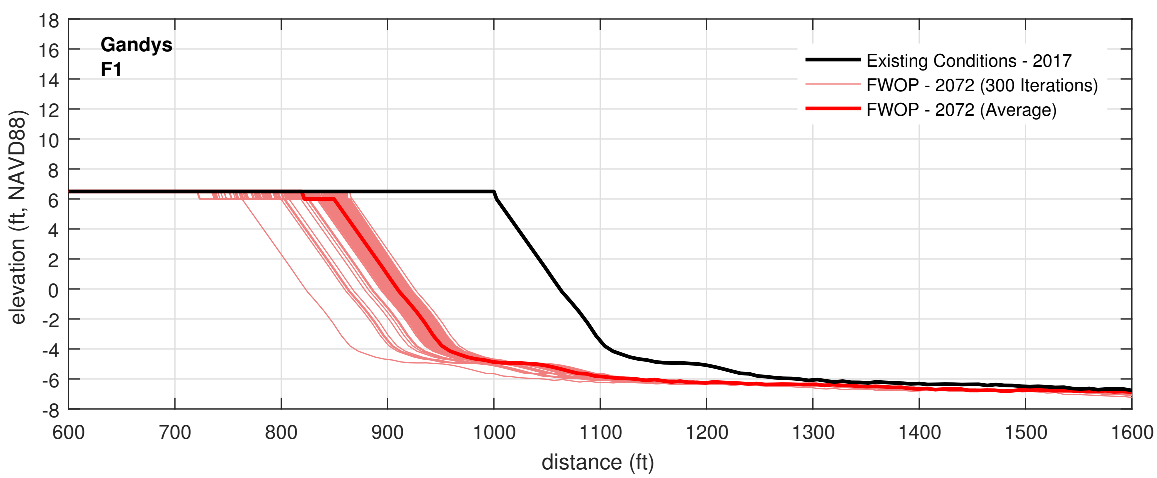


Figure 60: FWOP Morphology at Gandys Beach (F1)

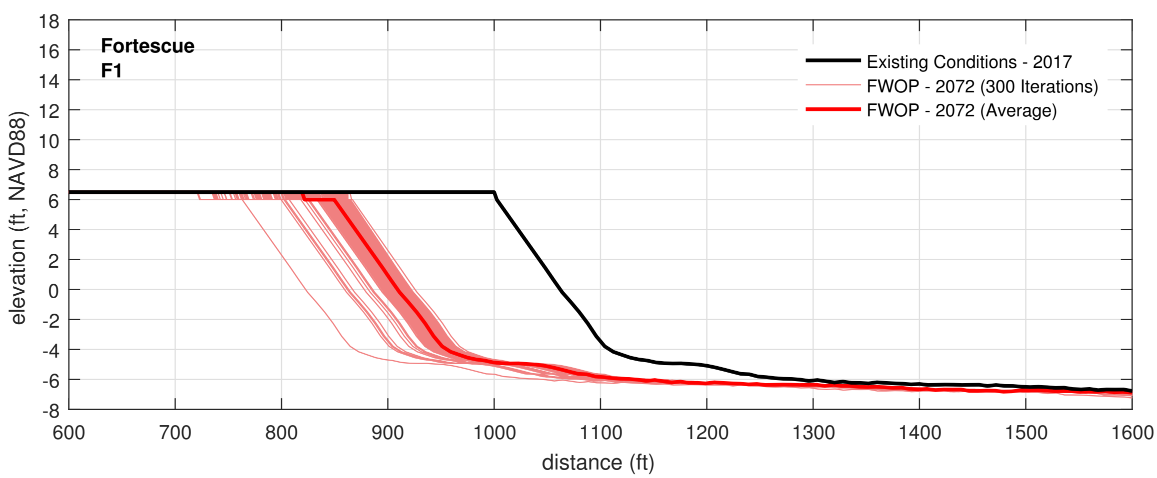


Figure 61: FWOP Morphology at Fortescue (F1)

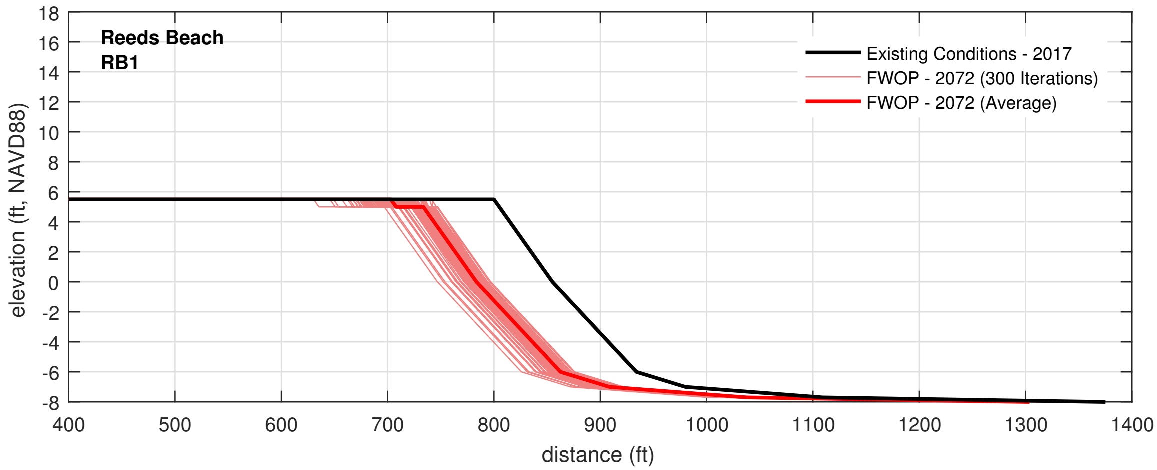


Figure 62: FWOP Morphology at Reeds Beach (RB1)

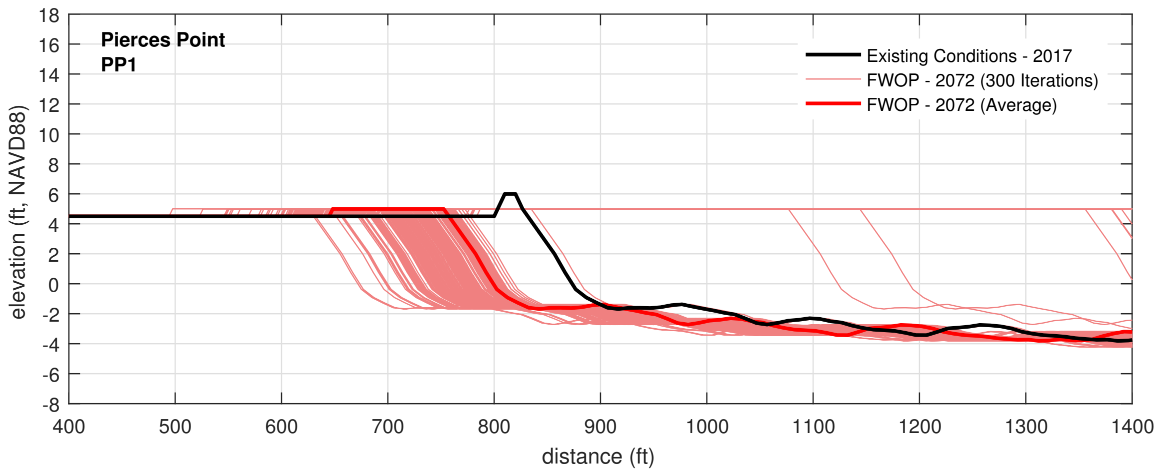


Figure 63: FWOP Morphology at Pierces Point (PP1)

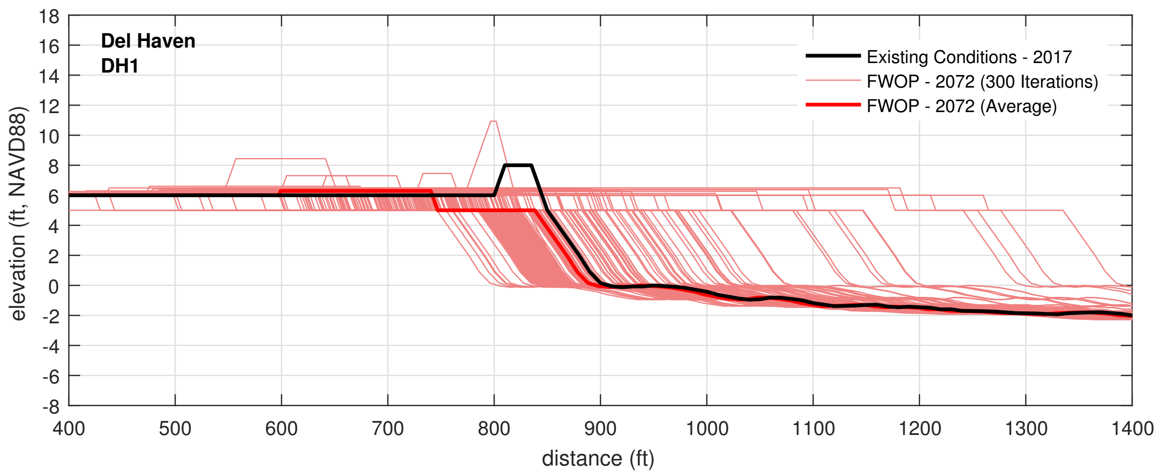


Figure 64: FWOP Morphology at Del Haven (DH1)

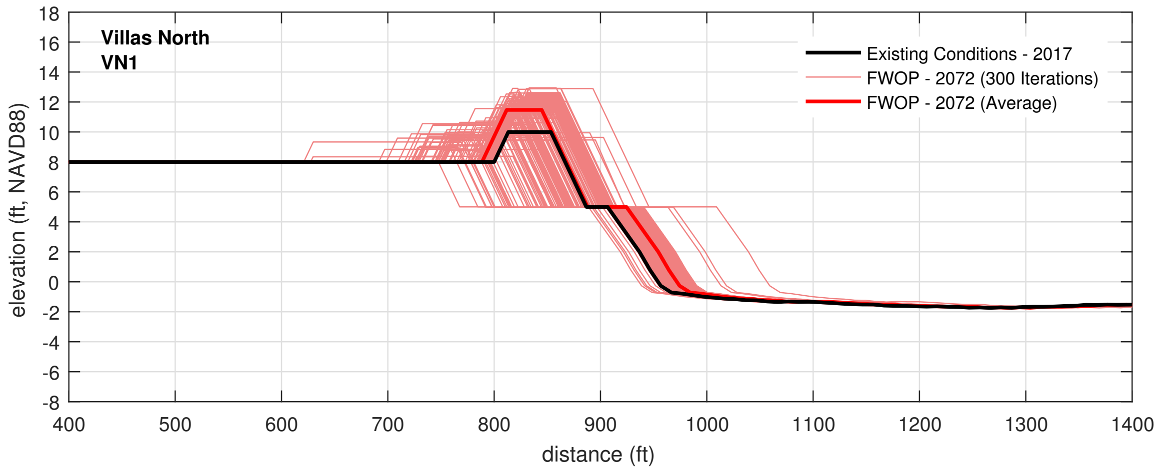


Figure 65: FWOP Morphology at Villas North (VN1)

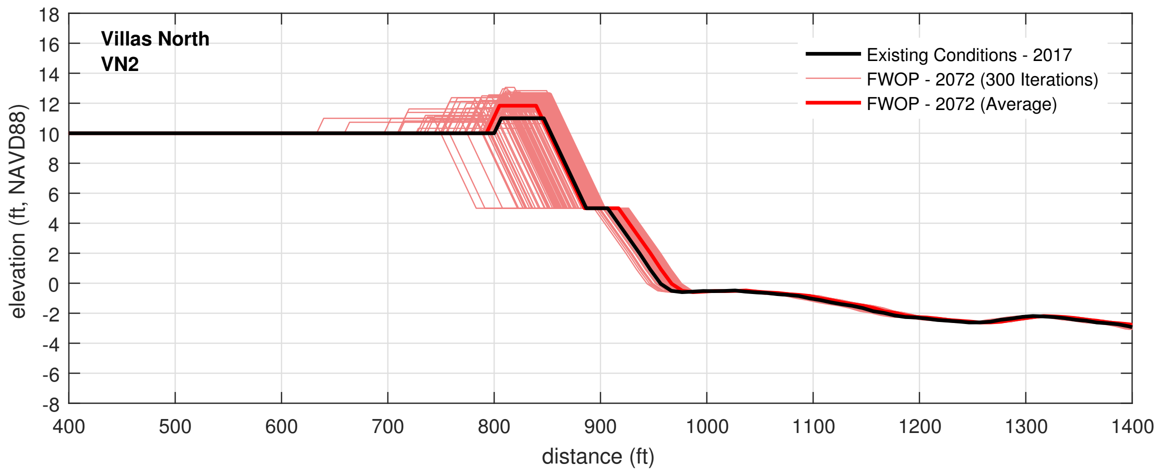


Figure 66: FWOP Morphology at Villas North (VN2)

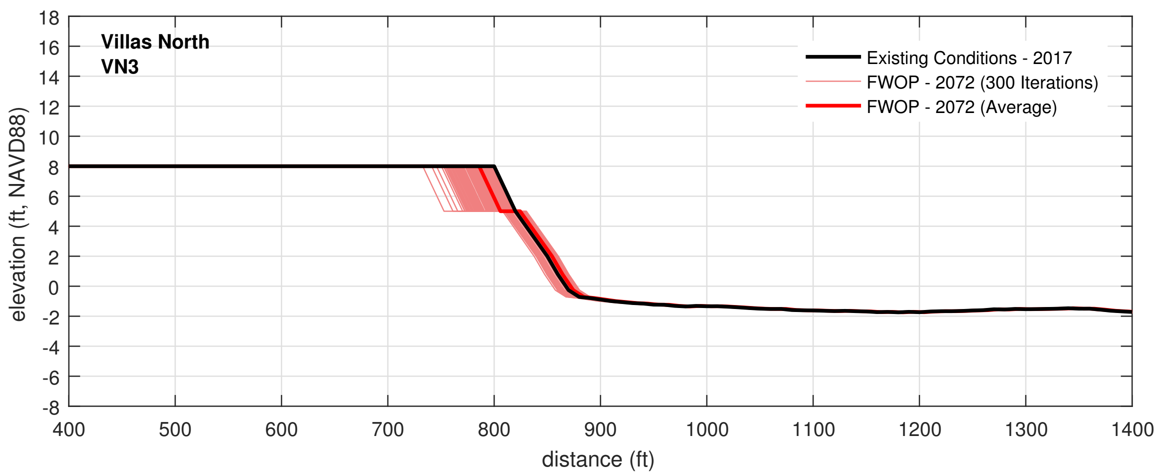


Figure 67: FWOP Morphology at Villas North (VN3)

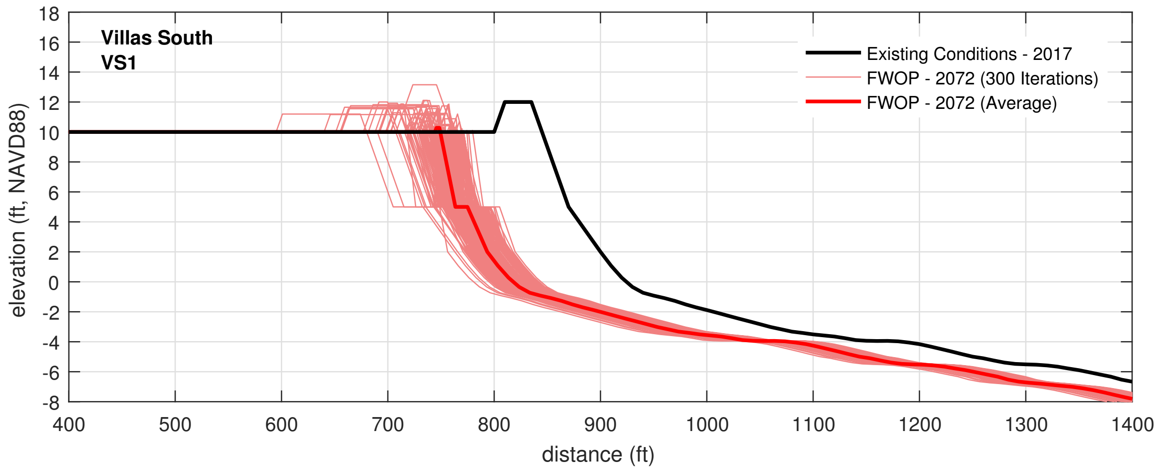


Figure 68: FWOP Morphology at Villas South (VS1)

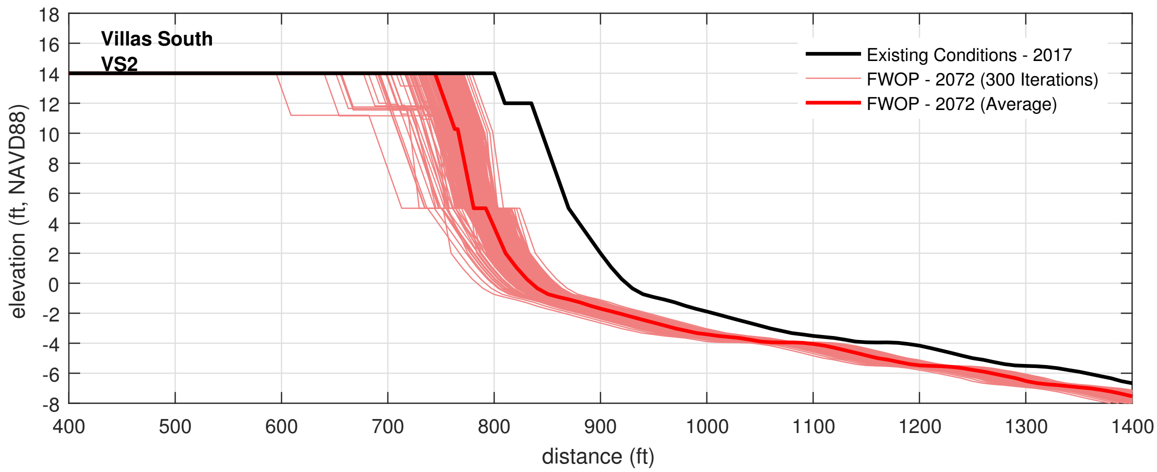


Figure 69: FWOP Morphology at Villas South (VS2)

5.0 ALTERNATIVE EVALUTION

5.1 DESIGN PROFILES

Dune elevations and berm widths from the Beach-fx alternative evaluation are presented in Table 24. All the design profiles have a dune slope of 1V:5H, foreshore slope of 1V:10H. Gandys Beach and Fortescue have a berm elevation of +6 ft NAVD88 and Reeds, Pierces Point, Del Haven, and Villas North, and Villas South have a berm elevation of +5 ft NAVD88. The berm elevations is selected to match the natural berm elevations at each location.

Table 24: Design Profiles (Alternative Evaluation)

Site	Dune Elv. (ft, NAVD88)	Total Berm Width (ft)
Gandys Beach	none	75
Fortescue	none	75
Reeds Beach	none	75
Pierces Point	none	75
Del Haven	8.0	75
Villas North	12.0	75
Villas South	12.0	75

*Berm width is measured from the seaward toe of the dune

5.2 NOURISHMENT FILL QUANTITIES

INITIAL CONSTRUCTION

A comparison of the Civil Engineering estimate of initial construction quantities and the calculated number in Beach-fx is presented in Table 25. Considering that Beach-fx is based on simplified representation of the profile, and that in some instances a single profile is used to represent an entire project site, the agreement between the Civil Engineering estimate and Beach-fx is considered good. The largest differences occur at Pierces where the Civil Engineering estimate is based on a shorter project length of approximately 2,000 feet and Del Haven where the Civil Engineering estimate was completed for a +12 ft NAVD88 dune, not the +8 ft NAVD88 dune modeled in Beach-fx.

PERIODIC NOURISHMENT

Table 26 presents the periodic nourishment fill quantities for an 8-year dredging cycle at each site based on the background erosion rate, diffusion losses, and SLC-induced erosion. An 8-year dredging cycle was selected to reduce project costs. At shorter dredging cycles, the required periodic nourishment fill quantities became relatively small for a dredging operation and it may not be sensible to mobilize a dredge.

Table 25: Initial Construction Quantities (Alternative Evaluation)

Site	Reach Length (ft)	Engineering Estimate (cy)	Beach-fx Result (cy)
Gandys	3,100	145,000	114,000
Fortescue	5,590	193,000	205,000
Reeds	4,840	264,000	155,000
Pierces	5,900	65,000[2]	124,000
Del Haven	5,290	287,000[1]	105,000[1]
Villas North	8,140	470,000	173,000
Villas South	8,515		314,000

[1] Engineering estimate for Del Haven is based on design dune at +12 ft NAVD88, Beach-fx design template has dune at +8 ft NAVD88.
[2] Engineering estimate for Pierces Point is based on a 2,000-ft long project

Table 26: Periodic Nourishment Quantities (Alternative Evaluation)

Site	Length (ft)	Background Erosion (ft/yr)	Diffusion Losses (ft/yr)	Int. SLC Erosion (ft/yr)	Periodic Nourishment (cy/operation)
Gandys	3,100	-2.5	-4.4	-0.3	79,000
Fortescue	5,590	-2.5	-2.8	-0.3	111,000
Reeds	4,840	-1	-1.2	-0.3	39,000
Pierces	5,900	-1	-5.9	-0.3	101,000
Del Haven	5,290	0	-1.7	-0.3	25,000
Villas North	8,140	+0.5	-1.0	-0.3	15,000
Villas South	8,515	-1.5	-1.2	-0.3	83,000

5.3 TERMINAL GROINS

Two terminal groins are proposed as complimentary features to the beach restoration projects at Gandys Beach and Fortescue. Analytical shoreline change modeling of beach restoration project at Gandys Beach shows that the project would be unstable without a terminal groin due to severe end losses of the fill. The rate at which the beachfill would erode would be so high that excessively frequent periodic nourishment would be required to maintain the project shoreline. Attempts to extend the periodic nourishment interval by increasing the fill volume would increase the project width and its perturbative effect on the shoreline alignment. This in turn would increase the beachfill loss rate so that the increased fill volume would do little to decrease the periodic nourishment frequency (Bodge 2003). The existing terminal groin at the northern end of Fortescue is in poor condition and will be too short to effectively limit sediment transport into Fortescue Creek. Over a 50-year project life, the cumulative savings on periodic nourishments are expected to greatly exceed the initial cost of the terminal groins.

6.0 SELECTED PLAN

6.1 DESIGN PROFILES

Dune elevations and berm widths from the Beach-fx optimization are presented in Table 27. All the design profiles have a dune slope of 1V:5H, foreshore slope of 1V:10H. Gandys Beach and Fortescue have a berm elevation of +6 ft NAVD88 and Villas South has a berm elevation of +5 ft NAVD88. The berm elevations is selected to match the natural berm elevations at each location. The results of the Beach-fx optimization show that Gandys Beach and Fortescue do not need a dune to maximize net benefits. However, a wider design berm is required since there is no dune. Villas South optimized to a design dune elevation of +12 ft NAVD88.

Beach-fx does not distinguish between the design berm width and advance berm width. The only input to Beach-fx is the total berm width (design + advance). Conceptually the design berm width is the width required to reduce wave and erosion damages, whereas the advance berm width is the additional width required to offset expected losses between nourishment operations. The advance berm width is proportional to the background erosion rate and diffusion. As a result the advance berm widths are the greatest at the northern sites that experience the highest rates of background erosion and diffusion.

Table 27: Optimized Design Profiles (Selected Plan)

Site	Dune Elv. (ft, NAVD88)	Design Berm Width (ft)	Advance Berm Width (ft)	Total Berm Width (ft)
Gandys Beach	none	30	45	75
Fortescue	none	30	45	75
Villas South	12.0	30	20	50

*Berm width is measured from the seaward toe of the dune

6.2 NOURISHMENT FILL QUANTITIES

INITIAL CONSTRUCTION

Initial construction quantities were performed by calculating cross-sectional areas at each survey profile and then computing volumes between adjacent profiles using the average-end-area method. The average-end-area method was applied by averaging adjacent profile areas and multiplying by the orthogonal distance between profile azimuths. Wedge volumes, where the adjacent profile azimuths differed, were not included in the volume. Taper volumes are included in the initial construction quantities and computed as a pyramid. Table 25 and Table 29 presents the initial construction quantities at each of the seven sites. A distinction is made between the design quantity, advance fill, and expected losses between the date of the last survey (Dec 2015 for Gandys & Fortescue, March 2017 for Villas South) and start of initial construction. Initial construction quantities (1.0 million cy) may exceed the available material from the navigation channel, predicted to be 930,000 cy, and is therefore split over two operations in 2022 and 2028. Gandys and Fortescue will be constructed in year 2022, and Villas South will be constructed in year 2028 during the 1st periodic nourishment cycle for Gandys Beach and Fortescue. In year 2034 all 3 sites will be on the same 6-year periodic nourishment cycle.

Design quantities are the amount of material needed to construct the design profile (i.e. 30 foot wide berm) and ensure that the design shoreline is relatively straight and follows the natural equilibrium shoreline. Advance fill is the additional material required to offset predicted losses before the next periodic nourishment operation. While advance fill quantities are conceptually the same thing, losses over a 6-year period, there are differences here in the way the two quantities are calculated. Advance fill quantities are calculated based on adding the advance fill berm w width and average-end-area method. Periodic nourishment quantities are computed based predicted losses over the length of the project, without using average-end-are method, resulting in differences between advance fill quantities and periodic nourishment quantities.

Table 28: Initial Construction Quantities in 2022 (Selected Plan)

Site	Length (ft)	Design Qty (cy)	Advance Fill (cy)	Losses to 2022 (cy)	Initial Construction (cy)
Gandys Beach	2,570	127,000	67,300	19,400	213,700
Fortescue	4,530	188,000	109,200	34,200	331,400
					545,100

Table 29: Initial Construction Quantities in 2028 (Selected Plan)

Site	Length (ft)	Design Qty (cy)	Advance Fill (cy)	Losses to 2028 (cy)	Initial Construction (cy)
Villas South	8,600	351,600	67,000	67,500	486,100
Gandys Beach	2,570				49,200*
Fortescue	4,530				67,500*
					602,800

* Periodic Nourishment Quantity

PERIODIC NOURISHMENT

Table 26 presents the periodic nourishment fill quantities for a 6-year dredging cycle at each site based on the background erosion rate, diffusion losses, and SLC-induced erosion. A 6-year dredging cycle was selected to reduce project costs. At shorter dredging cycles, the required periodic nourishment fill quantities became relatively small for a dredging operation and it may not be sensible to mobilize a dredge. The depths of closures, documented in Section 4.1, is used to convert the combined shoreline erosion rate to volumetric losses.

Table 30: Periodic Nourishment Quantities

Site	Length (ft)	Background Erosion (ft/yr)	Diffusion Losses (ft/yr)	Int. SLC Erosion (ft/yr)	Periodic Nourishment (cy/operation)
Gandys Beach	2,570	-2.5	-4.4	-0.3	49,200
Fortescue	4,530	-2.5	-2.8	-0.3	67,500
Villas South	8,600	-1.5	-1.2	-0.3	62,800
					179,500

MAJOR REHAB

Major replacement quantities were developed in accordance with ER1110-2-1407 to identify additional erosional losses from the project due to higher intensity (low frequency) storm events. The nourishment rates developed for the project alternatives include losses due to storms that have occurred within the analysis period. Storms of approximately 50-year return period and more frequent are encompassed in those rates. Major replacement losses are computed as the losses that would occur from the 50% risk event over the project life. The annual percent frequency event with a 50% risk during the 50-year period of analysis is 1.37%.

SBEACH was employed to compute volumetric erosion from the selected beach alternative design profile several storms with 50- and 100-yr return period storm parameters utilized in the Beach-fx model. Volumetric erosion quantities for the 73-yr event were obtained by averaging the results for these storms. Volumetric storm induced erosion was computed for each reach for the design beach profile. Based on local profile analyses and experience developed at the Philadelphia, and other Corps coastal Districts, it is estimated that approximately 60% of the material displaced during large storms will return to the foreshore within weeks and only the remaining 40% will require mechanical replacement onto the subaerial beach to regain the design cross-section. It is estimated that a volume of approximately 12,400 cy would be required to perform major rehabilitation in response to the 50% risk event. Additional details on Major Rehab quantities are provided in Attachment C.6.

TERMINAL GROINS

The recommended USACE plan for Gandys Beach includes placement of 214,000 cubic yards of sand for initial construction, with future periodic nourishment estimated to be 49,000 cubic yards every 6 years over a 50-year project life. The beachfill will be augmented by construction of a terminal groin at the northwest end of Gandys Beach, in order to prevent excessive end losses from the project area. The groin will be designed with sufficient permeability to allow for sediment bypassing northwest towards the Preserve without compromising the integrity of the beachfill project.

Analytical shoreline change modeling of beach restoration shows that the project would be unstable without a terminal groin due to severe end losses of the fill. The rate at which the beachfill would erode would be so high that excessively frequent periodic nourishment would be required to maintain the project shoreline. Attempts to extend the periodic nourishment interval by increasing the fill volume would increase the project width and its perturbative effect on the shoreline alignment. This in turn would increase the beachfill loss rate so that the increased fill volume would do little to decrease the periodic nourishment frequency (Bodge 2003).

The terminal groin will be a rubble-mound structure designed to mirror the cross-shore beach template, and will not be a total barrier to LST. The crest elevation of the groin will be established at about mean sea level to allow for transport over the groin at high tide. The groin will also include two layers of armor stone in order to increase the permeability of the structure to LST of sand. The permeability of the rubble-mound structure will allow hydrodynamic exchange across the groin, which is important to reducing rip currents and offshore losses (Basco & Pope, 2004).

USACE anticipates that periodic nourishment of the proposed beach over the project life will not only create and maintain sandy beach habitat in the Gandy Beach project area, but will also allow transport of sediment to the northwest into the TNC Preserve, which is sand-starved under existing conditions. It is expected that the nourishment Gandys Beach will restore the two natural processes, upland beach erosion and longshore sediment transport, primarily responsible for providing sediment to bay beaches.

Wave reflection is not expected to increase wave energy at any of the nearby sites based on the following reasons: (1) Wave conditions at the sites are dominated by short-period waves that result in lower wave reflection; (2) Beaches are generally efficient wave absorbers, particularly the shorter-period waves (EM 1110-2-1100 II-7-29); (3) Proposed groins will replace existing groin (Fortescue) or concrete seawall (Gandys Beach); (4) Groins will be constructed with stone which has a lower wave reflection coefficient than vertical walls.

6.3 STORMWATER MANAGEMENT IMPACT ASSESSMENT

A desktop assessment was completed to identify any potential impacts of with-project conditions to upland flooding and stormwater management. The selected plan is not expected to exacerbate existing upland and stormwater flooding.

Villas South already has high existing dunes and a stormwater management system with several outfall structures. The proposed dune (+12 ft NAVD88) is lower than the existing dunes that already act as an impediment to stormwater. The existing outfalls will be extended seaward to ensure that outfalls continue to drain properly to the bay.

The upland elevation at Gandys Beach and Fortescue are generally 1 to 2 feet higher than the proposed berm elevation along the beach. Therefore, it is not expected that the berm will exacerbate existing upland and stormwater flooding. The location of pile supported houses on the beach at both Gandys Beach (Figure 70) and Fortescue create a challenge for sand placement and the potential for a depression or low spot underneath the houses if sand is not placed here. If not filled in with sand this low spot could result in localized ponding from wave overtopping or rainfall. The project will require placement of sand by the Non-Federal sponsor underneath the houses to fill this potential depression.

Figure 70: Houses at Gandys Beach

7.0 GANDYS BEACH TERMINAL GROIN

7.1 BACKGROUND

The plan for Gandys Beach includes construction of a terminal groin (Figure 71) at the northwest end of the community to reduce rapid end-losses of the placed sand that otherwise would occur without the groin. Analytical shoreline change modeling of beach restoration shows that the project would be unstable without a terminal groin due to severe end losses of the fill. The rate at which the beachfill would erode would be so high that excessively frequent periodic nourishment would be required to maintain the project shoreline. Attempts to extend the periodic nourishment interval by increasing the fill volume would increase the project width and its perturbative effect on the shoreline alignment. This in turn would increase the beachfill loss rate so that the increased fill volume would do little to decrease the periodic nourishment frequency (Bodge 2003).

NAP, in response to ongoing coordination with U.S. Fish and Wildlife Service (USFWS) and The Nature Conservancy (TNC), completed a quantitative assessment of the sediment transport in the study area in the Future Without-Project Conditions and With-Project Conditions. The sediment transport assessment is used to develop a sediment budget for the project area and identify a range of rough order of magnitude (ROM) impacts from the proposed terminal groin at Gandys Beach.

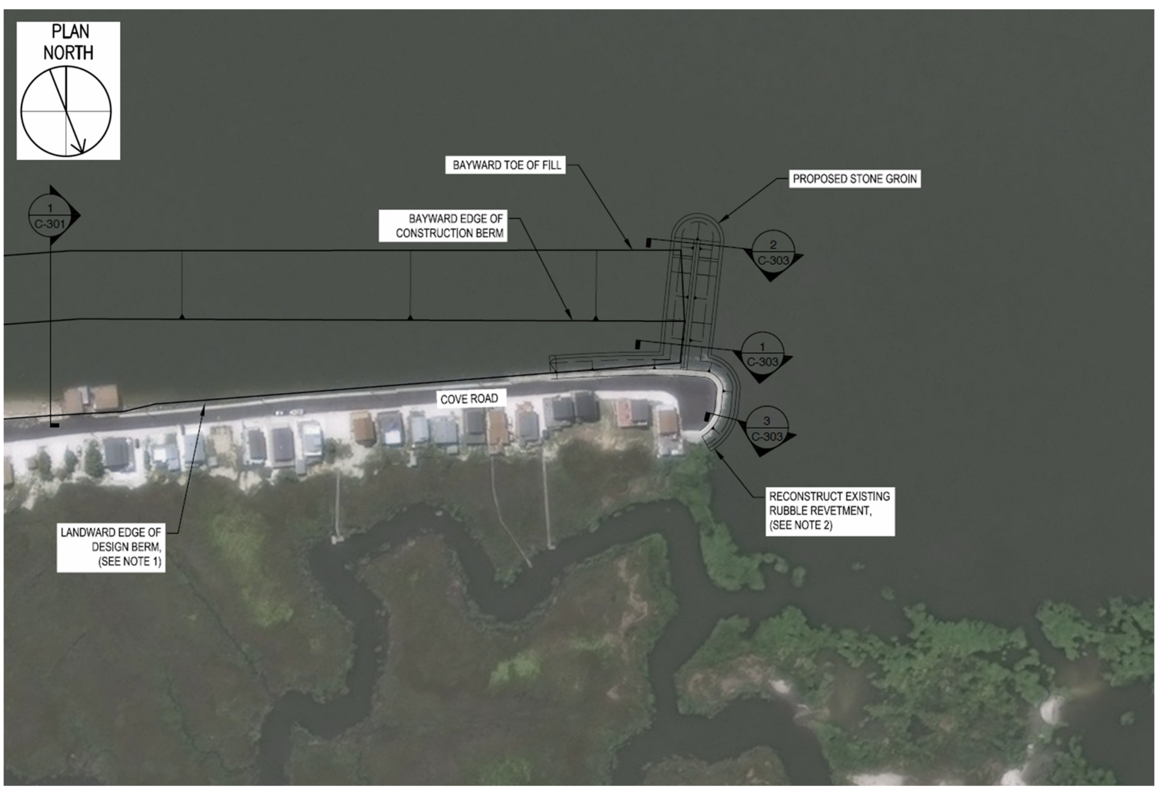


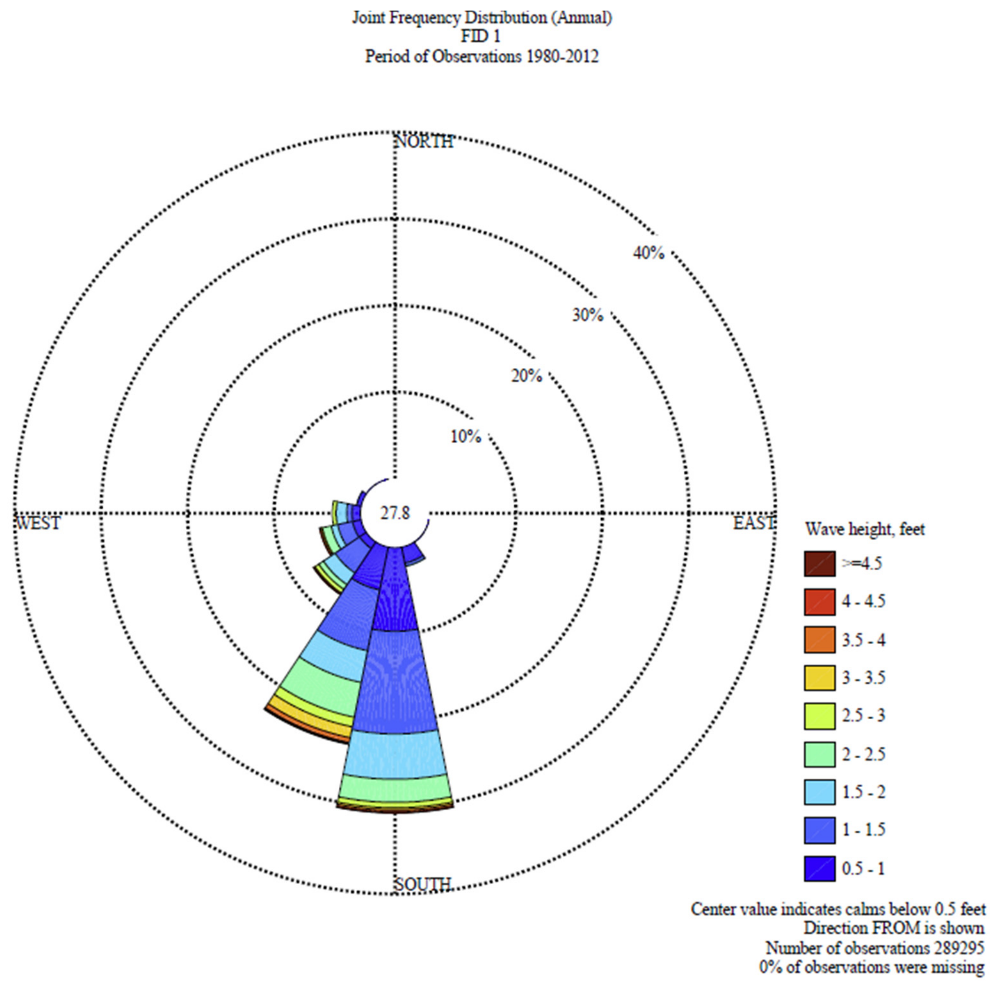
Figure 71: Proposed Terminal Groin at Gandys Beach

7.2 WAVE CONDITIONS

The engineering firm Hatch Mott MacDonald (HMM) completed an investigation in 2016 titled "Gandy's Beach Beachfront Sustainability Project". This investigation utilized numerical models of relevant physical processes (wind, waves, and currents) to estimate the potential Longshore Sediment Transport (LST) rate and direction along Gandys Beach and the adjacent TNC Preserve. At the request of NAP, HMM provided their modeled wave conditions at several locations (Figure 1) along the 8 foot contour line from a 22 year wave hindcast simulation (1980-2012) of Delaware Bay.

Figure 72: Wave Hindcast Output Locations

A wave rose, showing the joint probability of wave height and wave direction, is presented in Figure 73 for location FID 1. The wave hindcast results indicate the majority of wave conditions are from the South and SSW and capable of transporting sediment in either direction (east or west) along Gandys Beach.



Percentage of Occurrence

Wave height, feet	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Total	22.8						0.04	3.16	33	23.5	7.52	6.06	3.44	0.53	0.01		100
4.5–5									0.01	0.12							0.13
4–4.5									0.08	0.1	0.02						0.21
3.5–4									0.24	0.58	0.06						0.87
3–3.5									0.25	1.28	0.11	0.21					1.85
2.5–3									0.63	1.13	0.52	0.1	0.42				2.79
2–2.5									2.67	4.09	0.66	1.05					8.47
1.5–2								0.01	5.24	3.75	1.63	0.76	1.23				12.6
1–1.5								0.36	11.9	7.17	3.41	1.75	0.62				25.2
0.5–1							0.03	1.88	9.65	5.05	0.93	1.01	0.98	0.52			20.1
0–0.5	22.8							0.91	2.35	0.21	0.19	1.18	0.19				27.8

Figure 73: Wave Rose at FID 1

7.3 LONGSHORE SEDIMENT TRANSPORT

LST is the process by which incident waves, and to a lesser degree, tidal currents, mobilize sandy sediment in the swash zone and transport it in the alongshore direction. All coastal localities, including the Gandys Beach vicinity of the Delaware Bay shoreline, experience LST in either alongshore direction at different times, depending on the incident wave direction at any given time. Over long periods, transport in one direction will usually dominate transport in the other direction, with the dominant direction referred to as the direction of "net" transport.

Most studies of longshore transport have been conducted on ocean beaches with well-developed and gently sloping surf zones, making results from existing LST formulas less reliable at estuarine beaches, such as Gandys Beach. Nordstrom *et al*. (2003) conducted a field investigation of LST at an estuarine beach in Great South Bay, N.Y. and found that there is considerable uncertainty in LST estimates from existing formulas when applied to estuarine beaches. One of the differences between estuarine beaches and the typical ocean beaches is that the greatest energy concentration on estuarine beaches is at high water when plunging waves break on the upper foreshore and wave energy is converted directly to swash without an intermediate surf zone.

CERC FORMULA

LST is calculated here using the "CERC" formula (EM 1110-2-1100, III-2-10). The CERC formula calculates the potential LST, dependent on an available quantity of littoral material, based on the longshore component of wave energy flux or power. It is emphasized that the CERC formula approach computes "potential" transport based on the directional distribution of wave and associated current energy. However, this method assumes an ample sandy sediment supply available for transport, which may not be valid for existing conditions at Gandys Beach, due to the absence of an adequate supply of sand in the foreshore / swash zone.

The inputs required in the CERC formula are:

- Wave Conditions (breaking wave height, wave period, wave direction, water depth)
- Shoreline Azimuth
- K Coefficient (dependent on grain size)

The wave conditions are based on the 22-year wave hindcast from HMM. The significant wave height at the 8-foot depth contour is transformed to the breaking wave height using linear wave theory. The shoreline azimuth is obtained from the aerial imagery and varies along the project area. The K coefficient for this study is determined following guidance in EM 1110-2-1100. The K coefficient is based on the median grain size and shown to decrease in value with smaller median grain sizes (Figure 74). Sediment samples (Table 1) were collected by the Philadelphia District at four locations at Gandys Beach on September 23, 2016. Two samples were collected at the waterline and two samples were collected near the toe of the bulkheads. The grain size distribution for the four sediment samples is shown in Figure 75.

Table 31: Sediment Samples Collected at Gandys Beach

Sample	Location	Northing	Easting	D50 (mm)
GBG-1	Waterline	160908.4	283213.6	1.159
GBG-2	Bulkhead	160908.4	283213.6	0.574
GBG-3	Waterline	160280.9	285133.7	1.606
GBG-4	Bulkhead	160280.9	285133.7	0.590

Sample GBG-1 (D50 of 1.16 mm) collected at the waterline near the western end of Gandys Beach is used here to characterize existing and Future-Without Project Conditions at Gandys Beach. This sediment sample is believed to be most representative of the sediment available for LST at the western and eastern ends of Gandys Beach. Finer sediment may be present further up or down the beach profile, however the majority of sediment transport at steep estuarine beaches is expected to occur in the swash zone (Nordstrom *et al.*, 2003) where coarser sediment is found. Furthermore, a layer of stone and rubble debris is present along the upper beach profile that armors the beach and reduces sediment transport in this zone of the profile (Figure 76). The With-Project Conditions are based on a nourished beach with a D50 of 0.574 mm (GBG-2). The selected median grain size and associated K values for the Future-Without Project and With-Project Conditions are presented in Table 32.

Table 32: Selected K Coefficients

Condition	D50 (mm)	K
Future Without Project Condition	1.16	0.337
With Project Condition	0.57	0.077

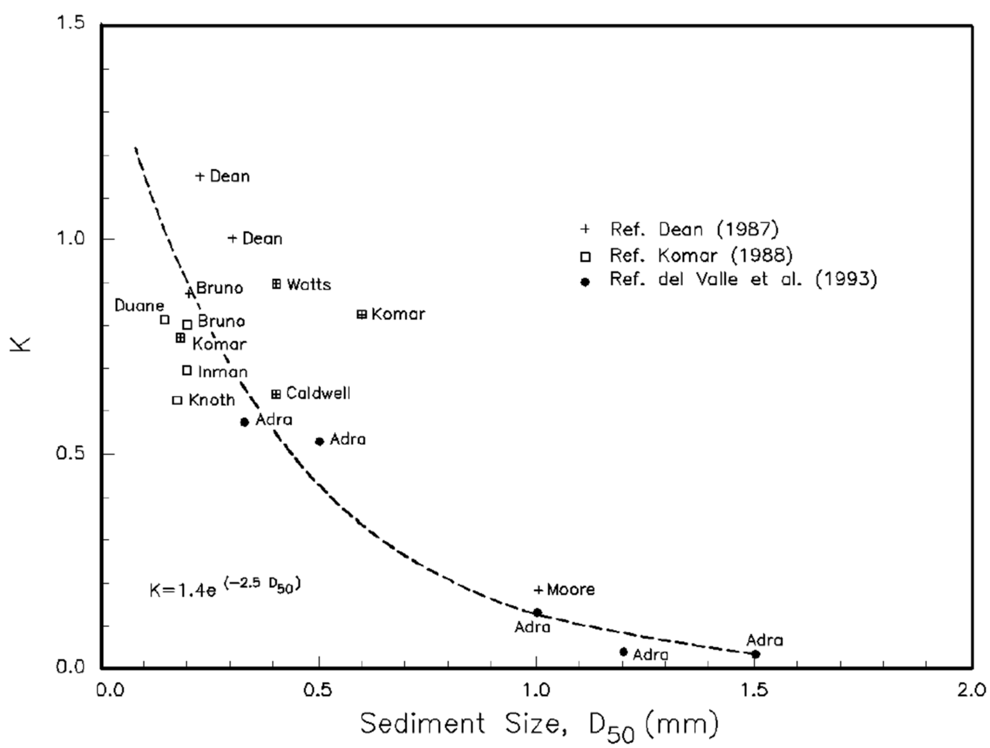


Figure 74: K Coefficient versus median grain size D50 (EM 1110-2-1100)

US Army Corps of Engineers
Philadelphia District

Philadelphia District
100 Penn Square East
Philadelphia PA 19107

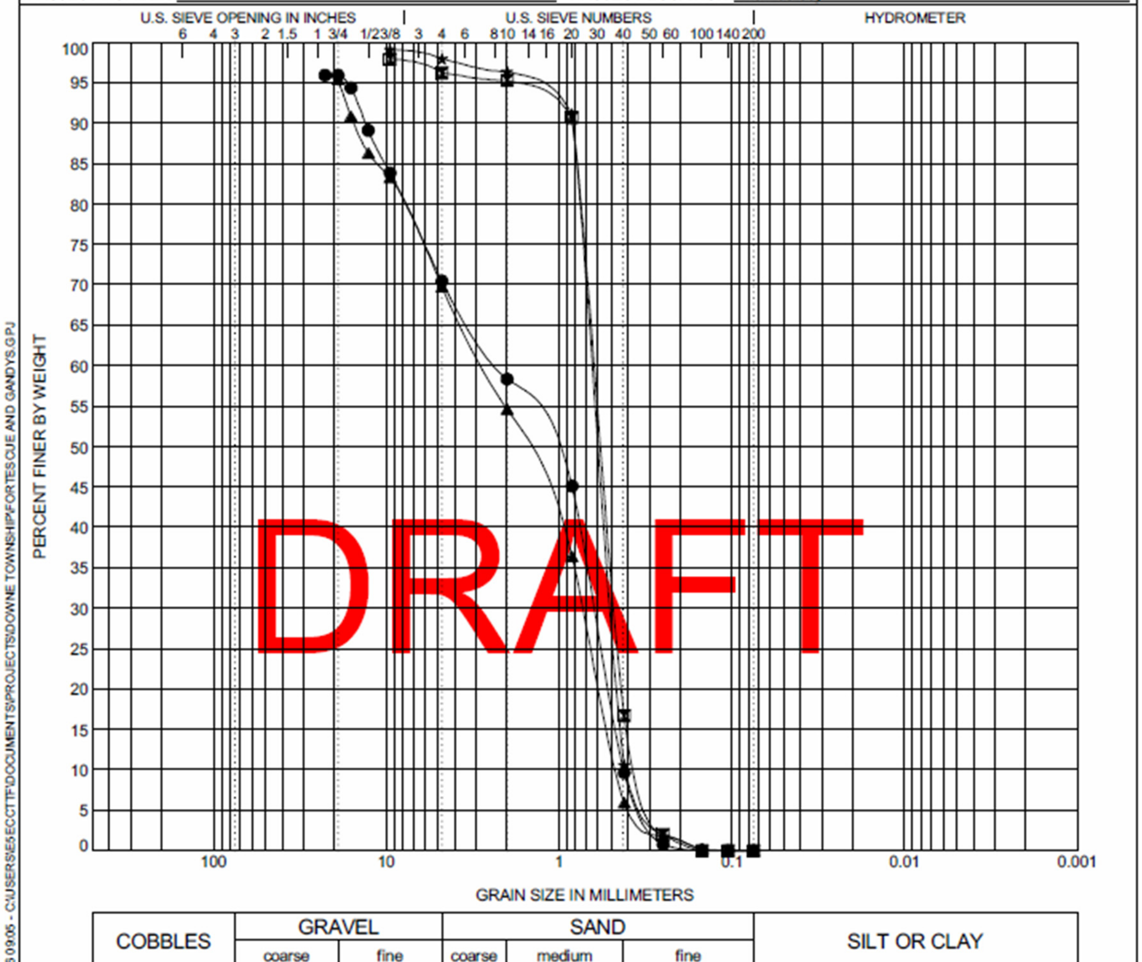
GRAIN SIZE DISTRIBUTION

CLIENT ______

PROJECT NAME Downe Township

PROJECT NUMBER ______

PROJECT LOCATION New Jersey



	Sample	Depth	Classification	LL	PL	PI	Cc	Cu
●	GBG-1	1.0	POORLY GRADED SAND with GRAVEL(SP)				0.41	5.33
⌧	GBG-2	1.0	POORLY GRADED SAND(SP)				1.08	1.90
▲	GBG-3	1.0	POORLY GRADED SAND with GRAVEL(SP)				0.42	5.91
★	GBG-4	1.0	POORLY GRADED SAND(SP)				0.94	1.58

	Sample	Depth	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	GBG-1	1.0	22.6	2.253	1.159	0.626	0.423	25.5	70.4	0.0	
⌧	GBG-2	1.0	9.51	0.63	0.574	0.476	0.332	1.7	96.2	0.0	
▲	GBG-3	1.0	19	2.724	1.606	0.726	0.461	25.7	69.7	0.0	
★	GBG-4	1.0	9.51	0.643	0.59	0.497	0.406	1.1	98.0	0.0	

Figure 75: Grain Size Distribution at Gandys Beach

Low Tide **High Tide**

Figure 76: Photographs of Gandys Beach at Low and High Tide

LST RESULTS

Annual LST rates in cubic yards per year are presented in Table 33 for Future-Without Project Conditions and in Table 34 for Future-With Project Conditions at the eastern and western end of Gandys Beach. The LST components (east, west), net transport, and gross transport are provided. As previously discussed, the CERC LST estimates represent the “potential” transport assuming an ample sandy sediment supply available for transport. The With Project LST rates are about 4 times greater because the median grain size is smaller and the associated K coefficient is higher.

Table 33: Future-Without Project Annual LST (K = 0.077)

Location	Azimuth	West (cy/year)	East (cy/year)	Net (cy/year)	Gross (cy/year)
West Gandys (FID 1)	195	4,773	-9,073	-4,301	13,846
East Gandys (FID 3)	228	23,562	-2,924	20,638	26,486

Notes: Positive LST values are to the west, negative values are to the east.

Table 34: With Project Annual LST (K = 0.337)

Location	Azimuth	West (cy/year)	East (cy/year)	Net (cy/year)	Gross (cy/year)
West Gandys (FID 1)	195	20,861	-39,660	-18,799	60,521
East Gandys (FID 3)	228	102,990	-12,781	90,209	115,771

SEDIMENT BYPASSING AT TERMINAL GROIN

David Kriebel *et al*. (2018) of Stockton University Coastal Research Center prepared a conceptual design and field evaluation report of the Holgate terminal groin for the Township of Long Beach, NJ. Kriebel *et al*. (2018) discuss the application of porous terminal groins, sometimes called "leaky" or "pass through" groins, by Olsen and Associates at Amelia Island FL and Bald Head Island, NC and by Baird and Associates in Barbados. The porous groin design is described as using a thin bedding layer or marine mattress and then only using armor stones for the groin cross section, with no secondary or core stone used. By carefully selecting somewhat uniform armor stone sizes, and without small core stone, the voids between armor stones remain large and allow substantial flow of water and movement of sediment. In addition, the groin elevation is kept low so that waves and water levels can carry sand over the groin. Kriebel *et al*. (2018) explain that there is no simple way to estimate the percentage of transport passing through the leaky groin structure and made an assumption that the leaky section of the groin would reduce sediment transport by 50%, but that this assumption is not well founded in any data.

The terminal groin at Gandys Beach will be a rubble-mound structure designed to mirror the cross-shore beach template, and will not be a total barrier to LST. The crest elevation of the groin decreases seaward by 7 feet between the trunk and the head, with the seaward portion of the groin below MHW of the established beachfill slope and allowing for transport over the groin at high tide. The groin will also include two layers of armor stone in order to increase the permeability of the structure to LST of sand. The permeability of the rubble-mound structure will allow hydrodynamic exchange across the groin, which is important to reducing rip currents and offshore losses.

The Gandys Beach terminal groin was intentionally designed to be "leaky" by not including steel or timber sheet pile stem and by using 2-layers of armor stone to reduce the amount of core stone required in the cross-section. Kriebel *et al*. (2018) suggests that a reasonable estimate of the impact of the "leaky" groin on sediment transport is a reduction of approximately 50%. Given the uncertainty in the bypassing rate through the "leaky" groin, analyses will consider a range of bypassing rates between 25 to 50%.

FORMULATING A SEDIMENT BUDGET

A sediment budget is an accounting of sediment gains and losses, or sources and sinks, within a specified control volume (cell), or a series of connecting cells, over a given period of time. Sediment budgets provide a conceptual and quantitative model of sediment transport pathways in coastal systems, as well as a framework for understanding complex coastal systems and their responses to coastal engineering projects.

The sediment budgets developed for Gandys Beach include the following:

$$\sum Qsource - \sum Qsink + P - SLR = \Delta V$$

ΔV = net volume change within cell (eroding shoreline is a negative value)

P = volume of material placed within cell (positive contribution to cell)

SLR = volume of material lost to sea level rise (negative contribution to cell, Bruun Rule).

Qsource = Net longshore sediment transport (LST) into cell

Qsink = Net longshore sediment transport (LST) out of cell

An active profile height of 12 feet, alongshore project length of 2,570 feet, and historical SLR rate of 1.06 feet over 100 years are used in the sediment budget calculations.

FUTURE WITHOUT PROJECT SEDIMENT BUDGET

A one-cell Future-Without Project sediment budget (Figure 77) was developed for Gandys Beach based on the sediment sources and sinks described above. For this project the net volume change within the cell is estimated to be -2,900 cy/yr based on the historical shoreline change rate (-2.5 ft/yr). The offshore losses from SLR are calculated using the Bruun Rule to be -300 cy/yr. The LST rates for the sediment leaving the cell to the east (2,900 cy/yr) and west (4,800 cy/yr) are estimated directly from the CERC results. The sediment budget assumes that no sediment is entering Gandys Beach from the left (west). This assumption is based on the large offset between the adjacent shorelines and the open water that now exists immediately to the west of Gandys Beach as a result of the high erosion rates observed at the Nature Preserve. The sediment transport entering cell from the east (right), 5,100 cy/yr, was calculated by balancing the sediment budget and is 25% of the potential sediment transport from the CERC results.

In the Future-Without Project Sediment Budget, 4,800 cy/yr of sediment is transported from Gandys Beach towards the Preserve, or 240,000 cubic yards over 50 years.

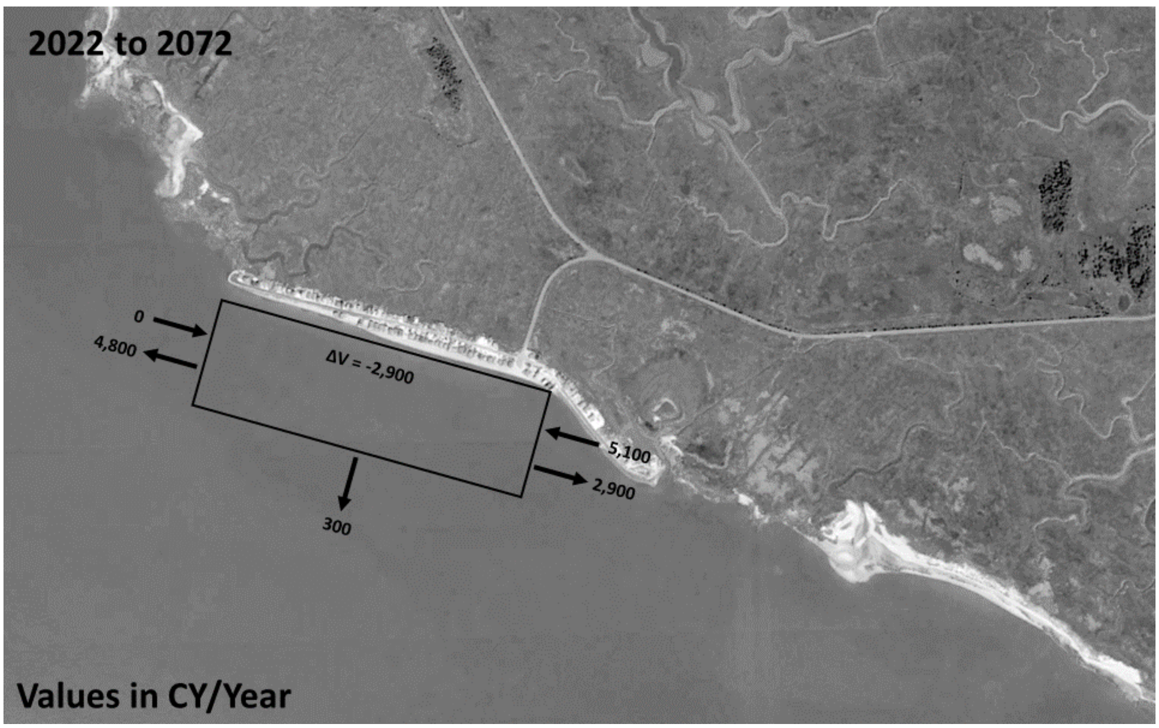


Figure 77: Future-Without Project Sediment Budget

WITH PROJECT SEDIMENT BUDGET

For the initial construction placement quantity (214,000 cy), a one-cell With Project sediment budget (Figure 78) was developed for Gandys Beach under the condition where the beach has been nourished with sediment and a permeable terminal groin (approximately 50% bypass rate) has been constructed at the western end of Gandys Beach. The sediment transport into Gandys Beach is assumed to be unchanged from the Future-Without Project condition, and losses from SLR are also assumed to be unchanged. The LST rates for the sediment leaving the cell to the east (12,800 cy/yr) and west (10,500 cy/yr) are estimated directly from the With Project CERC results. The With Project Sediment Budget is also representative of conditions in between scheduled periodic nourishment operations.

While it is difficult for USACE to speculate on the frequency and likelihood of funding for periodic nourishment, the initial construction volume is not expected to be fully transported out of the beach cell for approximately 11 years after placement. That being said, periodic nourishment is projected to be every 6 years; therefore, LST could potentially continue for approximately 5 years beyond the nourishment cycle if a cycle is missed or not funded.

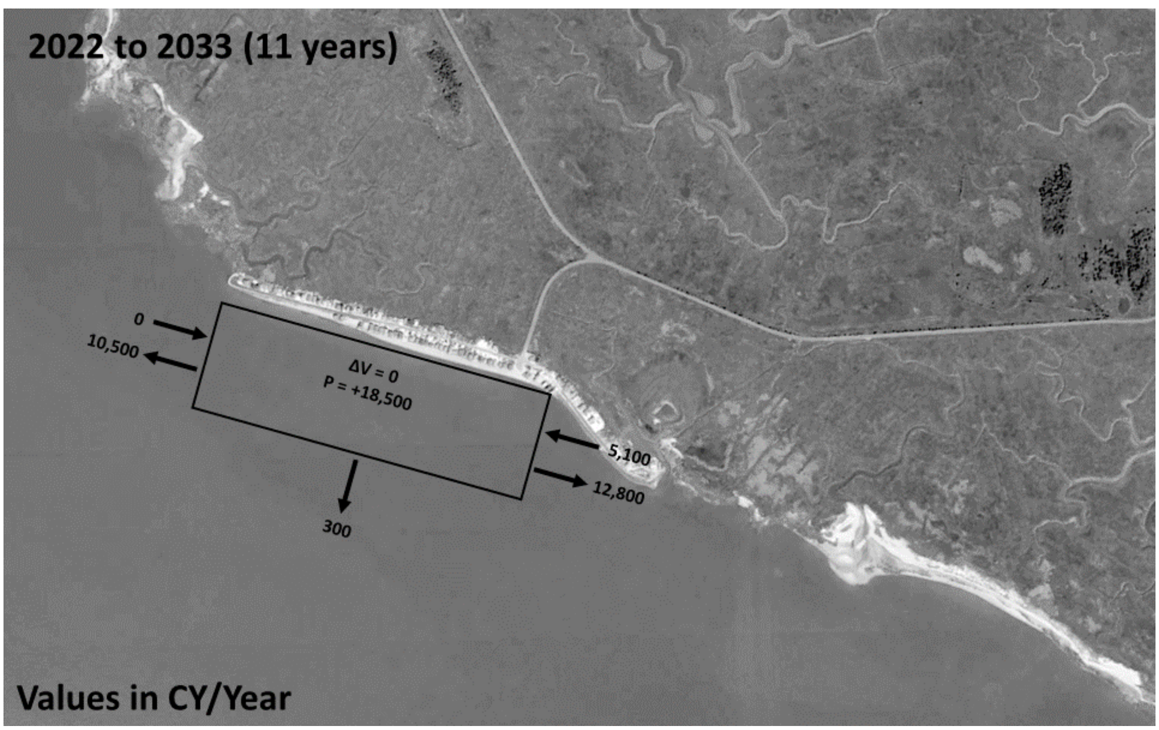


Figure 78: With Project Sediment Budget

IMPACTS TO NATURE PRESERVE

ROM impacts to LST towards the northwest are provided here based on the various sediment budgets developed above. It is also acknowledged that there is uncertainty in the CERC LST estimates that are not part of this assessment.

Table 35 presents the total LST towards the Nature Preserve from Gandys Beach over a 50-year period (2022-2072). Table 36 presents the change in LST relative to the Future-Without Project Condition over the 50-year period. Table 35 and Table 36 show that in the With-Project Condition the project is likely to increase LST towards the Nature Preserve. The increase in LST rates associated with restoring a sandy beach at Gandys Beach exceed the reduction in LST associated with the terminal groin.

The proposed terminal groin for Gandys Beach is intended to be a "leaky" groin with a likely bypass rate of approximately 50%. USACE developed with-project sediment budgets for groins with 25% and 50% permeability in order to provide a sensitivity analysis related to the potential impacts of the proposed terminal groin on LST.

Table 35: LST from Gandys Beach Towards Nature Preserve

Condition	Groin Bypassing (50%) (cy over 50 years)	Groin Bypassing (25%) (cy over 50 years)
Future Without Project	240,000	240,000
With Project	525,000	262,500

Table 36: Change in LST from Gandys Beach Towards Nature Preserve

Condition	Groin Bypassing (50%) (cy over 50 years)	Groin Bypassing (25%) (cy over 50 years)
With Project	+285,000	+22,500

7.4 TERMINAL GROIN SUMMARY

ROM impacts of the proposed terminal groin at Gandys Beach are developed based on LST calculations and sediment budgets. The assessment shows the proposed project at Gandys Beach is likely to increase sediment transport towards the Nature Preserve if the nourished beach is maintained with regular periodic nourishment operations.

8.0 CONCLUSIONS

This Hydrology, Hydraulics, and Coastal Appendix details the technical analyses supporting the New Jersey Dredge Material Utilization (DMU) Coastal Storm Risk Management Feasibility Study. The majority of coastal work focused on supporting the Beach-fx modeling effort. The SBEACH modeling work, shoreline change rates, and diffusion losses are critical components of Beach-fx that ultimately drive the economic damages, beach restoration quantities and costs, and plan selection. Several recommendations to the PDT were made based on the HHC technical analyses:

- Extend beach nourishment cycle from 4 years to 6 years to reduce project costs;
- Add terminal groins at Gandys Beach and Fortescue to reduce project costs over 50 years;
- Split Villas into two separate sites, Villas North and South, based on distinct differences in topo-bathymetric conditions and historical shoreline changes.

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1. Survey and CAD modeling

All survey data cited in this appendix is indexed to the NAVD 88 vertical datum and NAD 83 New Jersey State Plane, US Foot horizontal datum. Additionally all discussion of vertical dimensions in this appendix are referenced to NAVD 88 vertical datum. The timing of survey effort is noted on the various plan sheets.

The surveys were performed along predetermined transects that initiated on the landward limiting feature, which in most cases was the highest point of the existing dune or bulkhead. The transects then proceeded bayward approximately 3000' and included the use of a survey vessel to perform single beam bathymetry beyond where land based surveyors could safely obtain data. The transects were approximately 500' apart and profiles of existing ground were compiled along each transect. These profiles were used to develop a TIN (Triangular Irregular Network) surface for each site. This TIN surface was used to provide a model of existing ground (EG surface) and contours were extracted from this surface. Examples of survey profile and surface data are shown in Figures 1 &2 below.

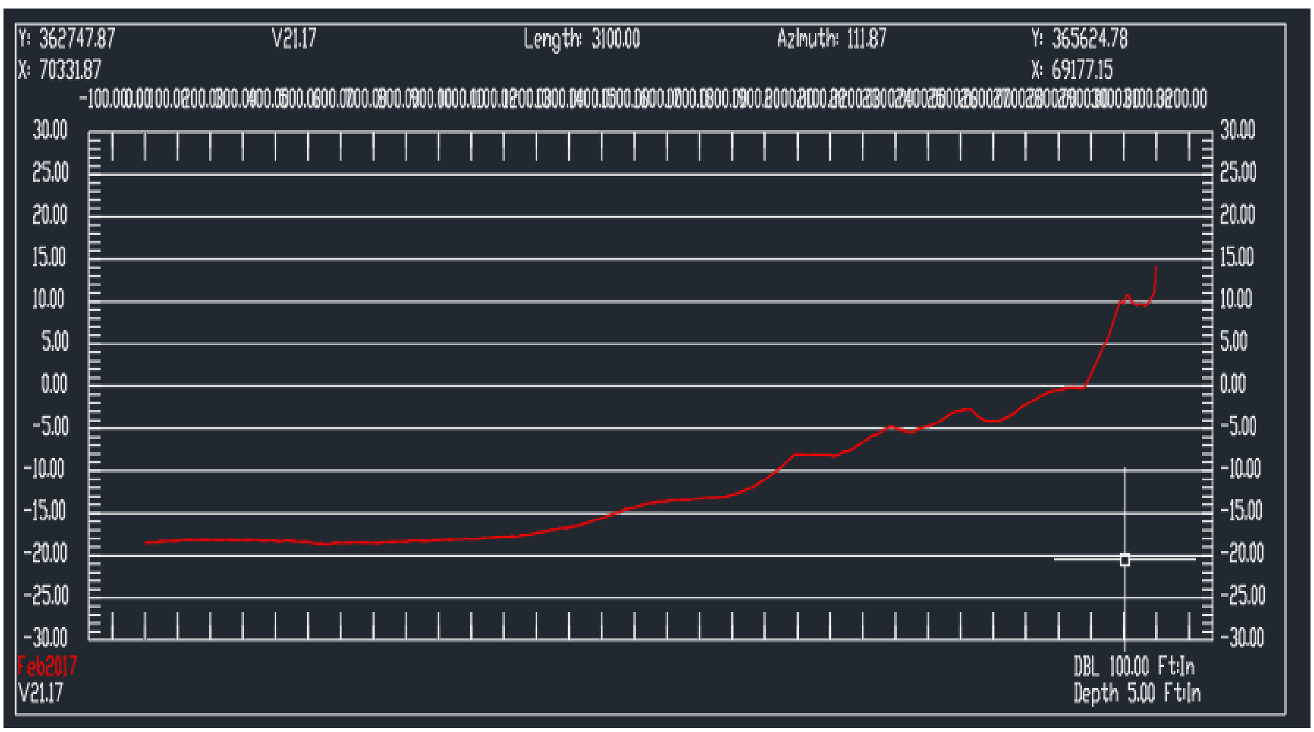


Figure 1 Example Profile provided by NAP Survey Branch

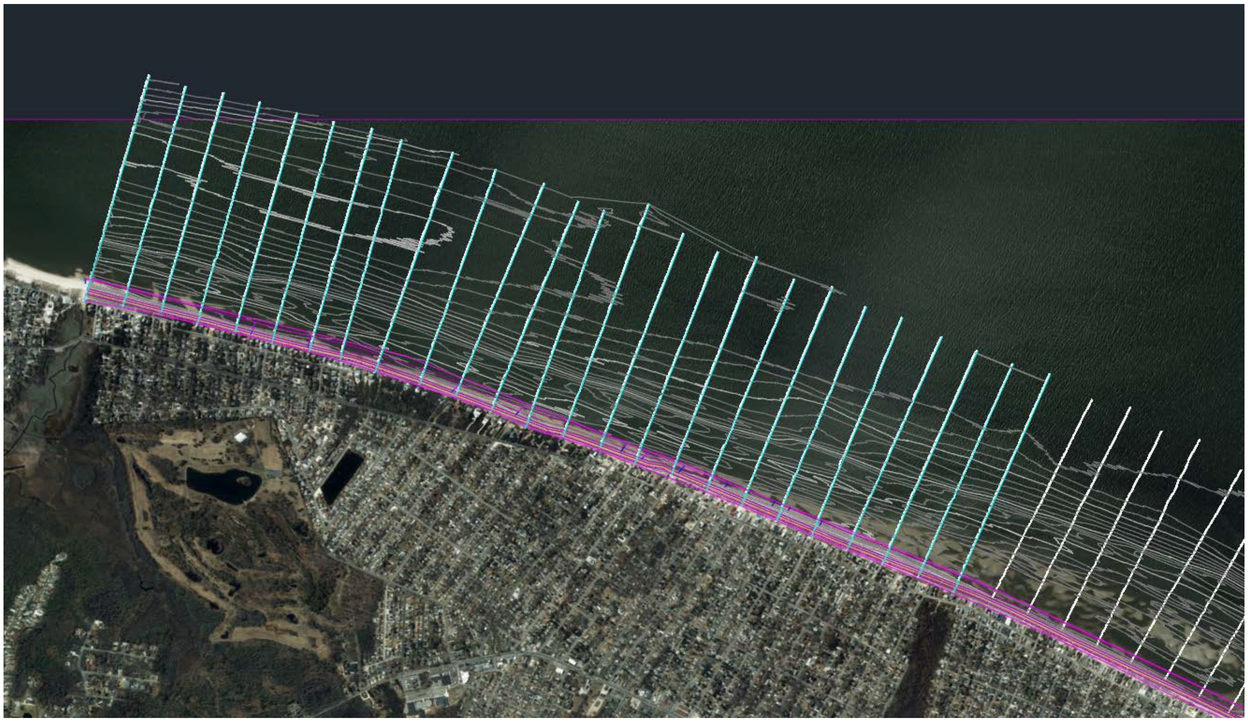


Figure 2 Example of survey data compiled to create EG surface showing contours.

While the actual quantities used to develop construction costs were obtained using the Average End Area Method and developed by the coastal engineer, civil designers created a finish ground (FG) surface from the design parameters (beachfill extents, dune and berm elevations and widths) and compared the FG and EG surfaces to create a Volume Surface which served as an additional reference point regarding quantity of beachfill needed to build the projects to the optimized design parameters. The Volume surface method could only serve as an approximation due to incomplete overlap between the EG and FG surfaces, particularly in the areas where the beachfill tapers extend the fill past the outermost survey transect.

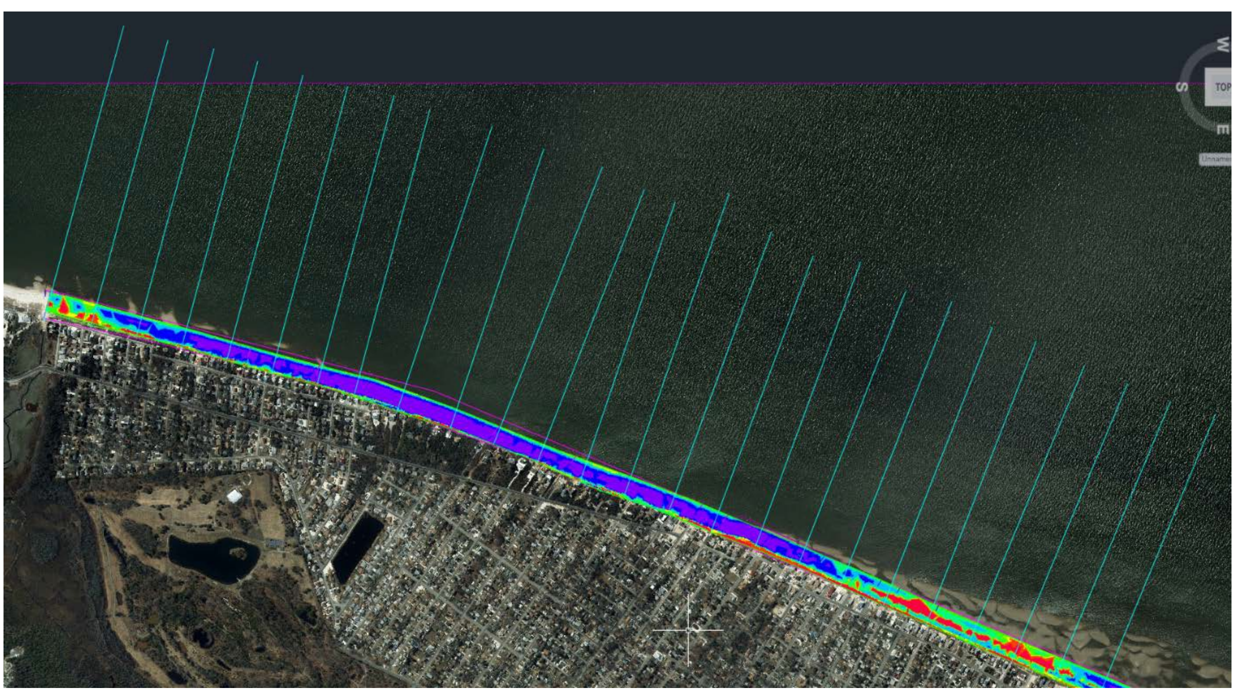


Figure 3 Example Volume Surface with Violet indicating area of greatest fill

2. Mapping Effort

Imagery used in beachfill plan drawings was obtained from *www.digitalglobe.com*. The imagery dates for Gandys and Fortescue were taken in AUG2015. The imagery dates for Villas Beach were taken on 08MAY2016. The mapping provided an appropriate level of detail & georeferencing of existing features, including previous beachfills in adjacent communities, existing roads, homes, groins, outfall structures, and delineation of existing beach access. The mapping guided the designers in locating the landward limit of fill in order to both minimize the quantity of beachfill by colocating the proposed dunes and berms with the highest existing ground features, and ensuring that existing structures were located landward of the project limits.

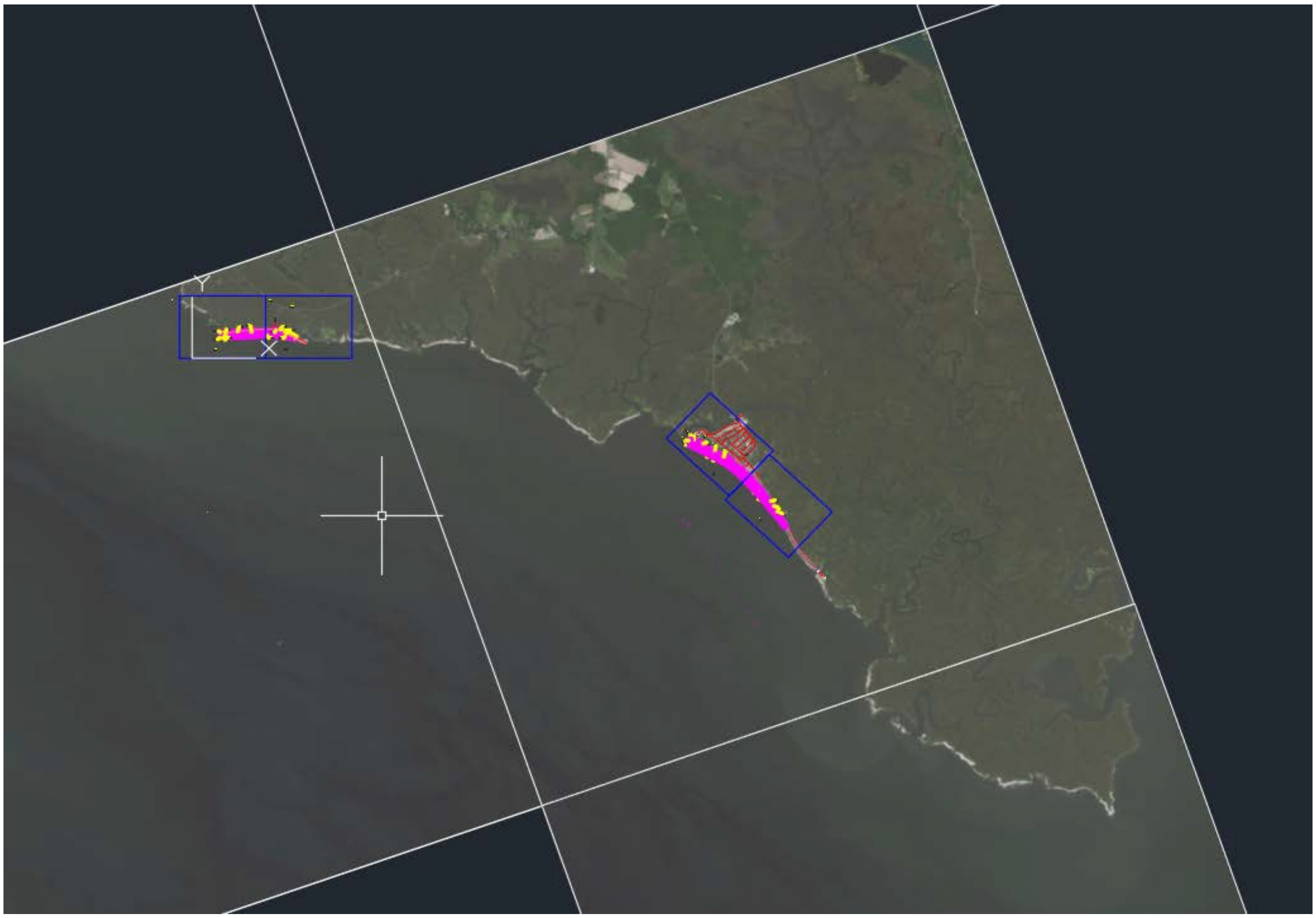


Figure 4 Example of Satellite Imagery used in NAP design plans.

3. Design of Beachfill

3.1 Gandys Beach

- *Existing Conditions/Historical Beachfill:* Gandys Beach occupies a narrow barrier of sand bordered by the Delaware Bay and a back barrier marsh. The existing shoreline can be described as concave with the center of the arc occurring in the central portion of the proposed project. Gandys Beach has a long history of shoreline retreat and a lack of sandy sediment suitable for the existence of beaches on the bayside margin of the community. The shoreline migration landward is in response to coastal erosion and sea level change. As a result of this shoreline retreat, significant portions of the shoreline have been bulkheaded by individual property owners. All of the bulkheaded properties are located so that high tide completely submerges the bayward shore. The condition of the existing bulkheads are highly variable, ranging from failed to good condition.

Figure 5 Brownfield Lot with abandoned sanitary sewer holding tank.

Figure 6 Existing homes with individual contiguous bulkheads @ low tide.

- *Final Feasibility Design:* The optimized design calls for a berm only beachfill with the parameters shown in Table 1 below. The full width of the design berm extends in front of all currently developed properties bayward of Cove Road,

Length of Design Berm	Length of Initial Construction	NW Taper	SE Taper	Length of Shoreline	Groin
2,507	2,507	0	786	3,293	NW End
Dune Elevation	**Dune Width**	**Berm Elevation**	**Design Berm Width**	**Advance Berm Width**	**Construction Berm Width**
N/A	N/A	6.0'	25'	45'	Varies

Table 1 Gandys Beach Optimized Design Characteristics

- *Groin Construction*: A new terminal groin is proposed for the northwestern end of the project in order to limit end losses of the beachfill. See Table 2 for dimensions. The new groin will be a rubble mound structure composed of armor stone, core stone, and marine mattress bedding. The new groin will tie into existing high ground at the existing rubble revetment that protects Cove Road at the northwestern end of the community.

Figure 7 Cove Road and adjacent rubble revetment looking SE in the vicinity of proposed terminal groin.

The new groin will require removal of the rubble revetment for a length of approximately 100’ in order to provide a consistent bearing surface for the new groin. The groin construction will also involve reconstruction of the adjacent revetment to mitigate the risk of flanking of the new structure. The groin is composed of three distinct segments:

a trunk section
b intermediate section
c head section

These sections are designed to mimic the immediately adjacent beachfill design berm width and the expected bayward slope of the beachfill. There is a 7’ change in elevation between the trunk and head section which will allow for a degree of longshore transport beyond the project limit to the northwest. It is possible that some of the groin construction can be performed from the landside.

Armor Stone Size	Corestone Size	Mattress Size	Mattress Projection beyond Toe		
W50 = 2 Ton	W50 = 250#	12" Thick	5', all conditions		
Trunk Length	Crest Width	Crest Elevation	Mattress Base Elevation	Side Slope	Toe Stone
75'	9'	7.0'	-6.0'	2H: 1V	6' wide, 3' high
Intermediate Length	Crest Width	Crest Elevation	Mattress Base Elevation	Side Slope	Toe Stone
70'	9'	varies, +7.0' to 0.0'	varies, -6.0' to -8.0'	2H: 1V	6' wide, 3' high
Head Length	Crest Width	Crest Elevation	Mattress Base Elevation	Side Slope	Toe Stone
65'	9'	0.0'	-8.0'	varies, 2h:1V to 3H:1V	9' wide, 3' high

Table 2 Gandys Beach Terminal Groin Characteristics

- *Public Access:* Current public access at Gandys Beach is limited to a single point at the intersection of Gandys Avenue and Cove Road. Two additional public access points will be required, at the northern and southern ends of the project to satisfy ER 1165-2-130 requirements for provision of access to points to be within one half mile of one another. The local sponsor has identified these two locations (see Appendix G; public access drawings) to fulfill the requirement. Vehicle access will be a necessary part of one or both of these new access points. Additionally sufficient public parking will be provided in accordance with ER 1165-2- 130.

Figure 8 View of Gandys Beach at public access @ end of Gandys Avenue.

3.2 Fortescue Beach

- *Existing Conditions/Historical Beachfill:* Fortescue Beach is a barrier beach that separates the Delaware Bay from a tidal marsh east of Fortescue Road. Shoreline migration landward is in response to coastal erosion and sea level change. As a result of this shoreline retreat, significant portions of the shoreline have been bulkheaded by individual property owners. Many of the bulkheaded properties are located so that high tide completely submerges the bayward shore. This is particularly true in the middle of the community. The condition of the existing bulkheads are highly variable, ranging from failed to good condition. Beach nourishment and shore protection structures were constructed at this location as a part of the statewide Hurricane Sandy recovery effort by the local sponsor. This is principally located at the NW end of the project.

Figure 9 Recently Constructed Public Access.

Figure 10 Dune with sand fence and plantings constructed by local sponsor.

Figure 11 Fortescue looking NW @ low tide.

Figure 12 Fortescue Beach, shoreline without bulkheading.

Final Feasibility Design: The optimized design calls for a berm only beachfill with the parameters shown in Table 3. The full width of design berm extends in front of all currently developed properties bayward of New Jersey and Delaware Avenues.

Length of Design Berm	Length of Initial Construction	SE Taper	NW Taper	Length of Shoreline	Groin
4,564	4,564	1,251	N/A	5,815	NW end
Dune Elevation	Dune Width	Berm Elevation	Design Berm Width	Advance Berm Width	Construction Berm Width
N/A	N/A	6.0'	25'	45'	Varies

Table 3 Fortescue Beach Optimized Design Characteristics

- *Groin Construction*: A new terminal groin is proposed for the northwestern end of the project in order to limit end losses of the beachfill. See Table 4 for dimensions. The new groin will be a rubble mound structure composed of armor stone, core stone, and marine mattress bedding. The new groin will tie into existing high ground landward of the existing timber jetty. It is planned that locating the new groin structure in this location will allow a significant portion of the groin to be constructed in the dry, using dewatering and possibly bracing techniques. The groin is composed of three distinct segments:

  a trunk section
  b intermediate section
  c head section

These sections are designed to mimic the immediately adjacent beachfill design berm width and the expected bayward slope of the beachfill. There is a 4' change in elevation between the trunk and head section which will minimize longshore transport beyond the project limit to the northwest and limit dredging requirement in Fortescue Creek.

Figure 13 Existing Groin Timber Stem looking landward.

Figure 14 Timber Stem and Stone Head looking bayward.

Armor Stone Size	Corestone Size	Mattress Size	Mattress Projection beyond Toe		
W50 = 2 Ton	W50 = 250#	12" Thick	5', all conditions		
Trunk Length	Crest Width	Crest Elevation	Mattress Base Elevation	Side Slope	Toe Stone
285'	9'	7.0'	-4.0'	2H: 1V	6' wide, 3' high
Intermediate Length	Crest Width	Crest Elevation	Mattress Base Elevation	Side Slope	Toe Stone
40'	9'	varies, +7.0' to 3.0'	varies, -4.0' to -8.0'	2H: 1V	6' wide, 3' high
Head Length	Crest Width	Crest Elevation	Mattress Base Elevation	Side Slope	Toe Stone
60'	9'	+3.0'	-8.0'	varies, 2h:1V to 3H:1V	9' wide, 3' high

Table 4 Fortescue Beach Groin Characteristics

- *Public Access:* Current public access at Fortescue Beach consists of 4 locations dispersed along the shoreline as shown in the public access drawings. One additional public access point will be required, in the middle of the project to satisfy ER 1165-2-130 requirements for access to points to be within one half mile of one another. The local sponsor has identified a likely location (see Appendix G; public access drawings) to fulfill the requirements. An easement for vehicle access may need to be obtained to allow vehicle access of the new dune at the southern end. Additionally sufficient public parking will be provided in accordance with ER 1165-2-130.

Figure 15 Fortescue Beach public access looking bayward.

3.3 Villas Beach

- *Existing Conditions/Historical Beachfill:* Villas Beach is a barrier beach that separates the Delaware Bay from the town of Villas, NJ. There are significant dunes present with windblown sand accumulating on the existing sedimentary bluff. The near shore is characterized by significant shoaling and shallow water.

Figure 16 Villas Beach looking northward, outfalls and dunes present.

Figure 17 Villas Beach looking northward at typical bulkhead condition and outfalls present.

Figure 18 Villas Beach, looking south at northern project limit, outfalls visible.

- *Final Feasibility Design:* The optimized design calls for a dune and berm beachfill with the parameters shown in Table 5 below. The design dune is planned to be co-located with the existing dune wherever possible to minimize construction costs. The design will tie into the existing shoreline using tapers at each end. There will be 11 outfalls that require extension beyond the edge of the new beach berm.

Length of Design Dune/Berm	Length of Initial Construction Dune	Southern Taper	Northern Taper	Length of Shoreline	Groin
7,442	7,442	1,000	1,072	9,514	none
Dune Elevation	Dune Width	Berm Elevation	Design Berm Width	Advance Berm Width	Construction Berm Width
12.0'	25'	5.0'	25'	20'	Varies,

Table 5 Villas Beach Optimized Design Characteristics

- *Public Access:* Current public access at Villas satisfies ER 1165-2-130 requirements for access to points to be within one half mile of one another. An easement for vehicle access may need to be obtained to allow vehicle access of the new dune at the southern end. Additionally sufficient public parking will be provided in accordance with ER 1165-2-130.

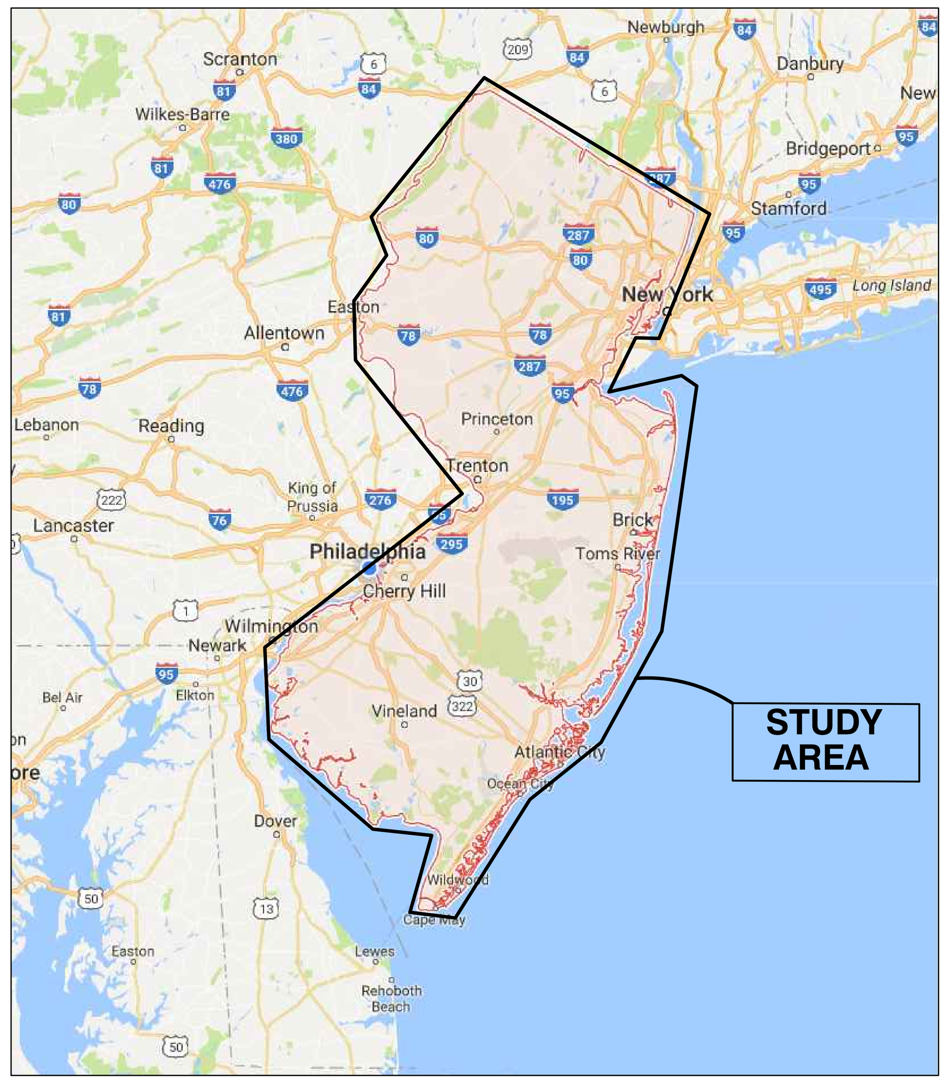
Figure 19 Fern Road beach access Villas NJ looking landward.

Figure 20 Village Road beach access Villas NJ looking landward.

DREDGE MATERIAL UTIILIZATION

DELAWARE RIVER & BAY NJ

FINAL FEASIBILITY REPORT



VICINITY MAP

10 0 5 10 20 40
SCALE IN MILES

PLAN NORTH

LOCATION MAP

2.5 0 2.5 5 10
SCALE IN MILES

PLAN NORTH

DRAWING INDEX

SHEET NUMBER	DESCRIPTION
GENERAL	
CS-101	COVER SHEET
CIVIL	
C-001	GENERAL INFORMATION SHEET
C-101	GENERAL PLAN
C-102	PLAN – GANDYS BEACH 1 OF 2
C-103	PLAN – GANDYS BEACH 2 OF 2
C-104	PLAN – FORTESCUE 1 OF 2
C-105	PLAN – FORTESCUE 2 OF 2
C-106	PLAN – VILLAS BEACH 1 OF 3
C-107	PLAN – VILLAS BEACH 2 OF 3
C-108	PLAN – VILLAS BEACH 3 OF 3
C-301	BEACHFILL CROSS SECTIONS
C-302	GROIN PROFILES
C-303	GANDYS BEACH GROIN & REVETMENT CROSS SECTIONS
C-304	FORTESCUE BEACH GROIN CROSS SECTIONS

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SUBMITTED:

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DREDGE MATERIAL
UTILIZATION
COVER SHEET
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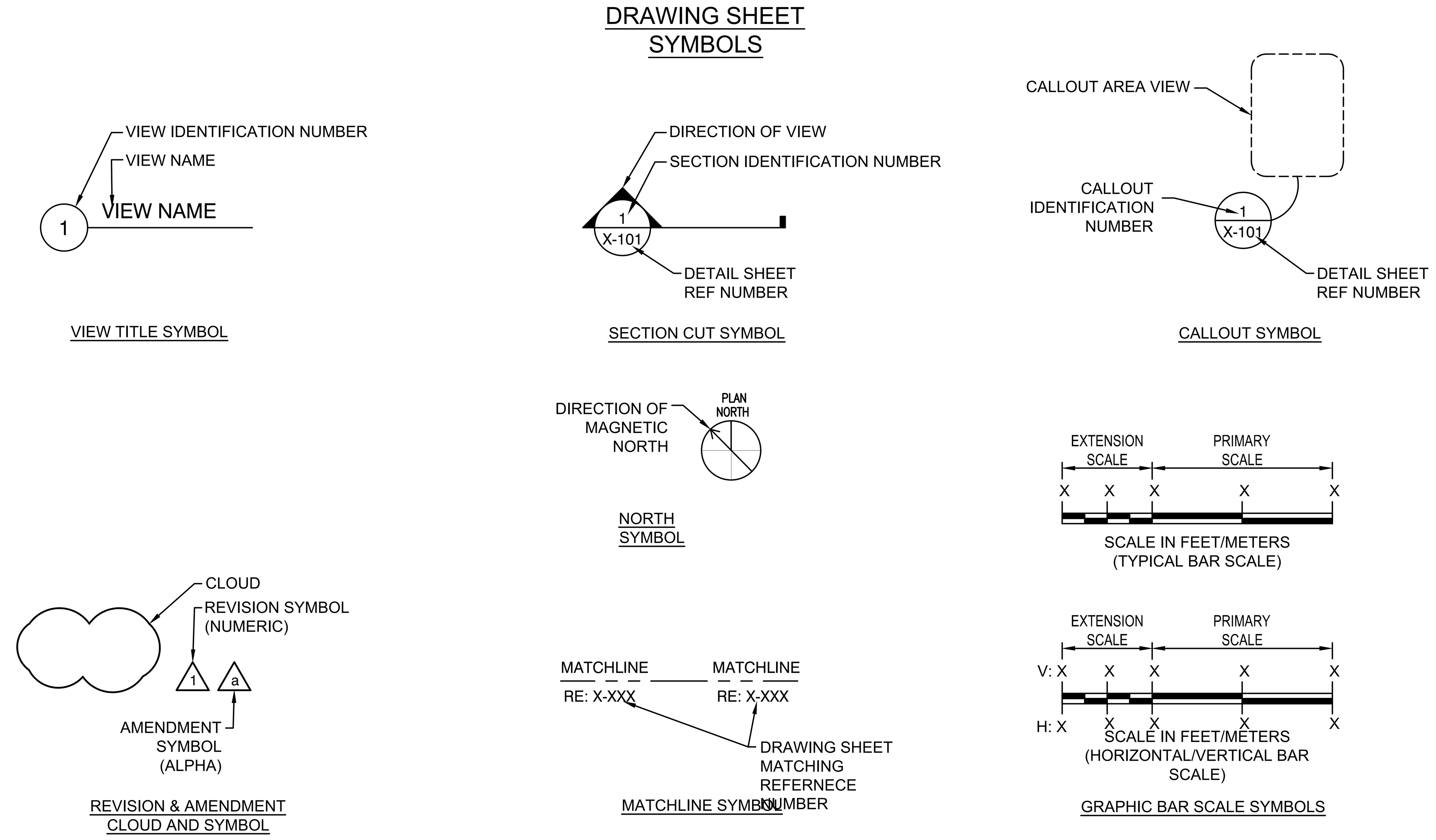
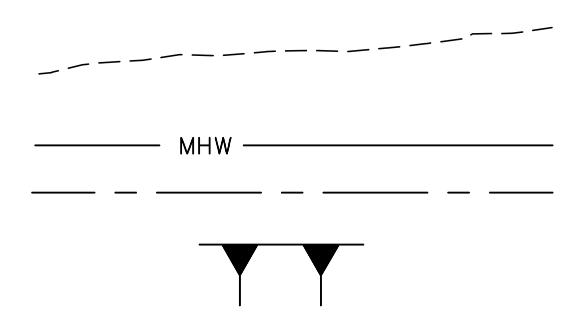
SHEET NUMBER
CS-101

SYMBOLS, ABBREVIATIONS AND GENERAL NOTES

DRAWING SHEET SYMBOLS

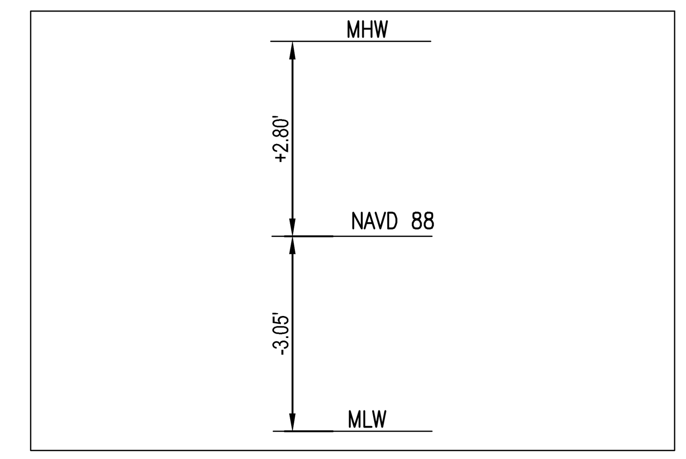


PLAN SYMBOLS LEGEND

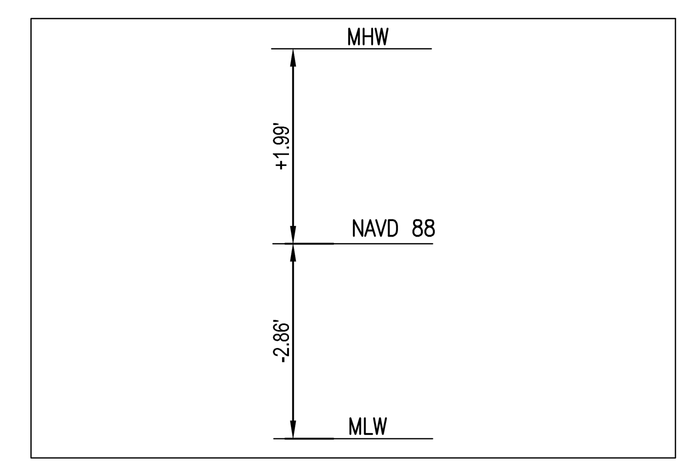


GENERAL NOTES:

1. ELEVATIONS ARE EXPRESSED IN FEET AND TENTHS AND REFER TO NORTH AMERICAN VERTICAL DATUM (NAVD 1988) .
2. HORIZONTAL CONTROL IS REFERENCED TO THE NEW JERSEY STATE PLANE COORDINATE SYSTEM (NAD 1983) .
3. BEACH CONDITIONS ARE DYNAMIC IN NATURE AND TOPOGRAPHY AND BATHYMETRY MAY DIFFER FROM THAT SHOWN ON THE CONTRACT DRAWINGS.
4. THE EXISTING BEACH CROSS SECTIONS SHOWN ON SHEET C-301 ARE A RESULT OF SURVEYS CONDUCTED IN 2015, AND CAN ONLY BE CONSIDERED REPRESENTATIVE OF THE CONDITIONS OCCURRING AT THAT TIME.



TIDAL REFERENCE (GANDYS & FORTESCUE)
SCALE=NTS



TIDAL REFERENCE (VILLAS SOUTH)
SCALE=NTS

ABBREVIATIONS

ABBRV	DESCRIPTION	ABBRV	DESCRIPTION	ABBRV	DESCRIPTION
AD	AREA DRAIN	FF	FINISHED FLOOR	PSI	POUNDS PER SQUARE INCH
ADDL	ADDITIONAL	FIN	FINISH	PIV	POST INDICATOR VALVE
AFF	ABOVE FINISHED FLOOR	FL	FLOOR	RAD	RADIUS
BD	BOARD	FM	FORCE MAIN	REINF	REINFORCEMENT
BIT	BITUMINOUS	FT	FOOT, FEET	REM	REMOVABLE
BL\B L	BASE LINE	FTG	FOOTING	ROW	RIGHT OF WAY
BLDG	BUILDING	G	GROUND	S	SOUTH
BM	BEAM	GOVT	GOVERNMENT	SCH	SCHEDULE
BMP	BEST MANAGEMENT PRACTICE	GR	GRADE	SECT	SECTION
BOT	BOTTOM	HORIZ	HORIZONTAL	SPEC	SPECIFICATION
BVCE	BEGINNING OF VERTICAL CURVE ELEVATION	HS	HIGH STRENGTH	SPRT	SUPPORT
BVCS	BEGINNING OF VERTICAL CURVE STATION	HT	HEIGHT	SQ	SQUARE
CL	CENTERLINE	HVY	HEAVY	SST	STAINLESS STEEL
CMU	CONCRETE MASONRY UNIT	IN	INCH	STA	STATION
CO	CLEAN OUT	INSUL	INSULATION, INSULATED	STD	STANDARD
COL	COLUMN	IINT	INTERIOR	STRUCT	STRUCTURAL
CONC	CONCRETE	INV	INVERT	SUSP	SUSPENDED
CONSTR	CONSTRUCTION	LL	LIVE LOAD	SYS	SYSTEM
CONT	CONTINUOUS	LP	LOW POINT	TEMP	TEMPORARY
CTRL	CONTROL	LT	LIGHT	TD	TRENCH DRAIN
CWL	CONTRACTOR WORK LIMITS	LVC	LENGTH OF VERTICAL CURVE	TDO	TRENCH DRAIN OUTLET PIPE
DET	DETAIL	JCT	JUNCTION	TELE	TELEPHONE
DGA	DENSE GRADED AGGREGATE	MATL	MATERIAL	TOPO	TOPOGRAPHY
DIA\ ø	DIAMETER	MAX	MAXIMUM	TYP	TYPICAL
DIM	DIMENSION	MIN	MINIMUM	UD	UNDERDRAIN
DL	DEAD LOAD	MISC	MISCELLANEOUS	UDO	UNDERDRAIN OUTLET PIPE
DWG	DRAWING	(N)	NEW	UE	UNDERGROUND ELECTRIC
E	EAST	N	NORTH	UGND	UNDERGROUND
EA	EACH	NLT	NOT LESS THAN	UNO	UNLESS NOTED OTHERWISE
ECM	EROSION CONTROL MAT	NTS	NOT TO SCALE	UOP	UNDERDRAIN OUTLET PIPE
EJ	EXPANSION JOINT	OC	ORIGINAL CONSTRUCTION	UXO	UNEXPLODED ORDINANCE
EL	ELEVATION	OD	OUTSIDE DIAMETER	VB	VINYL BASE
ELEC	ELECTRIC	OH	OVERHEAD	VC	VERTICAL CURVE
EOP	EDGE OF PAVEMENT	OPG	OPENING	VCT	VINYL COMPOSITION TILE
EOS	EDGE OF SHOULDER	OPP	OPPOSITE	VOL	VOLUME
EQ	EQUAL	PC	POINT OF CURVE	VERT	VERTICAL
EQUIP	EQUIPMENT	PD	PAVEMENT DRAIN	VTR	VENT THROUGH ROOF
EXH	EXHAUST	PI	POINT OF INFLECTION	W/	WITH
EXIST\(E)	EXISTING	PI	POINT OF INFLECTION	W	WEST
EXP	EXPANSION, EXPOSED	PIV	POINT OF VERTICAL INFLECTION	WL	WATER LEVEL
EXP JT	EXPANSION JOINT	POT	POINT OF TANGENT	WS	WATER SURFACE
EXT	EXTERIOR	PMP	PROBABLE MAXIMUM PRECIPITATION	W/O	WITHOUT
FIG	FIGURE SINGLE	PNL	PANEL		
FDTN	FOUNDATION	PSF	POUNDS PER SQUARE FOOT		

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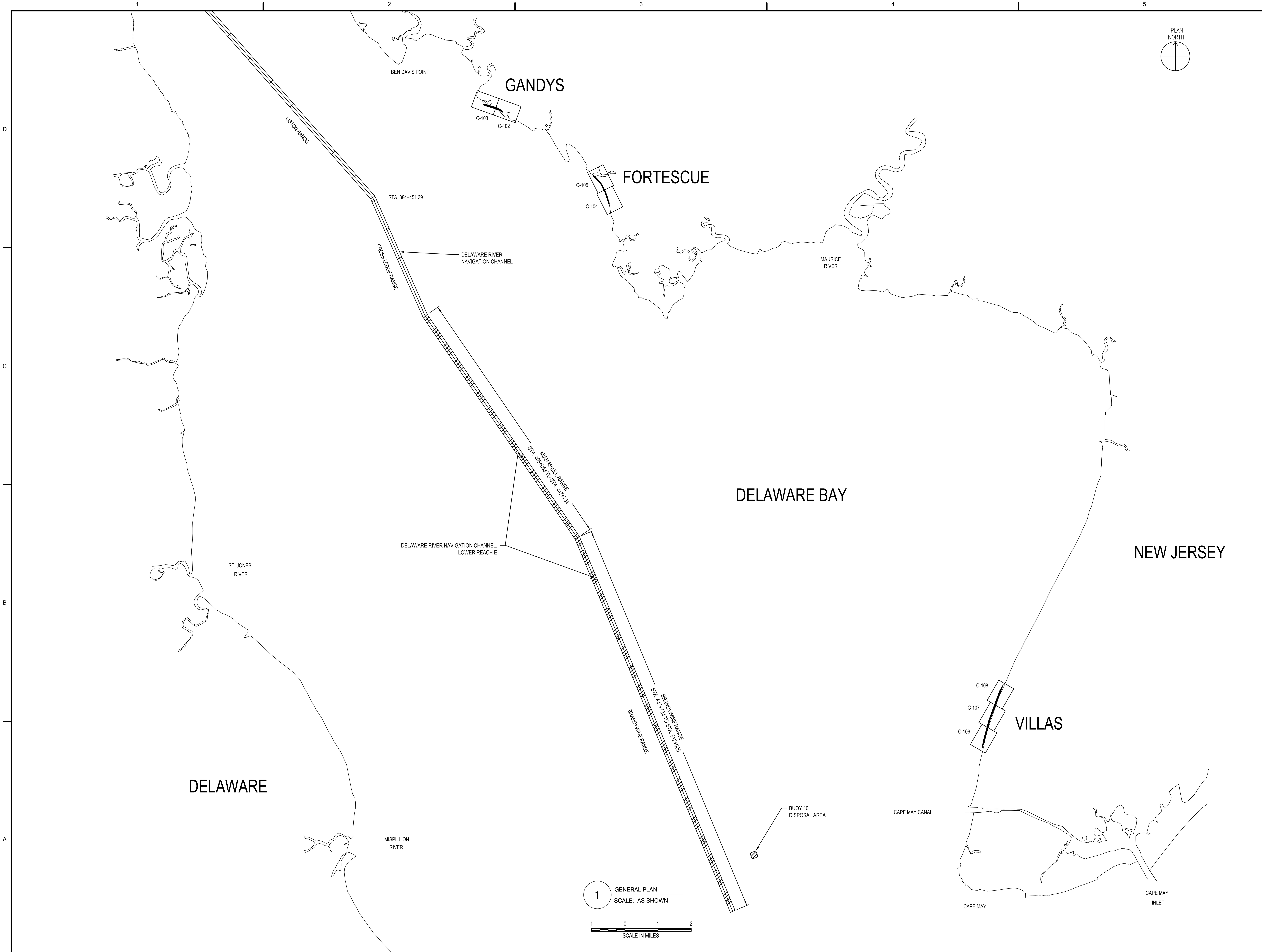
C-001



1 GENERAL PLAN
SCALE: AS SHOWN

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C-101

1 PLAN - GANDYS 1 OF 2
SCALE: AS SHOWN

100 0 100 200
SCALE IN FEET

NOTE:

1. LANDWARD EDGE OF BERM BASED ON EXISTING BULKHEAD LINE OR WHERE BERM TIES INTO EXISTING GRADE AT ELEV +6.0.

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DWG SCALE: 1" = 100'		CONTRACT NUMBER: -
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DELAWARE RIVER & BAY
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PLAN - GANDYS BEACH 1 OF 2
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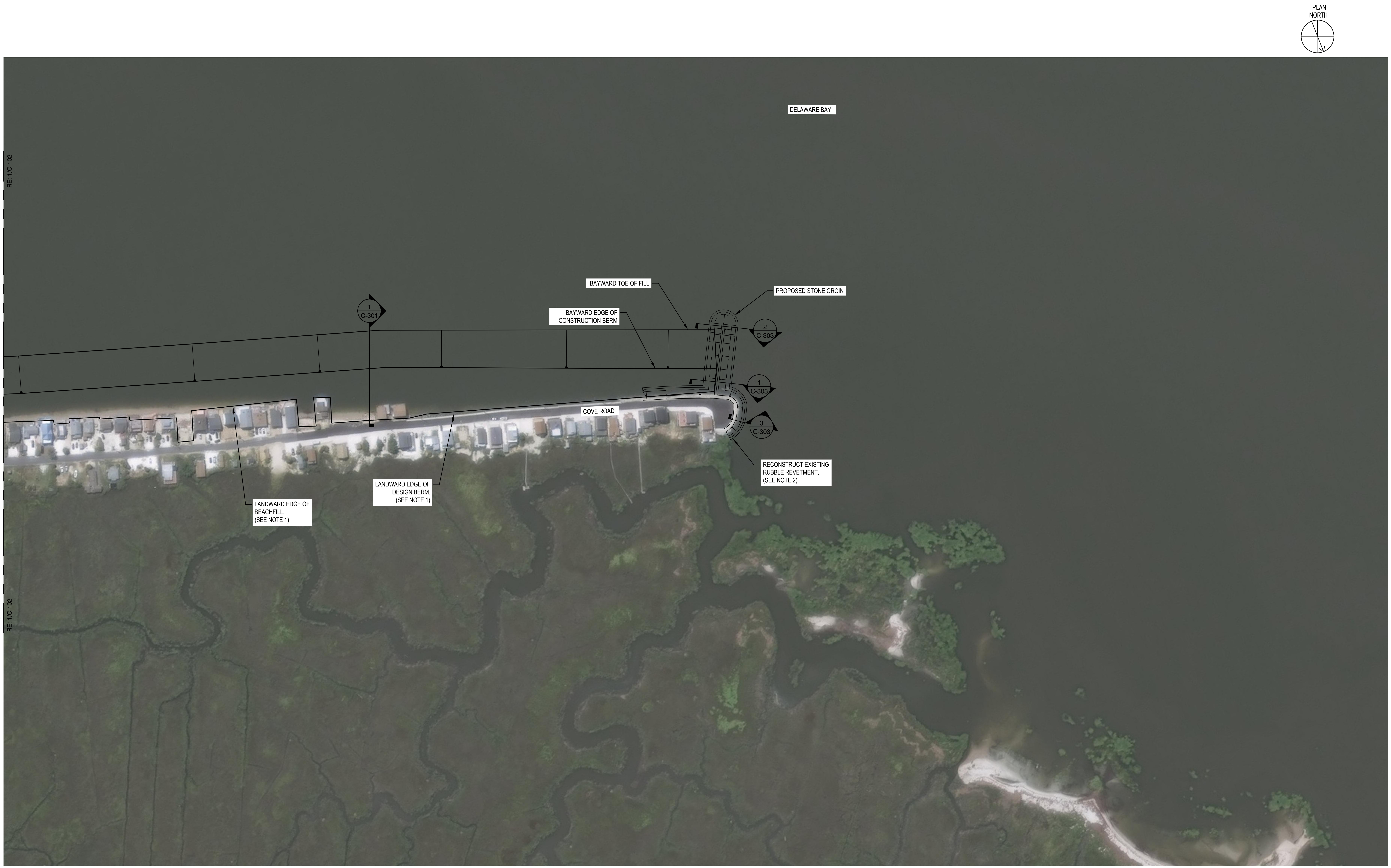
C-102



NOTE:

1. LANDWARD EDGE OF BERM BASED ON EXISTING BULKHEAD LINE, EXISTING RUBBLE REVETMENT, OR WHERE BERM TIES INTO EXISTING GRADE AT ELEV +6.0.
2. RECONSTRUCT RUBBLE REVETMENT TO UPGRADE ARMORING AND TOE PROTECTION AS SHOWN.

1 PLAN - GANDYS 2 OF 2
SCALE: AS SHOWN

100 0 100 200
SCALE IN FEET

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PLAN - GANDYS BEACH 2 OF 2
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C-103

1 PLAN - FORTESCUE 1 OF 2
SCALE: AS SHOWN

100 0 100 200
SCALE IN FEET

NOTE:

1. LANDWARD EDGE OF BERM BASED ON EXISTING BULKHEAD LINE OR WHERE BERM TIES INTO EXISTING GRADE AT ELEV +6.0.

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SHEET NUMBER
C-104

PLAN NORTH

1 PLAN - FORTESCUE 2 OF 2
SCALE: AS SHOWN

100 0 100 200
SCALE IN FEET

NOTES:

1. EXISTING TIMBER STEM GROIN TO REMAIN IN PLACE DURING CONSTRUCTION OF NEW GROIN.
2. EXCAVATION FOR LANDWARD PORTION OF NEW GROIN TO BE BRACED TO MINIMIZE DISTURBANCE OF EXISTING TIMBER GROIN.

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SHEET NUMBER
C-105

1 PLAN - VILLAS 1 OF 3
SCALE: AS SHOWN

100 0 100 200
SCALE IN FEET

NOTE:

1. EXISTING OUTFALL LENGTHENING REQUIRED TO MAINTAIN STORMWATER FLOWS FROM STORM SEWER SYSTEM.

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DELAWARE RIVER & BAY
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PLAN - VILLAS BEACH 1 OF 3
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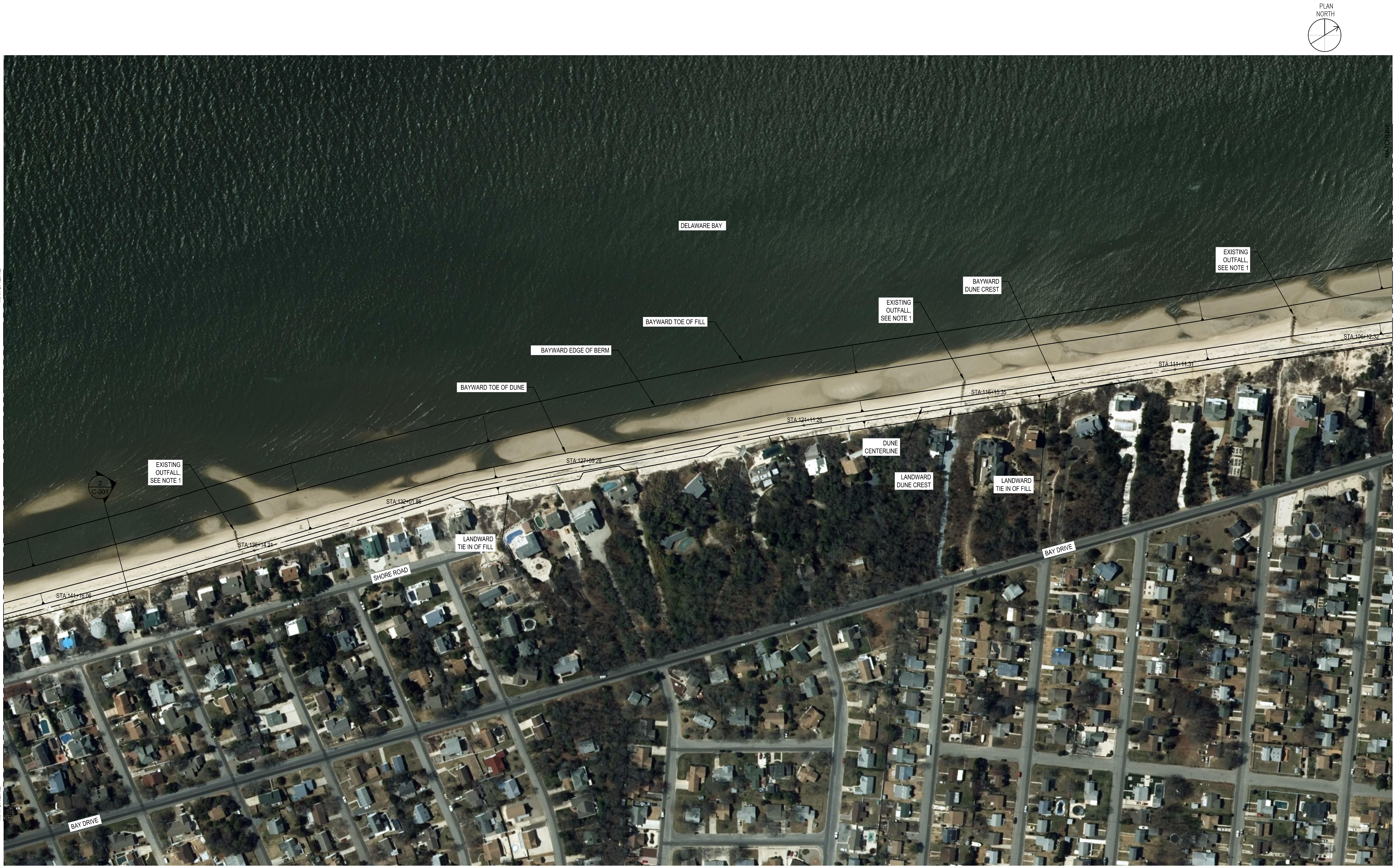
C-106



NOTE:

1. EXISTING OUTFALL LENGTHENING REQUIRED TO MAINTAIN STORMWATER FLOWS FROM STORM SEWER SYSTEM.

1 PLAN - VILLAS 2 OF 3
SCALE: AS SHOWN

100 0 100 200
SCALE IN FEET

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		SOLICITATION NUMBER: -
DWG SCALE: 1" = 100'		CONTRACT NUMBER: -
DWG. SIZE: 30"x42" Arch E1	FILE NAME: C-107 PLAN - VILLAS BEACH 2 OF 5.dwg	

DELAWARE RIVER & BAY
NJ
DREDGE MATERIAL UTILIZATION
PLAN - VILLAS BEACH 2 OF 3
FOR PLANNING PURPOSES ONLY

SHEET NUMBER
C-107

NOTE:

1. EXISTING OUTFALL LENGTHENING REQUIRED TO MAINTAIN STORMWATER FLOWS FROM STORM SEWER SYSTEM.

1 PLAN - VILLAS 3 OF 3
SCALE: AS SHOWN

100 0 100 200
SCALE IN FEET

US Army Corps of Engineers
Philadelphia District

MARK	ACTION	DESCRIPTION	DATE	BY
-	-			

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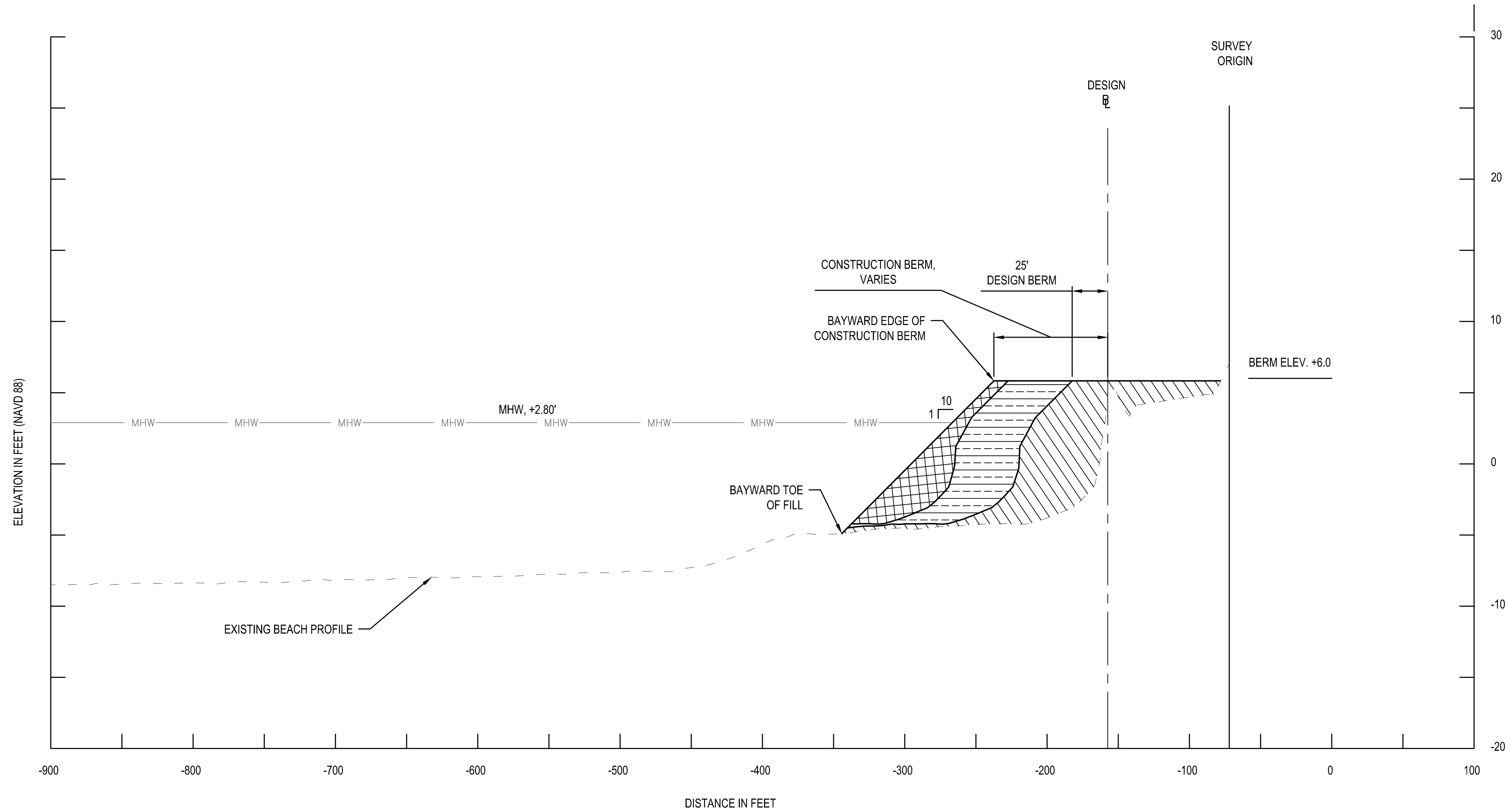
DWN BY: PTF	DESIGNED BY: PTF	ISSUE/RELEASE DATE: FFR 20SEP18
CKD BY: DAN	REVIEWED BY: TEH/GMG	PROJ. NUMBER: -
		SOLICITATION NUMBER: -
DWG SCALE: 1" = 100'		CONTRACT NUMBER: -
DWG. SIZE: 30"x42" Arch E1	FILE NAME: C-108 PLAN - VILLAS BEACH 3 OF 3.dwg	

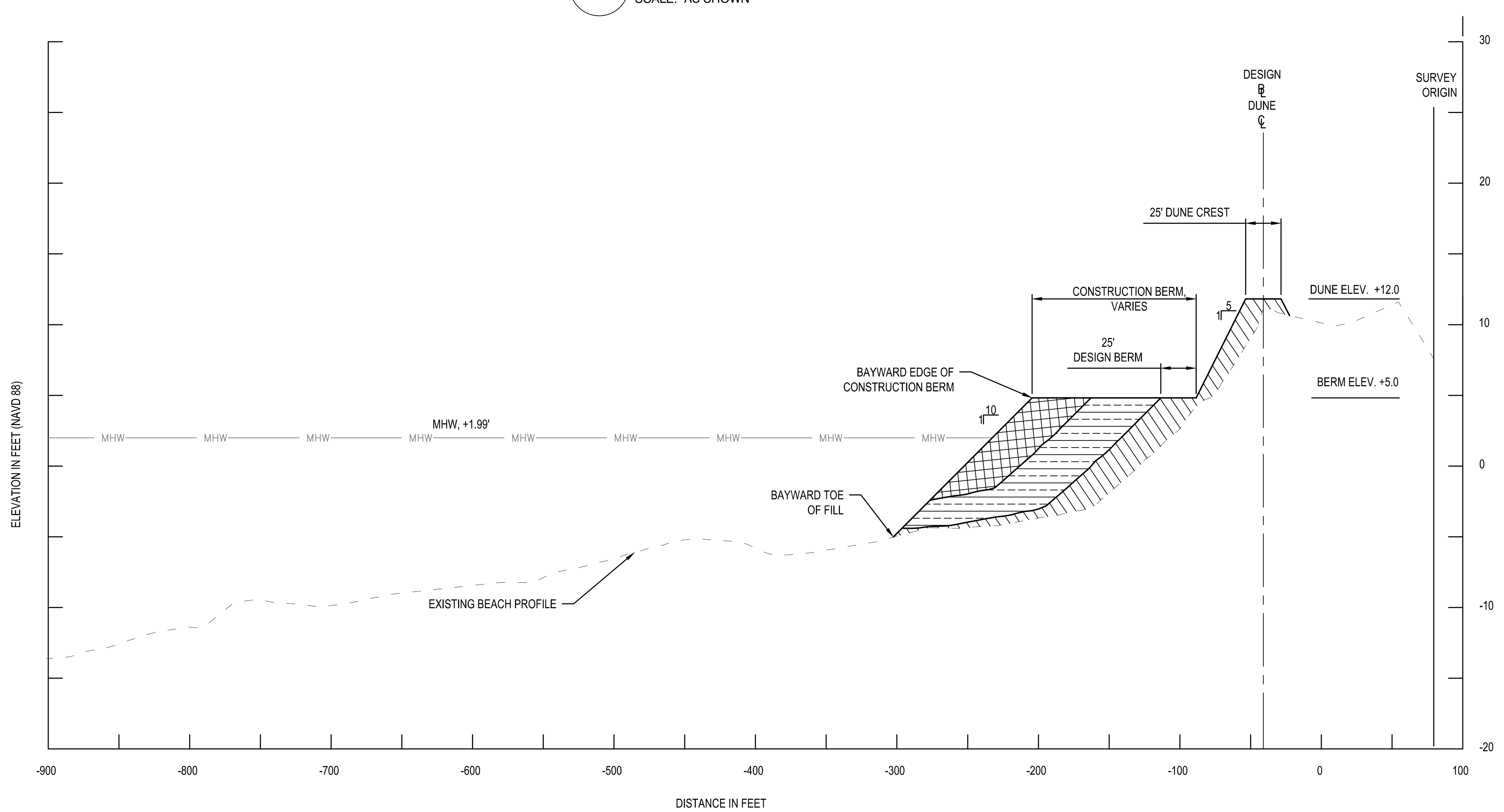
DELAWARE RIVER & BAY
NJ
DREDGE MATERIAL
UTIILIZATION
PLAN - VILLAS BEACH 3 OF 3
FOR PLANNING PURPOSES ONLY

SHEET NUMBER
C-108



1 TYPICAL SECTION - GANDYS AND FORTESCUE

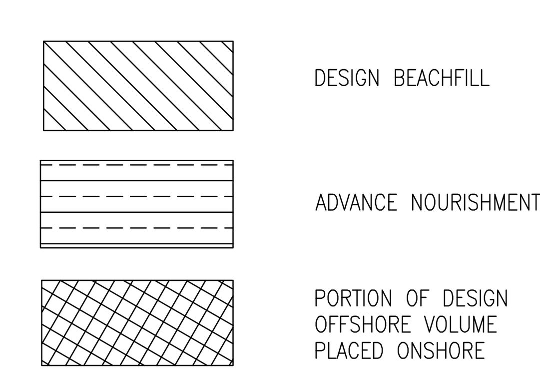
SCALE: AS SHOWN



2 TYPICAL SECTION - VILLAS

SCALE: AS SHOWN

HATCH LEGEND:



HORIZONTAL 50 0 50 100

VERTICAL 5 0 5 10

SCALE IN FEET

US Army Corps of Engineers ® Philadelphia District

DWN BY: PTF	DESIGNED BY: PTF	ISSUE/RELEASE DATE: FFR 20SEP18	
CKD BY: DAN	REVIEWED BY: TEH/GMG	PROJ. NUMBER: -	
		SOLICITATION NUMBER: -	
DWG SCALE: AS SHOWN		CONTRACT NUMBER: -	
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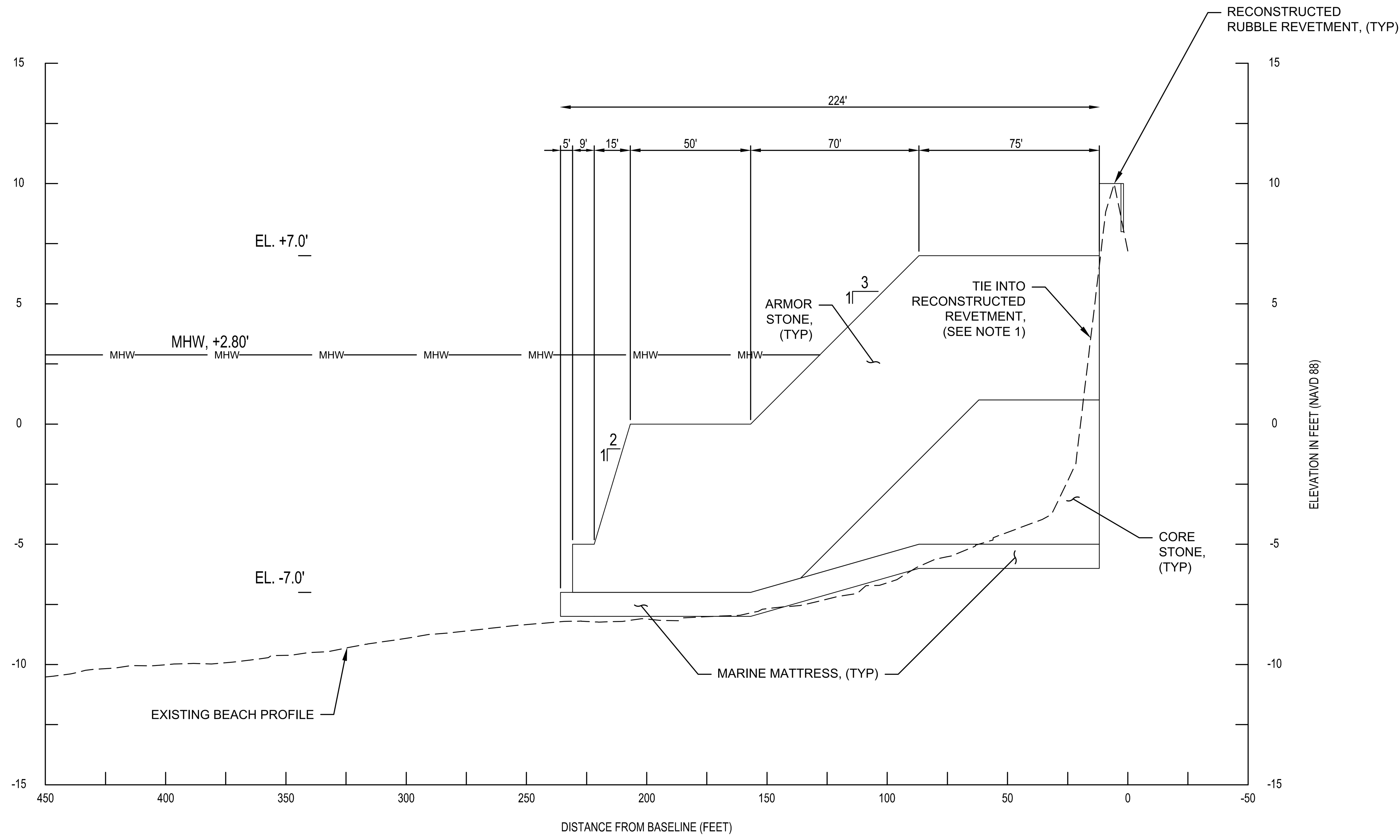
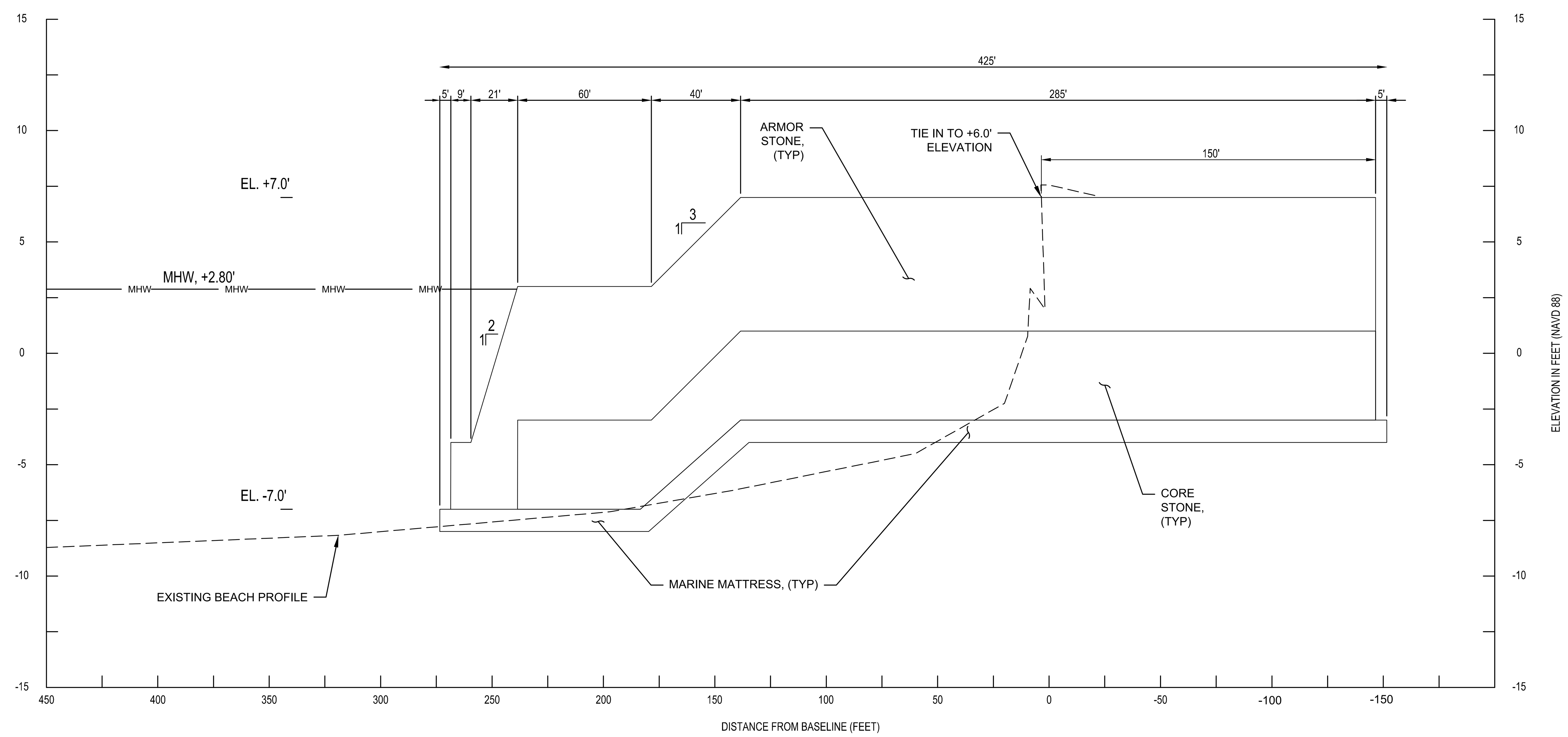
DELAWARE RIVER & BAY
NJ
DREDGE MATERIAL UTIILIZATION
BEACHFILL CROSS SECTIONS FOR PLANNING PURPOSES ONLY

SHEET NUMBER
C-301



1 PROFILE - GANDYS BEACH GROIN
SCALE: AS SHOWN



2 PROFILE - FORTESCUE BEACH GROIN
SCALE: AS SHOWN

HORIZONTAL 50 0 50 100
VERTICAL 5 0 5 10
SCALE IN FEET

NOTE:

1. REMOVE EXISTING REVETMENT OUTER LAYERS INCLUDING SLUSHED CONCRETE TO A DEPTH OF 6' MINIMUM. INSTALL (2) LAYERS OF ARMOR STONE ON THE FACE OF THE EXISTING REVETMENT TO THE LIMITS SHOWN ON C-103.

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Philadelphia District

DWN BY: PTF	DESIGNED BY: PTF	ISSUE/RELEASE DATE: FFR 20SEP18	
CKD BY: GEG/TEH	REVIEWED BY: DAN	PROJ. NUMBER: -	
		SOLICITATION NUMBER: -	
DWG SCALE: AS SHOWN		CONTRACT NUMBER: -	
DWG. SIZE: 30"x42" Arch E1	FILE NAME: C-302 GROIN PROFILES.dwg		

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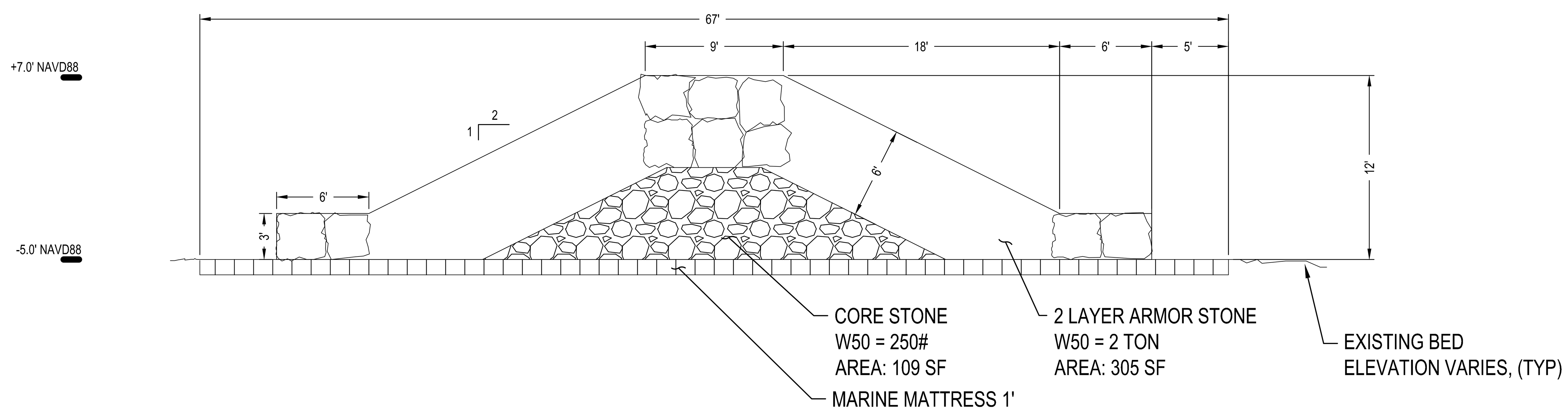
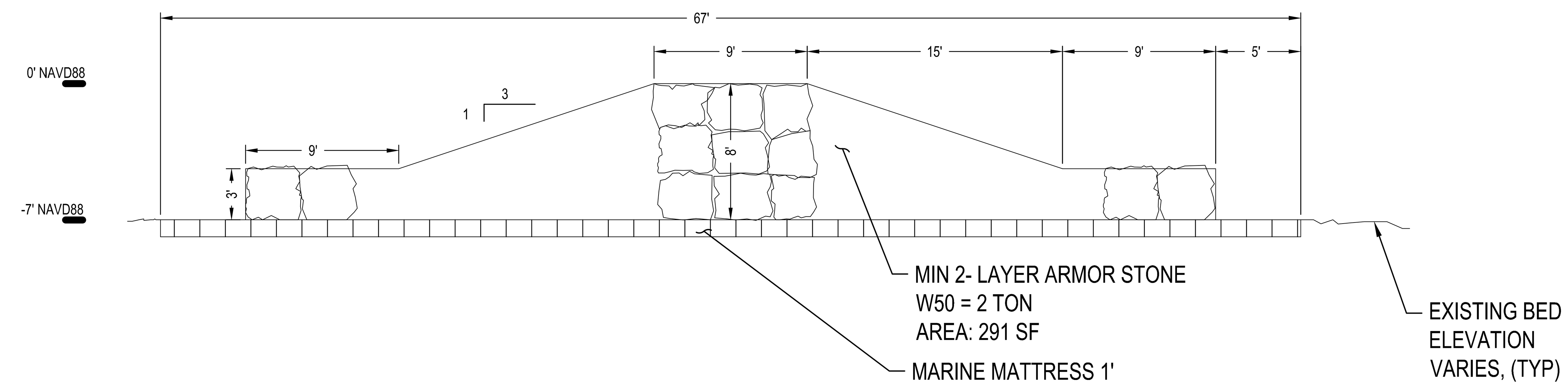
DELAWARE RIVER & BAY
NJ
DREDGE MATERIAL
UTILIZATION
GROIN PROFILES
FOR PLANNING PURPOSES ONLY

SHEET NUMBER
C-302



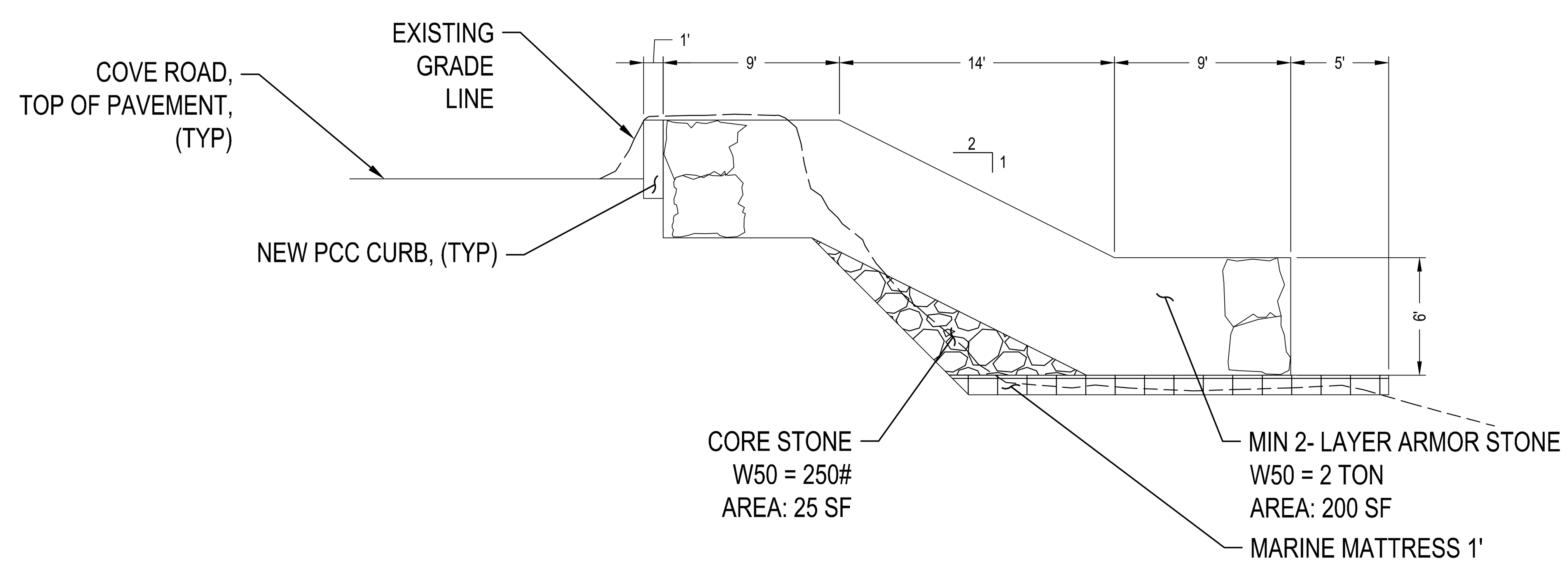
1 GROIN - TRUNK SECTION STA 0+00 TO STA 0+75

SCALE: 1" = 5'



2 GROIN - HEAD SECTION STA 1+45 TO STA 1+95

SCALE: 1" = 5'



3 REVETMENT - REPAIR SECTION

SCALE: 1" = 5'

5 0 5 10

SCALE IN FEET

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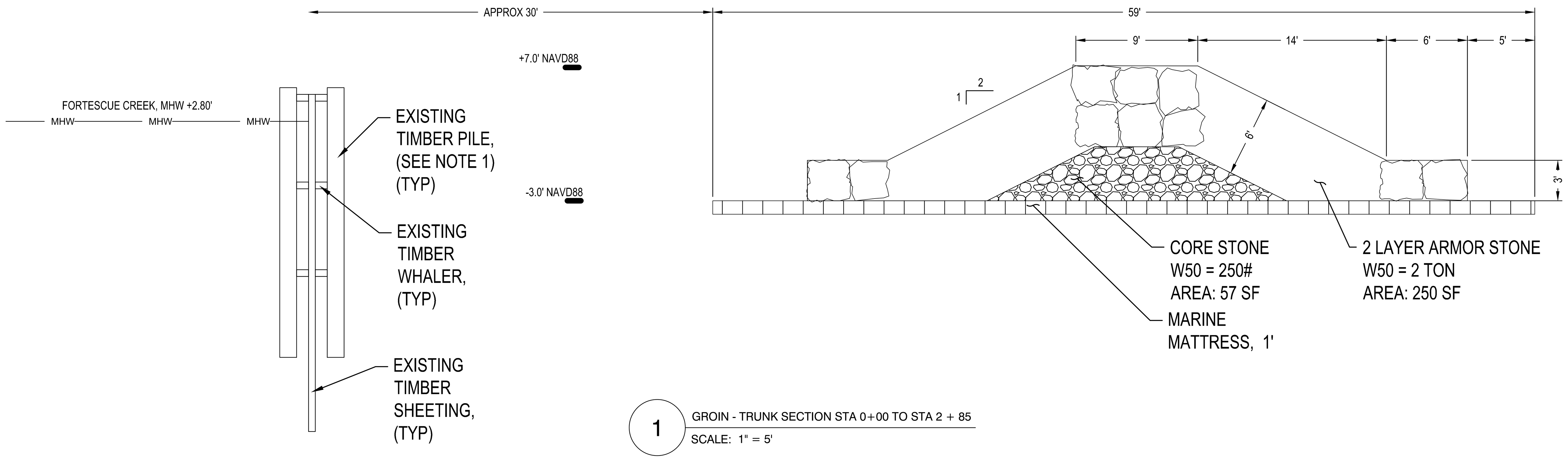
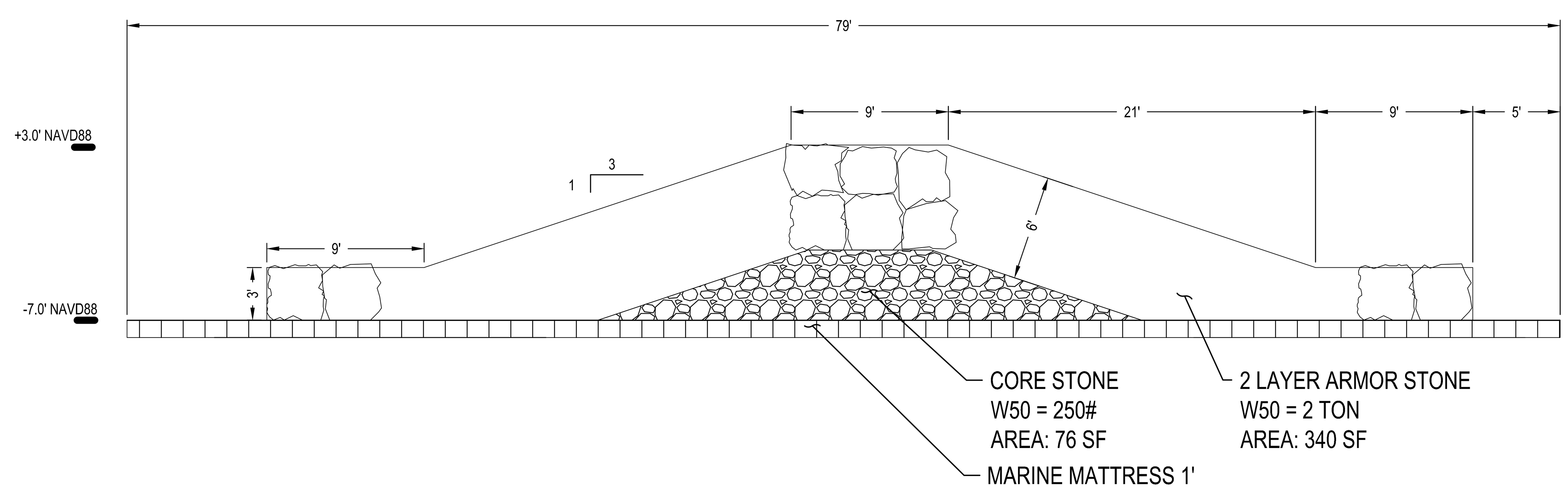
DELAWARE RIVER & BAY
NJ
DREDGE MATERIAL
UTILIZATION
GANDYS BEACH GROIN & REVETMENT CROSS SECTIONS
FOR PLANNING PURPOSES ONLY

SHEET NUMBER

C-303



1 GROIN - TRUNK SECTION STA 0+00 TO STA 2 + 85
SCALE: 1" = 5'



2 GROIN - HEAD SECTION STA 1+75 TO STA 2+35
SCALE: 1" = 5'

NOTE:

1. EXAMINE EXISTING TIMBER GROIN PRIOR TO EXCAVATION FOR CONSTRUCTION OF NEW STONE GROIN. UTILIZE EXCAVATION METHODS INCLUDING BRACING OF NEW EXCAVATION AS NECESSARY TO ENSURE STABILITY OF EXISTING TIMBER GROIN DURING CONSTRUCTION.

5 0 5 10
SCALE IN FEET

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DELAWARE RIVER & BAY
NJ
DREDGE MATERIAL UTILIZATION
FORTESCUE BEACH GROIN CROSS SECTIONS
FOR PLANNING PURPOSES ONLY

SHEET NUMBER
C-304

Appendix C3 – Cost Engineering

New Jersey Beneficial Use of Dredged Material for the Delaware River

APPENDIX C3 - COST ENGINEERING APPENDIX

LIST OF TABLES

<u>APPENDIX C3 - COST ENGINEERING APPENDIX</u>

INITIAL PROJECT CHARGES

1. <u>General</u>: This section presents detailed cost estimates for initial construction, nourishment, maintenance, and monitoring resulting in total and annualized project costs for storm damage reduction plans for the subject project. The selected oceanfront plans include dune grass, dune fencing, outfall extensions and suitable advance beach fill and periodic nourishment to ensure the integrity of the design. The plan requires the construction of two groins (Phase 1 & Phase 2), an initial beachfill (Phase 3) at 545,100 cubic yards and the combination of initial beachfill and the first cycle of periodic nourishment (Phase 4) at 602,800 cubic yards of beachfill to be placed along oceanfront from Delaware River Main Channel maintenance volume (Station 405+043 thru Station 512+102). Subsequent 6 year periodic nourishment of 179,500 cubic yards from the same borrow areas for 50 years. Also included is the placement at Villas South of 372,000 square feet of dune grass, 7,400 L.F of sand fence and outfall extension. The initial construction for each of the above plans includes design and advanced nourishment beachfill. Also included are provisions for periodic nourishment, beach profile and environmental monitoring, and to restore the design beach profile damaged by significant storm events beyond that designed for in the nourishment cycle quantity. The plan layout of the NED plan with typical improved beach sections and inlet frontage are shown in the section of the Main Report describing the NED Plan.

2. <u>Basis of Cost</u>: Cost estimates presented herein for the NED plan are based on October 2018 price levels. Initial beach fill costs are based on beach surveys taken in 2015 for Gandys and Fortescue; in 2017 for Villas. The unit prices were developed in accordance with the construction procedures outlined herein. All initial construction and periodic nourishment costs presented in this appendix are NED costs.

3. <u>Total First Cost for the NED Plan</u>: Initial beach fill costs are based on the assumption of a medium-size hopper dredge was used for placement of the beachfill, an average haul distance, an uploader located offshore. It was assumed that beachfill work would be performed by a dredging contractor and the work for installing the dune appurtenances performed by a subcontractor. NED real estate acquisition costs and pertinent contingency, engineering and design and construction management costs are also included. For more information, refer to the Main Report describing the NED Plan. Initial construction costs are shown in Table 1, Table 2 and Table 3.

ANNUAL CHARGES FOR THE NED PLAN

4. General: The estimate of annual charges for the NED plan is based on an economic project life of 50 years, a Federal Discount rate of 2.75% and an October 2018 price level. The annual charges include annualized first cost and interest during construction, the annualized periodic nourishment costs, post construction monitoring costs, and OMRR&R costs. It is noted that interest during construction was developed for the first cost of the beach fill project constructed over 11 month period and the following cycle over 9 month period. For the NED plan, the total annualized cost is $5,646,998. Periodic nourishment beach fill costs are based on the assumption that a medium-size hopper dredge was used for placement of the beach fill to be placed at 6-year cycles. Approximately 179,500 C.Y. of beach fill material was placed from borrow area sources. Periodic nourishment costs are shown in Table 4.

5. Mobilization and demobilization: Costs are based on the assumption that beach filling equipment located within 1,775 miles from the project site will perform the work and readily available; off the shelf construction equipment located within 500 miles from the project site will perform construction of the crossovers, dune fence, and dune vegetation. Construction access would be by local streets. The locations of the borrow area is displayed in the section of the Main Report describing the NED Plan.

6. Major Replacement Costs: Major rehabilitation costs is not included due to the 12,400 cubic yards being less than periodic nourishment of 179,500 cubic yards.

7. Monitoring Costs: Post construction monitoring costs include coastal and environmental monitoring over the 50-year project life.

8. Operation Maintenance Repair Replacement and Rehabilitation (OMRR&R) Costs: Total annualized OMRR&R costs are $0. Removed from project based on Cost ATR.

CONTINGENCIES, PRECONSTRUCTION ENGINEERING & DESIGN, AND CONSTRUCTION MANAGEMENT FOR THE NED PLAN

9. Contingencies: The estimated cost for each major subdivision or feature of the recommended project includes an item for "contingencies". The item for "contingencies" is an allowance against some adverse or unanticipated condition not susceptible to exact evaluation from the data at hand but which must be expressed or represented in the cost estimate. The contingency allowances used in the development of the cost estimate for the selected project were estimated as an appropriate percentage using Crystal Ball software for preparing risk analysis. Twenty five percent was applied to beach placement work to account for concerns about pumping distances and borrow area selection, and to account for larger required beach fill quantities at the time of construction due to future preconstruction erosion, concerns about availability of pumping equipment, variances in the travel distance for the pump plant, and for increases in labor and fuel prices.

10. Preconstruction Engineering & Design (P, E & D): Preconstruction Engineering and Design costs include local cooperative agreements, environmental and regulatory activities, general design memorandum, preparation of plans and specifications, engineering during construction, A/E liability actions, cost engineering, construction and supply contract award activities, project management, and the development of the PCA. P, E & D costs were estimated as lump sums

(including contingency) for the initial beach fill construction, for the periodic nourishment cycle. A contingency factor of 26.5% was included in the P, E & D costs.

11. Construction Management (S&A): Construction Management costs include contract administration, review of shop drawings, inspection and quality assurance, project office operation, contractor initiated claims and litigations, and government initiated claims and litigations. S&A related costs were estimated as lump sums for the initial beach fill construction, for the periodic nourishment cycle. A contingency factor of 26.5% was included in all S&A costs.

CONSTRUCTION AND FUNDING SCHEDULE FOR THE NED PLAN

12. General: The construction and project schedules of the NED plan are given in Tables 7 through Table 11 respectively of this Engineering Technical Appendix. The schedules are based on the timeliness of the report's approval and allocation of funds by OMB, the foregoing construction procedures, and the ability of local interests to implement the necessary items of local cooperation.

Table 1 – Total First Cost – NED Plan, Phase 1 & Phase 2

DREDGED MATERIAL UTILIZATION - Initial Construction
ROUGH ORDER ESTIMATE FOR GANDY'S BEACH
GROIN

8.78 Months of construction duration | Price Level: Oct-2018

Number	Product Description	Quantity	UOM	Unit Price	Estimated Amount	Contingency 27.0%	Total Estimated Amount
01	LANDS AND DAMAGES	1	JOB	LS	$0	$0	$0
02	RELOCATIONS	1	JOB	LS	$0	$0	$0
09	CHANNELS AND CANALS (Except Navigation Ports ar	1	JOB	LS	$0	$0	$0
10	BREAKWATERS AND SEAWALLS	1	JOB	LS	$3,903,907	$1,054,055	$4,957,962
17	BEACH REPLENISHMENT	1	JOB	LS	$0	$0	$0
30	PLANNING, ENGINEERING, AND DESIGN	1	JOB	LS	$737,238	$199,054	$936,292
31	CONSTRUCTION MANAGEMENT (S&I)	1	JOB	LS	$1,644,344	$443,973	$2,088,316
	TOTAL ESTIMATED AMOUNT =				$6,285,489		
	TOTAL ESTIMATED CONTINGENCY =					$1,697,082	
	PROJECT TOTAL ESTIMATED AMOUNT =						$7,982,571
	Rounded						$7,983,000

DREDGED MATERIAL UTILIZATION - Initial Construction
ROUGH ORDER ESTIMATE FOR FORTESCUE BEACH
GROIN

4.18 Months of construction duration | Price Level: Oct-2018

Number	Product Description	Quantity	UOM	Unit Price	Estimated Amount	Contingency 27.0%	Total Estimated Amount
01	LANDS AND DAMAGES	1	JOB	LS	$0	$0	$0
02	RELOCATIONS	1	JOB	LS	$0	$0	$0
09	CHANNELS AND CANALS (Except Navigation Ports ar	1	JOB	LS	$0	$0	$0
10	BREAKWATERS AND SEAWALLS	1	JOB	LS	$3,302,109	$891,569	$4,193,678
17	BEACH REPLENISHMENT	1	JOB	LS	$0	$0	$0
30	PLANNING, ENGINEERING, AND DESIGN	1	JOB	LS	$734,229	$198,242	$932,471
31	CONSTRUCTION MANAGEMENT (S&I)	1	JOB	LS	$861,257	$232,539	$1,093,796
	TOTAL ESTIMATED AMOUNT =				$4,897,595		
	TOTAL ESTIMATED CONTINGENCY =					$1,322,351	
	PROJECT TOTAL ESTIMATED AMOUNT =						$6,219,945
	Rounded						$6,220,000

Table 2 – Total First Cost – NED Plan, Phase 3

DREDGED MATERIAL UTILIZATION - Initial Construction
ROUGH ORDER ESTIMATE FOR Gandy's Beach, Fortescue Point
BEACHFILL MATERIAL FROM Delaware River Reach E

1 Dredge(s)
7.21 Months of construction duration
5.71 Month of Beach Nourishment
1.50 Disposal at Buoy 10

Price Level: Oct-2018

Number	Product Description	Quantity	UOM	Unit Price	Estimated Amount	Contingency 27.0%	Total Estimated Amount
01	LANDS AND DAMAGES	1	JOB	LS	$0	$0	$0
02	RELOCATIONS	1	JOB	LS	$0	$0	$0
09	CHANNELS AND CANALS (Except Navigation Ports ar	1	JOB	LS	$3,823,853	$1,032,440	$4,856,293
10	BREAKWATERS AND SEAWALLS	1	JOB	LS	$0	$0	$0
17	BEACH REPLENISHMENT	1	JOB	LS	$32,330,127	$8,729,134	$41,059,261
30	PLANNING, ENGINEERING, AND DESIGN	1	JOB	LS	$1,715,877	$463,287	$2,179,163
31	CONSTRUCTION MANAGEMENT (S&I)	1	JOB	LS	$1,679,359	$453,427	$2,132,786
	TOTAL ESTIMATED AMOUNT =				$39,549,215		
	TOTAL ESTIMATED CONTINGENCY =					$10,678,288	
	PROJECT TOTAL ESTIMATED AMOUNT =						$50,227,502
	Rounded						$50,228,000

Table 3 – Total First Cost – NED, Phase 4

DREDGED MATERIAL UTILIZATION - Initial Construction
ROUGH ORDER ESTIMATE FOR Villas Beach
BEACHFILL MATERIAL FROM Delaware River Reach E
Periodic Nourishment for Gandys Beach and Fortescue Beach

1 Dredge(s)
8.98 Months of construction duration
7.91 Month of Beach Nourishment
1.07 Disposal at Buoy 10
12 Outfalls, Months of construction duration

Price Level: Oct-2018

Number	Product Description	Quantity	UOM	Unit Price	Estimated Amount	Contingency 27.0%	Total Estimated Amount
01	LANDS AND DAMAGES	1	JOB	LS	$0	$0	$0
02	RELOCATIONS	1	JOB	LS	$0	$0	$0
09	CHANNELS AND CANALS (Except Navigation Ports ar	1	JOB	LS	$2,716,335	$733,410	$3,449,745
10	BREAKWATERS AND SEAWALLS	1	JOB	LS	$0	$0	$0
17	BEACH REPLENISHMENT	1	JOB	LS	$48,286,311	$13,037,304	$61,323,615
30	PLANNING, ENGINEERING, AND DESIGN	1	JOB	LS	$2,499,128	$674,765	$3,173,892
31	CONSTRUCTION MANAGEMENT (S&I)	1	JOB	LS	$2,977,898	$804,032	$3,781,930
	TOTAL ESTIMATED AMOUNT =				$56,479,672		
	TOTAL ESTIMATED CONTINGENCY =					$15,249,511	
	PROJECT TOTAL ESTIMATED AMOUNT =						$71,729,183
	Rounded						$71,729,000

Table 4 – Periodic Nourishment Costs, 6 Year Cycle

DREDGED MATERIAL UTILIZATION - Periodic Nourishment
ROUGH ORDER ESTIMATE FOR Gandy's Beach, Fortescue Point and Villas Beach (South)
BEACHFILL MATERIAL FROM Delaware River Reach E

1 Dredge(s) Price Level: Oct-2018
8.17 Months of Construction duration
3.96 Month of Beach Nourishment
4.21 Months of Disposal @ Artificial Island

Number	Product Description	Quantity	UOM	Unit Price	Estimated Amount	Contingency 27.0%	Total Estimated Amount
01	LANDS AND DAMAGES	1	JOB	LS	0	0	0
02	RELOCATIONS	1	JOB	LS	0	0	0
09	CHANNELS AND CANALS (Except Navigation Ports	1	JOB	LS	21,579,693	5,826,517	27,406,210
17	BEACH REPLENISHMENT	1	JOB	LS	18,293,343	4,939,203	23,232,545
30	PLANNING, ENGINEERING, AND DESIGN	1	JOB	LS	3,151,409	850,881	4,002,290
31	CONSTRUCTION MANAGEMENT (S&I)	1	JOB	LS	1,993,360	538,207	2,531,567
	TOTAL ESTIMATED AMOUNT =				45,017,805		
	TOTAL ESTIMATED CONTINGENCY =					12,154,807	
	PROJECT TOTAL ESTIMATED AMOUNT =						57,172,612
	Rounded						57,173,000

Table 4a – Periodic Nourishment Costs, 6 Year Cycle

DREDGED MATERIAL UTILIZATION - Periodic Nourishment
ROUGH ORDER ESTIMATE FOR Gandy's Beach, Fortescue Point and Villas Beach (South)
BEACHFILL MATERIAL FROM Delaware River Reach E

1 Dredge(s)
3.96 Months of Construction duration — Price Level: Oct-2018
3.96 Month of Beach Nourishment
0.00 Months of Disposal @ Artificial Island

Number	Product Description	Quantity	UOM	Unit Price	Estimated Amount	Contingency 27.0%	Total Estimated Amount
01	LANDS AND DAMAGES	1	JOB	LS	0	0	0
02	RELOCATIONS	1	JOB	LS	0	0	0
09	CHANNELS AND CANALS (Except Navigation Port	1	JOB	LS	0	0	0
17	BEACH REPLENISHMENT	1	JOB	LS	18,293,343	4,939,203	23,232,545
30	PLANNING, ENGINEERING, AND DESIGN	1	JOB	LS	2,134,444	576,300	2,710,744
31	CONSTRUCTION MANAGEMENT (S&I)	1	JOB	LS	1,126,287	304,097	1,430,384
	TOTAL ESTIMATED AMOUNT =				21,554,074		
	TOTAL ESTIMATED CONTINGENCY =					5,819,600	
	PROJECT TOTAL ESTIMATED AMOUNT =						27,373,674
	Rounded						27,374,000

DREDGED MATERIAL UTILIZATION - Periodic Maintenance
ROUGH ORDER ESTIMATE FOR Gandy's Beach, Fortescue Point and Villas Beach (South)
BEACHFILL MATERIAL FROM Delaware River Reach E

1 Dredge(s) — Price Level: Oct-2018
4.21 Months of Construction duration
0.00 Month of Beach Nourishment
4.21 Months of Disposal @ Artificial Island

Number	Product Description	Quantity	UOM	Unit Price	Estimated Amount	Contingency 27.0%	Total Estimated Amount
01	LANDS AND DAMAGES	1	JOB	LS	0	0	0
02	RELOCATIONS	1	JOB	LS	0	0	0
09	CHANNELS AND CANALS (Except Navigation Port	1	JOB	LS	21,579,693	5,826,517	27,406,210
17	BEACH REPLENISHMENT	1	JOB	LS	0	0	0
30	PLANNING, ENGINEERING, AND DESIGN	1	JOB	LS	1,016,965	274,581	1,291,546
31	CONSTRUCTION MANAGEMENT (S&I)	1	JOB	LS	867,073	234,110	1,101,183
	TOTAL ESTIMATED AMOUNT =				23,463,731		
	TOTAL ESTIMATED CONTINGENCY =					6,335,207	
	PROJECT TOTAL ESTIMATED AMOUNT =						29,798,938
	Rounded						29,799,000

Table 5 – Federal Standard, Year 0 and Year 6 to Buoy 10

DREDGED MATERIAL UTILIZATION - Maintenance
ROUGH ORDER ESTIMATE for Disposal at Buoy 10

1 Medium Hopper Dredge
5.63 Months of construction duration

Price Level: Oct-2018

Number	Product Description	Quantity	UOM	Unit Price	Estimated Amount	Contingency 27.0%	Total Estimated Amount
01	LANDS AND DAMAGES	1	JOB	LS	$0	$0	$0
02	RELOCATIONS	1	JOB	LS	$0	$0	$0
09	CHANNELS AND CANALS (Except Navigation Poi	1	JOB	LS	$16,255,213	$4,388,907	$20,644,120
30	PLANNING, ENGINEERING, AND DESIGN	1	JOB	LS	$1,016,965	$274,581	$1,291,546
31	CONSTRUCTION MANAGEMENT (S&I)	1	JOB	LS	$1,108,567	$299,313	$1,407,880
	TOTAL ESTIMATED AMOUNT =				$18,380,745		
	TOTAL ESTIMATED CONTINGENCY =					$4,962,801	
	PROJECT TOTAL ESTIMATED AMOUNT =						$23,343,546
	ROUNDED						$23,344,000

Table 6 – Federal Standard, Year 12 and 6 year cycle to Artificial Island

DREDGED MATERIAL UTILIZATION - Maintenance
ROUGH ORDER ESTIMATE for Disposal at Artificial Island CDF

1 Large Hopper Dredge

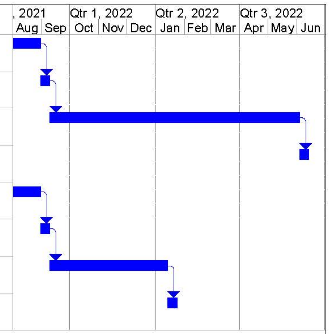
5.55 Months of construction duration

Price Level: Oct-2018

Number	Product Description	Quantity	UOM	Unit Price	Estimated Amount	Contingency 27.0%	Total Estimated Amount
01	LANDS AND DAMAGES	1	JOB	LS	$0	$0	$0
02	RELOCATIONS	1	JOB	LS	$0	$0	$0
09	CHANNELS AND CANALS (Except Navigation Po	1	JOB	LS	$27,477,565	$7,418,943	$34,896,508
30	PLANNING, ENGINEERING, AND DESIGN	1	JOB	LS	$1,016,965	$274,581	$1,291,546
31	CONSTRUCTION MANAGEMENT (S&I)	1	JOB	LS	$1,094,962	$295,640	$1,390,602
	TOTAL ESTIMATED AMOUNT =				$29,589,492		
	TOTAL ESTIMATED CONTINGENCY =					$7,989,163	
	PROJECT TOTAL ESTIMATED AMOUNT =						$37,578,655
	ROUNDED						$37,579,000

Table 7 – Construction Schedule – Initial Construction Phase 1, Year 2021

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	Work Plans & Submittals	30 days	Sun 8/1/21	Tue 8/31/21		
2	Mobilization	10 days	Tue 8/31/21	Fri 9/10/21	1	
3	Groin @ Gandys Beach	267 days	Fri 9/10/21	Sat 6/4/22	2	
4	Demobilization	10 days	Sat 6/4/22	Tue 6/14/22	3	
5	Work Plans & Submittals	30 days	Sun 8/1/21	Tue 8/31/21		
6	Mobilization	10 days	Tue 8/31/21	Fri 9/10/21	5	
7	Groin @ Fortescue Beach	126 days	Fri 9/10/21	Fri 1/14/22	6	
8	Demobilization	10 days	Fri 1/14/22	Mon 1/24/22	7	



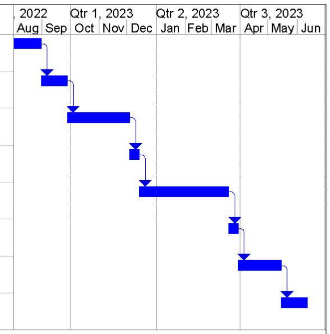
Project: DMU_NJ1
Date: Tue 4/2/19

Task	Inactive Milestone	Finish-only
Split	Inactive Summary	External Tasks
Milestone	Manual Task	External Milestone
Summary	Duration-only	Progress
Project Summary	Manual Summary Rollup	Deadline
External Tasks	Manual Summary	
External Milestone	Start-only	

Page 1

Table 8 – Construction Schedule – Initial Construction Phase 2, Year 2022

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	Work Plans & Submittals	30 days	Mon 8/1/22	Wed 8/31/22		
2	Mobilization	28 days	Wed 8/31/22	Wed 9/28/22	1	
3	Dredging and Beachfill - Gandys Beach	67 days	Wed 9/28/22	Sun 12/4/22	2	
4	Mobilize to Fortescue Beach	10 days	Sun 12/4/22	Wed 12/14/22	3	
5	Dredging and Beachfill - Fortescue Beach	96 days	Wed 12/14/22	Mon 3/20/23	4	
6	Mobilize to Disposal Area	10 days	Mon 3/20/23	Thu 3/30/23	5	
7	Dredging	46 days	Thu 3/30/23	Mon 5/15/23	6	
8	Demobilize	28 days	Mon 5/15/23	Mon 6/12/23	7	



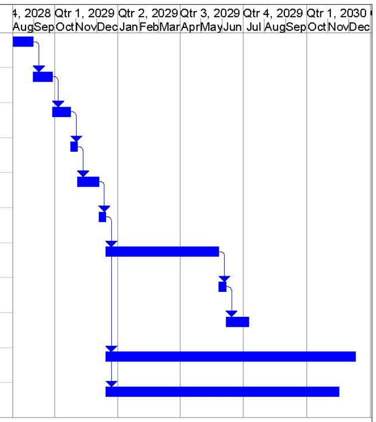
Project: DMU_NJ2
Date: Tue 4/2/19

Task	Inactive Milestone	Finish-only
Split	Inactive Summary	External Tasks
Milestone	Manual Task	External Milestone
Summary	Duration-only	Progress
Project Summary	Manual Summary Rollup	Deadline
External Tasks	Manual Summary	
External Milestone	Start-only	

Page 1

Table 9 - Construction Schedule – Initial Construction Phase 3, Year 2028

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	Work Plans & Submittals	30 days	Tue 8/1/28	Thu 8/31/28		
2	Mobilization	28 days	Thu 8/31/28	Thu 9/28/28	1	
3	Dredging and Beachfill - Gandys Beach	26 days	Thu 9/28/28	Tue 10/24/28	2	
4	Mobilize to Fortescue Beach	10 days	Tue 10/24/28	Fri 11/3/28	3	
5	Dredging and Beachfill - Fortescue Beach	31 days	Fri 11/3/28	Mon 12/4/28	4	
6	Mobilize to Villas South	10 days	Mon 12/4/28	Thu 12/14/28	5	
7	Dredging and Beachfill	164 days	Thu 12/14/28	Sun 5/27/29	6	
8	Mobilize to Disposal Area	10 days	Sun 5/27/29	Wed 6/6/29	7	
9	Dredging	33 days	Wed 6/6/29	Mon 7/9/29	8	
10	Outfalls	362 days	Thu 12/14/28	Tue 12/11/29	6	
11	Outfalls	338 days	Thu 12/14/28	Sat 11/17/29	6	



Project: DMU_NJ2028
Date: Tue 4/2/19

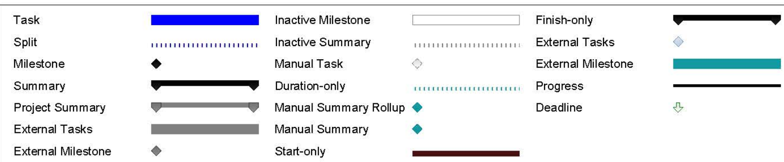
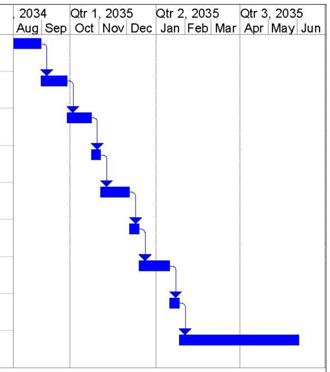


Table 10 - Construction Schedule – Periodic Nourishment, Year 2034, + 6 year Cycle

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	Work Plans & Submittals	30 days	Tue 8/1/34	Thu 8/31/34		
2	Mobilization	28 days	Thu 8/31/34	Thu 9/28/34	1	
3	Dredging and Beachfill - Gandys Beach	26 days	Thu 9/28/34	Tue 10/24/34	2	
4	Mobilize to Fortescue Beach	10 days	Tue 10/24/34	Fri 11/3/34	3	
5	Dredging and Beachfill - Fortescue Beach	31 days	Fri 11/3/34	Mon 12/4/34	4	
6	Mobilize to Villas South	10 days	Mon 12/4/34	Thu 12/14/34	5	
7	Dredging and Beachfill	33 days	Thu 12/14/34	Tue 1/16/35	6	
8	Mobilize to Disposal Area	10 days	Tue 1/16/35	Fri 1/26/35	7	
9	Dredging	128 days	Fri 1/26/35	Sun 6/3/35	8	



Project: DMU_NJ2034
Date: Wed 4/3/19

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Progress
Deadline

Page 1

Table 11 – Construction Schedule

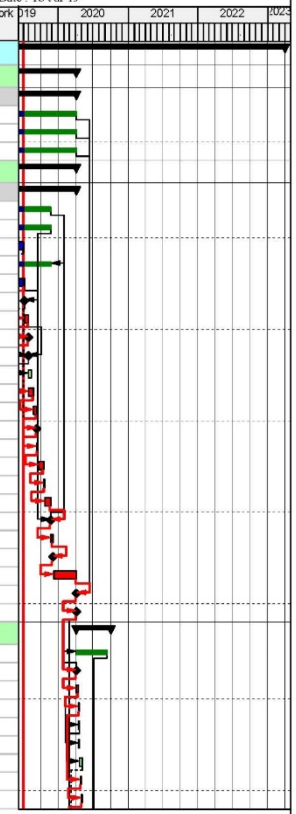
		Construction Duration (Mo)		2020				2021				2022				2023				2028				2029				2034				2035				2040				2041			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Initial Construction	Groin, Gandys	7.00								X	X	X																														
Initial Construction	Groin, Fortescue	4.15								X	X																															
Initial Construction	Gandys, Fortescue	7.21												X	X	X																										
Initial Construction/Periodic Nourishme	Villas South, Gandys, Fortescu	8.98																				X	X	X																		
Initial Construction	Villas South, Outfalls	12.00																				X	X	X	X																	
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																												X	X	X										
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																																			X	X	X			
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																																								
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																																								
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																																								
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																																								
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																																								

		Construction Duration (Mo)	2046				2047				2052				2053				2058				2059				2064				2065				2070				2071			
			Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Initial Construction	Groin, Gandys	7.00																																								
Initial Construction	Groin, Fortescue	4.15																																								
Initial Construction	Gandys, Fortescue	7.21																																								
Initial Construction/Periodic Nourishme	Villas South, Gandys, Fortescu	8.98																																								
Initial Construction	Villas South, Outfalls	12.00																																								
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																																								
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																																								
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17			X	X	X																																			
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17											X	X	X																											
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																			X	X	X						X	X	X											
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																																			X	X	X			
Periodic Nourishment	Villas South, Gandys, Fortescu	8.17																																								

Table 12 – Project Schedule

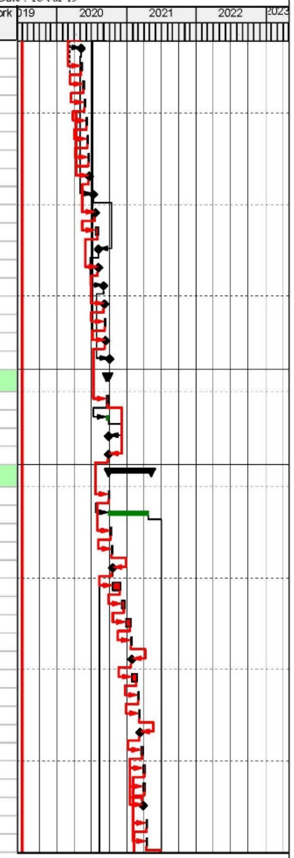
DEI R DREDE MATERIAL, NEW JERSEY | 1/5 | Data Date: 01-Jul-19 | Print Date : 18-Jul-19

Activity ID	Activity Name	Original Duration	Remaining Duration	Total Float	Start	Finish	Remaining Total Cost	Actual Total Cost	At Completion Total Cost	CEFMS Work Item Code
322658	**DEI R DREDE MATERIAL, NEW JERSEY**	1956	940	0	12-Jun-15 A	01-Apr-23	$451,324.82	$2,089,151.37	$2,540,476.19	
322658.22000	**Feasibility Studies - check**	329	190	0	12-Jun-15 A	02-Apr-20	$431,491.99	$2,070,854.89	$2,502,346.88	
322658.22000.22T00	**Feas Prog & Projt Mgmt**	329	190	0	12-Jun-15 A	02-Apr-20	$431,491.99	$2,070,854.89	$2,502,346.88	
FEA1774	Sandy Feas - FY15 - FY19	329	190	0	12-Jun-15 A	02-Apr-20	$311,159.52	$1,931,661.82	$2,242,821.34	56B5H2
FEA1776	FR Completion	329	190	0	12-Jun-15 A	02-Apr-20	$90,398.73	$116,126.81	$206,525.54	56F29B
FEA1778	Report Finalization and Review	329	190	0	12-Jun-15 A	02-Apr-20	$29,933.74	$23,066.26	$53,000.00	599H66
322658.1	**Feasibility Studies**	502	190	750	03-Apr-18 A	02-Apr-20	$19,832.83	$18,296.48	$38,129.31	
322658.1.22A00	**SMART Planning**	502	190	750	03-Apr-18 A	02-Apr-20	$19,832.83	$18,296.48	$38,129.31	
FEA-1620	Planning Support (ADM thru CWRB)	154	100	0	03-Apr-18 A	21-Nov-19	$0.00	$0.00	$0.00	55C27K
FEA-1630	Engineering Support (MFR thru CWRB)	154	100	0	03-Apr-18 A	21-Nov-19	$0.00	$0.00	$0.00	5423BK
FEA-1678	Section 106 Final	10	1	929	11-Apr-18 A	01-Jul-19	$0.00	$0.00	$0.00	
FEA-1785	USFWS Coordination	29	100	0	01-Mar-19 A	21-Nov-19	$19,832.83	$18,296.48	$38,129.31	5B7K97
FEA-1700	DQC of Final Report	20	5	0	10-Jun-19 A	08-Jul-19	$0.00	$0.00	$0.00	
FEA-1710	Final Report Complete	0	0	15		08-Jul-19	$0.00	$0.00	$0.00	
FEA-2000	ATR of Final Report	15	15	0	09-Jul-19	29-Jul-19	$0.00	$0.00	$0.00	
FEA-1720	Final Decision Document submitted for approval	0	0	0		29-Jul-19	$0.00	$0.00	$0.00	
FEA-1680	Cost Certification from Cost DX	0	0	910		29-Jul-19	$0.00	$0.00	$0.00	
FEA-1690	Complete Draft of Final FR/EA	10	10	910	30-Jul-19	12-Aug-19	$0.00	$0.00	$0.00	
FEA-1730	One Review Team Final Report Review	20	20	0	30-Jul-19	26-Aug-19	$0.00	$0.00	$0.00	
FEA-1735	Final Report Revisions Post One Review Team Review	10	10	0	27-Aug-19	10-Sep-19	$0.00	$0.00	$0.00	
FEA-1740	One Review Team Review Complete	0	0	0		10-Sep-19	$0.00	$0.00	$0.00	
FEA-1800	Prepare Package for State and Agency Review	5	5	0	11-Sep-19	17-Sep-19	$0.00	$0.00	$0.00	
FEA-1810	State and Agency Review (Final FR/EA/EIS and Draft Chief's Report)	20	20	0	18-Sep-19	16-Oct-19	$0.00	$0.00	$0.00	
FEA-1820	Response Letters to S&A comments (If required)	5	5	0	17-Oct-19	23-Oct-19	$0.00	$0.00	$0.00	
FEA-1830	OWPR & RIT Coordination of Final Report Packet & Chief's Report	20	20	0	24-Oct-19	21-Nov-19	$0.00	$0.00	$0.00	
FEA-1840	Chief Signs Report of the Chief of Engineers	0	0	0		21-Nov-19	$0.00	$0.00	$0.00	
FEA-1850	Chief's Report Forwarded to ASA(CW) (RIT TASK)	10	10	0	22-Nov-19	06-Dec-19	$0.00	$0.00	$0.00	
FEA-1860	ASA(CW) Signs Record of Decision if Not Authorized	0	0	0		06-Dec-19	$0.00	$0.00	$0.00	
FEA-1870	Feasibility Report Transmittal to Congress	80	80	0	09-Dec-19	02-Apr-20	$0.00	$0.00	$0.00	
FEA-1890	ASA CW Approval	0	0	0		02-Apr-20	$0.00	$0.00	$0.00	
FEA-1880	Transmitted Report to Congress	0	0	0		02-Apr-20	$0.00	$0.00	$0.00	
322658.30AP01	**Project Partnership Agreement (PPA)**	128	128	622	03-Apr-20	02-Oct-20	$0.00	$0.00	$0.00	
PPA5450	Prog & Project Mgmt	114	114	0	03-Apr-20	14-Sep-20	$0.00	$0.00	$0.00	
PPA5460	Start PPA Development	0	0	0	03-Apr-20		$0.00	$0.00	$0.00	
PPA5470	Draft PPA	10	10	0	03-Apr-20	16-Apr-20	$0.00	$0.00	$0.00	
PPA5480	Allocation of Funds Table	5	5	0	17-Apr-20	23-Apr-20	$0.00	$0.00	$0.00	
PPA5510	PPA Checklist	2	2	8	17-Apr-20	20-Apr-20	$0.00	$0.00	$0.00	
PPA5520	Sponsor Self-Certification and Letter of Interest	5	5	735	17-Apr-20	23-Apr-20	$0.00	$0.00	$0.00	
PPA5530	Draft PPA Package	10	10	8	21-Apr-20	04-May-20	$0.00	$0.00	$0.00	
PPA5490	Deviation Report	5	5	0	24-Apr-20	30-Apr-20	$0.00	$0.00	$0.00	
PPA5500	Cert of Legal Review	5	5	0	01-May-20	07-May-20	$0.00	$0.00	$0.00	

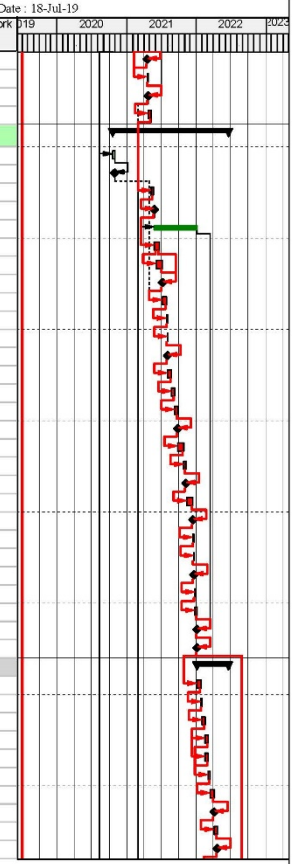


proj 322658- Ongoing Schedule-01-Jul-19

Activity ID	Activity Name	Original Duration	Remaining Duration	Total Float	Start	Finish	Remaining Total Cost	Actual Total Cost	At Completion Total Cost	CEFMS Work Item Code
FEA4150	HQ/NAD PPA Clearance	0	0	622		04-May-20	$0.00	$0.00	$0.00	
PPA5590	Determine Delegation of Auth	5	5	0	08-May-20	14-May-20	$0.00	$0.00	$0.00	
PPA5540	Perform ATR on PPA package	5	5	0	15-May-20	21-May-20	$0.00	$0.00	$0.00	
PPA5550	Final Draft PPA	5	5	0	22-May-20	29-May-20	$0.00	$0.00	$0.00	
PPA5560	Cost-Sharing Waivers	5	5	0	01-Jun-20	05-Jun-20	$0.00	$0.00	$0.00	
PPA5570	3rd Party Sub-Agrmts	5	5	0	08-Jun-20	12-Jun-20	$0.00	$0.00	$0.00	
PPA5580	All Other PPA Docs	5	5	0	15-Jun-20	19-Jun-20	$0.00	$0.00	$0.00	
PPA5600	Submit PPA Package	0	0	0		19-Jun-20	$0.00	$0.00	$0.00	
FEA4170	HQ USACE Draft PPA/Provided to Districts	0	0	622		07-Jul-20	$0.00	$0.00	$0.00	
PPA5610	MSC Approved PPA	0	0	0		22-Jul-20	$0.00	$0.00	$0.00	
PPA5620	HQUSACE PPA Review Activities	10	10	0	23-Jul-20	05-Aug-20	$0.00	$0.00	$0.00	
FEA4230	PPA Approval to MSC for Review	0	0	622		04-Aug-20	$0.00	$0.00	$0.00	
PPA5630	HQ Approved PPA	0	0	0		05-Aug-20	$0.00	$0.00	$0.00	
FEA4250	District Executes PPA	0	0	622		01-Sep-20	$0.00	$0.00	$0.00	
PPA5640	ASA (CW) Approves PPA	0	0	0		04-Sep-20	$0.00	$0.00	$0.00	
PPA5650	Local Sponsor Signs PPA and Certificates	5	5	0	08-Sep-20	14-Sep-20	$0.00	$0.00	$0.00	
PPA5660	PPA Executed - [Project name]	0	0	0		14-Sep-20	$0.00	$0.00	$0.00	
FEA4160	Submit PPA Package to HQ	0	0	622		02-Oct-20	$0.00	$0.00	$0.00	
322658.30BX0 PE&D Prog & Proj Mgmt		10	10	626	15-Sep-20	28-Sep-20	$0.00	$0.00	$0.00	
DDR3830	Initial Work Allow (PDT Resources)	10	10	0	15-Sep-20	28-Sep-20	$0.00	$0.00	$0.00	
DDR-PPM10(	FY-XX Program & Project Mgmt Resources	10	10	0	15-Sep-20	28-Sep-20	$0.00	$0.00	$0.00	
DDR3840	Receive Fed Funds	0	0	626		28-Sep-20	$0.00	$0.00	$0.00	
DDR3850	Receive Sponsor Funds	0	0	0		28-Sep-20	$0.00	$0.00	$0.00	
322658.30DA0 Plans & Specs		151	151	0	29-Sep-20	07-May-21	$0.00	$0.00	$0.00	
PLN1000	Kick-Off Mtng/Prepare 35% Design	5	5	0	29-Sep-20	05-Oct-20	$0.00	$0.00	$0.00	
PLN1220	Plans & Specs Resources	141	141	0	29-Sep-20	23-Apr-21	$0.00	$0.00	$0.00	
PLN1010	Review 35% Design	5	5	0	06-Oct-20	13-Oct-20	$0.00	$0.00	$0.00	
PLN1020	Incorporate 35% Design Review Comments	5	5	0	14-Oct-20	20-Oct-20	$0.00	$0.00	$0.00	
PLN1030	35% Design Complete	0	0	0		20-Oct-20	$0.00	$0.00	$0.00	
PLN1040	Prepare 65% Design	30	30	0	21-Oct-20	03-Dec-20	$0.00	$0.00	$0.00	
PLN1050	Review 65% Design	15	15	0	04-Dec-20	24-Dec-20	$0.00	$0.00	$0.00	
PLN1060	Incorporate 65% Design Review Comments & Other Review Comments (IEPF	17	17	0	28-Dec-20	22-Jan-21	$0.00	$0.00	$0.00	
PLN1070	Prep/Conduct Review Conference	4	4	0	25-Jan-21	28-Jan-21	$0.00	$0.00	$0.00	
PLN1080	65% Design Complete	0	0	0		28-Jan-21	$0.00	$0.00	$0.00	
PLN1090	Prepare 95% Design	20	20	0	29-Jan-21	26-Feb-21	$0.00	$0.00	$0.00	
PLN1100	Review 95% Design	5	5	0	01-Mar-21	05-Mar-21	$0.00	$0.00	$0.00	
PLN1110	Incorporate 95% Design Review Comments	5	5	0	08-Mar-21	12-Mar-21	$0.00	$0.00	$0.00	
PLN1120	95% Design Complete	0	0	0		12-Mar-21	$0.00	$0.00	$0.00	
PLN1130	Prepare Final Design	10	10	0	15-Mar-21	26-Mar-21	$0.00	$0.00	$0.00	
PLN1150	Conduct Agency Technical Review (ATR)	10	10	0	29-Mar-21	09-Apr-21	$0.00	$0.00	$0.00	
PLN1160	Conduct BCOE Review	10	10	0	29-Mar-21	09-Apr-21	$0.00	$0.00	$0.00	
PLN1140	Start ATR/ITR	0	0	0	29-Mar-21		$0.00	$0.00	$0.00	
PLN1170	Incorporate ATR Comments	5	5	0	12-Apr-21	16-Apr-21	$0.00	$0.00	$0.00	
PLN1180	Incorporate BCOE Review Comments	5	5	0	12-Apr-21	16-Apr-21	$0.00	$0.00	$0.00	

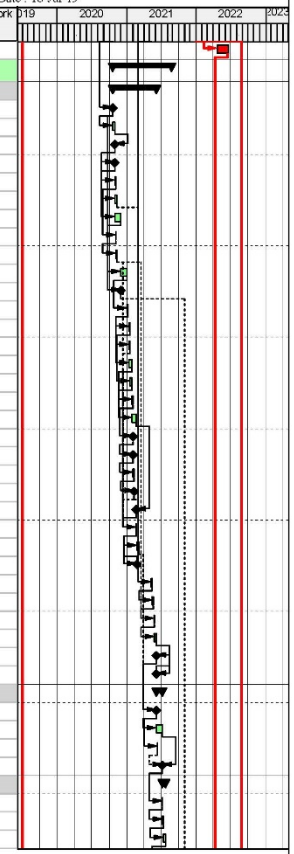


Activity ID	Activity Name	Original Duration	Remaining Duration	Total Float	Start	Finish	Remaining Total Cost	Actual Total Cost	At Completion Total Cost	CEFMS Work Item Code
PLN1190	BCOE Review Complete	0	0	0		16-Apr-21	$0.00	$0.00	$0.00	
PLN1200	Finalize Plans and Specs	5	5	0	19-Apr-21	23-Apr-21	$0.00	$0.00	$0.00	
PLN1210	Plans and Specs Complete	0	0	0		23-Apr-21	$0.00	$0.00	$0.00	
PLN1215	Water Quality Certificate	10	10	0	26-Apr-21	07-May-21	$0.00	$0.00	$0.00	
322658.30H00 Real Estate		416	416	0	21-Oct-20	20-Jun-22	$0.00	$0.00	$0.00	
RE3025	Sponsor: Prepare Survey Contract	5	5	171	21-Oct-20	27-Oct-20	$0.00	$0.00	$0.00	
RE3030	Sponsor: Survey Contract Award (milestone)	0	0	171		27-Oct-20	$0.00	$0.00	$0.00	
RE3000	Complete Real Estate Preliminary Assessment of W/O Project Condition	10	10	0	10-May-21	21-May-21	$0.00	$0.00	$0.00	
RE3005	Land Acquisition Authorized	0	0	0	24-May-21		$0.00	$0.00	$0.00	
RE1000	USACE RE District Support - Budget	153	153	0	24-May-21	03-Jan-22	$0.00	$0.00	$0.00	
RE3010	Gather Tract Ownership Data	20	20	0	24-May-21	21-Jun-21	$0.00	$0.00	$0.00	
RE3015	Acquisition of ROE-S	20	20	0	08-Jun-21	06-Jul-21	$0.00	$0.00	$0.00	
RE3020	ROE-S Acquired	0	0	0		06-Jul-21	$0.00	$0.00	$0.00	
RE3035	Sponsor: Metes and Bounds Survey	15	15	0	07-Jul-21	27-Jul-21	$0.00	$0.00	$0.00	
RE3040	Goverment Review Metes and Bounds Survey/Legal Description	5	5	0	28-Jul-21	03-Aug-21	$0.00	$0.00	$0.00	
RE3045	Sponsor: Prepare Title Contract	1	1	0	04-Aug-21	04-Aug-21	$0.00	$0.00	$0.00	
RE3050	Sponsor: Title Contract Award (milestone)	0	0	0		04-Aug-21	$0.00	$0.00	$0.00	
RE3060	Sponsor: Title Policy	15	15	0	05-Aug-21	25-Aug-21	$0.00	$0.00	$0.00	
RE3065	Gov't Review Title Policy	10	10	0	26-Aug-21	09-Sep-21	$0.00	$0.00	$0.00	
RE3070	Sponsor: Prepare Appraisal Scope	10	10	0	10-Sep-21	23-Sep-21	$0.00	$0.00	$0.00	
RE4070	Sponsor: Appraisal Contract Award (milestone)	0	0	0		23-Sep-21	$0.00	$0.00	$0.00	
RE4080	Sponsor: Appraisal Contract	22	22	0	24-Sep-21	26-Oct-21	$0.00	$0.00	$0.00	
RE4082	Gov't Review Appraisal	10	10	0	27-Oct-21	09-Nov-21	$0.00	$0.00	$0.00	
RE4084	Goverment Appraisal Review Complete	0	0	0		09-Nov-21	$0.00	$0.00	$0.00	
RE4086	Sponsor: Initiate Negotiations	22	22	0	10-Nov-21	13-Dec-21	$0.00	$0.00	$0.00	
RE4088	Sponsor: Negotiations Complete	0	0	0		13-Dec-21	$0.00	$0.00	$0.00	
RE4090	Sponsor: Execute Offer to Sell	5	5	0	14-Dec-21	20-Dec-21	$0.00	$0.00	$0.00	
RE4095	Sponsor: Closing/Land Payment	2	2	0	21-Dec-21	22-Dec-21	$0.00	$0.00	$0.00	
RE4096	Sponsor: Closed and Recorded	0	0	0		22-Dec-21	$0.00	$0.00	$0.00	
RE4097	Sponsor: Submit Real Estate Cert Documents	1	1	0	23-Dec-21	23-Dec-21	$0.00	$0.00	$0.00	
RE4099	Gov't Review Real Estate Cert Documents	5	5	0	27-Dec-21	03-Jan-22	$0.00	$0.00	$0.00	
RE5002	Real Estate Certified	0	0	0		03-Jan-22	$0.00	$0.00	$0.00	
RE5004	Obtain ROE-C (if required)	0	0	0		03-Jan-22	$0.00	$0.00	$0.00	
322658.30H00.01 Condemnation (if required)		117	117	0	04-Jan-22	20-Jun-22	$0.00	$0.00	$0.00	
RE5000	District Assemble DT	15	15	0	04-Jan-22	25-Jan-22	$0.00	$0.00	$0.00	
RE5005	District Review DT	5	5	0	26-Jan-22	01-Feb-22	$0.00	$0.00	$0.00	
RE5010	Division Review DT	10	10	0	02-Feb-22	15-Feb-22	$0.00	$0.00	$0.00	
RE5014	CBP Review DT	10	10	0	16-Feb-22	02-Mar-22	$0.00	$0.00	$0.00	
RE5012	DOJ Main Review DT	10	10	0	16-Feb-22	02-Mar-22	$0.00	$0.00	$0.00	
RE5015	FM&E Signs DT	10	10	0	03-Mar-22	16-Mar-22	$0.00	$0.00	$0.00	
RE5020	Transfer to Local AUSA	15	15	0	17-Mar-22	06-Apr-22	$0.00	$0.00	$0.00	
RE5025	DT Filed and Funds Deposited	0	0	0		06-Apr-22	$0.00	$0.00	$0.00	
RE5030	Government Files Motion for Possession	10	10	0	07-Apr-22	20-Apr-22	$0.00	$0.00	$0.00	
RE5040	Possession Granted (Link to Contract Award)	0	0	0		20-Apr-22	$0.00	$0.00	$0.00	



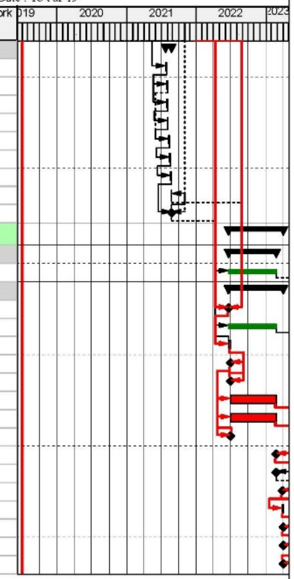
DEI R DREDE MATERIAL, NEW JERSEY | 4/5 | Data Date: 01-Jul-19 | Print Date : 18-Jul-19

Activity ID	Activity Name	Original Duration	Remaining Duration	Total Float	Start	Finish	Remaining Total Cost	Actual Total Cost	At Completion Total Cost	CEFMS Work Item Code
RE5050	Settelement/Judgement (Link to Project Closeout)	42	42	0	21-Apr-22	20-Jun-22	$0.00	$0.00	$0.00	
322658.30DP0 Procurement		213	213	203	20-Oct-20	26-Aug-21	$0.00	$0.00	$0.00	
322658.30DP0.01 Pre-Solicitation Phase		154	154	262	20-Oct-20	03-Jun-21	$0.00	$0.00	$0.00	
PROC1010	CAS Request	0	0	265		20-Oct-20	$0.00	$0.00	$0.00	
PROC2005	PDT Acquisition Strategy Meetings	5	5	265	21-Oct-20	27-Oct-20	$0.00	$0.00	$0.00	
PROC1003	Acquisition Strategy Meetings Complete	0	0	265		27-Oct-20	$0.00	$0.00	$0.00	
PROC1060	Issues Sources Sought	0	0	265		27-Oct-20	$0.00	$0.00	$0.00	
PROC1005	Prepare Draft Evaluation Criteria and Draft Source Selection Plan (SSP)	5	5	325	28-Oct-20	03-Nov-20	$0.00	$0.00	$0.00	
PROC1015	Prepare DIV 00 / DIV 01 Specs	10	10	324	28-Oct-20	10-Nov-20	$0.00	$0.00	$0.00	
PROC1080	Sources Sought/Analysis	22	22	265	28-Oct-20	30-Nov-20	$0.00	$0.00	$0.00	
PROC1055	Review Draft Evaluation Criteria and Draft Source Selection Plan (SSP)	1	1	325	04-Nov-20	04-Nov-20	$0.00	$0.00	$0.00	
PROC1520	Finalize Evaluation Criteria and Source Selection Plan (SSP)	3	3	325	05-Nov-20	09-Nov-20	$0.00	$0.00	$0.00	
PROC1013	Market Research/DSBS Analysis	22	22	265	01-Dec-20	31-Dec-20	$0.00	$0.00	$0.00	
PROC1145	COR Nomination (if required, see guide)	0	0	386		03-Dec-20	$0.00	$0.00	$0.00	
PROC1014	DD2579 SB Coordination Record	5	5	265	04-Jan-21	08-Jan-21	$0.00	$0.00	$0.00	
PROC1030	Prepare Consolidation Memo (if required, see guide)	5	5	265	11-Jan-21	15-Jan-21	$0.00	$0.00	$0.00	
PROC1020	Informal Acquisition Plan	5	5	287	11-Jan-21	15-Jan-21	$0.00	$0.00	$0.00	
PROC1017	Prepare & Approve Applicable J&A's (if required, see guide)	12	12	266	11-Jan-21	28-Jan-21	$0.00	$0.00	$0.00	
PROC1033	Review Consolidation Memo (if required, see guide)	5	5	265	19-Jan-21	26-Jan-21	$0.00	$0.00	$0.00	
PROC1035	Approve Consolidation Memo at District (if required, see guide)	5	5	265	27-Jan-21	02-Feb-21	$0.00	$0.00	$0.00	
PROC1018	HQ SCA Review/Approve J&A's (if required, see guide)	14	14	266	29-Jan-21	18-Feb-21	$0.00	$0.00	$0.00	
PROC1040	Consolidation Memo District Approval	0	0	265		02-Feb-21	$0.00	$0.00	$0.00	
PROC1045	Submit Consolidation Memo to PARC	0	0	265		02-Feb-21	$0.00	$0.00	$0.00	
PROC1047	PARC Consolidation Memo Review and Response to Comments	5	5	265	03-Feb-21	09-Feb-21	$0.00	$0.00	$0.00	
PROC1049	PARC Consolidation Memo Approval	0	0	265		09-Feb-21	$0.00	$0.00	$0.00	
PROC1019	J&A's Approved	0	0	266		18-Feb-21	$0.00	$0.00	$0.00	
PROC2060	Prepare Synopsis (Pre-Solicitation Notice)	1	1	266	19-Feb-21	19-Feb-21	$0.00	$0.00	$0.00	
PROC2080	Synopsis Period in FedBizOps	10	10	266	22-Feb-21	05-Mar-21	$0.00	$0.00	$0.00	
PROC2070	Issue Synopsis in FedBizOpps	0	0	266	22-Feb-21		$0.00	$0.00	$0.00	
PROC2015	Prepare Final Solicitation Document	5	5	203	10-May-21	14-May-21	$0.00	$0.00	$0.00	
PROC1540	Compliance Review (if required, see guide)	5	5	203	17-May-21	21-May-21	$0.00	$0.00	$0.00	
PROC1530	OC Review	3	3	203	24-May-21	26-May-21	$0.00	$0.00	$0.00	
PROC1550	Solicitation Review Board (SRB Peer Review) (if required, see guide)	5	5	203	27-May-21	03-Jun-21	$0.00	$0.00	$0.00	
PROC1580	RTA	0	0	203		03-Jun-21	$0.00	$0.00	$0.00	
PROC1570	SRB Peer Review Complete (if required, see guide)	0	0	203		03-Jun-21	$0.00	$0.00	$0.00	
322658.30DP0.02 Solicitation Phase		22	22	203	04-Jun-21	06-Jul-21	$0.00	$0.00	$0.00	
PROC1600	Advertise Milestone	0	0	203	04-Jun-21		$0.00	$0.00	$0.00	
PROC1630	Bid Preparation Period	22	22	203	04-Jun-21	06-Jul-21	$0.00	$0.00	$0.00	
PROC1610	Conduct Site Visit (If Required)	1	1	219	11-Jun-21	11-Jun-21	$0.00	$0.00	$0.00	
PROC1650	Proposal Submission (Bid Opening)	0	0	203		06-Jul-21	$0.00	$0.00	$0.00	
322658.30DP0.03 Evaluation Phase		12	12	203	07-Jul-21	22-Jul-21	$0.00	$0.00	$0.00	
PROC2090	CT Prepare Abstract of Bids	1	1	203	07-Jul-21	07-Jul-21	$0.00	$0.00	$0.00	
PROC1870	Prepare Pre-Award Survey	5	5	203	08-Jul-21	14-Jul-21	$0.00	$0.00	$0.00	
PROC1880	Subcontracting Plan review and approval if required	6	6	203	15-Jul-21	22-Jul-21	$0.00	$0.00	$0.00	



DEI R DREDE MATERIAL, NEW JERSEY | 5/5 | Data Date: 01-Jul-19 | Print Date : 18-Jul-19

Activity ID	Activity Name	Original Duration	Remaining Duration	Total Float	Start	Finish	Remaining Total Cost	Actual Total Cost	At Completion Total Cost	CEFMS Work Item Code
322658.30DP0.04 Award Phase		25	25	203	23-Jul-21	26-Aug-21	$0.00	$0.00	$0.00	
PROC1920	Prep of Award Documents and Supporting Justifications and Determinations	5	5	203	23-Jul-21	29-Jul-21	$0.00	$0.00	$0.00	
PROC1925	Environmental Review (if required)	3	3	205	30-Jul-21	03-Aug-21	$0.00	$0.00	$0.00	
PROC1940	Compliance Review - Pre-Award	2	2	203	30-Jul-21	02-Aug-21	$0.00	$0.00	$0.00	
PROC1930	OC Review	3	3	203	03-Aug-21	05-Aug-21	$0.00	$0.00	$0.00	
PROC1950	Peer Review - Pre-Award	5	5	203	06-Aug-21	12-Aug-21	$0.00	$0.00	$0.00	
PROC1970	Small Business Advance Award Notification (if required)	5	5	203	13-Aug-21	19-Aug-21	$0.00	$0.00	$0.00	
PROC1980	Congressional Notification (if required)	5	5	203	20-Aug-21	26-Aug-21	$0.00	$0.00	$0.00	
PROC1995	Affirmative Action Letter (DOL)	1	1	203	26-Aug-21	26-Aug-21	$0.00	$0.00	$0.00	
PROC1990	Contract Award - Groin Construction	0	0	203		26-Aug-21	$0.00	$0.00	$0.00	
322658.30D00 Construction E&D		195	195	0	20-Jun-22	01-Apr-23	$0.00	$0.00	$0.00	
322658.30D00.30DV0 E&D During Construction		170	170	4	21-Jun-22	24-Feb-23	$0.00	$0.00	$0.00	
END6330	E&D During Construction	170	170	4	21-Jun-22	24-Feb-23	$0.00	$0.00	$0.00	
322658.30D00.30DS0 Construction - Contract A (Enter Contract Number)		285	285	0	20-Jun-22	01-Apr-23	$0.00	$0.00	$0.00	
CONS1010	Contract Award - Initial Nourishment	0	0	0		20-Jun-22	$0.00	$0.00	$0.00	
CONS1000	Budgeted Construction Contingency	250	250	0	21-Jun-22	25-Feb-23	$0.00	$0.00	$0.00	
CONS1020	Construction NTP Period	10	10	0	21-Jun-22	30-Jun-22	$0.00	$0.00	$0.00	
CONS1040	Construction NTP Acknowledged	0	0	0		30-Jun-22	$0.00	$0.00	$0.00	
CONS1030	Issue NTP	0	0	0		30-Jun-22	$0.00	$0.00	$0.00	
CONS1060	Contract - Federal Funding	240	240	0	01-Jul-22	25-Feb-23	$0.00	$0.00	$0.00	
CONS1070	Contract - NonFederal Funding	240	240	0	01-Jul-22	25-Feb-23	$0.00	$0.00	$0.00	
CONS1050	Construction Start	0	0	0	01-Jul-22		$0.00	$0.00	$0.00	
CONS1080	Construction Completion(substantial)	0	0	0		25-Feb-23	$0.00	$0.00	$0.00	
CONS1090	Contract Required Completion	0	0	5		25-Feb-23	$0.00	$0.00	$0.00	
CONS1100	Physical Completion	0	0	0		27-Mar-23	$0.00	$0.00	$0.00	
CONS1110	Eval Constr Contractor	5	5	0	28-Mar-23	01-Apr-23	$0.00	$0.00	$0.00	
CONS1130	Contract Fiscal Completion	0	0	0		01-Apr-23	$0.00	$0.00	$0.00	
CONS1140	Contract Transfer Document Date	0	0	0		01-Apr-23	$0.00	$0.00	$0.00	
CONS1120	Contractor Evaluation Date	0	0	0		01-Apr-23	$0.00	$0.00	$0.00	



U.S. Army Corps of Engineers
Project : 2018_DMU_NJ
New Jersey Beneficial Use of Dredged Material for the Delaware River

2018_DMU_NJ

Estimated by	
Designed by	
Prepared by	Luis Alfredo Montes
Preparation Date	7/30/2018
Effective Date of Pricing	7/30/2018
Estimated Construction Time	Days

Designed by

Estimated by

Prepared by
Luis Alfredo Montes

Design Document	
Document Date	7/30/2018
District	Philadelphia District
Contact	Luis Alfredo Montes
Budget Year	2018
UOM System	Original

Direct Costs

LaborCost
EQCost
MatlCost
SubBidCost

Timeline/Currency

Preparation Date	7/30/2018
Escalation Date	7/30/2018
Eff. Pricing Date	7/30/2018
Estimated Duration	0 Day(s)
Currency	US dollars
Exchange Rate	1.000000

Costbook CB15EngA: MII English Cost Book 2015 Rev A

Labor : NJ180050_CapeMay

Note: General Decision Number: NJ180050 07/13/2018 NJ50 State: New Jersey Construction Type: Heavy County: Cape May County in New Jersey.

Labor Rates

LaborCost1
LaborCost2
LaborCost3
LaborCost4

Equipment EP16R01: MII Equipment 2016 Region 01

01 NORTHEAST

Sales Tax	7.00
Working Hours per Year	1,360
Labor Adjustment Factor	1.16
Cost of Money	3.50
Cost of Money Discount	2.80
Tire Recap Cost Factor	1.50
Tire Recap Wear Factor	1.80
Tire Repair Factor	0.15
Equipment Cost Factor	1.00
Standby Depreciation Factor	0.50

Fuel

Electricity	0.143
Gas	2.930
Diesel Off-Road	2.923
Diesel On-Road	3.393

Shipping Rates

Over 0 CWT	17.43
Over 240 CWT	12.24
Over 300 CWT	9.98
Over 400 CWT	8.61
Over 500 CWT	7.45
Over 700 CWT	7.45
Over 800 CWT	10.71

Description	Quantity	UOM	ContractCost	Escalation	Contingency	SIOH	ProjectCost
Project Cost Summary Report			**94,362,641.20**	**0.00**	**0.00**	**0.00**	**94,362,641.20**
3 Sites to Buoy 10	**1.00**	**EA**	*94,362,641.20* **94,362,641.20**	**0.00**	**0.00**	**0.00**	*94,362,641.20* **94,362,641.20**
Contract No. 1, Gandys Groin - Aug 2021	**1.00**	**JOB**	*3,903,907.40* **3,903,907.40**	**0.00**	**0.00**	**0.00**	*3,903,907.40* **3,903,907.40**
10 Breakwater	**1.00**	**JOB**	*3,903,907.40* **3,903,907.40**	**0.00**	**0.00**	**0.00**	*3,903,907.40* **3,903,907.40**
Contract No. 2, Fortescue Groin - Aug 2021	**1.00**	**JOB**	*3,302,108.72* **3,302,108.72**	**0.00**	**0.00**	**0.00**	*3,302,108.72* **3,302,108.72**
10 Breakwater	**1.00**	**JOB**	*3,302,108.72* **3,302,108.72**	**0.00**	**0.00**	**0.00**	*3,302,108.72* **3,302,108.72**
Contract No. 3, Dredging and Beachfill, Gandys & Fortescue - Aug 2022	**1.00**	**JOB**	*36,153,979.05* **36,153,979.05**	**0.00**	**0.00**	**0.00**	*36,153,979.05* **36,153,979.05**
09 Channels & Canals	**1.00**	**JOB**	*3,823,030.45* **3,823,030.45**	**0.00**	**0.00**	**0.00**	*3,823,030.45* **3,823,030.45**
17 Beach Replenishment	**1.00**	**JOB**	*32,329,528.72* **32,329,528.72**	**0.00**	**0.00**	**0.00**	*32,329,528.72* **32,329,528.72**
Variance due to rounding to the penny	**1.00**	**EA**	*1,419.87* **1,419.87**	**0.00**	**0.00**	**0.00**	*1,419.87* **1,419.87**
Contract No. 4, Villas, South - Aug 2028	**1.00**	**JOB**	*51,002,646.03* **51,002,646.03**	**0.00**	**0.00**	**0.00**	*51,002,646.03* **51,002,646.03**
09 Channels & Canals	**1.00**	**JOB**	*2,716,447.44* **2,716,447.44**	**0.00**	**0.00**	**0.00**	*2,716,447.44* **2,716,447.44**
17 Beach Replenishment	**1.00**	**JOB**	*48,287,490.31* **48,287,490.31**	**0.00**	**0.00**	**0.00**	*48,287,490.31* **48,287,490.31**
Variance due to rounding to the penny	**1.00**	**EA**	*1,291.71-* **1,291.71-**	**0.00**	**0.00**	**0.00**	*1,291.71-* **1,291.71-**

U.S. Army Corps of Engineers
Project : 2018_DMU_NJ_Periodic Nourishment
New Jersey Beneficial Use of Dredged Material for the Delaware River

2018_DMU_NJ_Periodic Nourishment

Estimated by
Designed by
Prepared by Luis Alfredo Montes

Preparation Date 8/17/2018
Effective Date of Pricing 8/17/2018
Estimated Construction Time Days

Designed by

Estimated by

Prepared by
Luis Alfredo Montes

Design Document	
Document Date	8/17/2018
District	Philadelphia District
Contact	Luis Alfredo Montes
Budget Year	2018
UOM System	Original

Direct Costs
LaborCost
EQCost
MatlCost
SubBidCost

Timeline/Currency

Preparation Date	8/17/2018
Escalation Date	8/17/2018
Eff. Pricing Date	8/17/2018
Estimated Duration	0 Day(s)
Currency	US dollars
Exchange Rate	1.000000

Costbook CB15EngA: MII English Cost Book 2015 Rev A

Labor : NJ180001_CapeMay
Note: General Decision Number: NJ180001 07/13/2018 NJ01 State: New Jersey Construction Type: Heavy County: Cape May County in New Jersey.

Labor Rates
LaborCost1
LaborCost2
LaborCost3
LaborCost4

Equipment EP16R01: MII Equipment 2016 Region 01

01 NORTHEAST

Sales Tax	7.00
Working Hours per Year	1,360
Labor Adjustment Factor	1.16
Cost of Money	3.50
Cost of Money Discount	2.80
Tire Recap Cost Factor	1.50
Tire Recap Wear Factor	1.80
Tire Repair Factor	0.15
Equipment Cost Factor	1.00
Standby Depreciation Factor	0.50

Fuel

Electricity	0.143
Gas	2.930
Diesel Off-Road	2.923
Diesel On-Road	3.393

Shipping Rates

Over 0 CWT	17.43
Over 240 CWT	12.24
Over 300 CWT	9.98
Over 400 CWT	8.61
Over 500 CWT	7.45
Over 700 CWT	7.45
Over 800 CWT	10.71

Description	Quantity	UOM	ContractCost	Escalation	Contingency	SIOH	ProjectCost
Project Cost Summary Report			**39,873,035.45**	**0.00**	**0.00**	**0.00**	**39,873,035.45**
			21,579,692.74				*21,579,692.74*
09 Channels and Canals	**1.00**	**JOB**	**21,579,692.74**	**0.00**	**0.00**	**0.00**	**21,579,692.74**
			21,579,692.74				*21,579,692.74*
09 Periodic Maintenance - Large Hopper Dredge	**1.00**	**JOB**	**21,579,692.74**	**0.00**	**0.00**	**0.00**	**21,579,692.74**
			3,007,642.74				*3,007,642.74*
09.01 Mobilization and Demobilization	**1.00**	**JOB**	**3,007,642.74**	**0.00**	**0.00**	**0.00**	**3,007,642.74**
			18,570,655.52				*18,570,655.52*
09.02 Dredging, Artificial Island	**1.00**	**JOB**	**18,570,655.52**	**0.00**	**0.00**	**0.00**	**18,570,655.52**
			1,394.48				*1,394.48*
Variance due to rounding to the penny	**1.00**	**EA**	**1,394.48**	**0.00**	**0.00**	**0.00**	**1,394.48**
			18,293,342.71				*18,293,342.71*
17 Beach Replenishment	**1.00**	**JOB**	**18,293,342.71**	**0.00**	**0.00**	**0.00**	**18,293,342.71**
			18,293,342.71				*18,293,342.71*
17 Periodic Nourishment & Artificial Island	**1.00**	**JOB**	**18,293,342.71**	**0.00**	**0.00**	**0.00**	**18,293,342.71**
			8,274,406.71				*8,274,406.71*
17.01 Mobilization and Demobilization	**1.00**	**JOB**	**8,274,406.71**	**0.00**	**0.00**	**0.00**	**8,274,406.71**
			10,018,829.82				*10,018,829.82*
17.02 Dredging and Beachfill, Dredge	**1.00**	**JOB**	**10,018,829.82**	**0.00**	**0.00**	**0.00**	**10,018,829.82**
			106.17				*106.17*
Variance due to rounding to the penny	**1.00**	**EA**	**106.17**	**0.00**	**0.00**	**0.00**	**106.17**

U.S. Army Corps of Engineers
Project : 2018_DMU_NJ_Periodic Nourishment
New Jersey Beneficial Use of Dredged Material for the Delaware River

2018_DMU_NJ_Periodic Nourishment

Estimated by	
Designed by	
Prepared by	Luis Alfredo Montes
Preparation Date	8/17/2018
Effective Date of Pricing	8/17/2018
Estimated Construction Time	Days

Designed by

Estimated by

Prepared by
Luis Alfredo Montes

Design Document	
Document Date	8/17/2018
District	Philadelphia District
Contact	Luis Alfredo Montes
Budget Year	2018
UOM System	Original

Direct Costs
LaborCost
EQCost
MatlCost
SubBidCost

Timeline/Currency

Preparation Date	8/17/2018
Escalation Date	8/17/2018
Eff. Pricing Date	8/17/2018
Estimated Duration	0 Day(s)
Currency	US dollars
Exchange Rate	1.000000

Costbook CB15EngA: MII English Cost Book 2015 Rev A

Labor : NJ180001_CapeMay
Note: General Decision Number: NJ180001 07/13/2018 NJ01 State: New Jersey Construction Type: Heavy County: Cape May County in New Jersey.

Labor Rates
LaborCost1
LaborCost2
LaborCost3
LaborCost4

Equipment EP16R01: MII Equipment 2016 Region 01

01 NORTHEAST

Sales Tax	7.00
Working Hours per Year	1,360
Labor Adjustment Factor	1.16
Cost of Money	3.50
Cost of Money Discount	2.80
Tire Recap Cost Factor	1.50
Tire Recap Wear Factor	1.80
Tire Repair Factor	0.15
Equipment Cost Factor	1.00
Standby Depreciation Factor	0.50

Fuel

Electricity	0.143
Gas	2.930
Diesel Off-Road	2.923
Diesel On-Road	3.393

Shipping Rates

Over 0 CWT	17.43
Over 240 CWT	12.24
Over 300 CWT	9.98
Over 400 CWT	8.61
Over 500 CWT	7.45
Over 700 CWT	7.45
Over 800 CWT	10.71

Description	Quantity	UOM	ContractCost	Escalation	Contingency	SIOH	ProjectCost
Project Cost Summary Report			**43,732,777.91**	**0.00**	**0.00**	**0.00**	**43,732,777.91**
			16,255,212.55				*16,255,212.55*
09 Channels and Canals, Federal Standard	**1.00**	**JOB**	**16,255,212.55**	**0.00**	**0.00**	**0.00**	**16,255,212.55**
			16,255,212.55				*16,255,212.55*
09 Maintenance & Buoy 10 - Medium Hopper Dredge	**1.00**	**JOB**	**16,255,212.55**	**0.00**	**0.00**	**0.00**	**16,255,212.55**
			1,942,512.55				*1,942,512.55*
09.01 Mobilization and Demobilization	**1.00**	**JOB**	**1,942,512.55**	**0.00**	**0.00**	**0.00**	**1,942,512.55**
			14,313,325.18				*14,313,325.18*
09.17 Dredging, Bottom Dump Buoy 10	**1.00**	**JOB**	**14,313,325.18**	**0.00**	**0.00**	**0.00**	**14,313,325.18**
			625.18-				*625.18-*
Variance due to rounding to the penny	**1.00**	**EA**	**625.18-**	**0.00**	**0.00**	**0.00**	**625.18-**
			27,477,565.36				*27,477,565.36*
09 Channels and Canals, Federal Standard, Year 2034	**1.00**	**JOB**	**27,477,565.36**	**0.00**	**0.00**	**0.00**	**27,477,565.36**
			27,477,565.36				*27,477,565.36*
Maintenance & Artificial Island - Large Hopper Dredge	**1.00**	**JOB**	**27,477,565.36**	**0.00**	**0.00**	**0.00**	**27,477,565.36**
			3,018,565.36				*3,018,565.36*
09.01 Mobilization and Demobilization	**1.00**	**JOB**	**3,018,565.36**	**0.00**	**0.00**	**0.00**	**3,018,565.36**
			24,462,831.53				*24,462,831.53*
09.17 Dredging, Artificial Island CDF	**1.00**	**JOB**	**24,462,831.53**	**0.00**	**0.00**	**0.00**	**24,462,831.53**
			3,831.53-				*3,831.53-*
Variance due to rounding to the penny	**1.00**	**EA**	**3,831.53-**	**0.00**	**0.00**	**0.00**	**3,831.53-**

Appendix C4 – Geotechnical Summary

A desktop study was conducted to compile available information from prior efforts to characterize subsurface conditions along the Delaware River and potential placement sites. Appendix C4 Geotechnical Data has been limited to that data directly applicable to the selected alternatives of the feasibility study. Refer to feasibility report, Section 10 (References) for a further list of references. No geotechnical field investigations were performed as part of the study.

The ongoing Delaware River Deepening Project is deepening the approximately 100-mile-long main navigation channel from 40 feet MLLW to 45 feet MLLW. New work dredging has been performed incrementally since 2010 and is anticipated to be completed in 2020. To date, Philadelphia District Operations Division has been maintaining only the original 40-foot MLLW channel depth; maintenance of the 45-foot MLLW channel will not begin until the final reach of new work dredging to 45-feet MLLW has been completed. There is no data available to directly characterize 45-foot channel maintenance dredging material, as such dredging has not occurred to date.

Following screening of potential alternatives, only three (3) potential New Jersey placement sites remained for dredged material utilization: Gandys Beach, Fortescue, and Villas (South). Dredged material utilization would essentially consist of placing maintenance dredging material as beachfill at these sites. To date, two very similar projects placing sandy material dredged from the Delaware River main navigation channel have been successfully completed for CSRM. The first was constructed at Oakwood Beach, New Jersey in 2014 (see feasibility report Section 2.4.3 Existing Coastal Storm Risk Management). A second larger project was constructed across the bay at Broadkill Beach, Delaware during 2015-2016 (see feasibility report Section 3.4.2 Southern Reach Alternative Evaluation and Comparison).

Proposed beachfill material for Gandys Beach, Fortescue, and Villas (South) would be maintenance dredging material from the deepened navigation channel. Decades of maintenance dredging in the lower Delaware River and Bay have found the material in these reaches to be consistently granular. Navigation channel shoals generally match the existing channel bottom materials. Most of the dredged material from the lower reaches has been placed at the Buoy 10 open water disposal site near the mouth of Delaware Bay or brought north to the Artificial Island CDF (see feasibility report, Figure 16 for a map of these sites). Buoy 10 represents a good analog for future maintenance dredging material and could potentially be used directly as a beachfill source. Logs of seven (7) vibracores collected from within the boundaries of Buoy 10 and results of associated grain-size analyses are provided in Appendix C4. In 2012-2013, a geotechnical investigation consisting of 51 vibracores and associated laboratory testing was completed by Gahagan & Bryant Associates, Inc. to characterize the future new work dredged material in Reach E. This reach of the navigation channel is in proximity to the proposed beachfill sites and is their most likely source for material. An analysis of associated grain-size data from this investigation is provided in the Appendix C4. The findings of these two data sources are in close agreement with one another.

In-situ grain sizes for Gandys Beach, Fortescue, and Villas (South) were estimated from past field investigation findings. An analysis of associated grain-size data for each respective beach is included in Appendix C4 Geotechnical Data. Note that each of these site has been subject to long-term erosion and prior restoration efforts. As such, the grain size findings are not indicative of natural material and would be expected to vary widely based on sampling locations and dates.

Buoy 10 Vibracore Logs

Schnabel Engineering

TEST BORING LOG

Project:	VIBRATIONAL CORING AREAS A AND C CAPE MAY VILLAS, NEW JERSEY
Boring Number:	NJV-765
Contract Number:	04151127.16
Sheet:	1 of 1

Boring Contractor: ALPINE OCEAN SEISMIC SURVEY
NORWOOD, NEW JERSEY

Boring Foreman: N. CUPIC

Drilling Method: VIBRACORE

Drilling Equipment: 271B PNEUMATIC VIBRACORE

Schnabel Representative: M. PENZONE

Dates Started: 6/10/07 **Finished:** 6/10/07

Location: 42243.77 N; 325886.26 E

Ground Surface Elevation: -33.5± (feet)

Groundwater Observations

	Date	Time	Depth	Casing	Caved
Raw (See Note 2)	6/10	---	35.5'	N/A	N/A
Corrected	6/10	---	33.5'	N/A	N/A

DEPTH (FT)	STRATA DESCRIPTION	CLASS.	ELEV. (FT)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	POORLY GRADED SAND, CONTAINS SHELL FRAGMENTS - BROWN GRAY	SP					S-1 SIEVE	(0.0 to 5.0 ft)
5.0	POORLY GRADED SAND, CONTAINS SHELL FRAGMENTS - BROWN GRAY 4" GRAVEL LAYER	SP	-38.5		5		S-2 SIEVE	(5.0 to 10.0 ft)
10.0	POORLY GRADED SAND WITH GRAVEL - BROWN	SP	-43.5		10		S-3 SIEVE	(10.0 to 11.6 ft)
11.6	POORLY GRADED SAND - GRAY	SP	-45.1				S-4 SIEVE	(11.6 to 15.0 ft)
15.0	POORLY GRADED SAND WITH SILT - DARK GRAY	SP-SM	-48.5		15		S-5 SIEVE	(15.0 to 16.1 ft) Recovery = 81%
16.1	BOTTOM OF BORING @ 16.1 FT.		-49.6					

Comments:

1. VISUAL DESCRIPTIONS WERE MADE DURING CORE OPENING PROCEDURES BY ASTM D2487 AND CLASSICATION BY ASTM D422.
2. FOR DEPTH TO MUDLINE NOMENCLATURE, REFER TO THE GENERAL NOTES.
3. NORTHING & EASTINGS REFERENCE NAD83, NJ STATE PLANE COORDINATE SYSTEM.
4. ELEVATIONS REFERENCE NAVD88 DATUM.

Schnabel Schnabel Engineering

TEST BORING LOG

Project: VIBRATIONAL CORING AREAS A AND C CAPE MAY VILLAS, NEW JERSEY

Boring Number: NJV-766

Contract Number: 04151127.16

Sheet: 1 of 1

Boring Contractor: ALPINE OCEAN SEISMIC SURVEY NORWOOD, NEW JERSEY

Boring Foreman: N. CUPIC

Drilling Method: VIBRACORE

Drilling Equipment: 271B PNEUMATIC VIBRACORE

Schnabel Representative: M. PENZONE

Dates Started: 6/10/07 **Finished:** 6/10/07

Location: 41883.15 N; 325434.48 E

Ground Surface Elevation: -27.3± (feet)

Groundwater Observations

	Date	Time	Depth	Casing	Caved
Raw (See Note 2)	6/10	---	27.5'	N/A	N/A
Corrected	6/10	---	27.3'	N/A	N/A

DEPTH (FT)	STRATA DESCRIPTION	CLASS.	ELEV. (FT)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	POORLY GRADED SAND, CONTAINS SHELL FRAGMENTS - TAN	SP					S-1 SIEVE	(0.0 to 5.0 ft)
5.0	POORLY GRADED SAND, CONTAINS SHELL FRAGMENTS - TAN	SP	-32.3		5		S-2 SIEVE	(5.0 to 7.7 ft)
7.7	POORLY GRADED GRAVEL WITH SAND, CONTAINS SHELL FRAGMENTS - TAN GRAY	GP	-35.0				S-3 SIEVE	(7.7 to 10.0 ft)
10.0	POORLY GRADED GRAVEL WITH SAND, CONTAINS SHELL FRAGMENTS - TAN GRAY	GP	-37.3		10		S-4 SIEVE	(10.0 to 11.3 ft)
11.3	POORLY GRADED SAND, CONTAINS SHELL FRAGMENTS - GRAY BROWN	SP	-38.6				S-5 SIEVE	(11.3 to 15.0 ft)
15.0	POORLY GRADED SAND WITH GRAVEL - DARK GRAY BROWN	SP	-42.3		15		S-6 SIEVE	(15.0 to 16.8 ft)
16.8	BOTTOM OF BORING @ 16.8 FT.		-44.1					Recovery = 84%

Comments:

1. VISUAL DESCRIPTIONS WERE MADE DURING CORE OPENING PROCEDURES BY ASTM D2487 AND CLASSICATION BY ASTM D422.
2. FOR DEPTH TO MUDLINE NOMENCLATURE, REFER TO THE GENERAL NOTES.
3. NORTHING & EASTINGS REFERENCE NAD83, NJ STATE PLANE COORDINATE SYSTEM.
4. ELEVATIONS REFERENCE NAVD88 DATUM.

Schnabel Engineering — **TEST BORING LOG**

Project: VIBRATIONAL CORING
AREAS A AND C
CAPE MAY VILLAS, NEW JERSEY

Boring Number: NJV-767
Contract Number: 04151127.16
Sheet: 1 of 1

Boring Contractor: ALPINE OCEAN SEISMIC SURVEY, NORWOOD, NEW JERSEY
Boring Foreman: N. CUPIC
Drilling Method: VIBRACORE
Drilling Equipment: 271B PNEUMATIC VIBRACORE
Schnabel Representative: M. PENZONE
Dates Started: 6/10/07 **Finished:** 6/10/07
Location: 41445.53 N; 325761.66 E

Ground Surface Elevation: -28.5± (feet)

Groundwater Observations

	Date	Time	Depth	Casing	Caved
Raw (See Note 2)	6/10	---	29.0'	N/A	N/A
Corrected	6/10	---	28.5'	N/A	N/A

DEPTH (FT)	STRATA DESCRIPTION	CLASS.	ELEV. (FT)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	POORLY GRADED SAND, CONTAINS SHELL FRAGMENTS - TAN	SP					S-1 SIEVE	(0.0 to 3.8 ft)
3.8	POORLY GRADED SAND WITH GRAVEL, CONTAINS SHELL FRAGMENTS - TAN GRAY	SP	-32.3				S-2 SIEVE	(3.8 to 5.0 ft)
5.0	POORLY GRADED SAND WITH SILT AND GRAVEL, CONTAINS SHELL FRAGMENTS - TAN GRAY	SP-SM	-33.5		5		S-3 SIEVE	(5.0 to 7.5 ft)
7.5	POORLY GRADED SAND WITH SILT - GRAY BROWN	SP-SM	-36.0				S-4 SIEVE	(7.5 to 10.0 ft)
10.0	POORLY GRADED SAND WITH GRAVEL - GRAY BROWN	SP	-38.5		10		S-5 SIEVE	(10.0 to 15.0 ft)
15.0	POORLY GRADED SAND - GRAY BROWN	SP	-43.5		15		S-6 SIEVE	(15.0 to 16.8 ft)
16.8	BOTTOM OF BORING @ 16.8 FT.		-45.3					Recovery = 84%

Comments:
1. VISUAL DESCRIPTIONS WERE MADE DURING CORE OPENING PROCEDURES BY ASTM D2487 AND CLASSICATION BY ASTM D422.
2. FOR DEPTH TO MUDLINE NOMENCLATURE, REFER TO THE GENERAL NOTES.
3. NORTHING & EASTINGS REFERENCE NAD83, NJ STATE PLANE COORDINATE SYSTEM.
4. ELEVATIONS REFERENCE NAVD88 DATUM.

TEST BORING LOG 04151127.16_NJ_CAPEMAY_VILLAS.GPJ SCHNABEL.GDT 9/13/07

DRILLING LOG	DIVISION North Atlantic	INSTALLATION Philadelphia District	SHEET 1 OF 1 SHEETS

1. PROJECT Bouy 10, Delaware Bay	9. COORDINATE SYSTEM State Plane - New Jersey; HORIZONTAL NAD 83; VERTICAL NAVD88
	10. SIZE AND TYPE OF BIT Alpine 4"
2. HOLE NUMBER NJV-906; LOCATION COORDINATES N 42138.6 E 326200.6	11. MANUFACTURER'S DESIGNATION OF DRILL Hydraulic Vib Driver
3. DRILLING AGENCY WILMINGTON DISTRICT	12. TOTAL SAMPLES; DISTURBED 5; UNDISTURBED 0
4. NAME OF DRILLER Lester Gaughf	13. TOTAL NUMBER CORE BOXES 0
5. DIRECTION OF BORING ☒ VERTICAL ☐ INCLINED; DEG FROM VERTICAL ---; BEARING	14. ELEVATION GROUND WATER See Remarks
	15. DATE BORING STARTED 8/31/14; COMPLETED 8/31/14
6. THICKNESS OF OVERBURDEN >	16. ELEVATION TOP OF BORING -20'
7. DEPTH DRILLED INTO ROCK	17. TOTAL CORE RECOVERY FOR BORING N/A
8. TOTAL DEPTH OF BORING 13.75'	18. SIGNATURE AND TITLE OF INSPECTOR

ELEV	DEPTH	LEGEND	FIELD CLASSIFICATION OF MATERIALS (Description)	BOX OR SAMPLE NO. f	REMARKS
	0.0		SAND (SP), gray, fine to medium grained.	S-1	USCS Gravel = 1; Sand = 97; Fines = 2; SP
	5.0			S-2	Gravel = 2; Sand = 94; Fines = 4; SP
-28.5				S-3	Gravel = 1; Sand = 99; Fines = 0; SP
-29.5			GRAVEL (GP), fine grained, some sand, 2" clay lense at 8.5'.	S-4	Gravel = 29; Sand = 59; Fines = 1; SP
-33.8	10.0		SAND (SP), gray, fine to medium grained.	S-4	Gravel = 3; Sand = 96; Fines = 1; SP

BOTTOM OF BOREHOLE AT 13.8 ft

DRILLING LOG	DIVISION: North Atlantic	INSTALLATION: Philadelphia District	SHEET 1 OF 1 SHEETS

1. PROJECT: Bouy 10, Delaware Bay	9. COORDINATE SYSTEM: State Plane - New Jersey; HORIZONTAL: NAD 83; VERTICAL: NAVD88
	10. SIZE AND TYPE OF BIT: Alpine 4"
2. HOLE NUMBER: NJV-907; LOCATION COORDINATES: N 42064.8 E 325401.5	11. MANUFACTURER'S DESIGNATION OF DRILL: Hydraulic Vib Driver
3. DRILLING AGENCY: WILMINGTON DISTRICT	12. TOTAL SAMPLES: DISTURBED 4; UNDISTURBED 0
4. NAME OF DRILLER: Lester Gaughf	13. TOTAL NUMBER CORE BOXES: 0
5. DIRECTION OF BORING: ☒ VERTICAL ☐ INCLINED; DEG FROM VERTICAL: ---; BEARING:	14. ELEVATION GROUND WATER: See Remarks
	15. DATE BORING: STARTED 8/31/14; COMPLETED 8/31/14
6. THICKNESS OF OVERBURDEN: >	16. ELEVATION TOP OF BORING: -20'
7. DEPTH DRILLED INTO ROCK:	17. TOTAL CORE RECOVERY FOR BORING: N/A
8. TOTAL DEPTH OF BORING: 16.5'	18. SIGNATURE AND TITLE OF INSPECTOR:

ELEV	DEPTH	LEGEND	FIELD CLASSIFICATION OF MATERIALS (Description)	BOX OR SAMPLE NO. f	REMARKS
	0.0		SAND (SP), brownish gray, fine to medium grained, trace gravel, and shell fragments.	S-1	USCS Gravel = 0; Sand = 99; Fines = 1; SP
	5.0			S-2	Gravel = 0; Sand = 100; Fines = 0; SP
-29.0	10.0		SAND (SP-SC), gray, medium grained, with some clay.	S-3	Gravel = 1; Sand = 93; Fines = 6
-32.5	15.0		SAND (SP), gray, medium grained.	S-4	Gravel = 2; Sand = 98; Fines = 1; SP
-36.5					

BOTTOM OF BOREHOLE AT 16.5 ft

DRILLING LOG	DIVISION North Atlantic	INSTALLATION Philadelphia District	SHEET 1 OF 1 SHEETS

1. PROJECT Bouy 10, Delaware Bay	9. COORDINATE SYSTEM State Plane - New Jersey; HORIZONTAL NAD 83; VERTICAL NAVD88
	10. SIZE AND TYPE OF BIT Alpine 4"
2. HOLE NUMBER NJV-908; LOCATION COORDINATES N 41547.5 E 325625.7	11. MANUFACTURER'S DESIGNATION OF DRILL Hydraulic Vib Driver
3. DRILLING AGENCY WILMINGTON DISTRICT	12. TOTAL SAMPLES; DISTURBED 5; UNDISTURBED 0
4. NAME OF DRILLER Lester Gaughf	13. TOTAL NUMBER CORE BOXES 0
5. DIRECTION OF BORING ☒ VERTICAL ☐ INCLINED; DEG FROM VERTICAL ---; BEARING	14. ELEVATION GROUND WATER See Remarks
	15. DATE BORING STARTED 8/31/14; COMPLETED 8/31/14
6. THICKNESS OF OVERBURDEN >	16. ELEVATION TOP OF BORING -19.8'
7. DEPTH DRILLED INTO ROCK	17. TOTAL CORE RECOVERY FOR BORING N/A
8. TOTAL DEPTH OF BORING 13.75'	18. SIGNATURE AND TITLE OF INSPECTOR

ELEV	DEPTH	LEGEND	FIELD CLASSIFICATION OF MATERIALS (Description)	BOX OR SAMPLE NO. f	REMARKS
	0.0		SAND (SP), gray, medium to coarse grained, trace gravel.	S-1	USCS Gravel = 1; Sand = 98; Fines = 0; SP
-22.8			SANDY GRAVEL (GP), light gray.	S-2	Gravel = 25; Sand = 75; Fines = 1; SP
-24.3	5.0		SAND (SP), dark gray, medium grained, some gravel.	S-3	Gravel = 8; Sand = 91; Fines = 1; SP
-26.6			SAND (SP), dark gray, fine to medium grained, trace organics, 2" dark gray organic silt lense at 11'.	S-4	Gravel = 2; Sand = 93; Fines = 4; SP
-29.6	10.0		GRAVELLY SAND (SP), dark gray.	S-5	Gravel = 27; Sand = 72; Fines = 1; SP
-33.6					

BOTTOM OF BOREHOLE AT 13.8 ft

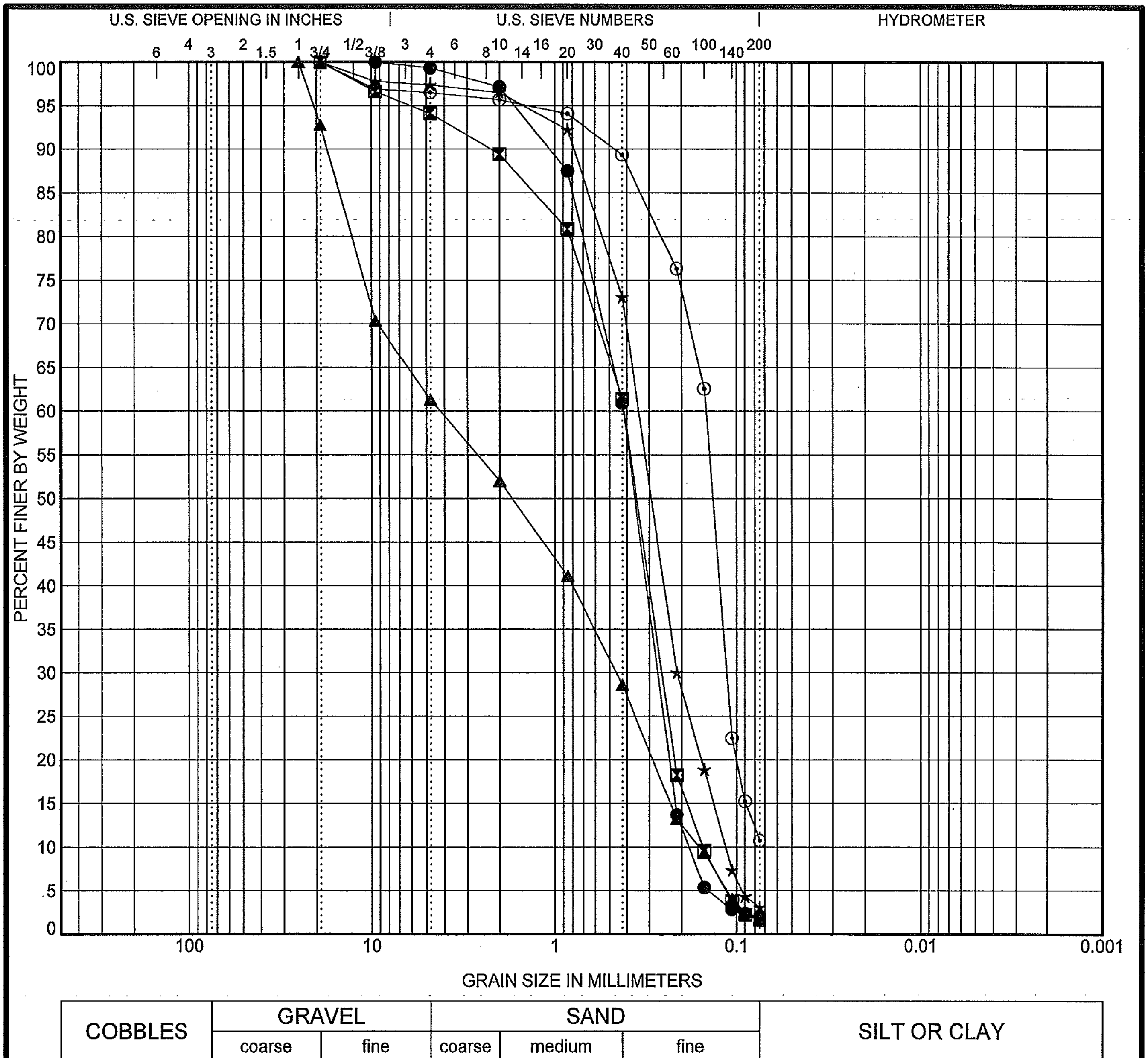
DRILLING LOG	DIVISION: North Atlantic	INSTALLATION: Philadelphia District	SHEET 1 OF 1 SHEETS

1. PROJECT: Bouy 10, Delaware Bay	9. COORDINATE SYSTEM: State Plane - New Jersey; HORIZONTAL: NAD 83; VERTICAL: NAVD88
	10. SIZE AND TYPE OF BIT: Alpine 4"
2. HOLE NUMBER: NJV-909; LOCATION COORDINATES: N 41713.6 E 326214.5	11. MANUFACTURER'S DESIGNATION OF DRILL: Hydraulic Vib Driver
3. DRILLING AGENCY: WILMINGTON DISTRICT	12. TOTAL SAMPLES: DISTURBED 4; UNDISTURBED 0
4. NAME OF DRILLER: Lester Gaughf	13. TOTAL NUMBER CORE BOXES: 0
5. DIRECTION OF BORING: ☒ VERTICAL ☐ INCLINED; DEG FROM VERTICAL: ---; BEARING:	14. ELEVATION GROUND WATER: See Remarks
	15. DATE BORING: STARTED 8/31/14; COMPLETED 8/31/14
6. THICKNESS OF OVERBURDEN: >	16. ELEVATION TOP OF BORING: -12'
7. DEPTH DRILLED INTO ROCK:	17. TOTAL CORE RECOVERY FOR BORING: N/A
8. TOTAL DEPTH OF BORING: 13.75'	18. SIGNATURE AND TITLE OF INSPECTOR:

ELEV	DEPTH	LEGEND	FIELD CLASSIFICATION OF MATERIALS (Description)	BOX OR SAMPLE NO.	REMARKS
	0.0		SAND (SP), gray, fine to medium grained, trace gravel.	S-1	USCS Gravel = 1; Sand = 99; Fines = 0; SP
	5.0			S-2	Gravel = 2; Sand = 98; Fines = 0; SP
				S-3	Gravel = 1; Sand = 98; Fines = 1; SP
	10.0			S-4	Gravel = 4; Sand = 95; Fines = 1; SP
-25.8					

BOTTOM OF BOREHOLE AT 13.8 ft

Buoy 10 Laboratory Test Results



Specimen		Classification	LL	PL	PI	Cc	Cu
●	NJV-765 0.0 ft	**Poorly graded SAND, contains shell fragments - brown gray (SP)**				**0.95**	**2.30**
⊠	NJV-765 5.0 ft	**Poorly graded SAND, contains shell fragments - brown gray (SP)**				**1.04**	**2.72**
▲	NJV-765 10.0 ft	**Poorly graded SAND with gravel - brown (SP)**				**0.32**	**26.38**
★	NJV-765 11.6 ft	**Poorly graded SAND - gray (SP)**				**1.14**	**3.00**
⊙	NJV-765 15.0 ft	**Poorly graded SAND with silt - dark gray (SP-SM)**				**1.20**	**2.02**

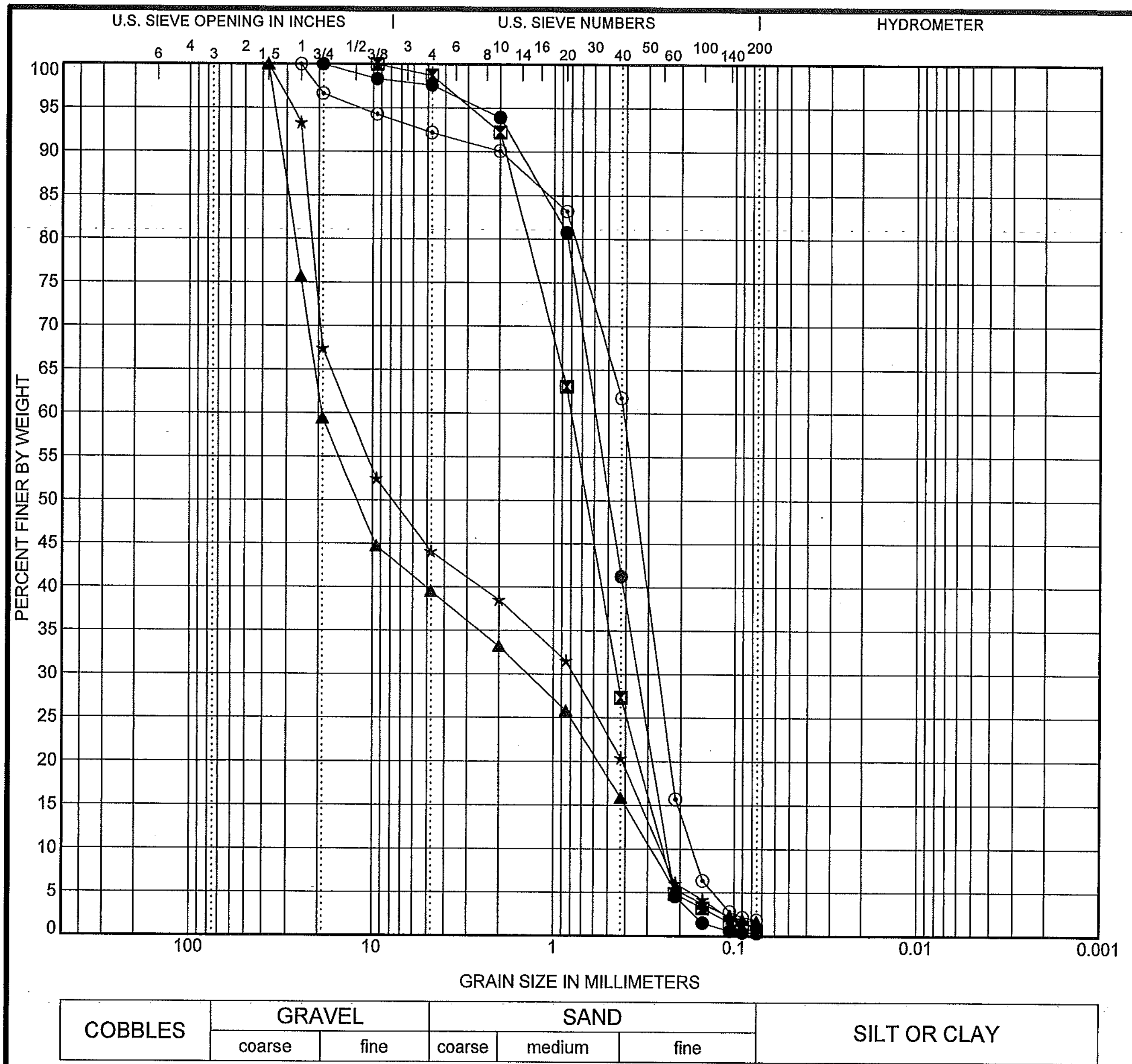
Specimen		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	NJV-765 0.0 ft	9.5	0.419	0.27	0.182	0.7	97.2	2.1	
⊠	NJV-765 5.0 ft	19	0.415	0.256	0.153	5.9	92.5	1.6	
▲	NJV-765 10.0 ft	25	4.205	0.46	0.159	38.7	59.7	1.6	
★	NJV-765 11.6 ft	19	0.344	0.212	0.115	2.6	94.3	3.1	
⊙	NJV-765 15.0 ft	19	0.147	0.113		3.5	85.8	10.7	

Schnabel Engineering

GRADATION CURVES

Project: VIBRATIONAL CORING
AREAS A AND C
CAPE MAY VILLAS, NEW JERSEY

Contract: 04151127.16



	Specimen		Classification	LL	PL	PI	Cc	Cu
●	**NJV-766**	**0.0 ft**	**Poorly graded SAND, contains shell fragments - tan (SP)**				**0.85**	**2.51**
⊠	**NJV-766**	**5.0 ft**	**Poorly graded SAND, contains shell fragments - tan (SP)**				**1.01**	**3.22**
▲	**NJV-766**	**7.7 ft**	**Poorly graded GRAVEL with sand, contains shell fragments - tan gray (GP)**				**0.35**	**66.49**
★	**NJV-766**	**10.0 ft**	**Poorly graded GRAVEL with sand, contains shell fragments - tan gray (GP)**				**0.17**	**52.45**
⊙	**NJV-766**	**11.3 ft**	**Poorly graded SAND, contains shell fragments - gray brown (SP)**				**0.97**	**2.41**

	Specimen		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**NJV-766**	**0.0 ft**	**19**	**0.59**	**0.343**	**0.235**	**2.4**	**97.3**	**0.3**	
⊠	**NJV-766**	**5.0 ft**	**9.5**	**0.801**	**0.448**	**0.249**	**1.3**	**98.1**	**0.6**	
▲	**NJV-766**	**7.7 ft**	**37.5**	**19.176**	**1.384**	**0.288**	**60.5**	**37.8**	**1.7**	
★	**NJV-766**	**10.0 ft**	**37.5**	**13.463**	**0.773**	**0.257**	**55.9**	**43.0**	**1.1**	
⊙	**NJV-766**	**11.3 ft**	**25**	**0.414**	**0.263**	**0.172**	**7.9**	**90.3**	**1.9**	

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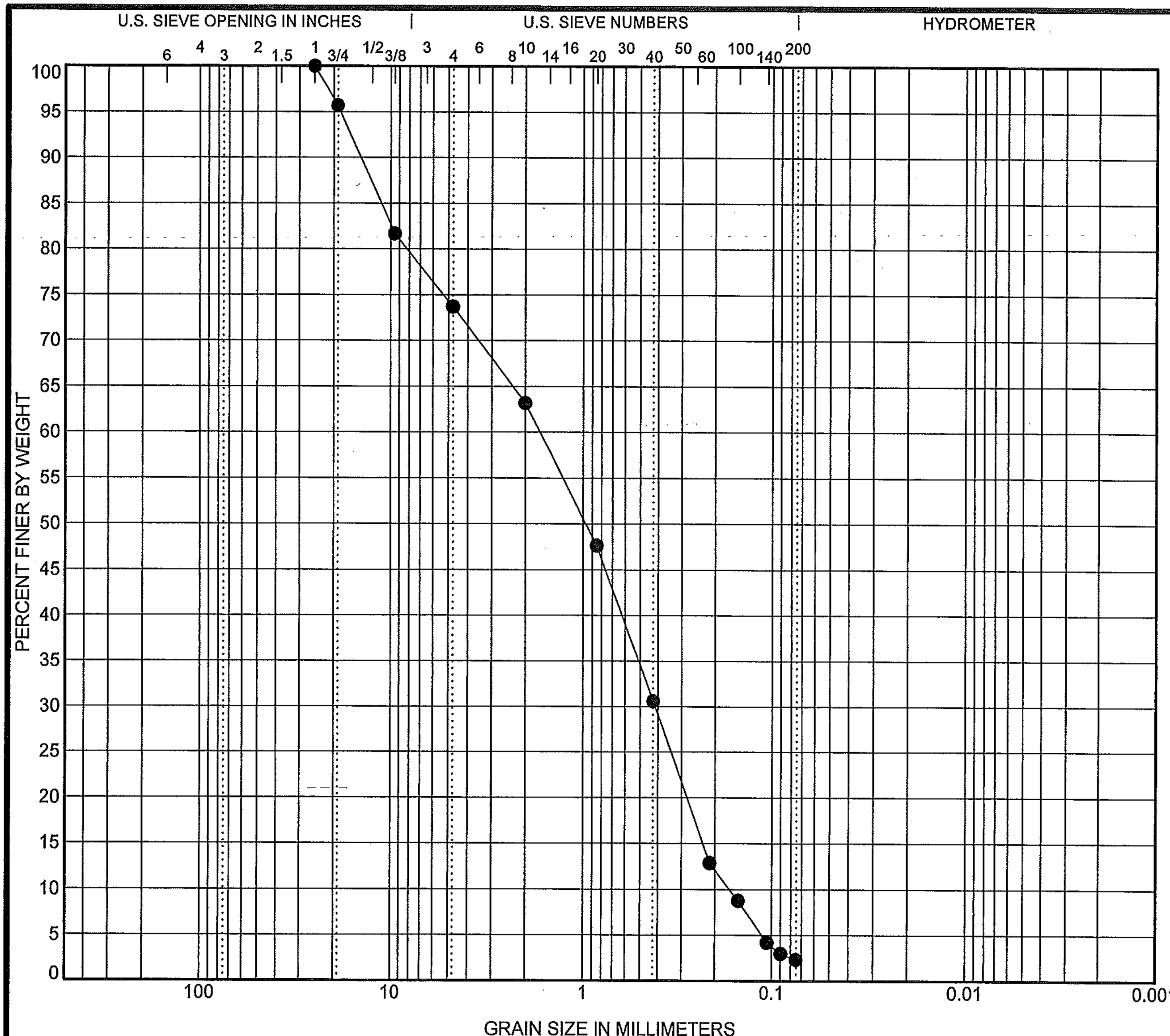
GRADATION CURVES

Project: VIBRATIONAL CORING
AREAS A AND C
CAPE MAY VILLAS, NEW JERSEY
Contract: 04151127.16



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen	Classification	LL	PL	PI	Cc	Cu
●	NJV-766 15.0 ft	**Poorly graded SAND with gravel - dark gray brown (SP)**				**0.62**	**10.09**

	Specimen	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	NJV-766 15.0 ft	**25**	**1.678**	**0.415**	**0.166**	**26.3**	**71.4**	**2.3**	

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GRADATION CURVES

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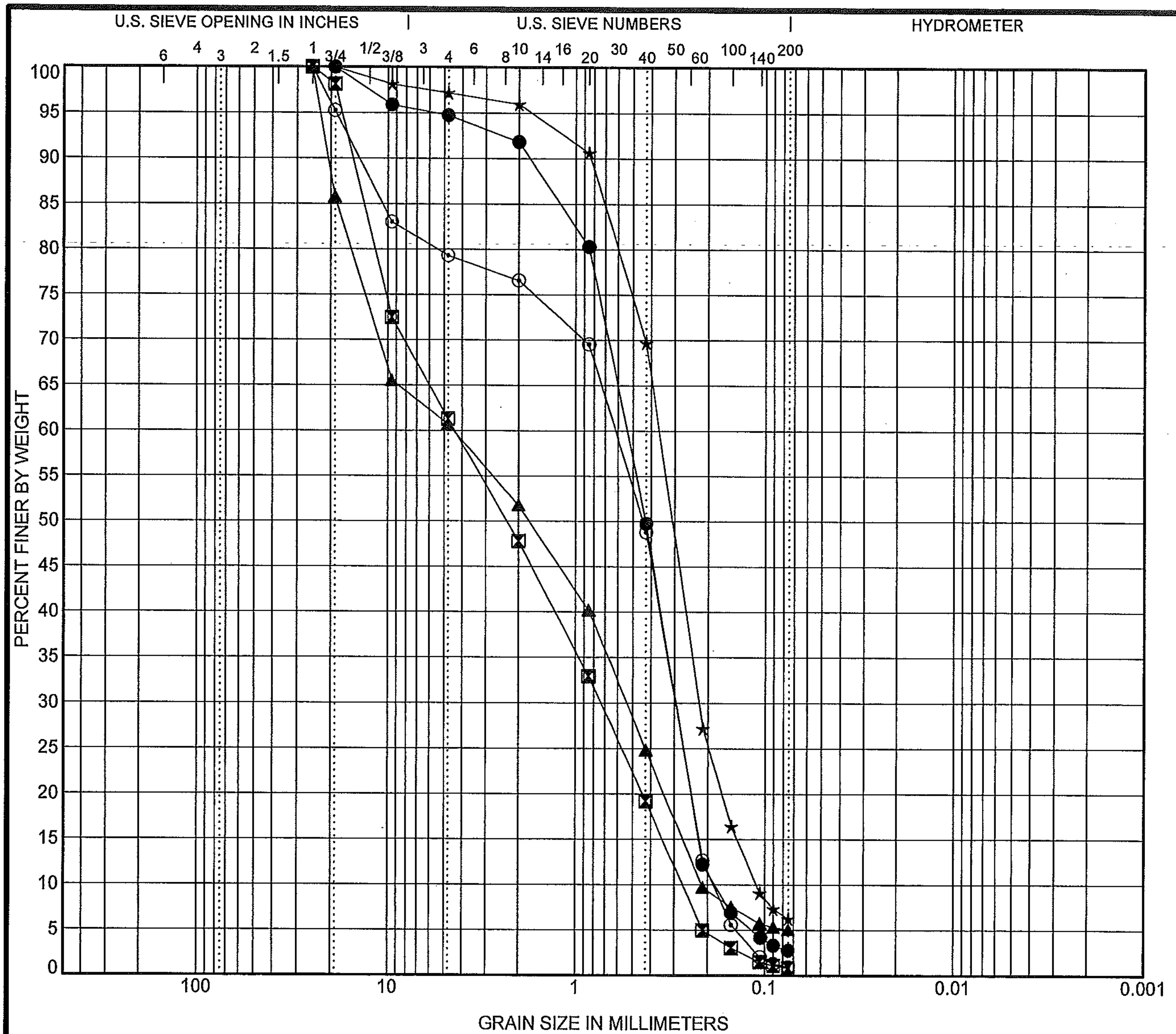
Contract: 04151127.16

US GRAIN SIZE 04151127.16 NJ CAPEMAY VILLAS.GPJ SCHNABEL.GDT 9/12/07



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen		Classification	LL	PL	PI	Cc	Cu
●	NJV-767	0.0 ft	**Poorly graded SAND, contains shell fragments - tan (SP)**				0.88	2.92
⊠	NJV-767	3.8 ft	**Poorly graded SAND with gravel, contains shell fragments - tan gray (SP)**				0.45	16.13
▲	NJV-767	5.0 ft	**Poorly graded SAND with silt and gravel, contains shell fragments - tan gray (SP-SM)**				0.30	20.60
★	NJV-767	7.5 ft	**Poorly graded SAND with silt - gray brown (SP-SM)**				1.23	3.27
⊙	NJV-767	10.0 ft	**Poorly graded SAND with gravel - gray brown (SP)**				0.76	3.32

	Specimen		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	NJV-767	0.0 ft	19	0.536	0.295	0.183	5.3	92.0	2.8	
⊠	NJV-767	3.8 ft	25	4.372	0.733	0.271	38.7	60.5	0.8	
▲	NJV-767	5.0 ft	25	4.433	0.537	0.215	39.3	55.6	5.1	
★	NJV-767	7.5 ft	19	0.363	0.222	0.111	2.8	91.0	6.2	
⊙	NJV-767	10.0 ft	25	0.618	0.296	0.186	20.7	78.4	0.9	

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GRADATION CURVES

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AREAS A AND C
CAPE MAY VILLAS, NEW JERSEY

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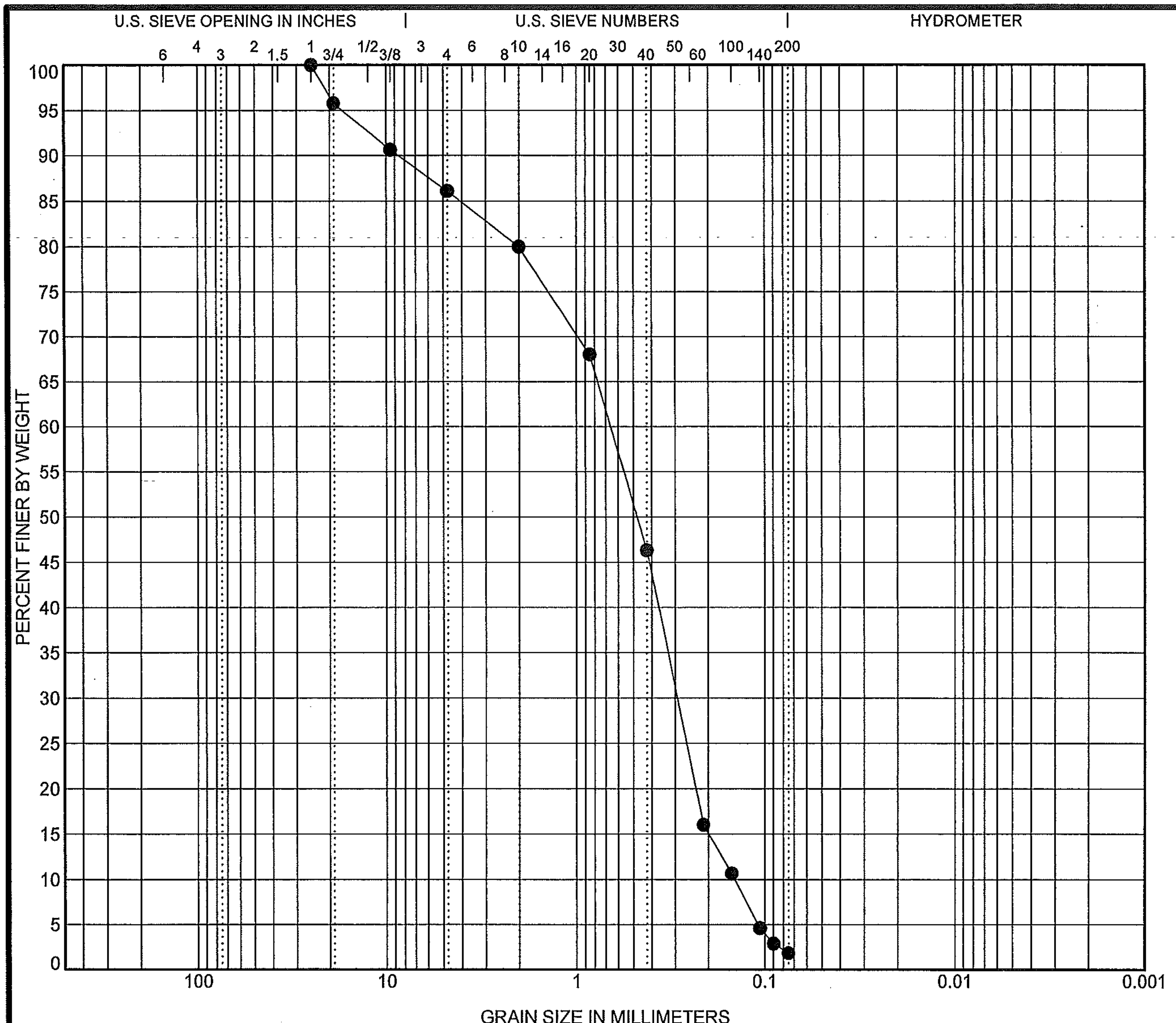
US GRAIN SIZE 04151127.16 NJ CAPEMAY VILLAS.GPJ SCHNABEL.GDT 9/12/07



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen	Classification	LL	PL	PI	Cc	Cu
●	**NJV-767 15.0 ft**	**Poorly graded SAND - gray brown (SP)**				**0.90**	**4.55**

	Specimen	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**NJV-767 15.0 ft**	**25**	**0.658**	**0.292**	**0.145**	**13.9**	**84.3**	**1.8**	

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GRADATION CURVES

Project: VIBRATIONAL CORING
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CAPE MAY VILLAS, NEW JERSEY

Contract: 04151127.16

US GRAIN SIZE 04151127.16 NJ CAPEMAY VILLAS.GPJ SCHNABEL.GDT 9/12/07

US Army Corps of Engineers
Philadelphia District

Philadelphia District
100 Penn Square East
Philadelphia PA 19107

GRAIN SIZE DISTRIBUTION

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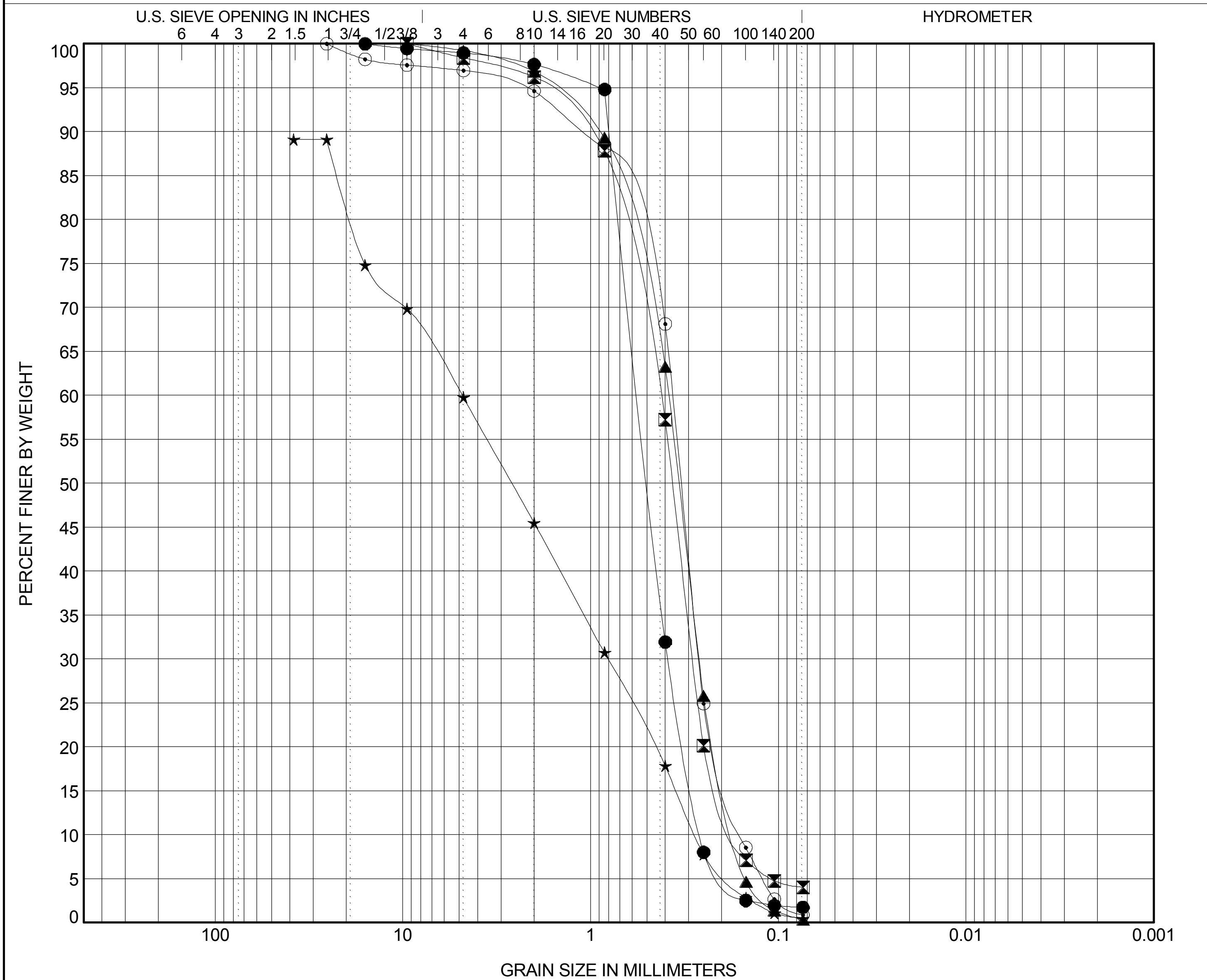

	Sample	Depth	Classification	LL	PL	PI	Cc	Cu
●	**NJV-906**	**0.0**	**POORLY GRADED SAND(SP)**				**1.02**	**2.14**
⧗	**NJV-906**	**3.5**	**POORLY GRADED SAND(SP)**				**1.12**	**2.56**
▲	**NJV-906**	**7.0**	**POORLY GRADED SAND(SP)**				**1.06**	**2.26**
★	**NJV-906**	**8.5**	**POORLY GRADED SAND with GRAVEL(SP)**				**0.49**	**17.35**
⊙	**NJV-906**	**9.5**	**POORLY GRADED SAND(SP)**				**1.22**	**2.35**

	Sample	Depth	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**NJV-906**	**0.0**	**15.875**	**0.557**	**0.495**	**0.385**	**0.26**	**1.0**	**97.2**	**1.8**	
⧗	**NJV-906**	**3.5**	**9.5**	**0.428**	**0.365**	**0.283**	**0.167**	**1.6**	**94.4**	**4.1**	
▲	**NJV-906**	**7.0**	**9.5**	**0.384**	**0.339**	**0.263**	**0.17**	**0.8**	**98.9**	**0.4**	
★	**NJV-906**	**8.5**	**38.1**	**4.816**	**2.626**	**0.806**	**0.278**	**29.3**	**59.3**	**0.5**	
⊙	**NJV-906**	**9.5**	**25.4**	**0.366**	**0.328**	**0.264**	**0.156**	**3.0**	**96.0**	**1.0**	

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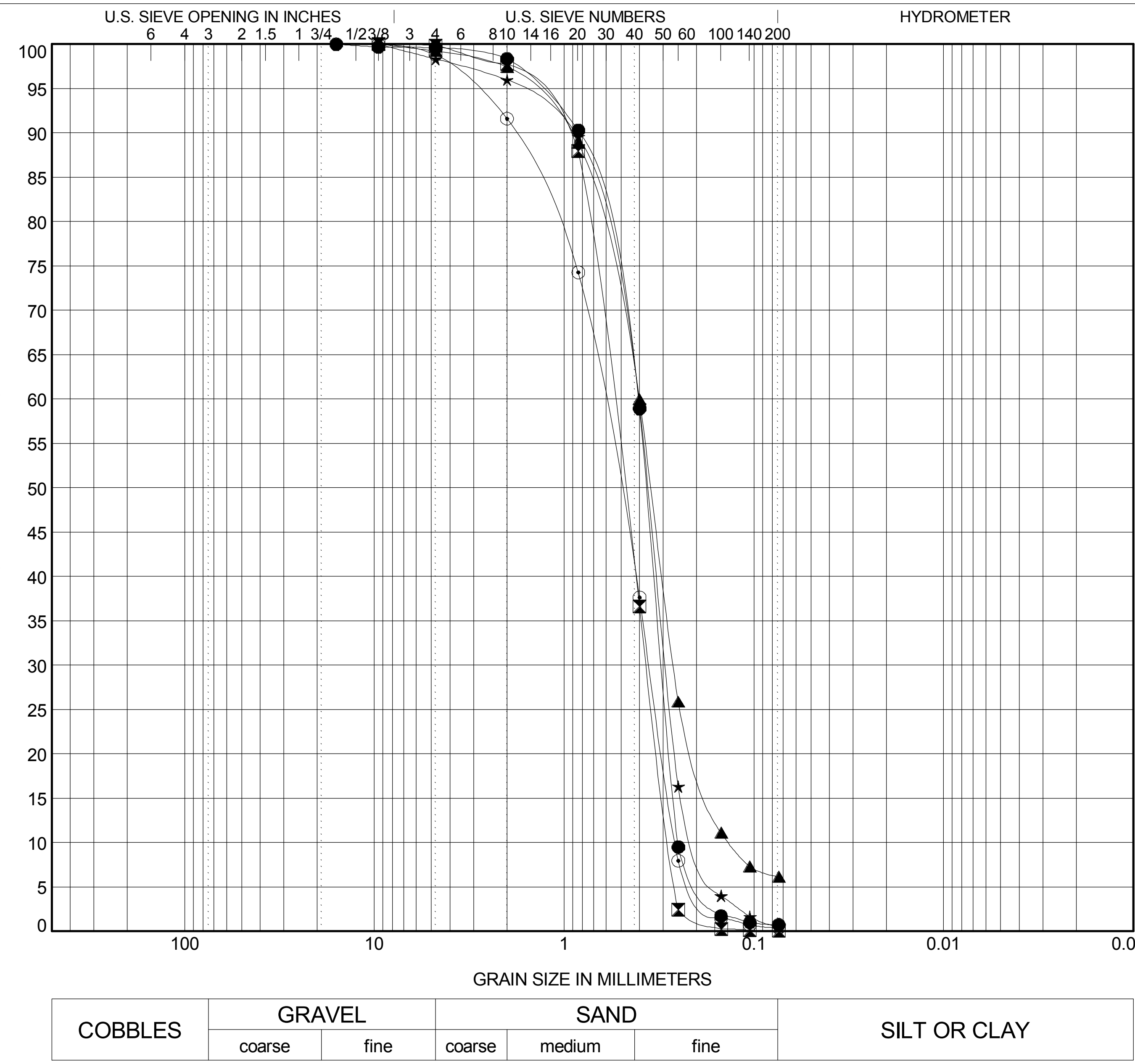

Sample		Depth	Classification	LL	PL	PI	Cc	Cu
●	NJV-907	0.0	POORLY GRADED SAND(SP)				0.90	1.63
⧗	NJV-907	4.0	POORLY GRADED SAND(SP)				0.86	2.02
▲	NJV-907	9.0					1.30	2.98
★	NJV-907	12.5	POORLY GRADED SAND(SP)				1.08	2.12
⊙	NJV-908	0.0	POORLY GRADED SAND(SP)				0.77	2.44

Sample		Depth	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	NJV-907	0.0	15.875	0.41	0.367	0.304	0.251	0.4	98.9	0.8	
⧗	NJV-907	4.0	9.525	0.561	0.486	0.365	0.277	0.1	99.8	0.1	
▲	NJV-907	9.0	9.525	0.4	0.349	0.264	0.134	0.8	93.0	6.2	
★	NJV-907	12.5	9.525	0.406	0.361	0.29	0.192	1.7	97.8	0.5	
⊙	NJV-908	0.0	9.5	0.629	0.514	0.354	0.258	1.2	98.4	0.4	

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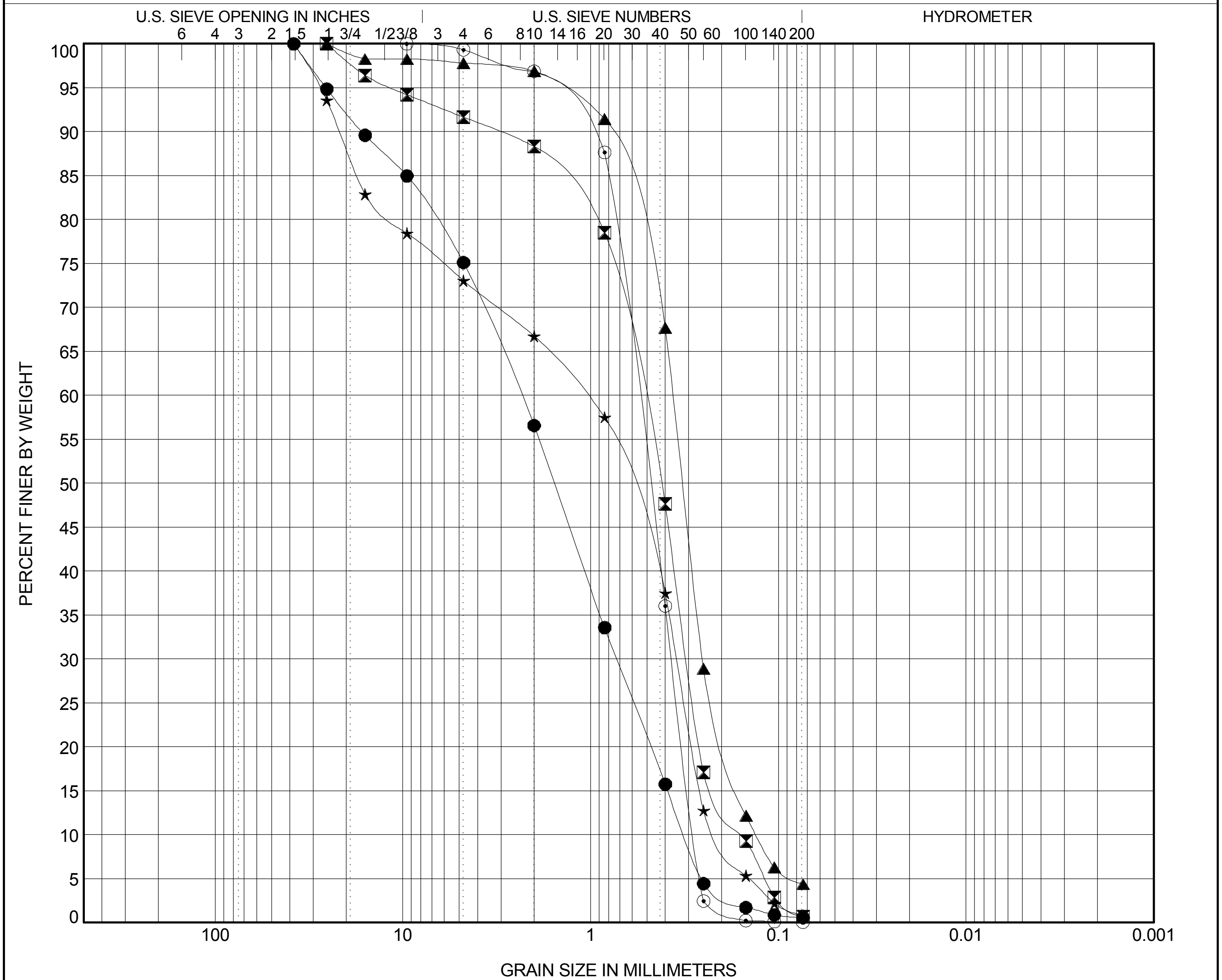

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Sample	Depth	Classification	LL	PL	PI	Cc	Cu
● NJV-908	3.0	**POORLY GRADED SAND with GRAVEL(SP)**				0.71	7.45
⧗ NJV-908	4.5	**POORLY GRADED SAND(SP)**				1.11	3.45
▲ NJV-908	6.8	**POORLY GRADED SAND(SP)**				1.35	2.79
★ NJV-908	9.8	**POORLY GRADED SAND with GRAVEL(SP)**				0.55	5.16
⊙ NJV-909	0.0	**POORLY GRADED SAND(SP)**				0.86	2.03

Sample	Depth	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● NJV-908	3.0	38.1	2.347	1.561	0.724	0.315	24.9	74.5	0.6	
⧗ NJV-908	4.5	25.4	0.538	0.423	0.305	0.156	8.3	90.9	0.8	
▲ NJV-908	6.8	25.4	0.364	0.323	0.253	0.131	2.2	93.4	4.5	
★ NJV-908	9.8	38.1	1.061	0.636	0.347	0.206	26.9	72.2	0.9	
⊙ NJV-909	0.0	9.525	0.565	0.489	0.368	0.278	0.7	99.3	0.1	

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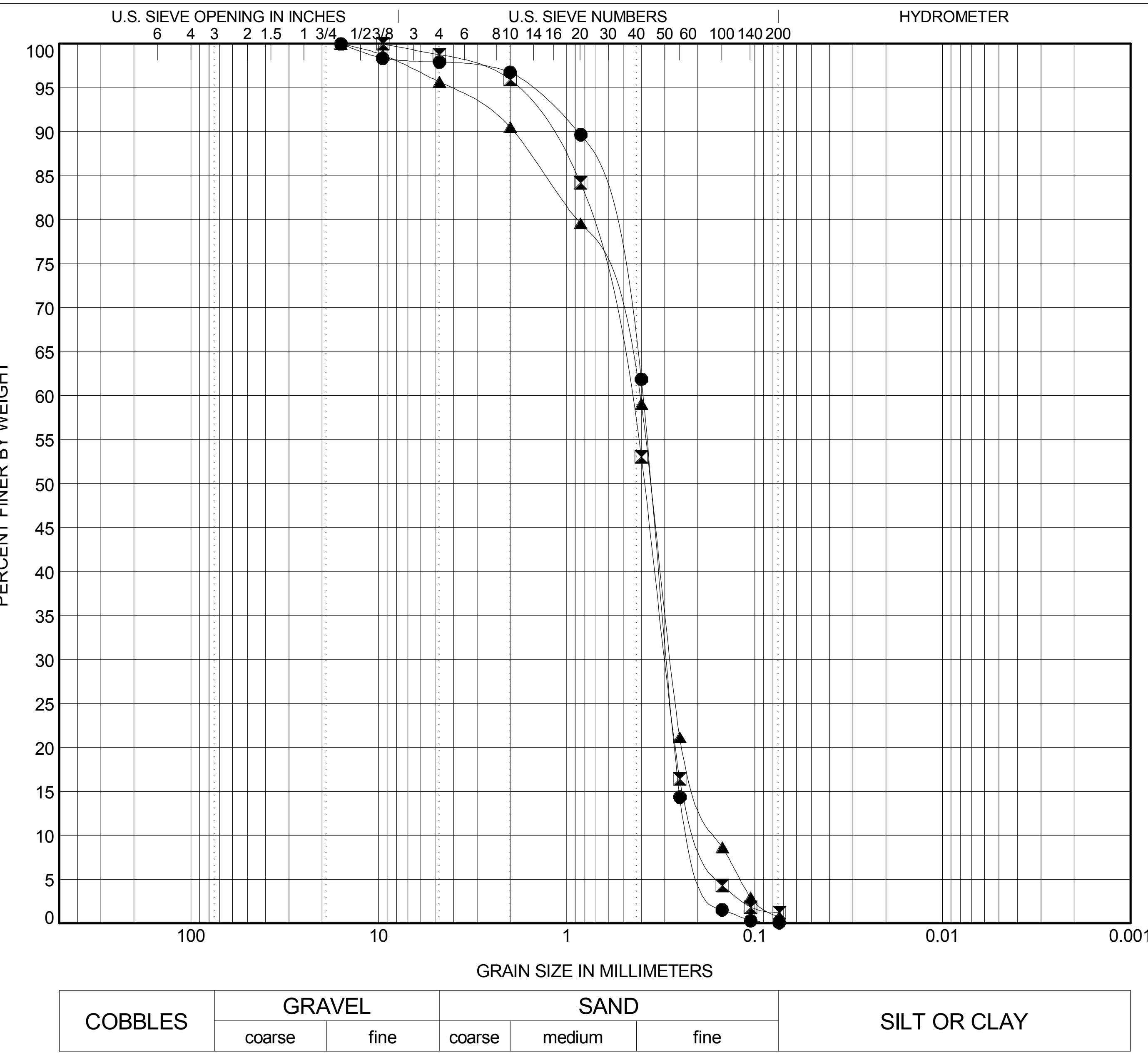

	Sample	Depth	Classification	LL	PL	PI	Cc	Cu
●	**NJV-909**	**3.0**	**POORLY GRADED SAND(SP)**				**1.04**	**1.87**
⧗	**NJV-909**	**6.8**	**POORLY GRADED SAND(SP)**				**0.99**	**2.49**
▲	**NJV-909**	**10.3**	**POORLY GRADED SAND(SP)**				**1.20**	**2.63**

	Sample	Depth	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**NJV-909**	**3.0**	**15.875**	**0.393**	**0.356**	**0.292**	**0.209**	**2.1**	**97.8**	**0.1**	
⧗	**NJV-909**	**6.8**	**9.525**	**0.472**	**0.385**	**0.297**	**0.19**	**1.2**	**97.5**	**1.3**	
▲	**NJV-909**	**10.3**	**15.875**	**0.413**	**0.357**	**0.279**	**0.157**	**4.3**	**94.8**	**0.9**	

GRAIN SIZE D50 (BEACHFILL) - GINT STD US LAB.GDT - 10/20/14 13:25 - I:\ADMIN\SOFTWARE\GINT\PROJECTS\RSM VIBRACORES- MANASQUAN 2014\MANASQUAN.GPJ

BUOY 10

Data obtained from Philadelphia District Geotechnical Section for samples obtained and tested in November 2016.

BORING #	SAMPLE ID	DEPTH IN BORING (FT)	MOIST. CONTENT (%)	% COBBLE	% GRAVEL	% SAND	% SILT/CLAY	SPECIFIC GRAVITY	LL	PL	PI	LI	USCS	D_{50} (mm)
NJV-765		0			0.7	97.2	2.1						SP	0.360
NJV-765		5			5.9	92.5	1.6						SP	0.360
NJV-765		10			38.7	59.7	1.6						SP	1.700
NJV-765		11.65			2.6	94.3	3.1						SP	0.295
NJV-765		15			3.5	85.8	10.7						SP-SM	0.120
NJV-766		0			2.4	97.3	0.3						SP	0.500
NJV-766		5			1.3	98.1	0.6						SP	0.620
NJV-766		7.7			60.5	37.8	1.7						GP	10.700
NJV-766		10			55.9	43.0	1.1						GP	7.600
NJV-766		11.3			7.9	90.3	1.9						SP	0.325
NJV-766		15			26.3	71.4	2.3						SP	1.000
NJV-767		0			5.3	92.0	2.8						SP	0.420
NJV-767		3.8			38.7	60.5	0.8						SP	2.150
NJV-767		5			39.3	55.6	5.1						SP-SM	1.700
NJV-767		7.5			2.8	91.0	6.2						SP-SM	0.305
NJV-767		10			20.7	78.4	0.9						SP	0.430
NJV-767		15			13.9	84.3	1.8						SP	0.480
NJV-906		0			1.0	97.2	1.8						SP	0.495
NJV-906		3.5			1.6	94.4	4.1						SP	0.365
NJV-906		7			0.8	98.9	0.4						SP	0.339
NJV-906		8.5			40.2	59.3	0.5						SP	0.806
NJV-906		9.5			3.0	96.0	1.0						SP	0.264

BUOY 10

Data obtained from Philadelphia District Geotechnical Section for samples obtained and tested in November 2016.

BORING #	SAMPLE ID	DEPTH IN BORING (FT)	MOIST. CONTENT (%)	% COBBLE	% GRAVEL	% SAND	% SILT/CLAY	SPECIFIC GRAVITY	LL	PL	PI	LI	USCS	D_{50} (mm)
NJV-907		0			0.4	98.9	0.8						SP	0.367
NJV-907		4			0.1	99.8	0.1						SP	0.486
NJV-907		9			0.8	93.0	6.2						SP	0.349
NJV-907		12.5			1.7	97.8	0.5						SP	0.361
NJV-908		0			1.2	98.4	0.4						SP	0.514
NJV-908		3			24.9	74.5	0.6						SP	1.561
NJV-908		4.5			8.3	90.9	0.8						SP	0.423
NJV-908		6.8			2.2	93.4	4.5						SP	0.323
NJV-908		9.8			26.9	72.2	0.9						SP	0.636
NJV-909		0			0.7	99.3	0.1						SP	0.489
NJV-909		3			2.1	97.8	0.1						SP	0.356
NJV-909		6.8			1.2	97.5	1.3						SP	0.385
NJV-909		10.3			4.3	94.8	0.9						SP	0.357

AVG: 1.084

AVG (excluding outlying GP samples): 0.595

Reach E Laboratory Test Results

Data obtained from March 2013 report prepared by GBA "Delaware River Main Channel Deepening Project - Supplemental Geotechnical Subsurface Investigation, Reach E - Stations 350+000 to 515+000"

Coarse-grained samples

BORING #	SAMPLE ID	DEPTH IN BORING (FT)	MOIST. CONTENT (%)	% COBBLE	% GRAVEL	% SAND	% SILT/CLAY	SPECIFIC GRAVITY	LL	PL	PI	LI	USCS	D_{50} (mm)
DRV-129-R4	A	1-2	20.9	0	0.9	95.3	3.8	2.66					SP	0.2808
DRV-130	B	5-6	12.1	0	34.7	64.4	0.9	2.67					SP	0.7651
DRV-131-R2	A	0-1	7.3	0	55.2	42.1	2.7	2.67					GP	6.1513
DRV-132	A	0.5-2.5	18.2	0	15.3	83.6	1.1	2.66					SP	0.4042
DRV-133	A	0-1	83.8	0	0	17.3	82.7	2.66	69	23	46	1	CH	0.0121
DRV-133	B	4.5-5.5	59.3				89*	2.68	56	21	35	1		0.0104
DRV-134	B	2-3	15.7	0	5.7	92.1	2.2	2.66					SP	0.4318
DRV-135-R2	A	2-3	14.6	0	1.0	96.3	2.7	2.66					SP	0.5747
DRV-136-R2	A	0-0.5	14.0	0	9.7	51.9	38.4	2.70						0.1031
DRV-136-R2	B	2-3	11.1	0	16.8	57.6	25.6	2.67						0.3342
DRV-136-R2	C	3.6-4.5	12.2	0	14.2	72.4	13.4	2.65						0.4456
DRV-137-R3	A	0-1.5	18.4	0	1.0	93.6	5.4	2.66						0.3143
DRV-138-R2	A	0-2.2(R1), 0-1.5(R2)	13.2	0	52.6	42.8	4.6	2.65					GP	5.8115
DRV-138-R1	B	1.5-2.5	15.4	0	5.0	91.9	3.1	2.66					SP	0.5173
DRV-139	A	0.5-1.5	27.2	0	0	81.6	18.4	2.66						0.1009
DRV-139	B	3.5-4.5	25.2	0	0	68.9	31.1	2.68						0.0960
DRV-140	A	0.5-1.5	20.8	0	1.0	93.4	5.6	2.67						0.2954
DRV-140	B	3.5-4.0	90.1				86*	2.68	84	29	55	1		0.0065
DRV-141	A	0-1	20.9	0	0.1	92.2	7.7	2.68						0.1570
DRV-141	B	5.5-6.5	72.7				81*	2.69	63	24	39	1		0.0079
DRV-142	A	1-2	29.6	0	0	83.6	16.4	2.67	NP	NP	NP	NP	SM	0.1856
DRV-143-R2	A	0.5-1.5	25.9	0	1.9	80.1	18.0	2.70						0.1041
DRV-143-R2	C	5.5-6.5	24.5	0	0	88.3	11.7	2.67						0.1928
DRV-144	A	1-2	15.5	0	2.1	95.8	2.1	2.67						0.4905
DRV-144	B	2.5-3.5	10.4	0	31.0	59.2	9.8	2.67						0.4077
DRV-144	D	4.6-5.2	30.5	0	4.7	71.4	23.9	2.64						0.3444
DRV-145	A	0.5-1.5	16.3	0	0.9	94.8	4.3	2.67						0.3912
DRV-145	B	3-4	26.3	0	0.5	84.7	14.8	2.67						0.2061
DRV-146	A	0-3	31.6	0	0	88.1	11.9	2.68						0.1052
DRV-147	A	0-4	27.8	0	0	80.2	19.8	2.68						0.0981
DRV-148-R3	A	0-3	26.7	0	0	77.4	22.6	2.68						0.1013
DRV-149	A	0-1	21.4	0	0.2	95.0	4.8	2.66						0.1941

Data obtained from March 2013 report prepared by GBA "Delaware River Main Channel Deepening Project - Supplemental Geotechnical Subsurface Investigation, Reach E - Stations 350+000 to 515+000"

Coarse-grained samples

BORING #	SAMPLE ID	DEPTH IN BORING (FT)	MOIST. CONTENT (%)	% COBBLE	% GRAVEL	% SAND	% SILT/CLAY	SPECIFIC GRAVITY	LL	PL	PI	LI	USCS	D_{50} (mm)
DRV-149	B	1-6	26.2	0	0	79.2	20.8	2.69						0.1149
DRV-150	A	0-6	21.8	0	0	87.8	12.2	2.66						0.1901
DRV-151	A	0-2	15.8	0	0.7	97.1	2.2	2.67						0.3911
DRV-151	B	3-5	21.1	0	1.0	82.7	16.3	2.66						0.3949
DRV-152	A	0-2	18.9	0	1.6	95.1	3.3	2.65					SP	0.2869
DRV-153-R2	A	0-1	13.7	0	7.4	91.6	1.0	2.66						0.5022
DRV-153-R2	B	3-4	37.8				95*	2.72						0.0033
DRV-154-R3	A	0.5-1.5	5.5	0	50.1	48.5	1.4	2.66						4.7933
DRV-154-R3	B	2.5-3.5	22.3	0	1.2	78.9	19.9	2.68						0.1906
DRV-154-R3	C	4-5	20.9				24*	2.67	NP	NP	NP	NP		
DRV-155-R2	A	0-2	17.3	0	4.8	94.1	1.1	2.65					SP	0.3550
DRV-156	A	0-1.3	11.7	0	19.7	78.9	1.4	2.65						0.5712
DRV-156	B	3-4	22.3	0	0	84.6	15.4	2.67						0.1890
DRV-156	C	6-7.5	28.7	0	0	73.6	26.4	2.67	35	19	16	1	SC	0.1126
DRV-157	A	0-1.5	17.5	0	1.4	88.8	9.8	2.67						0.3875
DRV-157	B	1.6-3.2	37.1				60*	2.71	50	16	34	1		0.0247
DRV-158	A	1-3	18.0	0	0.7	98.5	0.8	2.65					SP	0.3816
DRV-159	A	0.5-2	12.8	0	5.3	93.3	1.4	2.65						0.4845
DRV-159	B	3.5-4.5	24.1	0	0	71.4	28.6	2.67						0.1694
DRV-160	A	1-2	19.7	0	4.6	84.6	10.8	2.67						0.1926
DRV-160	B	5-6	22.6	0	0	83.3	16.7	2.66						0.1591
DRV-161	A	0.5-1.5	20.5	0	1.2	91.8	7.0	2.67						0.1531
DRV-161	B	2-3.5	17.3	0	2.2	70.1	27.7	2.66	NP	NP	NP	NP	SM	0.1390
DRV-161	C	4-4.9	22.0	0	0	10.2	89.8	2.70	33	17	16	0	CL	0.0142
DRV-162	B	1.5-2.5	21.3	0	0.3	78.6	21.1	2.68						0.2080
DRV-163	A	0.5-0.9	14.2	0	5.3	93.0	1.7	2.68						0.5103
DRV-163	B	2.5-3	23.5	0	0	38.2	61.8	2.68						
DRV-164	A	1.5-3	19.3	0	0	90.8	9.2	2.66						0.3074
DRV-165	B	3.5-5	13.5	0	10.8	85.9	3.3	2.66					SP	0.5723
DRV-166-R2	A	0.5-1.5	17.4	0	0.4	97.6	2.0	2.67						0.2940
DRV-166-R2	B	3-5	16.2	0	0	65.2	34.8	2.67						0.1509
DRV-167-R2	B	2.5-3.6	22.9	0	0	94.7	5.3	2.68						0.2761
DRV-168	A	0-2	17.3	0	1.1	97.3	1.6	2.67						0.2756

Data obtained from March 2013 report prepared by GBA "Delaware River Main Channel Deepening Project - Supplemental Geotechnical Subsurface Investigation, Reach E - Stations 350+000 to 515+000"

Coarse-grained samples

BORING #	SAMPLE ID	DEPTH IN BORING (FT)	MOIST. CONTENT (%)	% COBBLE	% GRAVEL	% SAND	% SILT/CLAY	SPECIFIC GRAVITY	LL	PL	PI	LI	USCS	D_{50} (mm)
DRV-168	B	3-5	29.7				83*	2.69	33	18	15	1		0.0230
DRV-169	A	0-3	18.0	0	0.8	96.6	2.6	2.66					SP	0.2998
DRV-170	B	1.3-3.3	24.2	0	0.1	97.8	2.1	2.68					SP	0.2907
DRV-171-R2	B	2-3	18.2	0	2.7	92.3	5.0	2.66						0.3893
DRV-172	A	1-2.5	17.9	0	0.3	98.1	1.6	2.64					SP	0.3450
DRV-173	A	0-2	26.0	0	0	62.3	37.7	2.65						0.1227
DRV-173	B	2-4	15.7	0	0	94.0	6.0	2.66						0.3350
DRV-174	A	0-4	13.0	0	0.3	94.5	5.2	2.66						0.3807
DRV-175	B	2-4	17.9	0	0.5	91.8	7.9	2.66						0.2595
DRV-176	A	0-4	20.1	0	0.3	95.5	4.2	2.67					SP	0.2246
DRV-177	A	0-3	20.6	0	0.4	97.3	2.3	2.68						0.2575
DRV-177	B	3.5-7	14.0	0	15.6	80.7	3.7	2.66					SP	0.4014
DRV-178	A	0-4	20.0	0	0.2	97.0	2.8	2.67					SP	0.2275
DRV-178	B	4-6	23.4				24*	2.66	NP	NP	NP	NP		
DRV-179	A	0-4	15.6	0	2.4	96.5	1.1	2.66					SP	0.5191
DRV-179	B	4-6	23.9				25*	2.66	NP	NP	NP	NP		

AVG (all samples): 0.4742

AVG (coarse samples only): 0.5277

In-situ Grain Size Data for Potential Beachfill Sites

GANDY'S

Data obtained from Philadelphia District Geotechnical Section for samples obtained and tested in November 2016.

BORING #	SAMPLE ID	DEPTH IN BORING (FT)	MOIST. CONTENT (%)	% COBBLE	% GRAVEL	% SAND	% SILT/CLAY	SPECIFIC GRAVITY	LL	PL	PI	LI	USCS	D_{50} (mm)
	GBG-1	1		0	25.5	70.4	0.0						SP	1.159
	GBG-2	1		0	1.7	96.2	0.0						SP	0.574
	GBG-3	1		0	25.7	69.7	0.0						SP	1.606
	GBG-4	1		0	1.1	98.0	0.0						SP	0.590

AVG: 0.982

Data obtained from 18 FEB 2016 report prepared by Hatch Mott MacDonald titled "Gandy's Beach Beachfront Sustainability Project"

BORING #	SAMPLE ID	DEPTH IN BORING (FT)	MOIST. CONTENT (%)	% COBBLE	% GRAVEL	% SAND	% SILT/CLAY	SPECIFIC GRAVITY	LL	PL	PI	LI	USCS	D_{50} (mm)
	T 2.1													0.712
	T 7.1													0.435
	T 7.2													4.000
	T 7.3													0.574
	T 15.2													0.500
	T 15.4													1.173
	T-2 4													
	T-15 1													

AVG: 1.232

AVG (excluding T 7.2 outlier): 0.679

OVERALL AVG: 1.132

OVERALL AVG (excluding T 7.2 outlier): 0.814

FORTESCUE

Data obtained from Philadelphia District Geotechnical Section for samples obtained and tested in November 2016.

BORING #	SAMPLE ID	DEPTH IN BORING (FT)	MOIST. CONTENT (%)	% COBBLE	% GRAVEL	% SAND	% SILT/CLAY	SPECIFIC GRAVITY	LL	PL	PI	LI	USCS	D_{50} (mm)
	FSG-1	1		0	0.6	99.0	0.0						SP	0.693
	FSG-2	1		0	0.0	89.3	0.0						SP	0.324
	FSG-3	1		0	0.4	98.9	0.0						SP	0.380
	FSG-4	1		0	1.6	97.5	0.0						SP	0.456
	FSG-5	1		0	1.2	97.6	0.0						SP	0.635
	FSG-6	1		0	0.0	100.0	0.0						SP	0.486

AVG: 0.496

VILLAS

Data obtained from "Villas & Vicinity, NJ, Interim Feasibility Study, Final Feasibility Report and Environmental Assessment" dated JAN 1999

BORING #	SAMPLE ID	DEPTH IN BORING (FT)	MOIST. CONTENT (%)	% COBBLE	% GRAVEL	% SAND	% SILT/CLAY	SPECIFIC GRAVITY	LL	PL	PI	LI	USCS	D_{50} (mm)
	CVM-1			0	0.0	99.8	0.2							0.260
	CVM-3			0	0.0	95.2	4.8							0.240
	CVM-4			0	0.0	99.2	0.8							0.390
	CVM-5			0	0.0	99.5	0.5							0.310
	CVM-7			0	0.0	99.6	0.4							0.430
	CVM-9			0	0.0	97.0	3.0							0.260
	CVM-11			0	0.0	99.5	0.5							0.320
	CVM-14			0	0.0	97.9	2.1							0.290

AVG: 0.313