APPENDIX H

MASTER BEACH NOURISHMENT PLAN

Carteret County North Carolina

carteret county Shore protection office

protectthebeach.com

BOGUE BANKS MASTER BEACH NOURISHMENT PLAN

SUMMARY REPORT | MARCH 4, 2016

moffatt & nichol

COASTAL TECH
COASTAL TECHNOLOGY CORPORATION

BOGUE BANKS MASTER BEACH NOURISHMENT PLAN
CARTERET COUNTY, NC

SUMMARY REPORT

Prepared For:

carteret county Shore protection office
protectthebeach.com

Prepared By:

moffatt & nichol

March 4, 2016

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1.0 EXECUTIVE SUMMARY

Carteret County, the Carteret County Beach Commission, and the Shore Protection Office (SPO) seek to provide long-term, sustaining management of Bogue Banks beaches. In 2001, by state legislation, the Carteret County Beach Commission was established, and a room occupancy tax (ROT) for funding beach nourishment and related functions was put in place mainly as a response to the hurricanes of the 1990's (Bertha, Fran and Floyd) and subsequent storms. Carteret County intends to maintain Bogue Banks beaches via implementation of this proposed Master Beach Nourishment Plan (MBNP) with guidance from the SPO and oversight by the Beach Commission.

Carteret County is specifically seeking federal and state permits to allow implementation of this MBNP as a non-federal shoreline protection and inlet management project over a multi-decadal period to preserve Bogue Banks' tax base, infrastructure, and tourist oriented economy. An inter-local agreement was developed and executed by each municipality on Bogue Banks creating an effective and efficient approach for a long-term and sustainable implementation of this MBNP.

The proposed program incorporates actions within multiple oceanfront municipalities to nourish recipient beaches, via use of multiple sand sources, over a multi-decadal timeline with revolving nourishment-project events. This MBNP identifies engineering design elements including: sand volumes required to yield the desired level of protection throughout Bogue Banks; sand volume triggers to initiate nourishment events; sand borrow source locations, volumes, quality, and viability; the expected capacity of the recipient beaches for nourishment; and the projected timing of nourishment events. A primary MBNP goal is to offset natural and anthropogenic erosion effects by optimizing use of existing high quality borrow sources to nourish prioritized recipient beaches to provide a spatially-equivalent level of protection to upland property along Bogue Banks.

In the process of completing past projects and monitoring, Bogue Banks has developed a large and impressive dataset that was the underpinning of all the analyses. Major findings of these datasets and analyses completed for the MBNP are listed below.

<u>Volume Need</u>

The analysis shows an overall annual background erosion loss along Bogue Banks (without Fort Macon) of roughly 452,200 cy with a 50-yr nourishment need of 22.6 Mcy just to keep up with historical erosion patterns. Again, the estimate compares favorably to the USACE estimate of approximately 356,247 cy/yr and a 50 year need of 17.8 Mcy.

To estimate storm losses, the overall dataset was restricted to the three years which covered Hurricanes Isabel, Ophelia, and Irene to estimate potential hurricane storm losses. Based on the results, it is expected that the need for a given storm may range between 1.4 – 1.7 Mcy. Given that storms have occurred once every three years or so, the storm need over 50 years may range between 22.4 – 27.2 Mcy, which is equivalent to the background erosion loss/need.

The overall (background and storm) sediment need over the 50 year planning horizon based on the analytical/empirical analysis is between 45.0 and 49.8 Mcy. Accounting for USACE guidelines for sea level change, the value increases to 46.8 to 51.6 Mcy.

As for the existing beach profiles, numerical modeling was completed to determine that the beach and dune system are considered to provide a sufficient level of protection along all of the Bogue Banks reaches for a 25-year return period design storm event, or its equivalent.

Hotspots Investigation

It is important to understand the existing hotspots and why they may be present given that these are areas that will likely require more frequent nourishments to maintain an equal level of protection as compared to more stable reaches. A primary hotspot under investigation has been historically observed approximately between survey Transects 37 and 52 in Emerald Isle-East and Indian Beach/Salter Path-West. An additional potential hotspot can also be observed in beach profile monitoring data from 2008 – 2012 in Pine Knoll Shores-East (between Transects 66 and 76).

The wave transformation model results indicate a significant gradient in mean annual wave energy along Bogue Banks, with wave energy increasing from west to east. This result alone would indicate that gradients in sediment transport-causing wave energy may be responsible for the increased erosion seen in the middle portions of Bogue Banks.

The sediment transport component of the model results further indicates gradients in net accumulated alongshore transport that would result in greater removal of sediment from these hotspot areas than is supplied by the updrift reaches.

The alongshore transport gradient observed in the local model results is believed to be primarily due to the increased wave energy affecting the shoreline in the western reaches. This increased wave energy at both hotspots is believed to be due to a combination of wave sheltering effects of Cape Lookout as well as localized bathymetric/geologic features.

Bogue Inlet

Bogue Inlet has been the subject of local project efforts in the past. Bogue Inlet is considered a shallow draft inlet with authorized dimensions of 150 ft wide and 8 ft deep which has historically been dredged by sidecaster dredges. In the late 1990's through early 2000's, the inlet shifted toward the Point at Emerald Isle and seriously threatened homes and infrastructure at that location. The inlet was successfully relocated in early 2005 and the adjacent inlet area has been relatively stable ever since.

An analytical study of Bogue Inlet channel morphology was conducted using historical aerial imagery from 1938 – 2011. The study was conducted by defining and then measuring a small set of geometric parameters such as the position and alignment of the main ebb channel and the two landward channels connecting Bogue Inlet with Bogue Sound and the White Oak River.

A product of the initial analytical study is a proposed area, or “safe box,” within which the main channel of Bogue Inlet would be allowed move, without triggering engineering intervention (see Figure 1-1). The limits of the “safe box” were set so that subsequent channel migration did not threaten adjacent inlet shorelines/infrastructure by erosion within 3 years (in order to provide adequate time for an inlet relocation project to occur).

A program of numerical model simulations was then envisioned to confirm or revise (i.e. potentially narrow) the limits of the proposed “safe box”. The dynamically coupled wave, flow, sediment transport, and bathymetry change (morphodynamic) model simulations were run for several idealized (schematized) inlet channel configurations. The model simulations were intended to provide an indication of whether there is a certain (approximate) lateral position, channel orientation, or combinations of both which, once reached, may speed up (or inhibit recovery from) migration of the channel to unacceptable positions near Bogue Banks or Bear Island.

The numerical model results do not indicate a channel position, rotation, or combination of parameters that suggest that proposed “safe box” should be refined.

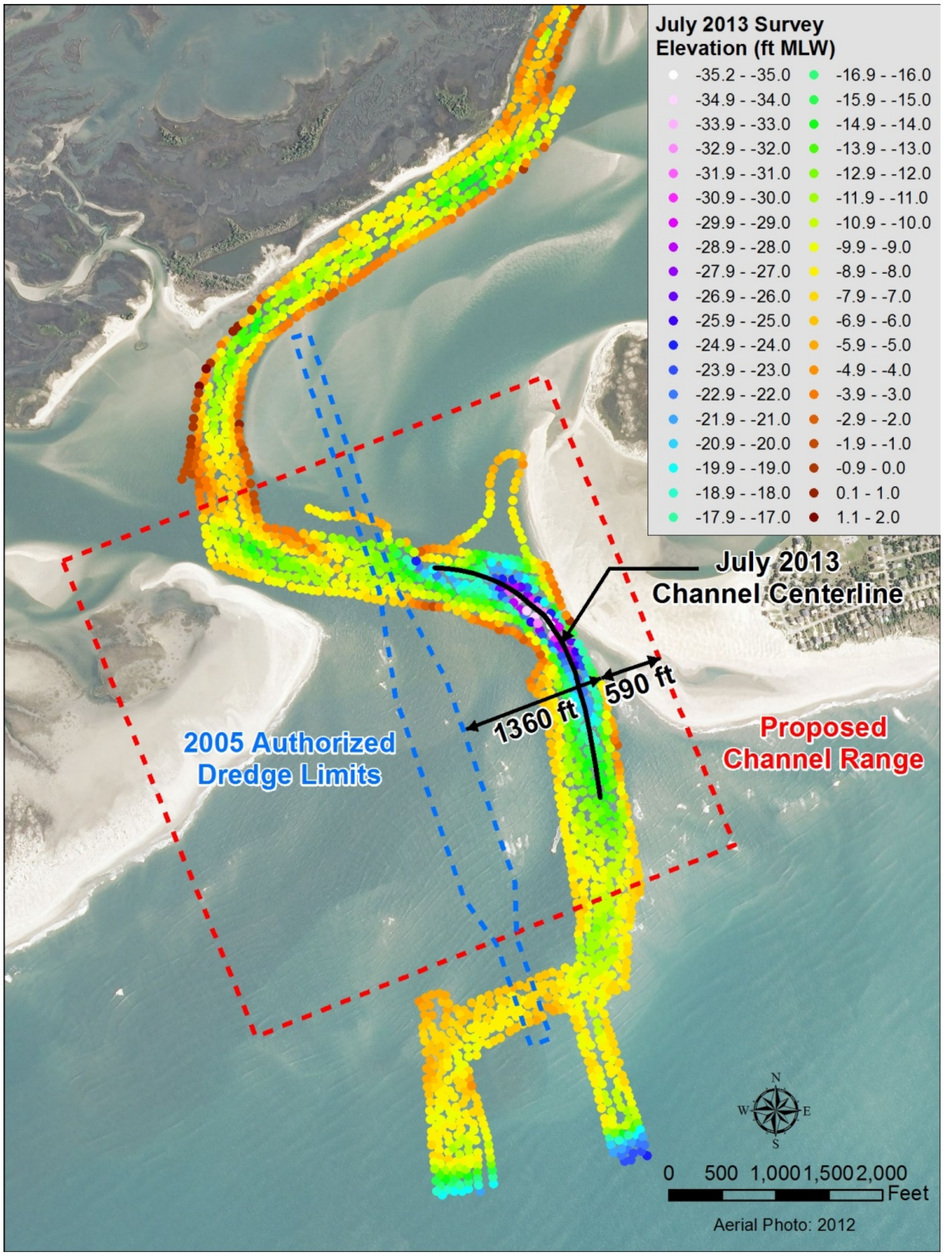

Figure 1-1: Bogue Inlet Current Channel Alignment

<u>Level of Protection and Nourishment Trigger Determination</u>

In addition to the study of Bogue Inlet to determine an optimal solution for protection of infrastructure adjacent to the inlet, the overall beach nourishment need to provide adequate protection for infrastructure along Bogue Banks was also needed.

As outlined previously, the current beach profiles are adequate to provide protection for a 25-yr event, while some targeted dune building in various reaches would be required to provide protection for a 50-yr event. A project of approximately 2.2 Mcy would be needed to provide this 50-yr event level of protection (LoP).

Since current funding streams are needed to meet the overall maintenance requirements, providing a LoP for a 50-yr event across the entire island was determined to not be feasible, and therefore a 25-yr event LoP was selected.

With the 25-yr event selected as the finalized level of protection, the development of nourishment triggers was completed. These triggers indicate a minimum volume of material necessary to protect against a 25-yr event. Again, it is important to note that the potential of triggers at all of the computation elevations was considered, but ultimately the elevation of -12 ft NAVD was selected.

The resulting overall average nourishment trigger for Bogue Banks is 238 cy/ft (see Table 1-1). This result makes sense in the fact that the 225 cy/ft original trigger was based on profile volumes in Atlantic Beach (which had weathered the hurricanes well) AFTER the hurricanes. It would only make sense that the PRE-storm volume would be higher and given that the past hurricanes over the last decade have had roughly 1.2 -1.5 Mcy this would mean that the prestorm volume was approximately 10-13 cy/ft higher than the 225 cy/ft after the event. Therefore, the overall average of 238 cy/ft for the entire island was determined to be very reasonable.

Table 1-1: Revised Calculated Trigger Volumes Above -12 ft NAVD88 for Various RP Events

Reach	Reach Length (ft)	50-yr, -12 ft Trigger (cy)	25-yr, -12 ft Trigger (cy)	Adjusted 25-yr, -12 ft Trigger (cy)	Preliminary -12 ft Trigger (cy)	-12 ft 2011 Volume (cy)
Bogue Inlet (1-8)	7,432	238	103	238	235	389
Emerald Isle West - A (9-11)	4,056	282	230	230		277
Emerald Isle West - B (12-22)	14,283	319	272	272	266	295
Emerald Isle West - C (23-25)	4,005	323	242	242		303
Emerald Isle Central - A (26-32)	10,428	237	213	213	211	292
Emerald Isle Central - B (33-36)	5,374	277	207	207		262
Emerald Isle East - A (37-44)	8,814	268	214	214	221	242
Emerald Isle East - B (45-48)	4,406	299	235	235		264
Indian Beach/Salter Path - West (49-52)	5,275	243	216	216	224	263
Indian Beach/Salter Path - East (53-58)	7,575	241	229	229		298
Pine Knoll Shores - West (59-65)	9,063	235	196	196	211	253
Pine Knoll Shores - East - A (66-70)	6,564	271	218	218		240
Pine Knoll Shores East - B (71-76)	8,251	287	222	222		262
Atlantic Beach - West (77-81)	5,388	269	225	225	254	281
Atlantic Beach - Central (82-89, 91-96)	13,771	375	248	248		291
Atlantic Beach - Circle (90)	1,006	408	364	364		330
Atlantic Beach - East (97-102)	6,011	318	276	276		384
TOTAL	**121,702**					
AVERAGE		**288**	**230**	**238**	**233**	**290**
					Weighted	

Engineering Alternatives Considered

Multiple alternatives were considered to meet the project need including, No Action (Status Quo), Relocation/Abandonment, the USACE 50-yr project, Beach Nourishment Only (With Various Sources), and Beach Nourishment with Inlet Management (Non-structural and Structural).

With the exception of Beach Nourishment with Inlet Management, none of the other alternatives could meet the projects purpose and need.

In summary, non-structural inlet management is needed at both Beaufort Inlet and Bogue Inlet to meet the overall project needs. Management of these inlets will provide needed protection to the adjacent inlet shoulder volumes and infrastructure while providing the secondary benefit of a needed sand source to meet the 50-yr project sediment needs.

If all examined sand sources are incorporated (upland, AIWW, offshore, and inlets) approximately 50,253,057 cy of material would be available and would meet the 50-year sediment need (background and storm based erosion) of 45 Mcy to 49.8 Mcy (46.8 to 51.6 Mcy for moderate sea level change). The total volume available when the renewable (Bogue and Beaufort Inlets) and non-renewable (upland, AIWW, and offshore) sources are combined is tabulated in Table 1-2.

Table 1-2: Total Volume Available

Source	50-Yr Total Volume (cy)
Renewable	25,130,000
Non-Renewable	25,123,057
TOTAL	**50,253,057**

Preferred Alternative

Therefore, based on the above analyses, the preferred alternative is Beach Nourishment with Non-structural Inlet Management. This is the only option that provides adequate sand sources to provide a 25-yr event LoP for all of Bogue Banks as well as provide adequate infrastructure and habitat protection along the shoreline surrounding Bogue Inlet (inlet "shoulders"). Revised triggers for -12 ft NAVD shall be utilized as shown in Table 1-1. The resulting reaches are on average 2-3 miles long with the exception of the Pine Knoll Shores and Atlantic Beach reaches which are somewhat longer and cover the entire Town in each case. For the proposed reaches, the weighted trigger is 233 cy/ft with triggers varying from 211 cy/ft for Emerald Isle Central to 266 cy/ft for portions of Emerald Isle West (Table 1-1). Through additional analysis, it was determined that renourishment intervals for various reaches would be needed at 3, 6, and 9 year intervals starting in 2019 (see Table 1-3). Please note that the nourishment volume approximates the need for background erosion only. It is expected that named storm losses will be handled separately through FEMA reimbursement projects.

Table 1-3: Renourishment Intervals and Preliminary Projects Based on Detailed Subreach and Management Reach Approaches

Year	Detailed Subreach Nourishment Volume (cy)	Management Reach Nourishment Volume (cy)	Nourishment Project (Yr)
2019	640,332	686,067	3
2022	1,686,018	1,839,351	6
2025	1,163,781	967,920	9
2028	1,686,018	1,839,351	6
2031	640,332	686,067	3
2034	2,209,467	2,121,204	6,9
2037	640,332	686,067	3
2040	1,686,018	1,839,351	6
2043	1,163,781	967,920	9
2046	1,686,018	1,839,351	6
2049	640,332	686,067	3
2052	2,209,467	2,121,204	6,9
2055	640,332	686,067	3
2058	1,686,018	1,839,351	6
2061	1,163,781	967,920	9
2064	1,686,018	1,839,351	6
TOTAL	**21,228,045**	**21,612,609**	

Again, it is very important to note that the results are based upon average background erosion rates across the island. Storm effects and other factors could drastically alter future nourishment requirements. The plan will nourish areas as they reach the nourishment triggers via gradual erosion or in response to future storms which of course cannot be predicted. It is also expected that the current funding streams would be sufficient for at least the next 20 years and possibly even longer.

Based on the overall sediment need comprised of background erosion (22.6 Mcy), anticipated storm erosion (22.4 – 27.2 Mcy), and moderate sea level rise (1.8 Mcy), Carteret County is requesting permission to place 46.8 to 51.6 Mcy of material on the beach over the next 50 years using a combination of borrow sources which include offshore sources (Old and Current ODMDS, Area Y, and Area Z), inlets (Bogue Inlet Channel and Morehead City Outer Harbor), and upland sources (sand mines and AIWW disposal areas).

The MBNP and Preferred Alternative include the following elements:

- Renourishment events are expected to be required at 3, 6, and 9 year intervals starting in 2019 - based upon average background erosion rates. Actual renourishment events will be dependent upon actual erosion, and available funding – including FEMA funding in response to future storms for which the timing and severity cannot be reasonably predicted.

- Sand from offshore sources (1st priority), inlet sources (2nd priority) and upland sources (3rd priority) is proposed to be excavated and placed on the beach. These primary sand sources are sufficient to maintain the design beach at a 25-year LoP with advance fill varying from 25 to 50 cubic yards per foot – depending upon actual future erosion rates and available funding.

- Sand obtained from the USACE maintenance dredging of the Morehead City Harbor Channel and Bogue Inlet AIWW "crossings" is proposed to be used as part of the primary sand sources; maintenance dredging is proposed to be performed by the USACE under their permit authority, but USACE dredging and beach-fill placement are assumed to continue and are an integral part of the MBNP.

- If the main channel at Bogue Inlet migrates outside the "safe box", the main channel is proposed to be relocated by the Applicant, Carteret County, to the location constructed in 2005 with the excavated material used to nourish the beach as part of the primary sand sources.

Carteret County is also requesting an allowable construction timeframe extending from November 16 through April 30 for construction of all future projects required for the Bogue Banks Master Beach Nourishment Plan. The request stems from the growing economic burden necessary to provide reasonable buffers against coastal storm and long-term erosional forces. Analysis of historical data shows an accelerated inflation of cost (greater than the typical 3% to 5%) experienced by the beach placement projects for Bogue Banks and harbor maintenance projects which is a concerning trend for coastal initiatives in Carteret County. The requested allowable construction timeframe from November 16 to April 30 to conduct the Bogue Banks project will help to mitigate these issues by allowing additional time for project construction, removing some of the burden from and consequently preventing them from passing the risk on to sponsors in the form of elevated construction costs. To support the requested construction timeframe, environmental precautions similar to those implemented during the 2013 Post Hurricane Irene Renourishment will most likely be a necessity.

2.0 PROJECT PURPOSE AND NEED

2.1 Project Purpose

The Bogue Banks Master Beach Nourishment Plan (MBNP) project purpose is:

- to establish a regional programmatic plan to facilitate authorization and implementation of shoreline nourishment/maintenance events on Bogue Banks including management of Bogue Inlet;

- to provide long-term shoreline stabilization on Bogue Banks to:
  - provide an equivalent level of storm protection to upland property along Bogue Banks and the associated local, state, and federal tax bases;
  - to provide long-term protection to Bogue Banks tourism industry, State and local infrastructure, and oceanfront or inlet adjacent structures
  - maintain natural resources and associated recreational uses while avoiding and minimizing adverse environmental impacts to the extent feasible;

- to consolidate community resources to financially and logistically manage beaches on Bogue Banks and manage Bogue Inlet in an effective manner by reducing/eliminating the time and need for individual authorizations.

2.2 Project Need

After pronounced hurricane activity in the 1990's (Hurricanes Bertha, Fran, and Floyd), Carteret County leadership began to take formal steps to address erosion concerns along the ~25-mile long island of Bogue Banks. Figure 2-1 shows some of the damage from these hurricanes.

Figure 2-1: 1990's Hurricane Damage

In 1984, the U.S. Army Corps of Engineers (USACE) conducted a *Reconnaissance Study* relative to Coastal Storm Damage Reduction (CSDR) for Bogue Banks, but none of the analyzed coastal storm damage reduction plans were found to be economically feasible at that time (USACE, 2013). A USACE *Feasibility Study* was authorized by congressional resolution in 1998 and a *Feasibility Study Agreement* was executed in February 2001 after which federal funding became available; the *Feasibility Study* culminated in the August 2013 report - "Integrated Feasibility Report and Draft Environmental Impact Statement" for the USACE CSDR project for Bogue Banks. Congressional authorization and federal funding for this project are unlikely and remain uncertain due to lack of financial support by the present and prior administrations relative to the Shore Protection Program for ultimate implementation of the project.

In 1994, a USACE Section 111 Study was requested by Pine Knoll Shores to determine if damages to the beach can be directly attributable to the Federal Navigation Project (SPO website). In 2001, the USACE completed a Section 111 Study that addressed the impacts of dredging Morehead City Harbor upon the beaches of Bogue Banks. The study found no direct evidence that the harbor project has had a negative impact on any of the shorelines in the vicinity, including Pine Knoll Shores. However, the report suggested that alternative sand management practices in conjunction with harbor maintenance may be beneficial with regard to long-term stability of the shoreline (USACE, 2001).

However, with the advent of the hurricanes in the 1990's, County and Town leaders determined that action was needed. Occupancy tax legislation was developed to create a beach nourishment reserve fund and a County-wide Beach Commission was formed to manage the funds and make decisions regarding engineering intervention (i.e. nourishment) along Bogue Banks.

Consultants were retained by the Beach Commission to develop and implement the previous locally-funded Bogue Banks Restoration Project which placed material, in three phases, along Bogue Banks: Phase I) Indian Beach/Salter Path and Pine Knoll Shores (1.73 Mcy, 2002), Phase II) Emerald Isle Central and Emerald Isle East (1.87 Mcy, 2003), and Phase III) Emerald Isle West (0.69 Mcy, 2005) (see Figure 2-2).

In 2003, the USACE completed a 933 study investigating the beneficial placement of beach fill to be obtained by maintenance dredging of the Morehead City Harbor navigation project and by recycling previously dredged material from the adjacent Brandt Island confined disposal area (USACE, 2013). Phase I of the Section 933 project (2004) placed approximately 700,000 cy of material in Indian Beach/Salter Path while Phase II (2007) placed approximately 508,000 cy of material in Pine Knoll Shores (see Figure 2-2).

In 2004 and 2007, two FEMA-funded restoration efforts were undertaken due to storm damage from Hurricanes Isabel and Ophelia, respectively. These efforts resulted in the placement of about 1.4 Mcy of sand along Bogue Banks. Most recently, in 2013, a post-Irene restoration project, partially funded by FEMA, was constructed, placing approximately 965,000 cy of sand along Bogue Banks (see Figure 2-2).

In 2010, the USACE completed a “Dredged Material Management Plan” for the Morehead City Harbor navigation project. The base plan includes periodic placement of material on Fort Macon, Atlantic Beach, and west through Pine Knoll Shores at regular intervals to ameliorate the losses of material that would normally have been provided through natural sand bypassing currently interrupted by the navigation project” (USACE, 2010).

Since 1978 roughly 11 million cubic yards of sand have been placed upon the beaches of Bogue Banks – as illustrated in Figure 2-2 - at a total cost of about $95 million. While the Corps of Engineers’ Dredged Material Management Plan and Interim Operation Plan for the Morehead City Harbor Federal Navigation Project hold some promise for eastern Bogue Banks, long-term beach nourishment for the entire island is needed to provide for pro-active management of County beaches.

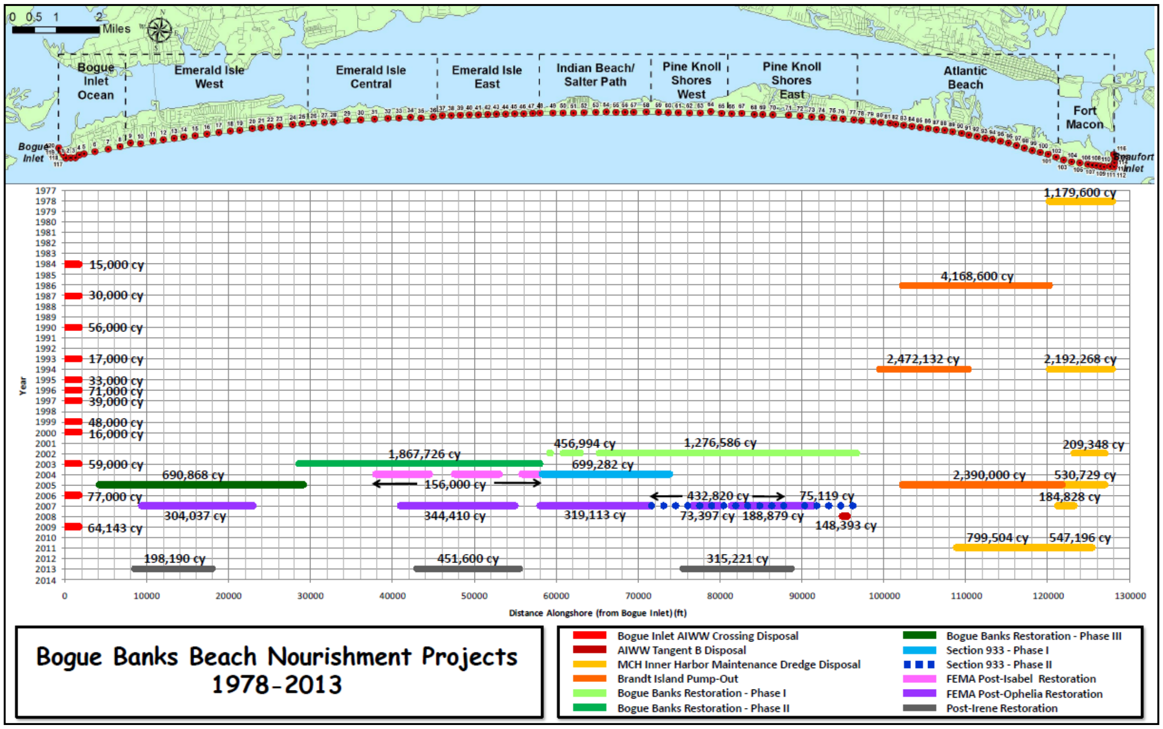

Figure 2-2: Beach Nourishment Project Completed Since 1978 Along Bogue Banks

3.0 PREFERRED ALTERNATIVE

3.1 Determination of Volume Need

One of the most reliable ways to analyze beach behavior and develop estimates for potential future beach nourishment needs is to examine past beach evolution with recognition of prior nourishment projects. Historical shoreline positions and beach profile morphology (including the associated volume changes) provide a basis for understanding the physics and sediment processes that caused the beach evolution. This assessment is also necessary to calibrate and validate shoreline and profile change models of the region that are used to assess alternatives.

Historical surveyed beach profiles and volume changes have been documented consistently in beach profile monitoring reports annually since 2004. These annual surveys have been performed along Bogue Banks, Bear Island, and Shackleford Banks as part of Carteret County's Bogue Banks Beach and Nearshore Mapping Program. This includes 122 profiles along Bogue Banks, 18 on Bear Island, and 24 profiles on Shackleford Banks. In addition to these annual monitoring surveys, additional complete surveys along Bogue Banks (alone) were completed in 1999, 2000, and 2003. All the profiles cover both onshore (dune to wading depth) and offshore (wading depth to 30 feet).

The analytical/empirical and numerical modeling portions of the study considered historical and present shoreline/volumetric change rates, present sand volumes existing as of the June 2011 beach profile survey (selected since immediately before effects of Hurricane Irene), and forward-looking sand volumes required to achieve an equal level of protection (LoP) for property and infrastructure along developed reaches of the shoreline.

3.1.1 Historical Analysis

The first stage of the analytical/empirical analysis of historical data was to assess volumetric change over the period of 1999 to 2012 (13 years). Various beach profile volumes and changes were calculated over various time periods as the data allowed.

A key aspect of the historical profile evolution assessment is to determine volumetric changes in the beach profile. As limited by the data (i.e. not all surveys extend to the same offshore depth), volumetric changes between consecutive surveys were calculated at each of the 112 oceanfront transects along Bogue Banks above the following elevations (NAVD88) (see Figure 3-1):

- +1.1 ft contour equivalent to MHW (represents the subaerial beach)
- -5 ft contour (dune and recreational beach)

- -12 ft contour (includes the offshore bar)
- -16 ft contour (equidistant point between -12 ft to ~depth of closure)
- -20 ft contour (near depth of closure based on previous USACE, Olsen and M&N studies related to DMMP)
- -30 ft contour (full extents of the possible active beach profile)

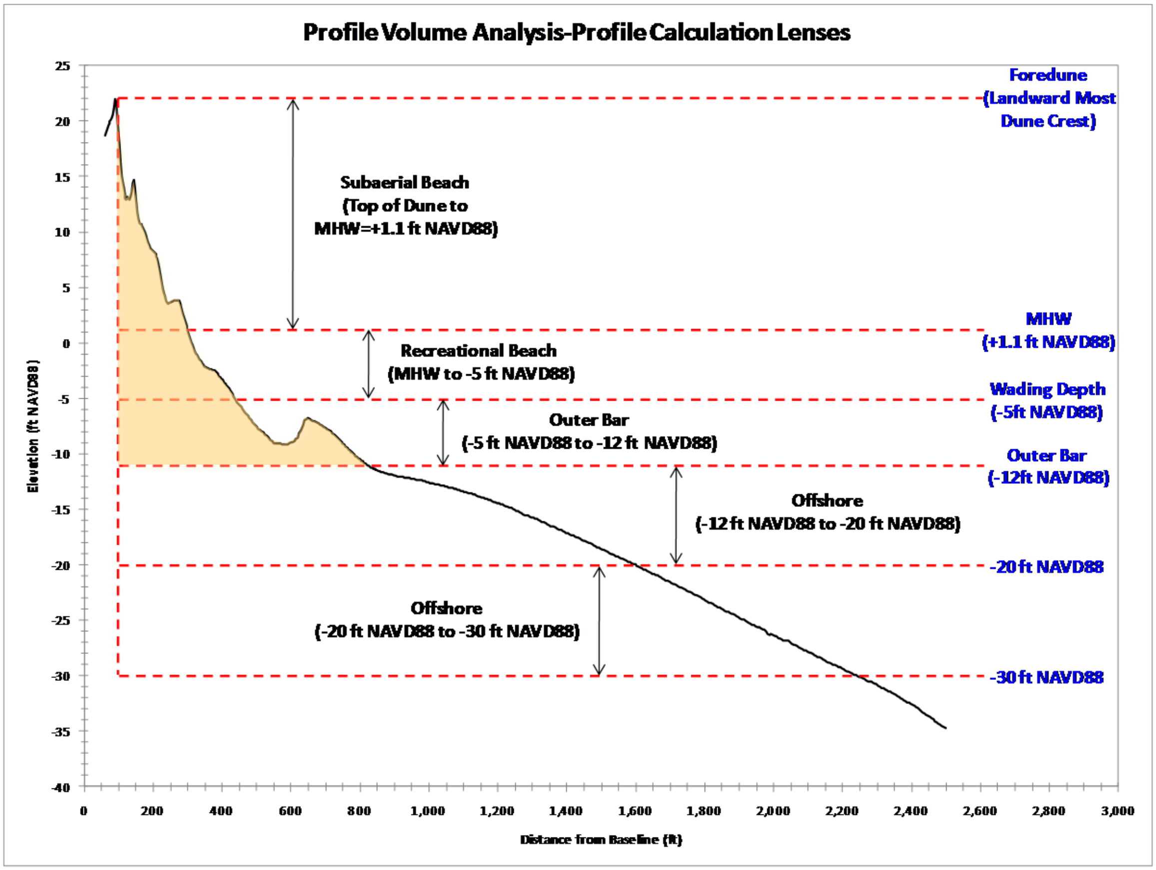

Figure 3-1: Volumetric Calculation Lenses for Historical Analysis

Past nourishment activities between consecutive surveys are also taken into account. The amounts of this nourishment were "netted out" by subtracting the average placement volume per transect, where applicable, from the volume change to obtain estimates of historical background volume change rates. The transect locations and placement quantities of these past projects are illustrated in Figure 3-2.

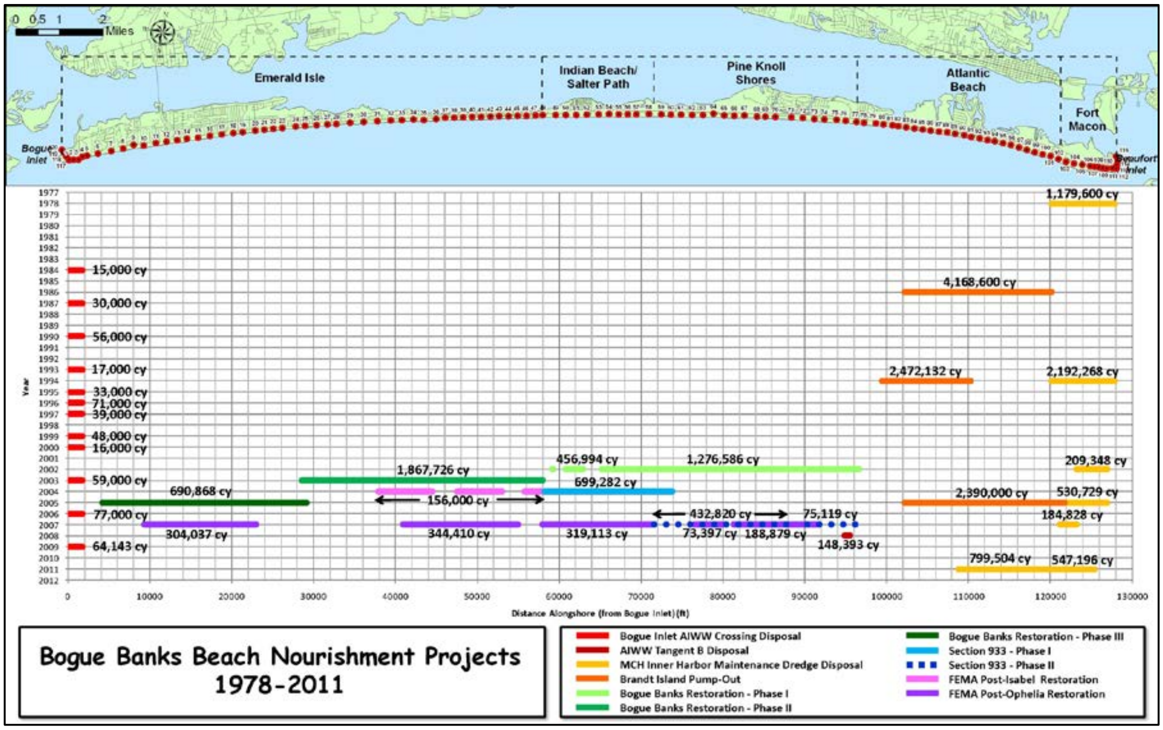

Figure 3-2: Nourishment Projects and Placement Locations Used to Determine Background Erosion Rates

3.1.2 Statistical Analysis

A statistical analysis of historical volume changes was performed to capture and quantify the variability inherent within the existing data. This allowed for a more confident prediction of future sediment needs based on historical volume changes by assigning probabilities of exceedance to the volume changes. Crystal Ball software, a Microsoft Excel Add-in program which uses a Monte Carlo simulation, was used to develop future volume needs based on confidence intervals. More background information on Crystal Ball and this approach can be found in Chapter 4.0 of the Engineering Report.

Table 3-1 summarizes the Crystal Ball analyses for the management reaches included within the MBNP. The 50% probability scenario, using volume changes calculated above -12 ft NAVD88, was considered to most accurately represent average historical volume change rates. These results also compare favorably with the sediment need determined by the USACE for the 50 year study. Within the Crystal Ball analyses, a few of the reaches were accretional under the 50% probability scenario even though history has shown that most areas of the island have required nourishment at one time or another. Therefore, the 55% - 70% probability scenarios were used in those reaches which showed accretion under the 50% scenario. **Based on these results, Table 3-1 shows an overall annual loss along Bogue Banks (without Fort Macon) of roughly 452,220 cy with a 50-yr nourishment need of 22.6 Mcy just to keep up with historical erosion patterns.**

Table 3-1: Crystal Ball Analysis Result Table for Annual Volume Change and 50-yr Nourishment Need

Reach	Reach Length (ft)	USACE Initial Placement Density (cy/ft)	USACE Annual Renourishment (cy)	+1.1 ft Annual Loss 50% (cy)	+1.1 ft Annual Loss Density 50% (cy/ft)	-5 ft Annual Loss 50% (cy)	-5 ft Annual Loss Density 50% (cy/ft)	-12 ft Annual Loss 50% (cy)	-12 ft Annual Loss Density 50% (cy/ft)	-16 ft Annual Loss 50% (cy)	-16 ft Annual Loss Density 50% (cy/ft)	-20 ft Annual Loss 50% (cy)	-20 ft Annual Loss Density 50% (cy/ft)		-12 ft Annual Loss 50% (All Loss)(cy)	-12 ft Annual Loss Density 50% (All Loss) (cy/ft)
Bogue Inlet (1-8)	7,432	60.0	-19,228	-4,170	-0.6	-18,555	-2.5	-39,468	-5.3	-134,450	-18.1	-163,229	-22.0		-39,468	-5.3
Emerald Isle West - A (9-11)	4,056	12.2	-24,225	-176	0.0	318	0.1	-5,384	-1.3	-3,004	-0.7	1,273	0.3		-5,384	-1.3
Emerald Isle West - B (12-22)	14,283	2.0	-16,233	10,828	0.8	26,970	1.9	33,886	2.4	45,035	3.2	79,421	5.6		-4,768	-0.3
Emerald Isle West - C (23-25)	4,005	0.1	-295	2,063	0.5	7,128	1.8	6,254	1.6	7,218	1.8	19,898	5.0		-1,566	-0.4
Emerald Isle Central - A (26-32)	10,428	1.0	-5,245	-1,377	-0.1	2,913	0.3	-982	-0.1	19,080	1.8	54,148	5.2		-14,093	-1.4
Emerald Isle Central - B (33-36)	5,374	0.9	-2,133	676	0.1	-6,347	-1.2	-10,890	-2.0	-11,250	-2.1	1,711	0.3		-10,890	-2.0
Emerald Isle East - A (37-44)	8,814	16.9	-22,025	-7,074	-0.8	-24,000	-2.7	-40,472	-4.6	-73,944	-8.4	-20,702	-2.3		-40,472	-4.6
Emerald Isle East - B (45-48)	4,406	12.8	-8,410	-6,634	-1.5	-14,088	-3.2	-23,272	-5.3	-12,302	-2.8	7,201	1.6		-23,272	-5.3
Indian Beach/Salter Path - West (49-52)	5,275	19.6	-18,144	-31,167	-5.9	-34,982	-6.6	-54,380	-10.3	-35,560	-6.7	-19,498	-3.7		-54,380	-10.3
Indian Beach/Salter Path - East (53-58)	7,575	4.1	-23,753	-9,396	-1.2	-5,706	-0.8	-8,187	-1.1	-25,398	-3.4	-9,784	-1.3		-8,187	-1.1
Pine Knoll Shores - West (59-65)	9,063	3.5	-31,057	-9,343	-1.0	-14,833	-1.6	-13,726	-1.5	-12,095	-1.3	-11,184	-1.2		-13,726	-1.5
Pine Knoll Shores - East - A (66-70)	6,564	10.5	-19,056	-7,364	-1.1	-15,605	-2.4	-24,709	-3.8	-32,204	-4.9	-12,895	-2.0		-24,709	-3.8
Pine Knoll Shores East - B (71-76)	8,251	19.0	-31,562	-24,631	-3.0	-27,929	-3.4	-46,360	-5.6	-85,297	-10.3	-88,549	-10.7		-46,360	-5.6
Atlantic Beach - West (77-81)	5,388	22.9	-26,533	-2,248	-0.4	567	0.1	-125	0.0	-4,475	-0.8	-2,924	-0.5		-5,881	-1.1
Atlantic Beach - Central (82-89, 91-96)	13,771	47.5	-52,361	-45,628	-3.3	-78,963	-5.7	-96,718	-7.0	-150,104	-10.9	-128,399	-9.3		-96,718	-7.0
Atlantic Beach - Circle (90)	1,006	53.2	-4,280	-5,851	-5.8	-10,397	-10.3	-12,948	-12.9	-22,234	-22.1	-19,431	-19.3		-12,948	-12.9
Atlantic Beach - East (97-102)	6,011	80.5	-51,707	-15,394	-2.6	-25,279	-4.2	-49,398	-8.2	-48,566	-8.1	-32,756	-5.4		-49,398	-8.2
TOTAL ANNUAL VOLUME CHANGE	**121,702**	**20.1**	**-356,247**	**-156,886**	**-1.3**	**-238,788**	**-2.0**	**-386,879**	**-3.2**	**-579,550**	**-4.8**	**-345,699**	**-2.8**		**-452,220**	**-3.7**
50-yr Nourishment Need	**121,702**	**36.6**	**-17,812,350**	**-7,844,300**		**-11,939,400**		**-19,343,950**		**-28,977,500**		**-17,284,950**			**-22,611,000**	

While the historical dataset does include some storm events (Hurricanes Isabel, Ophelia, and Irene), the effects of these storms were mainly seen at the higher exceedance results (i.e., 65-100% probabilities). Therefore, the previous analyses is assumed to be representative of normal background erosional patterns, but a separate analysis of an individual storm impacts is appropriate to give a sense of the overall sediment need from a storm perspective as well.

To assess storm impacts, the overall dataset was restricted to the three years of 2003 to 2005 which included Hurricanes Isabel, Ophelia, and Irene and re-run in Crystal Ball. Table 3-2 shows the results of the Crystal Ball analysis for losses above -12 ft and -16 ft at various exceedance probablities, summed across all the management reaches included within the MBNP. **Based on the results, it is expected that the need for a given storm may range between 1.4 – 1.7 Mcy. Given that storms have occurred once every three years or so, the storm need over 50 years may range between 22.4 – 27.2 Mcy**

Table 3-2: Crystal Ball Estimate of Individual Storm Volume Loss

Probability	Storm Loss Above -12 ft NAVD (cy)	Storm Loss Above -16 ft NAVD (cy)
85%	-1,644,909	-1,847,667
84%	-1,636,034	-1,839,681
80%	-1,602,871	-1,809,816
75%	-1,567,196	-1,776,197
70%	-1,534,995	-1,747,197
65%	-1,506,039	-1,719,307
60%	-1,477,667	-1,693,397
55%	-1,450,894	-1,668,206
50%	-1,424,153	-1,644,355

Therefore, the overall (background and storm) sediment need over the 50 year planning horizon based on the analytical/empirical analysis is between 45.0 and 49.8 Mcy. An analysis of sea level change effects was also completed and utilizing the USACE recommendation for moderate sea level change, the total sediment need for the next 50 years increases to 46.8 to 51.6 Mcy.

3.2 Determination of Level of Protection

In addition to historical volume change, determination of how the beach would respond to various return period events would also need to be quantified by modeling. Storm-induced beach profile evolution simulations were conducted for representative survey transects in each reach / subreach using the SBEACH numerical model. The primary purpose of the beach profile evolution numerical modeling is to assess the level of protection from storm surge and waves afforded by the beach and dune system system – under existing conditions and with different project alternatives. See Chpater 7.0 of the

Engineering Report for more detail concerning the level of protection determination and associated analysis.

3.2.1 Representative Transects and Reaches

The number of transects in the regular Bogue Banks beach profile monitoring program (112) is too great to efficiently simulate existing conditions and proposed alternative projects at each and every transect. Therefore, 18 transects were selected within each reach and subreach that are representative of existing conditions beach profile morphology in each area.

Table 3-3 gives the representative transects for which levels of protection have been simulated in SBEACH, along with the length of shoreline represented. Representative transects were selected based on physical beach characteristics, historical erosion rates, and geopolitical boundaries. Figure 3-3 shows the location of the transect locations within each reach.

Table 3-3: Reach Description and Representative Profile Transects

Reach	Bogue Banks Transects	Length (feet)	Representative Transect
Bogue Inlet – Ocean (1-8)	1 through 8	7,432	6
Emerald Isle – West (9-25)	9 through 11	4,056	11
	12 through 22	14,283	17
	23 through 25	4,005	25
Emerald Isle – Central (26-36)	26 through 32	10,428	30
	33 through 36	5,374	35
Emerald Isle – East (37-48)	37 through 44	8,814	42
	45 through 48	4,406	46
Indian Beach – Salter Path (49-58)	49 through 52	5,275	50
	53 through 58	7,575	58
Pine Knoll Shores – West (59-65)	59 through 65	9,063	65
Pine Knoll Shores – East (66-76)	66 through 70	6,564	70
	71 through 76	8,251	75
Atlantic Beach (77-102)	77 through 81	5,388	79
	82 through 89 & 91 through 96	13,771	85
	90	1,006	90
	97 through 102	6,011	100
Fort Macon State Park (103-112)	103 through 112	6,691	105

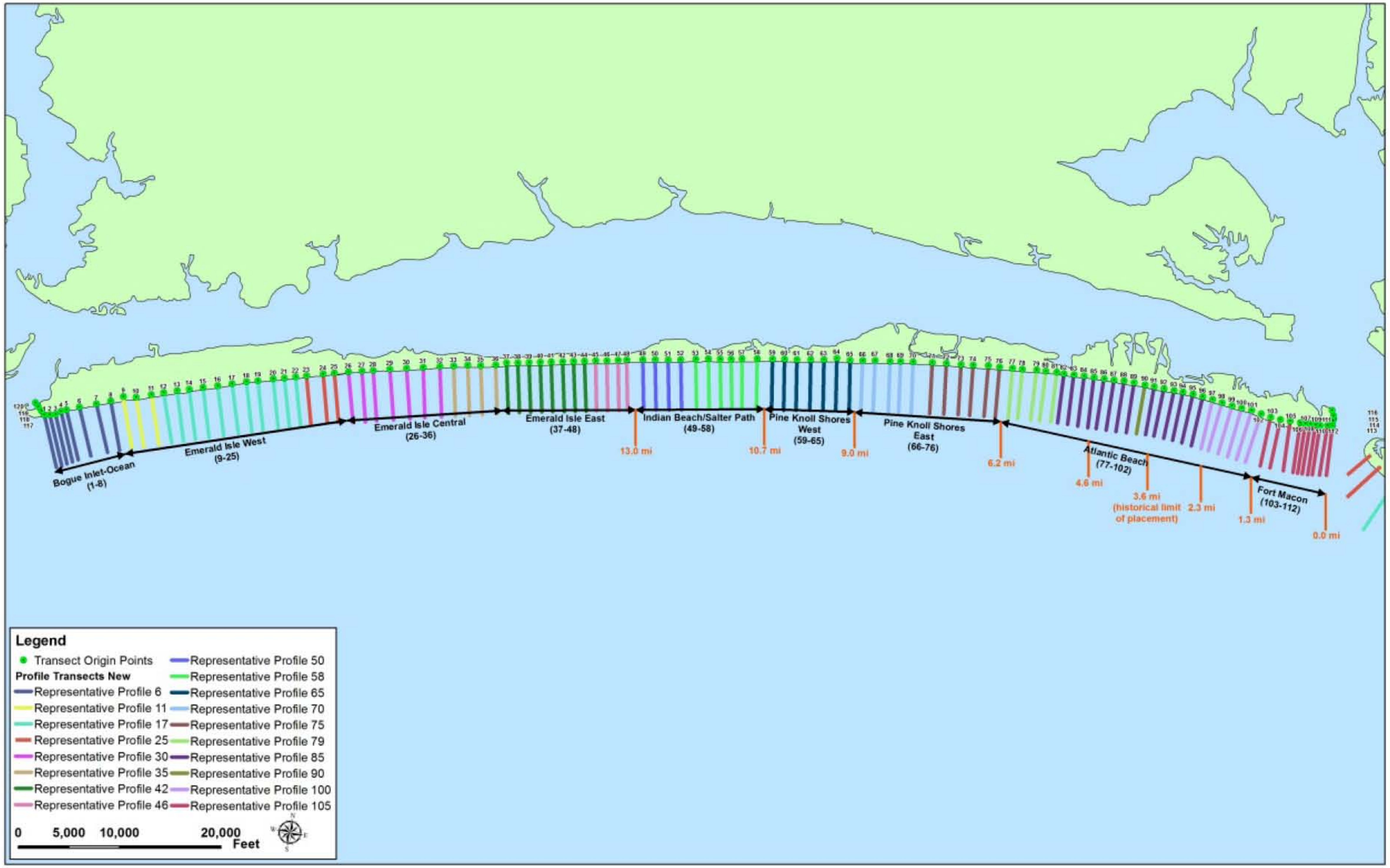

Figure 3-3: Location of Representative Transects

3.2.2 Modeling Approach

The level of protection afforded is determined as the profile's ability to resist breaching and severe overtopping during extreme storm events of a certain annual probability of exceedance (stated as return period, the inverse of this probability) so as to avoid damage to upland structures.

For both the existing conditions simulations and future design template scenarios, SBEACH was run for various return period events (2-yr, 5-yr, 10-yr, 25-yr, 50-yr, and 100-yr design storms). The post-storm beach and dune profiles resulting from the SBEACH simulations were inspected and coastal engineering judgment applied to conclude the level of protection afforded by the profiles. The level of protection offered was evaluated by assessing the landward limit of dune erosion and potential for dune flooding / overtopping – indicated by the SBEACH simulations of the synthetic design storms – relative to the position of the most seaward line of development (most seaward or "first row" of upland structures) at each of the 18 representative transects along Bogue Banks (Table 3-3).

Level of protection is indicated as a set of qualitative categories indicating the degree to which the first row of structures would be impacted by a specific design storm. The LoP categories used in this study and their definitions are:

- Undermined – Profile eroded to the position of (or landward of) the first row of structures, thus undermining their foundations. This is considered a severe impact for the present level of protection analysis.

- Threatened – Profile eroded to very near the seaward limits of the first row of structures, such that the stability of the foundations may be threatened. This is considered a severe impact for the present level of protection analysis.

- Major Overtopping – Eroded profile, water level, and maximum wave crest elevation, combined with position and elevation of first row of structures, indicate that the lower levels of structures are likely to be flooded or impacted by moving water. This is considered a severe impact for the present level of protection analysis.

- Minor Overtopping – Eroded profile, water level, and maximum wave crest elevation indicate that the dune would be overtopped, but overtopping at first row of structures appears to be minimal. This category of impact is not considered, in the present study, as a severe impact for the level of protection analysis.

- No Impact – Neither the eroded profile, water level, nor the maximum wave crest elevation indicate that sediment movement or moving water will occur at the first row of structures.

The "first row of structures" positions utilized in the LoP evaluations were digitized from 2011 aerial photography. Structures positions used in the LoP analysis were an average of the positions adjacent to each representative transect, based on a line connecting the seaward edges of the structures along the island's length.

3.2.3 Level of Protection with Existing Conditions (June 2011) Profiles

The LoP offered by the existing beach and dune system was evaluated by assessing the results of the existing conditions SBEACH simulations for the design storms. The June 2011 profiles were selected as representative of the existing conditions since the 2012 profiles were impacted by Hurricane Irene. Table 3-4 summarizes the level of protection resulting at each of the 18 representative transects for the 25-year, 50-year, and 100-year return period (4%, 2%, and 1% annual chance, respectively) synthetic design storms. Based on these results, the June 2011 existing conditions of the beach and dune system are considered to provide a sufficient level of protection along all of the Bogue Banks reaches for up to a 25-year return period design storm event. Beyond this, the beach and dune system is not sufficient to protect infrastructure from damage.

Table 3-4: Level of Protection for Existing Conditions SBEACH Profiles

Reach	Bogue Banks Transect	Initial Volume (cy/ft)	25-year RP Level of Protection	50-year RP Level of Protection	100-year RP Level of Protection
Bogue Inlet – Ocean (1-8)	6	254.1	No Impact	No Impact	Minor Overtopping
Emerald Isle – West (9-25)	11	265.3	No Impact	Undermined	Undermined
	17	300.6	No Impact	Undermined	Undermined
	25	292.3	No Impact	Undermined	Undermined
Emerald Isle – Central (26-36)	30	266.3	No Impact	No Impact	No Impact
	35	230.8	No Impact	Undermined	Undermined
Emerald Isle – East (37-47)	42	230.5	No Impact	Undermined	Undermined
	46	254.6	No Impact	Undermined	Undermined
Indian Beach – Salter Path (48-58)	50	290.2	No Impact	No Impact	No Impact
	58	266.6	No Impact	No Impact	No Impact
Pine Knoll Shores – West (59-65)	65	235.3	No Impact	Minor Overtopping	Undermined
Pine Knoll Shores – East (66-77)	70	271.1	No Impact	Minor Overtopping	Major Overtopping
	75	276.2	No Impact	Minor Overtopping	Major Overtopping
Atlantic Beach (78-102)	79	269.3	No Impact	Minor Overtopping	Undermined
	85	300.9	No Impact	Threatened	Undermined
	90	363.8	No Impact	Undermined	Undermined
	100	494.9	No Impact	No Impact	No Impact
Fort Macon State Park (103-110)	105	364.7	n/a	n/a	n/a

3.2.4 MBNP Level of Protection Determination

As outlined in the previous section, the current beach profiles are adequate to provide protection for a 25-yr event. Therefore, various beach nourishment design scenarios were modeled to determine what size project would be required to bring the existing beach conditions up to a 50 year LoP. The SBEACH existing profiles were modified with respect to dune height, dune width, and/or beach berm width until the profile performed acceptably under the 50 year design storm condition. It was determined that a project of approximately 2.2 Mcy, with some targeted dune building in various reaches, would be required to provide protection for a 50-yr event.

While this initial project does seem feasible it is important to note that the project would likely cost between $22 - $27.5M based on recent dredging/placement costs. Since this project cost would likely be borne mainly by the County and Towns, the amount of time that it would take to raise this level of funds at current funding streams would be 5 – 7 years. **Since current funding streams are needed to meet the overall maintenance requirements, providing a LoP for a 50-yr event across the entire island was determined to not be feasible, and therefore a 25-yr event LoP was selected**. The County and Towns could always work toward a 50-yr level of protection if an unusual number of quiet years were to be experienced, but it was decided that it would be most prudent to select the 25-yr event LoP as the basis of design for the MBNP.

3.2.5 Nourishment Trigger Determination

With the 25-yr event now selected as the finalized level of protection, the development of nourishment triggers could commence. A nourishment trigger defines the minimum volume of material a profile can contain and still protect against the specified return period event. Again, it is important to note that the potential of nourishment triggers at all of the computation elevations was considered, but ultimately the elevation of -12 ft NAVD was selected due to historical placement limits of nourishment material as well as the ability of this portion of the profile to absorb the majority of the wave energy.

In order to determine the nourishment triggers, the representative profiles in each of the reaches were "eroded" (modified with respect to dune height, dune width, and/or beach berm width) until the profile was just able to protect the first line of infrastructure against damage. Table 3-6 shows the resulting trigger volumes determined form SBEACH modeling above -12 ft NAVD for both the 25-yr and 50-yr events as well as the amount in place as of 2011 (pre Hurricane Irene). Interestingly, the island wide average 25-yr trigger was computed to be 230 cy/ft, which is nearly identical to the previously used 225 cy/ft over the last 13 years.

Table 3-5. Calculated Volume Triggers Above -12 ft NAVD88 for Various RP Events

Reach	Reach Length (ft)	50-yr, -12 ft Trigger (cy)	25-yr, -12 ft Trigger (cy)	-12 ft 2011 Volume (cy)
Bogue Inlet (1-8)	7,432	238	103	389
Emerald Isle West - A (9-11)	4,056	282	230	277
Emerald Isle West - B (12-22)	14,283	319	272	295
Emerald Isle West - C (23-25)	4,005	323	242	303
Emerald Isle Central - A (26-32)	10,428	237	213	292
Emerald Isle Central - B (33-36)	5,374	277	207	262
Emerald Isle East - A (37-44)	8,814	268	214	242
Emerald Isle East - B (45-48)	4,406	299	235	264
Indian Beach/Salter Path - West (49-52)	5,275	243	216	263
Indian Beach/Salter Path - East (53-58)	7,575	241	229	298
Pine Knoll Shores - West (59-65)	9,063	235	196	253
Pine Knoll Shores - East - A (66-70)	6,564	271	218	240
Pine Knoll Shores East - B (71-76)	8,251	287	222	262
Atlantic Beach - West (77-81)	5,388	269	225	281
Atlantic Beach - Central (82-89, 91-96)	13,771	375	248	291
Atlantic Beach - Circle (90)	1,006	408	364	330
Atlantic Beach - East (97-102)	6,011	318	276	384
TOTAL	**121,702**			
AVERAGE		**288**	**230**	**290**

However, there were concerns with the calculation as completed for the Bogue Inlet reach (103 cy) which is significantly affected by the shape of the profile at the inlet. For this reason, the 50-yr trigger volume of 238 cy was selected as the final value for the Bogue Inlet subreach. Once the Bogue Inlet result was revised, the resulting overall average rose to 238 cy/ft (see Table 3-6). This result makes sense in the fact that the 225 cy/ft original trigger was based on profile volumes in Atlantic Beach (which had weathered the hurricanes well) AFTER the hurricanes. It would only make sense that the PRE-storm volume would be higher and given that the past hurricanes over the last decade have had roughly 1.2 -1.5 Mcy of erosion this would mean that the pre-storm volume island-wide was approximately 10-13 cy/ft higher than the 225 cy/ft after the event. Therefore, the overall average of 238 cy/ft for the entire island was determined to be very reasonable.

Table 3-6: Revised Volume Triggers Above -12 ft NAVD88 for Various RP Events

Reach	Reach Length (ft)	50-yr, -12 ft Trigger (cy)	25-yr, -12 ft Trigger (cy)	Adjusted 25-yr, -12 ft Trigger (cy)	Preliminary -12 ft Trigger (cy)	-12 ft 2011 Volume (cy)
Bogue Inlet (1-8)	7,432	238	103	238	235	389
Emerald Isle West - A (9-11)	4,056	282	230	230		277
Emerald Isle West - B (12-22)	14,283	319	272	272	266	295
Emerald Isle West - C (23-25)	4,005	323	242	242		303
Emerald Isle Central - A (26-32)	10,428	237	213	213	211	292
Emerald Isle Central - B (33-36)	5,374	277	207	207		262
Emerald Isle East - A (37-44)	8,814	268	214	214	221	242
Emerald Isle East - B (45-48)	4,406	299	235	235		264
Indian Beach/Salter Path - West (49-52)	5,275	243	216	216	224	263
Indian Beach/Salter Path - East (53-58)	7,575	241	229	229		298
Pine Knoll Shores - West (59-65)	9,063	235	196	196	211	253
Pine Knoll Shores - East - A (66-70)	6,564	271	218	218		240
Pine Knoll Shores East - B (71-76)	8,251	287	222	222		262
Atlantic Beach - West (77-81)	5,388	269	225	225	254	281
Atlantic Beach - Central (82-89, 91-96)	13,771	375	248	248		291
Atlantic Beach - Circle (90)	1,006	408	364	364		330
Atlantic Beach - East (97-102)	6,011	318	276	276		384
TOTAL	**121,702**					
AVERAGE		**288**	**230**	**238**	**233**	**290**
					Weighted	

Nonetheless, while determination of the individual subreach triggers was needed, it would not be practicable to have individual nourishment actions be dictated by a single subreach while adjacent subreaches would not require sand placement. Therefore, the individual subreaches were re-examined to determine which subreaches should be grouped together for nourishment reach determination. Table 3-6 also shows the proposed management reaches and the weighted trigger volume above -12 ft NAVD based on the subreach lengths. The resulting management reaches are on average 2-3 miles long with the exception of the Pine Knoll Shores and Atlantic Beach management reaches which are somewhat longer and cover the entire Town in each case. For the proposed management reaches, the weighted trigger is 233 cy/ft with triggers varying from 211 cy/ft for Emerald Isle Central to 266 cy/ft for portions of Emerald Isle West.

3.3 Determination of Preferred Alternative

A detailed assessment of numerous alternatives to meet the volume need and LoP can be found in Sections 8.3 through 8.7 of the Engineering Report. The alternatives include:

- No Action (Status Quo)
- Reloaction/Abandonment
- USACE SAW 50-yr Federal Storm Damage Reduction Project

- Beach Renourishment Only
  - Upland Sources Only
  - AIWW Sources Only
  - Offshore Sources Only
  - Upland/AIWW/Offshore Sources Combination

- Beach Renourishment and Inlet Management
  - Non-Structural Inlet Management
  - Structural Inlet Management
  - Hybrid Approach (Structural & Non-Structural Inlet Management)

Based on both numerical modeling and analytical analyses, the preferred alternative is Beach Nourishment with Non-structural Inlet Management. This is the only option that provides adequate sand sources to provide and maintain a 25-yr event LoP for all of Bogue Banks as well as provide adequate infrastructure and habitat protection along the Bogue Inlet shoulders. A summary of the information pertinent to the preferred alternative is provided in the following sections, including native beach and borrow source characteristics, nourishment volumes and renourishment intervals, project construction window, and funding sources.

3.3.1 Native Beach and Borrow Source Sediment Data

3.3.1.1 Native Beach Sediment Data

Before the series of nourishment projects which took place along Bogue Banks in the 2000's, native beach data was collected by the USACE as well as CSE. These data indicate a native grain size ranging from 0.2 mm to 0.3 mm. For this report, a median grain size of 0.3 mm is selected as the best representation of the native beach based upon the 64 samples analyzed by CSE in 2001. Table 3-7 summarizes the available native beach data. More detail on these studies can been seen in Section 3 of Appendix A.

Table 3-7: Available Native Beach Data

Date	Source	Mean Grain Size (mm)	Coverage
1976	USACE	0.17	Atlantic Beach (4 transects)
1999	CSE	0.3	Bogue Banks (6 transects; 20,000 ft apart)
2001	USACE	0.19	Bogue Inlet Area
2001	USACE	0.19	West Emerald Isle
2001	USACE	0.2	East Emerald Isle
2001	USACE	0.2	Indian Beach
2001	USACE	0.19	Pine Knoll Shores
2001	USACE	0.19	Atlantic Beach
2001	USACE	0.22	Fort Macon
2001	CSE	0.3	Indian Beach/Salter Path & Pine Knoll Shores (16 transects)

3.3.1.2 Potential Borrow Sources for the Bogue Banks MBNP

In 2012, Alpine and Coastal Tech conducted a geotechnical investigation of the main potential offshore borrow areas near Bogue Banks to identify beach-compatible sand resources for the long term beach nourishment needs of Carteret County. The sites investigated were the Old Ocean Dredge Material Disposal Site (ODMDS) located directly offshore of Beaufort Inlet, the Current ODMDS just south of the Old ODMDS, Area Y and Z directly offshore of Emerald Isle, and the main ebb channel of Bogue Inlet, as shown in Figure 3-4. The 2012 investigation consisted of 164 twenty-foot vibracores extracted in the Old ODMDS, Current ODMDS, Area Y, and Area Z. There were an additional 5 ten-foot vibracores extracted in Bogue Inlet by Alpine Ocean Seismic Survey. Analysis of vibracores collected in 2002 by the USACE in the Morehead City Outer Harbor was also conducted to ensure compatibility and verify the quantity of any material available for placement as a result of the USACE Morehead City Harbor Dredged Material Management Plan (DMMP). The results of the sand search investigation is summarized for each site in the following sections while a detailed report can be found in Appendix A. In addition, research was conducted to estimate potential sediment quantities in upland sediment sources (sand mines) and AIWW disposal areas.

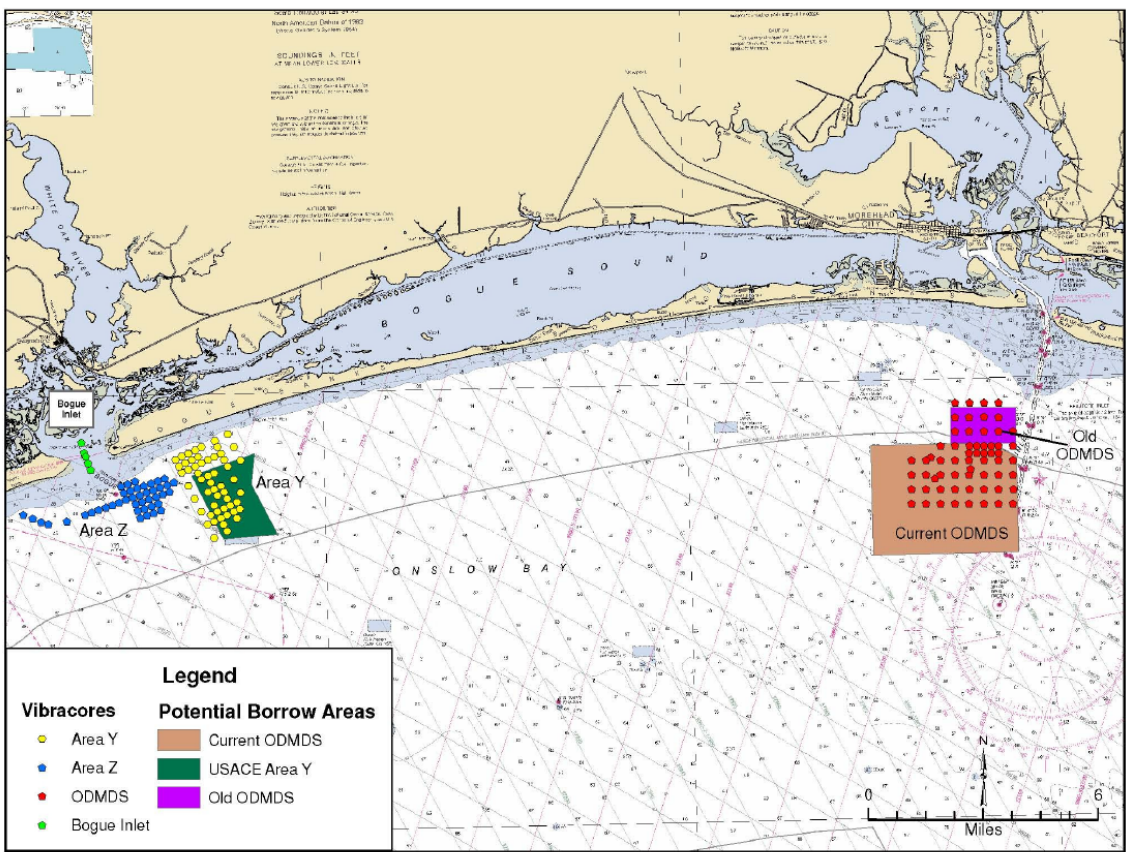

Figure 3-4: Potential Borrow Areas and 2012 Vibracore Locations (Coastal Tech, 2013)

The material in the proposed borrow areas must meet the characteristics prescribed by North Carolina Administrative Code (NCAC) "Technical Standards for Beach Fill Projects" (15A NCAC 07H .0312) resulting in the parameters listed in **Table 3-8**.

Table 3-8: Native Beach Characteristics and Rule Parameters

Characteristic	2001 Native	NCAC Requirements	Required Borrow Site Parameters
Fines (<#230)	Reported: 0%, Assumed: <1%	<1% +5%	≤ 6%
Sand (>#230 & <#10)	Reported at 98.68%	-	-
Granular (>#10 & <#4)	Reported combined at 1.32%, Assumed 0.7% each	0.7% + 5%	≤ 6%
Gravel (>#4)		0.7% + 5%	≤ 6%
Calcium Carbonate	Reported at 15-20%	20% + 15%	≤ 35%

3.3.1.3 Old ODMDS

This site is located directly north of the Current ODMDS in State waters. The Old ODMDS was split into two sections; designated Old ODMDS 1 and Old ODMDS 2, to maximize the potential borrow area volume as shown in Figure 3-5.

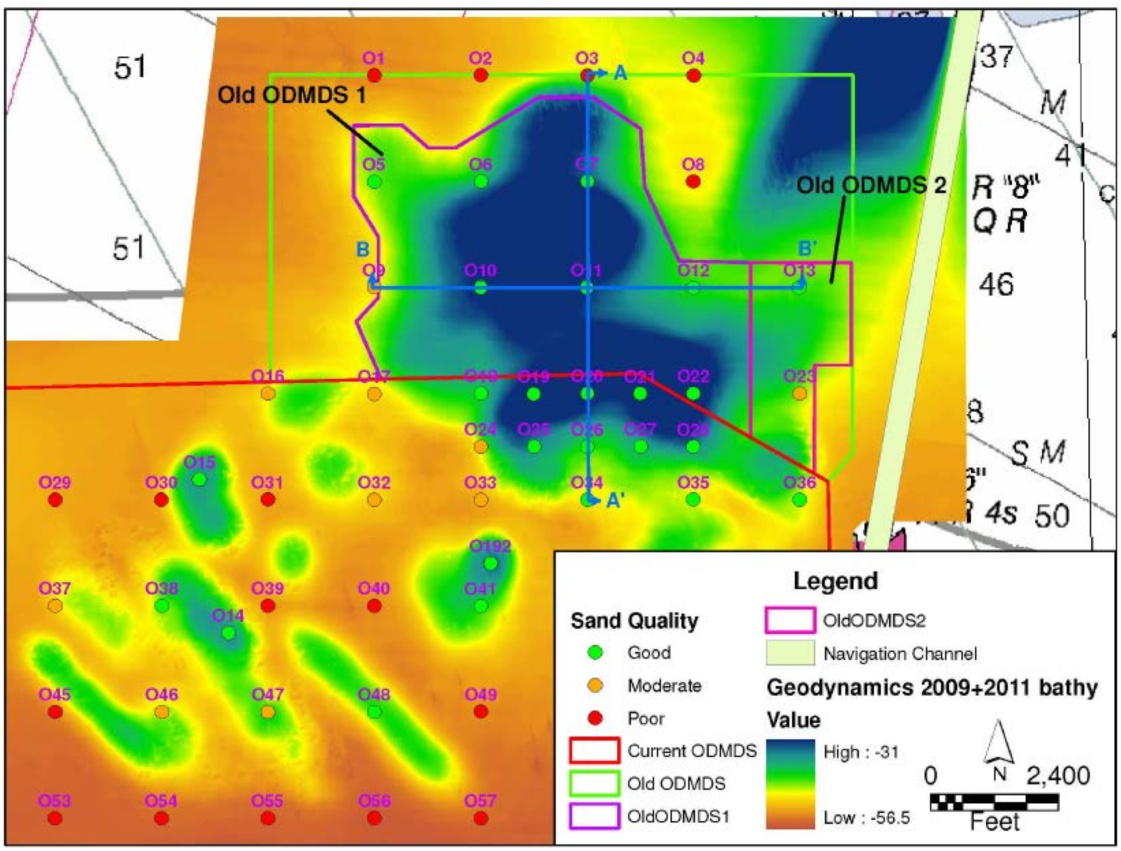

Figure 3-5: Old ODMDS Site and Vibracore Locations (Coastal Tech, 2013)

3.3.1.3.1 Old ODMDS 1

Old ODMDS 1 borrow area is location on the boarder of Current ODMDS. This area consists of fine grained, poorly sorted quartz sand with a mean grain size of 0.30 millimeters (mm) and an overfill factor of 1.30. This area is estimated to contain 13.1 Million cubic yards (Mcy) of beach compatible sand. The characteristics of this material are compliant with the parameters defined by the NCAC as shown in Table 3-9.

Table 3-9: Old ODMDS 1 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Old ODMDS 1
Fines (<#230)	≤ 6%	**0.53%**
Sand (>#230 & <#10)	-	**96.00%**
Granular (>#10 & <#4)	≤ 6%	**2.14%**
Gravel (>#4)	≤ 6%	**1.33%**
Calcium Carbonate	≤ 35%	**13.55%**

3.3.1.3.2 Old ODMDS 2

Old ODMDS 2 borrow area is similar to Old ODMDS 1 with a slightly larger mean grain size of 0.32 mm and an overfill factor of 1.25. This area is estimated to contain 1.1 Mcy of beach compatible sand that meet the NCAC criteria as listed in Table 3-10.

Table 3-10: Old ODMDS 2 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Old ODMDS 2
Fines (<#230)	≤ 6%	**0.20%**
Sand (>#230 & <#10)	-	**96.30%**
Granular (>#10 & <#4)	≤ 6%	**2.49%**
Gravel (>#4)	≤ 6%	**1.01%**
Calcium Carbonate	≤ 35%	**13.57%**

3.3.1.4 Current ODMDS

The Current ODMDS is located south of the Old ODMDS just outside of the 3-mile jurisdictional line in Federal waters. This area was divided into eight potential borrow areas consisting of one large mound and seven smaller disposal mounds within this location. The seven small disposal mounds were then grouped according to the level of confidence in the granularmetric data.

3.3.1.4.1 Current ODMDS 1

Current ODMDS 1 is an extension of the large mound located in Old ODMDS 1 as shown below in Figure 3-6; therefore, they have very similar sediment properties. The mean grain size is 0.30 mm and an overfill factor of 1.25 and meet all of the NCAC compatibility requirements as listed in Table 3-11. This site contains approximately 3.27 Mcy of beach compatible material. This number has been adjusted from that in Appendix A (4.23 Mcy) by subtracting out the Hurricane Irene renourishment amount which was dredged from this borrow area.

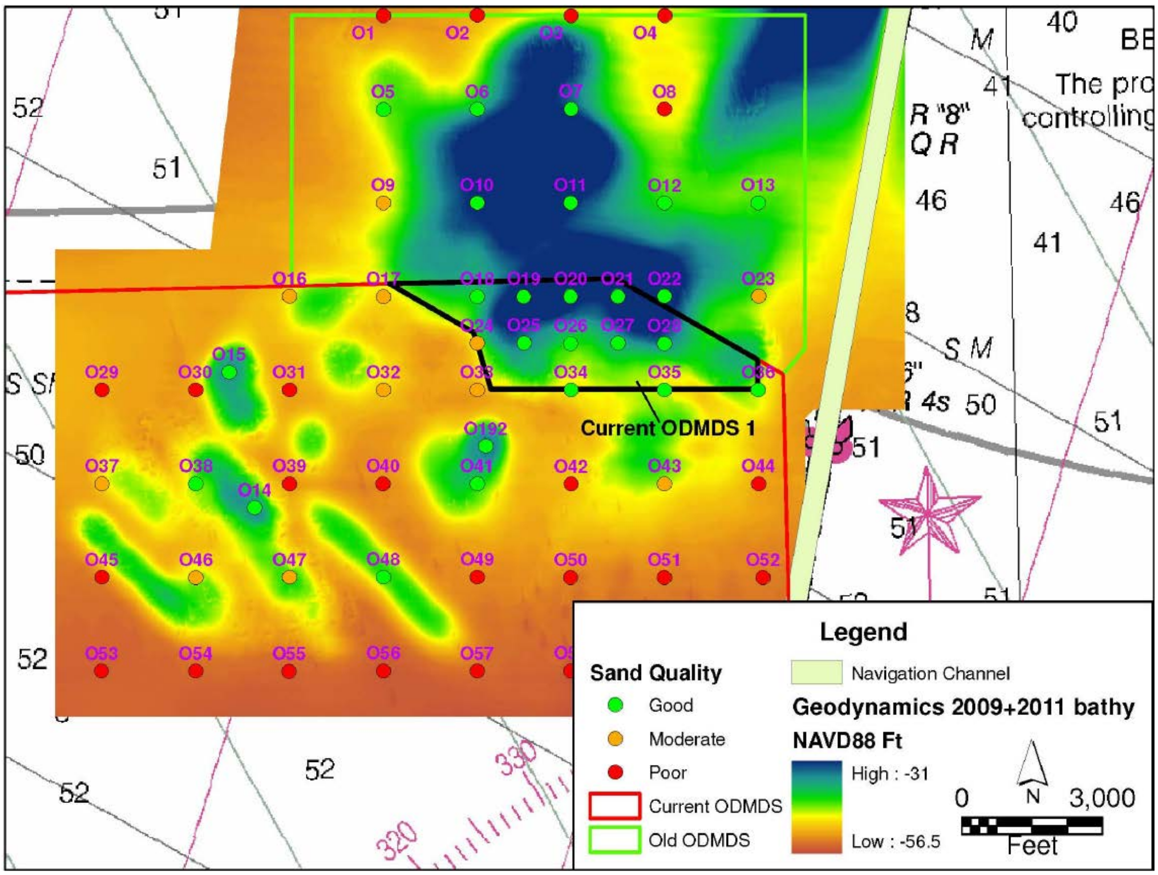

Figure 3-6: Current ODMDS 1 Site and Vibracore Locations (Coastal Tech, 2013)

Table 3-11: Current ODMDS 1 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Current ODMDS 1
Fines (<#230)	≤ 6%	**0.52%**
Sand (>#230 & <#10)	-	**96.06%**
Granular (>#10 & <#4)	≤ 6%	**2.06%**
Gravel (>#4)	≤ 6%	**1.36%**
Calcium Carbonate	≤ 35%	**13.29%**

3.3.1.4.2 Higher Confidence Mounds

The higher confidence mounds include mounds where at least one vibracore penetrates the thickest portion of the mound. This allows for more accurate representation of the stratigraphy to be defined. The higher confidence mounds include Mounds O-15, O-192, O-48, O14, and O-47, which are shown in Figure 3-7.

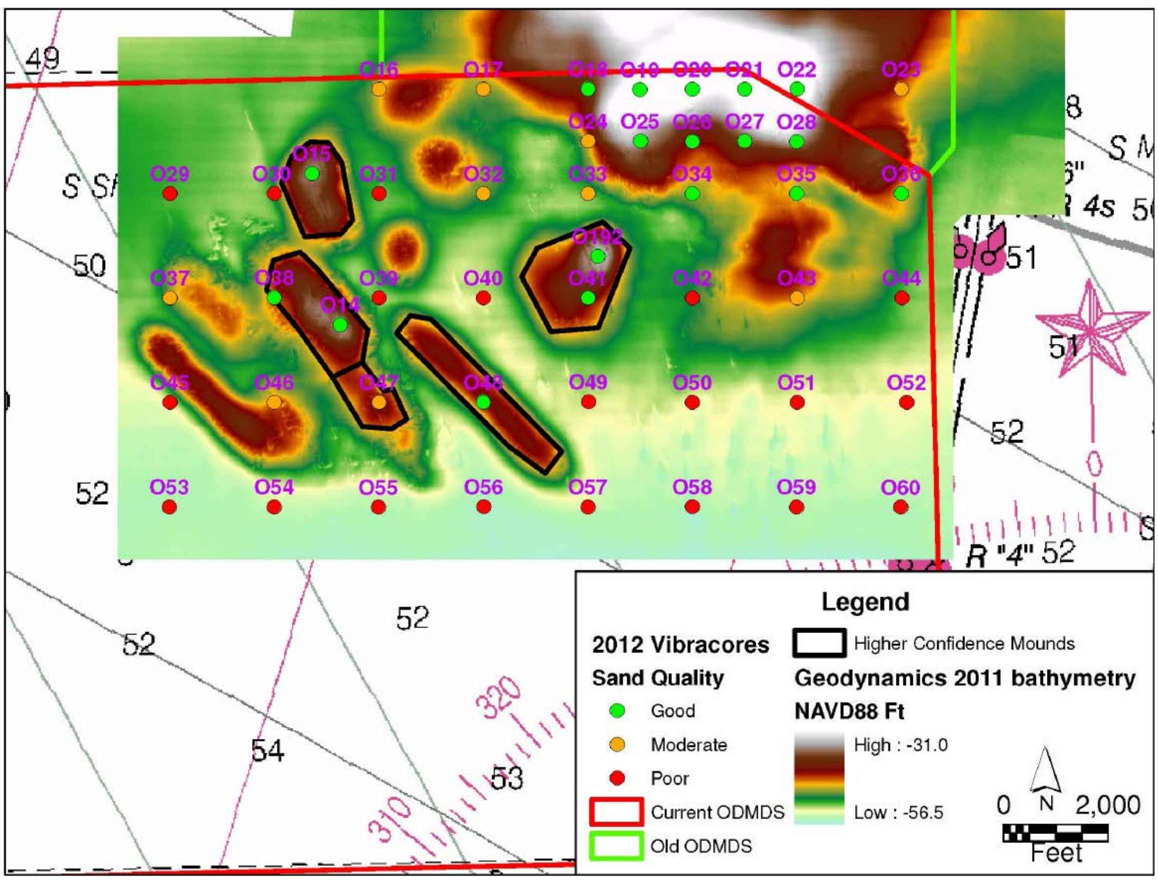

Figure 3-7: Higher Confidence Mound Sites and Vibracore Locations (Coastal Tech, 2013)

Mound O-15

Mound O-15 is located west of Current ODMDS 1 and has vibracore O-15 passing directly through the thickest section of the mound. This potential borrow area consists of fine grained, moderately sorted quartz sand and has a mean grain size of 0.24 mm, which is smaller than the native mean grain size. This results in a larger overfill factor of 1.60 and Mound O-15 being assigned a "B" ranking. All parameters defined by NCAC were met, as shown in Table 3-12; therefore, the material is considered beach compatible. The total amount of beach compatible material in this mound is approximately 356,000 cubic yards (cy).

Table 3-12: Mound O-15 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Mound O-15
Fines (<#230)	≤ 6%	**0.07%**
Sand (>#230 & <#10)	-	**99.23%**
Granular (>#10 & <#4)	≤ 6%	**0.54%**
Gravel (>#4)	≤ 6%	**0.16%**
Calcium Carbonate	≤ 35%	**10.10%**

Mound O-192

Mound O-192 is located southwest of Current ODMDS 1 and has vibracore O-192 and O-41 passing through this mound with O-192 passing through the thickest section of the mound. This potential borrow area consists of fine grained, poorly sorted quartz sand and has a mean grain size of 0.36 mm, which is coarser than the previous mound. This results in a smaller overfill factor of 1.25 and Mound O-192 being assigned an "A" ranking. All parameters defined by NCAC were met, as shown in Table 3-13; therefore, the material is considered beach compatible. The total amount of beach compatible material in this mound is approximately 785,270 cy.

Table 3-13: Mound O-192 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Mound O-192
Fines (<#230)	≤ 6%	**0.13%**
Sand (>#230 & <#10)	-	**93.07%**
Granular (>#10 & <#4)	≤ 6%	**3.43%**
Gravel (>#4)	≤ 6%	**3.37%**
Calcium Carbonate	≤ 35%	**19.59%**

Mound O-48

Mound O-48 is located southwest of Current ODMDS 1 and has vibracore O-48 passing through the middle of the mound. This potential borrow area consists of fine grained, moderately sorted quartz sand and has a mean grain size of 0.2 mm, which is significantly finer than the native sediment. This results in a larger overfill factor of 2.25 and Mound O-48 being assigned a "C" ranking. All parameters defined by NCAC were met, as shown in Table 3-14; therefore, the material is considered beach compatible. The total amount of beach compatible material in this mound is approximately 468,740 cy.

Table 3-14: Mound O-48 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Mound O-48
Fines (<#230)	≤ 6%	**5.91%**
Sand (>#230 & <#10)	-	**92.83%**
Granular (>#10 & <#4)	≤ 6%	**1.11%**
Gravel (>#4)	≤ 6%	**0.15%**
Calcium Carbonate	≤ 35%	**7.76%**

Mound O-14/O-47

Mound O-14/O-47 is located west of Mound O-48 and has vibracore O-14, O-47, and O-38 passing through the mound. This mound was split because it was assigned two different cut depths to maximize beach quality material being removed. Even though this area was split, the sediment properties were analyzed and recorded as one site. This potential borrow area consists of fine grained, poorly sorted quartz sand and has a mean grain size of 0.38 mm, which is coarser than the native sediment. This results in a smaller overfill factor of 1.20 and Mound O-14/O-47 being assigned an "A" ranking. All parameters defined by NCAC were met, as shown in Table 3-15; therefore, the material is considered beach compatible. The total amount of beach compatible material in this mound is approximately 566,028 cy.

Table 3-15: Mound O-14/O-47 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Mound O-14 / O-47
Fines (<#230)	≤ 6%	**0.23%**
Sand (>#230 & <#10)	-	**93.43%**
Granular (>#10 & <#4)	≤ 6%	**4.71%**
Gravel (>#4)	≤ 6%	**1.63%**
Calcium Carbonate	≤ 35%	**19.80%**

3.3.1.4.3 Lower Confidence Mounds

The lower confidence mounds include mounds where the vibracore is located along the edge and none that penetrate the thickest portion of the mound. This prevents an accurate representation of the stratigraphy to be defined. The lower confidence mounds include

Mounds O-35 and O-46, which are shown in Figure 3-8. Coastal Tech recommends that these mounds be sampled with additional vibracores in the thickest portion of the mounds to confirm the sediment characteristic inferred from the existing cores.

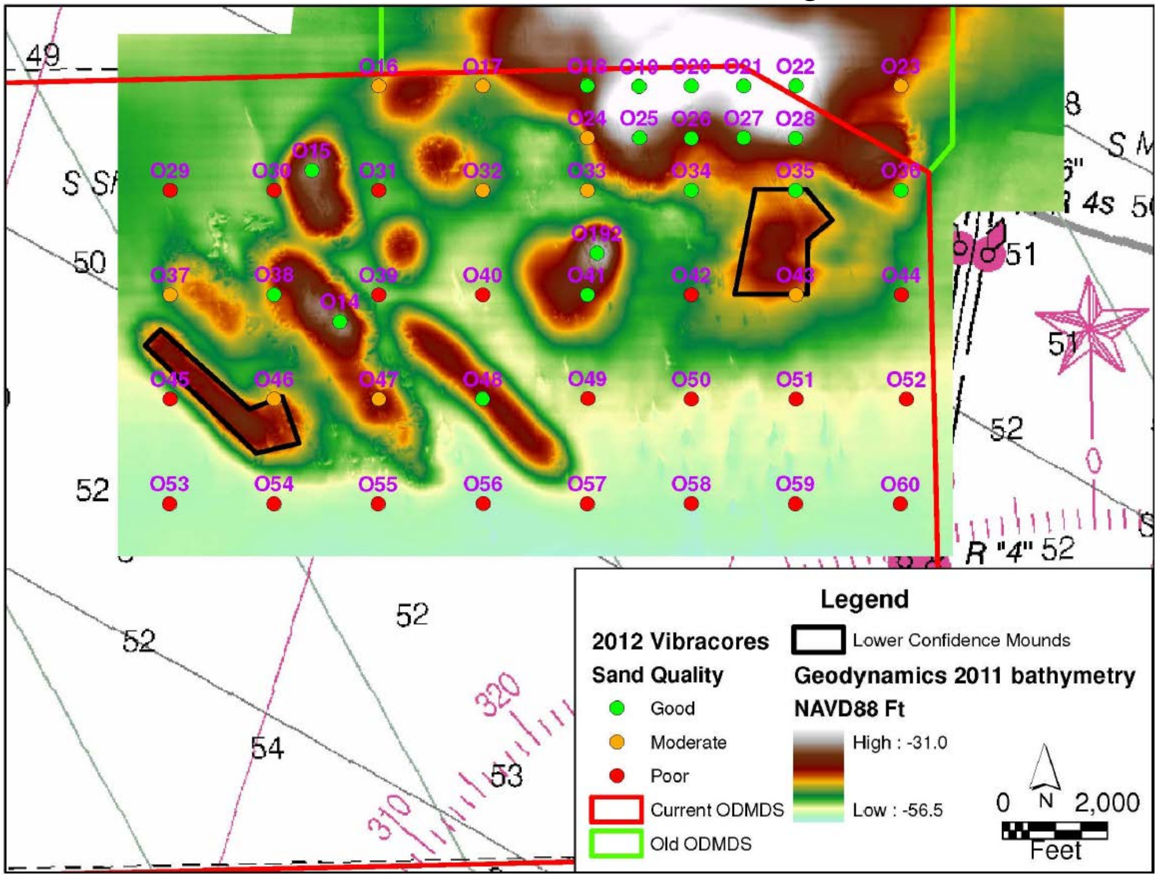

Figure 3-8: Lower Confidence Mound Sites and Vibracores (Coastal Tech, 2013)

Mound O-35

Mound O-35 is located south of Current ODMDS 1 and shares data from vibracore O-35 which was used in the analysis of Current ODMDS 1. Vibracore O-43 passes through the southern edge of this mound. These vibracores were weighted equally when the mound composite was created. This potential borrow area consists of fine grained, poorly sorted quartz sand. An overfill factor of 1.3 was calculated and Mound O-35 was assigned a "B" ranking due to the lack of sampling in the middle of the area. All parameters defined by NCAC were met, as shown in Table 3-16 below; therefore, the material is considered beach compatible. The total amount of beach compatible material in this mound is approximately 499,500 cy.

Table 3-16: Mound O-35 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Mound O-35
Fines (<#230)	≤ 6%	**0.31%**
Sand (>#230 & <#10)	-	**96.08%**
Granular (>#10 & <#4)	≤ 6%	**2.65%**
Gravel (>#4)	≤ 6%	**0.96%**
Calcium Carbonate	≤ 35%	**15.20%**

Mound O-46

Mound O-46 is located southwest of Current ODMDS 1 and only has vibracore O-46 passing through the edge of the mound. This potential borrow area consists of fine grained, poorly sorted quartz sand and has a mean grain size of 0.4 mm, which is coarser than the native sediment. An overfill factor of 1.25 was calculated and Mound O-46 was assigned a "B" ranking due to the lack of sampling in the middle of the area. All parameters defined by NCAC were met except for Granular, as shown in Table 3-17. It is believed that, upon further sampling in the center of the area, the percent granular may fall within the guidelines defined. The total amount of potential beach compatible material in this mound is approximately 493,564 cy.

Table 3-17: Mound O-46 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Mound O-35
Fines (<#230)	≤ 6%	**0.37%**
Sand (>#230 & <#10)	-	**90.60%**
Granular (>#10 & <#4)	≤ 6%	**6.27%**
Gravel (>#4)	≤ 6%	**2.76%**
Calcium Carbonate	≤ 35%	**18.17%**

3.3.1.4.4 Contingency Mounds

The remaining mounds in the Current ODMDS lack a vibracore within the boundary of the mound, as shown in Figure 3-9. Conceptual cut depths were assumed from the surrounding vibracores and potential volumes were calculated. These mounds do not have sediment characteristics defined. The potential volumes these mounds contain are shown in Table 3-18 with a total volume of approximately 320,000 cy.

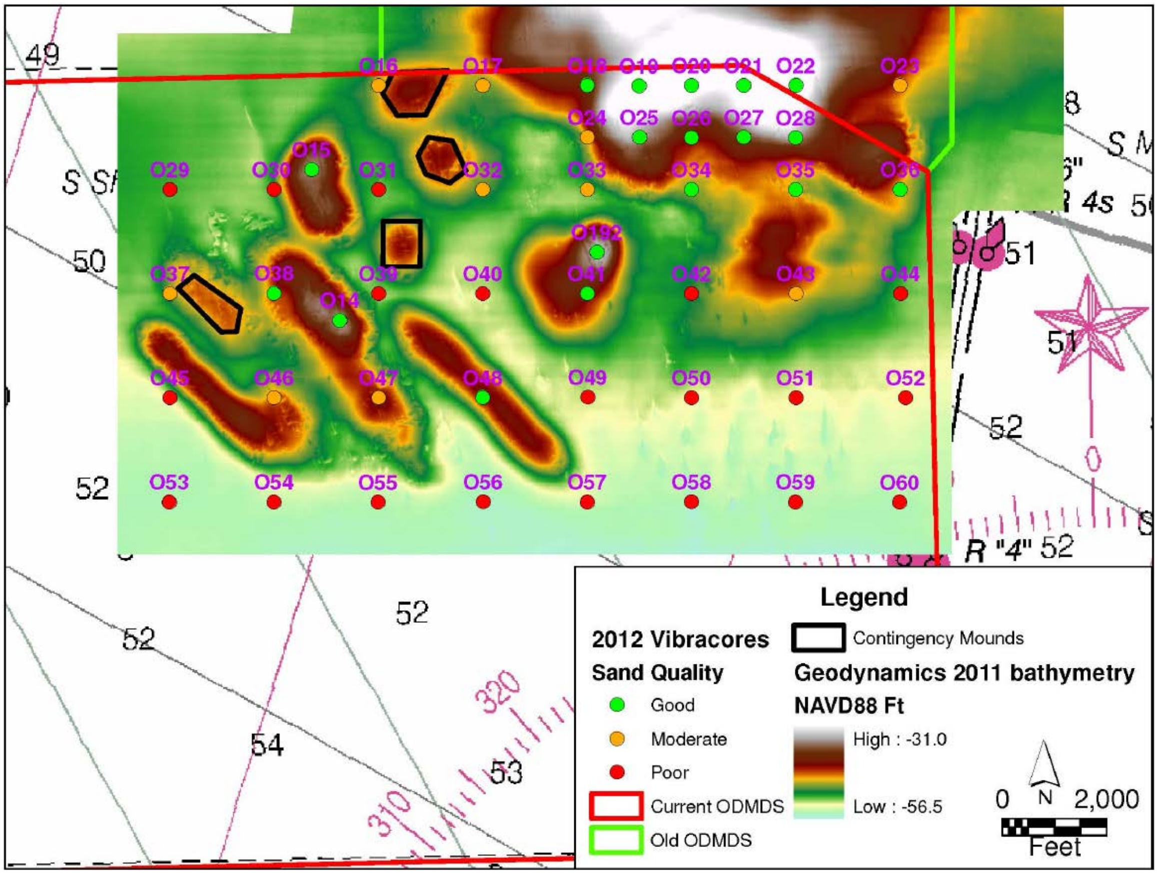

Figure 3-9: Contingency Mound Sites and Vibracores

Table 3-18: Contingency Mound Potential Volumes (Coastal Tech, 2013)

Mound	Cut Elevation NAVD88	Volume (cy)
O-16	-50 ft	95,326
O-39	-52 ft	94.352
O-37/O-38	-51 ft	71.233
O-32	-50 ft	58,543
	Total	**319,454**

3.3.1.5 Area Y

Area Y is located off of Emerald Isle within State waters where fifty-five vibracores were taken. Vibracores were initially taken on a 1000 foot by 1000 foot grid; however, a significant amount of fines were found in the surficial layer. The spacing was then increased to a 2000 foot grid spacing and two areas were identified as potential sites as shown in Figure 3-10.

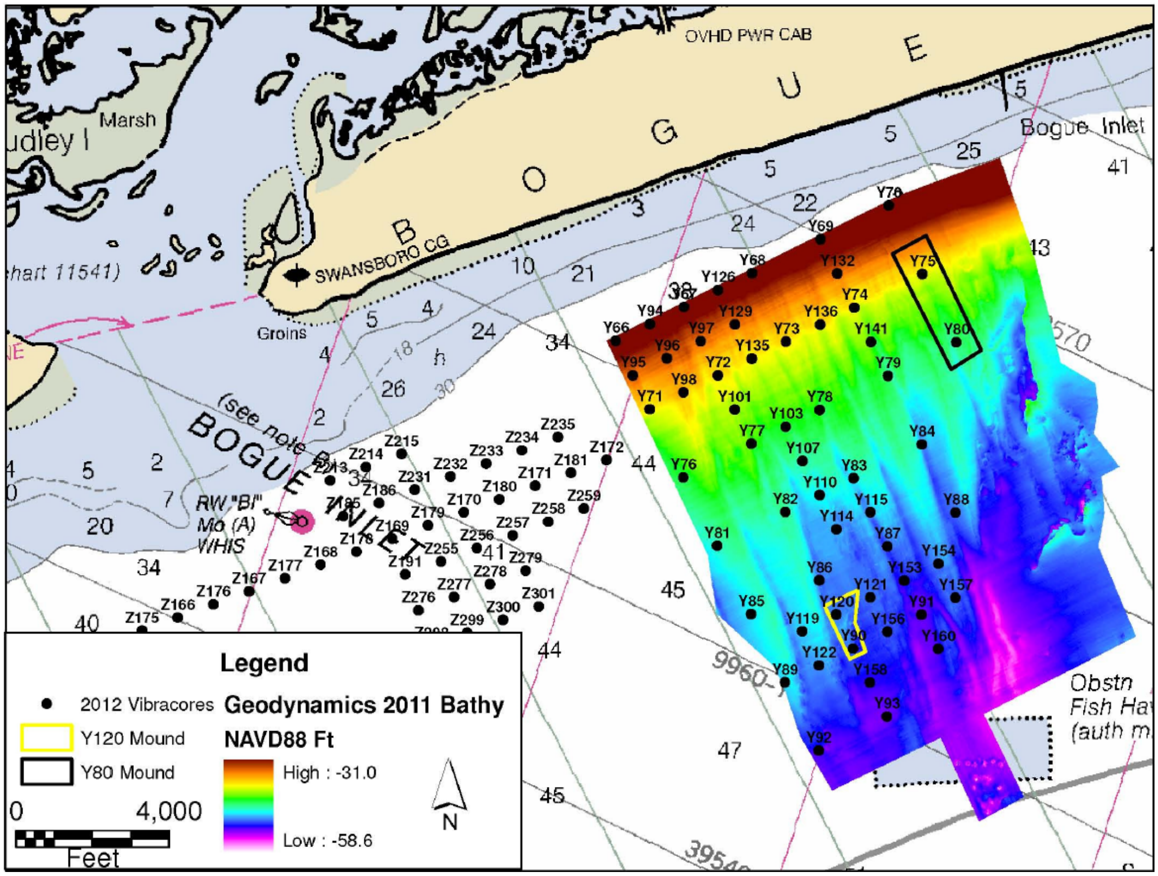

Figure 3-10: Area Y Site and Vibracores (Coastal Tech, 2013)

3.3.1.5.1 Vibracores Y-80 / Y-75

Vibracores Y-80 and Y-75 are 2000 feet apart and, due to the hardbottom buffer to the east, no vibracores were taken on that side. The vibracores taken to the west of Y-80 and Y-75 are not beach compatible. This potential borrow area consists of fine grained, moderately well sorted quartz sand and has a mean grain size of 0.23 mm, which is finer than the native sediment. All parameters defined by NCAC were met as shown below in Table 3-19. Although the parameters are met, the area should be considered a low priority with a “C” ranking due to insufficient vibracores to designate a reliable borrow area and poor quality of sediment. The potential volume is estimated at 1.08 Mcy; however, the rectangular area defined is purely conceptual and not based on the vibracores.

Table 3-19: Vibracores Y-80 & Y-75 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Vibracores Y-80 / Y-75
Fines (<#230)	≤ 6%	**2.37%**
Sand (>#230 & <#10)	-	**97.55%**
Granular (>#10 & <#4)	≤ 6%	**0.08%**
Gravel (>#4)	≤ 6%	**0.00%**
Calcium Carbonate	≤ 35%	**1.85%**

3.3.1.5.2 Vibracores Y-120 / Y-90

Vibracores Y-120 and Y-90 are 1000 feet apart and are located along a ridge; however, the sediment color is dark in color. This potential borrow area also exceeds the requirement set by NCAC for Gravel as shown in Table 3-20; therefore, would not be considered beach compatible. The total amount of material in this mound is approximately 379,675 cy.

Table 3-20: Vibracores Y-120 & Y-90 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Vibracores Y-120 / Y-90
Fines (<#230)	≤ 6%	**2.04%**
Sand (>#230 & <#10)	-	**86.60%**
Granular (>#10 & <#4)	≤ 6%	**3.43%**
Gravel (>#4)	≤ 6%	**7.93%**
Calcium Carbonate	≤ 35%	**1.50%**

3.3.1.6 Area Z

Area Z consisted of forty-three vibracores that were taken southeast of Bogue Inlet in efforts to locate the White Oak River channel, shown in Figure 3-11. Vibracore Z-174 was the only sample showed a possibility of having beach compatible material; however, it exceeded the Gravel requirement as shown in Table 3-21.

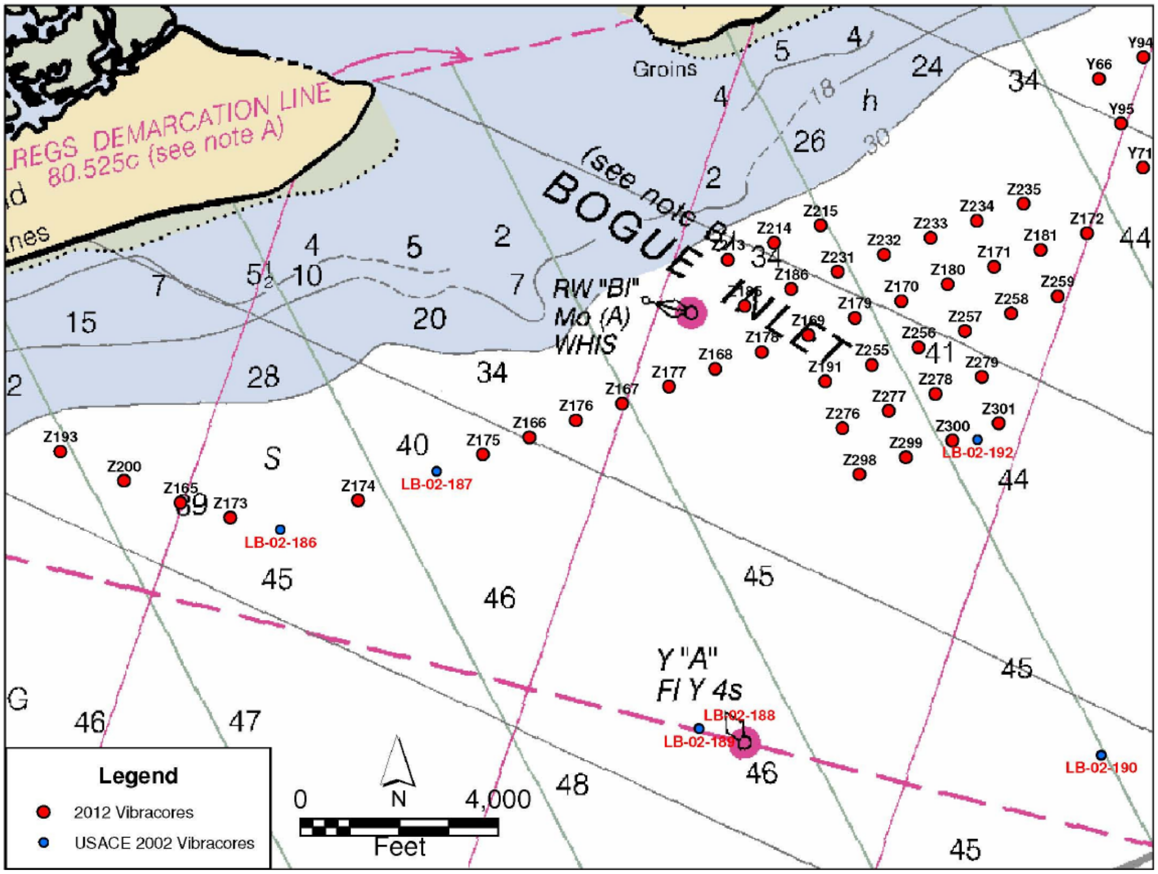

Figure 3-11: Area Z Site and Vibracores (Coastal Tech, 2013)

Table 3-21: Vibracore Z-174 Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Vibracore Z-174
Fines (<#230)	≤ 6%	**1.34%**
Sand (>#230 & <#10)	-	**84.57%**
Granular (>#10 & <#4)	≤ 6%	**2.28%**
Gravel (>#4)	≤ 6%	**11.81%**
Calcium Carbonate	≤ 35%	**11.10%**

3.3.1.7 Bogue Inlet Channel

Five vibracores were taken within the template of the 2005 Bogue Inlet relocation project shown in Figure 3-12. This area is fed by the surrounding beaches. The mean grain size is 0.33 mm and an overfill factor of 1.15 and meet all of the NCAC compatibility requirements as listed in Table 3-22. This site contains approximately 850,000 cy to 1 Mcy of beach compatible material.

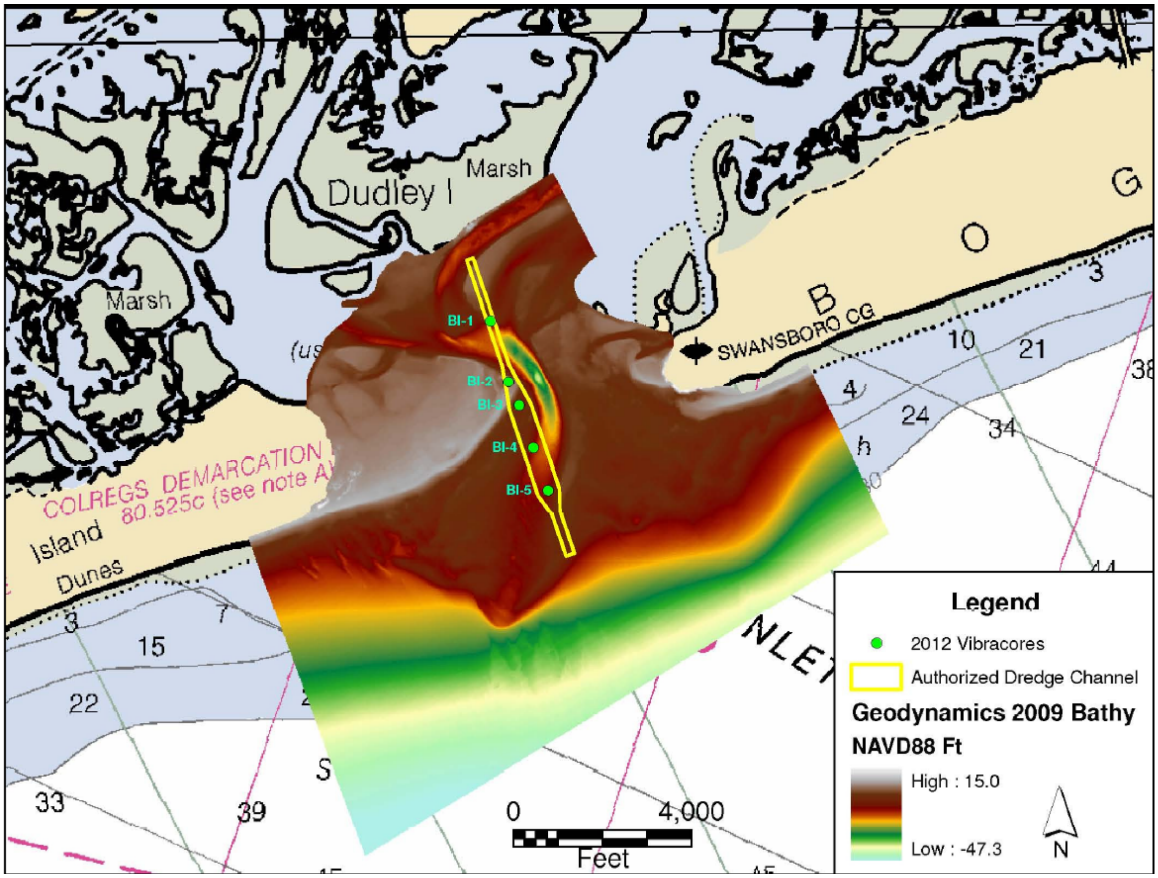

Figure 3-12: Bogue Inlet Channel Site, Vibracores, and Authorized Channel Location (Coastal Tech, 2013)

Table 3-22: Bogue Inlet Channel Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Vibracore Z-174
Fines (<#230)	≤ 6%	**0.15%**
Sand (>#230 & <#10)	-	**96.61%**
Granular (>#10 & <#4)	≤ 6%	**2.40%**
Gravel (>#4)	≤ 6%	**0.84%**
Calcium Carbonate	≤ 35%	**14.96%**

3.3.1.8 Morehead City Outer Harbor

The Outer Harbor consists of the Cutoff and Range A out to Station 110+00 as shown in Figure 3-13. Since this is a federal navigation project, the requirements for beach compatibility only limit the silt content to less than 10%. The characteristics of the sediment in this area meet that requirement and are listed below in Table 3-23. The USACE Morehead City Harbor draft Dredged Material Management Plan (DMMP) estimates that the Outer Harbor is shoaling at a rate of 1.2 Mcy per year (2012). Depending on the final DMMP, there could be between 228,000-635,000 cy of sand available for beach placement annually. A mid-range amount of 400,000 cy/yr is assumed to be available from this source.

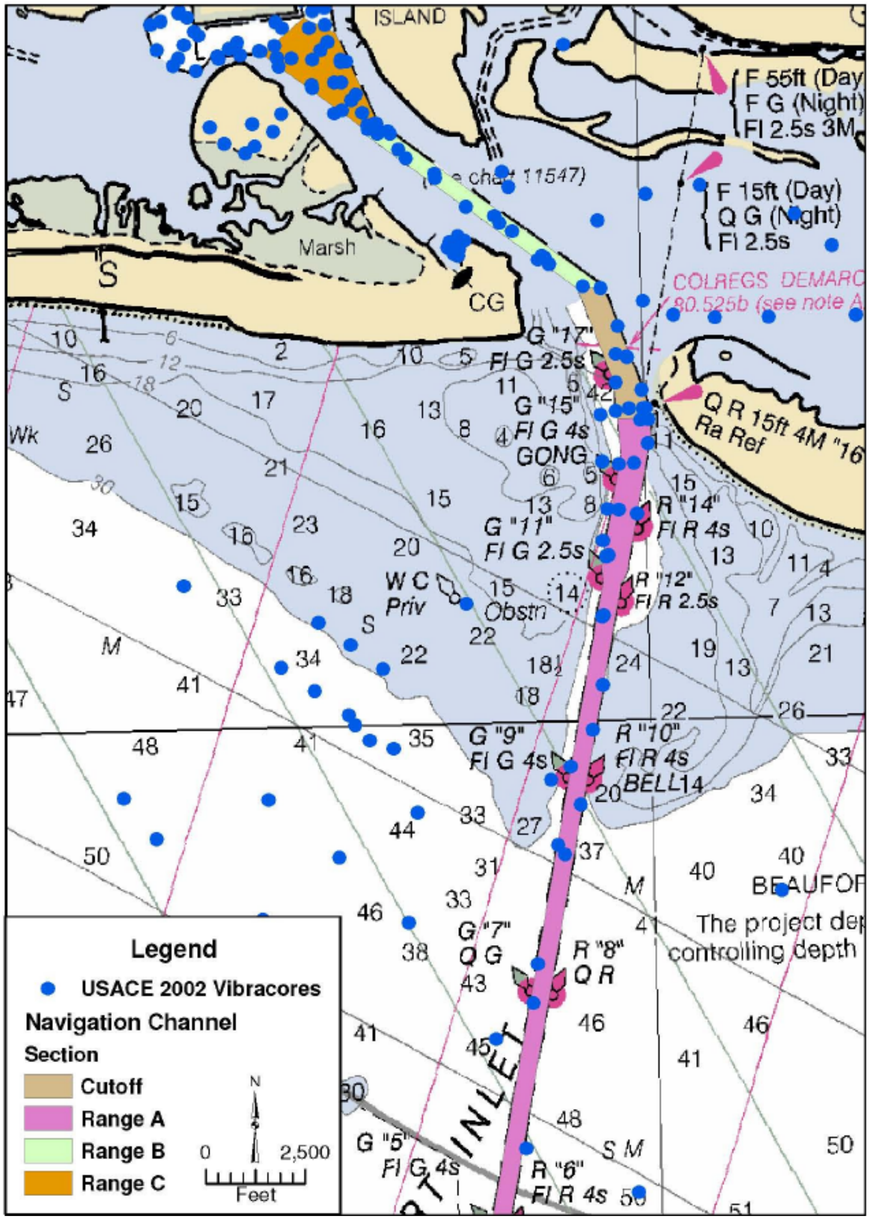

Figure 3-13: Morehead City Channel Vibracore and Reach Locations (Coastal Tech, 2013)

Table 3-23: Morehead City Outer Harbor Characteristics and NCAC Parameters (Coastal Tech, 2013)

Characteristic	Required Borrow Site Parameters	Morehead City Outer Harbor
Fines (<#230)	≤ 6%	**<1%**
Sand (>#230 & <#10)	-	**Not Reported**
Granular (>#10 & <#4)	≤ 6%	**Not Reported**
Gravel (>#4)	≤ 6%	**6.40%**
Calcium Carbonate	≤ 35%	**15.70%**

3.3.1.9 Upland Sources and AIWW Disposal Areas

The Division of Energy, Mineral and Land Resources of the North Carolina Department of Environment and Natural Resources (NCDENR) has a database of permitted active and inactive upland mines. From this database, a list of active sand and gravel mines within 30 miles of Bogue Banks (estimated to be feasible from a trucking cost persepective), which included mines in the surrounding counties of Craven, Jones, and Onslow, was generated. Based on a description of the material from various mine owners, a list of potential upland sources was compiled containing approximately 1,380,700 cy of material. However, if the need arises, further testing would have to be completed to verify the compatibility based on the current state rules for beach compatibility.

The USACE performs maintenance dredging for navigation along the AIWW and disposes the sand in specific disposal areas. A visual inspection of aerial photography for each disposal area was performed and areas that were in close proximity to a historical vibracore location were examined first. If the sand described by the vibracore and associated geotechnical report met the beach compatibility standards, it was determined to be a viable site. It is important to note that a majority of these areas have not had a sediment analysis performed; therefore, it cannot be confirmed that the sand meets the compatibility criteria. A sand thickness was assumed for each area of 5 feet and volumes were then calculated based on this assumption and the area of the disposal island found from ArcGIS. Assuming that 90% of the available sand will be placed, the total volume available from the dredge disposal areas is 1,288,800 cy.

Given the limited amount of sand in the upland sources and AIWW disposal areas compared to the total 50-yr need, these soucres should be considered for the overall project but solely for possible use for small "hotspot" projects in the future, if needed, because they do not meet the 50-yr need.

3.3.1.10 Summary of Sediment Data - Total Available Volume

The total volume available when the upland sources, AIWW disposal areas, and the offshore sources (Old ODMDS, Current ODMDS, Area Y, and Area Z) are combined is presented in Table 3-24. The total non-renewable volume available from these sources is

25,123,057 cy. The overall sediment need for Bogue Banks over the 50 year planning horizon based on the analytical/empirical analysis is between 45.0 and 49.8 Mcy (46.8 to 51.6 Mcy for moderate sea level change). Therefore, the volume of the combined upland, AIWW, and offshore sources will not be enough to meet the 50 year need by itself.

Table 3-24: Summary of Non-Renewable Potential Borrow Areas

Area	Total Volume (cy)
Sand Mines	1,380,700
AIWW Disposal Areas	1,288,800
Offshore Sources	22,453,557
TOTAL	**25,123,057**

In addition to the upland, AIWW, and offshore borrow sources, Bogue and Beaufort Inlets could also provide material on a cyclical basis as they regularly shoal and have to be dredged by the USACE for navigation purposes. These renewable borrow areas could potentially provide approximately 25,130,000 cy over 50 years, as shown in Table 3-25, which, by itself, is not enough to cover the 50 year need of between 45.0 and 49.8 Mcy (46.8 to 51.6 Mcy for moderate sea level change).

Table 3-25: Volume of Renewable Potential Borrow Areas (Coastal Tech, 2013)

<table>
<tr><th>Area</th><th>Section</th><th>Volume</th><th>Dredging Frequency</th><th>50 yr Total</th></tr>
<tr><td>MHC Outer Harbor</td><td>Cutoff+Range A to STA 110</td><td>400,000 cy (assumed)</td><td>1 years</td><td>20,000,000</td></tr>
<tr><td rowspan="2">Bogue Inlet</td><td>Inlet Relocation</td><td>850,000 cy</td><td>10 years</td><td>4,250,000</td></tr>
<tr><td>AIWW Crossing</td><td>44,000 cy</td><td>2.5 years</td><td>880,000</td></tr>
<tr><td colspan="4">Totals:</td><td>25,130,000</td></tr>
</table>

However, if all mentioned sources are incorporated (upland, AIWW, offshore, and inlets) approximately 50,253,057 cy of material would be available and would meet the 50-year sediment need of 45 Mcy to 49.8 Mcy (46.8 to 51.6 Mcy with moderate sea level change). The total volume available when the renewable and non-renewable sources are combined is tabulated in Table 3-26.

Table 3-26: Total Volume Available

Source	50-Yr Total Volume (cy)
Renewable	25,123,057
Non-Renewable	25,123,057
TOTAL	**50,253,057**

3.3.2 Nourishment Volumes and Renourishment Intervals

As stated previously, based on a level of protection anaylsis performed in SBEACH (see Chapter 7.0 of the Engineering Report), it was determined that the current beach condition provides for a 25-yr level of protection. The cost required to increase this to a 50-yr level of protection was considered too high for the current funding stream. Therefore, maintaining the 25-yr level of protection was deemed the basis for the MBNP. Nourishment triggers for the volume of material above -12 ft NAVD to be utilized are shown below in Table 3-27. This is the minimum volume of material required to provide a 25-yr level of protection. The resulting management reaches are on average 2-3 miles long with the exception of the Pine Knoll Shores and Atlantic Beach management reaches which are somewhat longer and cover the entire Town in each case. For the proposed management reaches, the weighted trigger is 233 cy/ft with triggers varying from 211 cy/ft for Emerald Isle Central to 266 cy/ft for portions of Emerald Isle West (Table 3-27).

Table 3-27: Revised Calculated Trigger Volumes Above -12 ft NAVD88 for Various RP Events

Reach	Reach Length (ft)	50-yr, -12 ft Trigger (cy)	25-yr, -12 ft Trigger (cy)	Adjusted 25-yr, -12 ft Trigger (cy)	Preliminary -12 ft Trigger (cy)	-12 ft 2011 Volume (cy)
Bogue Inlet (1-8)	7,432	238	103	238	235	389
Emerald Isle West - A (9-11)	4,056	282	230	230		277
Emerald Isle West - B (12-22)	14,283	319	272	272	266	295
Emerald Isle West - C (23-25)	4,005	323	242	242		303
Emerald Isle Central - A (26-32)	10,428	237	213	213	211	292
Emerald Isle Central - B (33-36)	5,374	277	207	207		262
Emerald Isle East - A (37-44)	8,814	268	214	214	221	242
Emerald Isle East - B (45-48)	4,406	299	235	235		264
Indian Beach/Salter Path - West (49-52)	5,275	243	216	216	224	263
Indian Beach/Salter Path - East (53-58)	7,575	241	229	229		298
Pine Knoll Shores - West (59-65)	9,063	235	196	196	211	253
Pine Knoll Shores - East - A (66-70)	6,564	271	218	218		240
Pine Knoll Shores East - B (71-76)	8,251	287	222	222		262
Atlantic Beach - West (77-81)	5,388	269	225	225	254	281
Atlantic Beach - Central (82-89, 91-96)	13,771	375	248	248		291
Atlantic Beach - Circle (90)	1,006	408	364	364		330
Atlantic Beach - East (97-102)	6,011	318	276	276		384
TOTAL	**121,702**					
AVERAGE		**288**	**230**	**238**	**233**	**290**
					Weighted	

To estimate the time when the next round of nourishment projects will be needed, the 2011 volumes above -12 ft NAVD were assumed to erode at an average annual loss rate, calculated based on statistical analysis of beach profile data using Microsoft Excel and Crystal Ball add-on (see Chapter 4.0 of the Engineering Report), until the trigger would be reached. This was completed for both the individual subreaches as well as the management reaches and results are presented in Table 3-28 and Table 3-29.

Table 3-28: Estimated Years Until First Round of Nourishment Projects – Individual Subreach Basis

Reach	Reach Length (ft)	Preliminary -12 ft Trigger (cy)	-12 ft 2011 Volume (cy)	Years to 25 yr Trigger 50%	Years to 25 yr Trigger 55%	Years to 25 yr Trigger 60%	Years to 25 yr Trigger 65%	Years to 25 yr Trigger 70%	Years to 25 yr Trigger 75%	Years to 25 yr Trigger 85%
Bogue Inlet (1-8)	7,432	238	389	28	18	13	10	8	7	5
Emerald Isle West - A (9-11)	4,056	230	277	36	19	13	10	7	6	4
Emerald Isle West - B (12-22)	14,283	272	295	68	68	68	68	68	21	8
Emerald Isle West - C (23-25)	4,005	242	303	156	156	26	14	9	7	4
Emerald Isle Central - A (26-32)	10,428	213	292	59	59	30	20	15	12	8
Emerald Isle Central - B (33-36)	5,374	207	262	27	17	13	10	8	7	5
Emerald Isle East - A (37-44)	8,814	214	242	6	5	4	4	3	3	2
Emerald Isle East - B (45-48)	4,406	235	264	6	4	3	2	2	2	1
Indian Beach/Salter Path - West (49-52)	5,275	216	263	5	4	3	3	3	2	2
Indian Beach/Salter Path - East (53-58)	7,575	229	298	64	33	22	16	13	10	7
Pine Knoll Shores - West (59-65)	9,063	196	253	38	23	16	13	10	8	6
Pine Knoll Shores - East - A (66-70)	6,564	218	240	6	5	4	3	3	3	2
Pine Knoll Shores East - B (71-76)	8,251	222	262	7	6	5	4	3	3	2
Atlantic Beach - West (77-81)	5,388	225	281	51	51	26	17	12	10	6
Atlantic Beach - Central (82-89, 91-96)	13,771	248	291	6	6	5	4	4	4	3
Atlantic Beach - Circle (90)	1,006	364	330	-3	-2	-2	-1	-1	-1	-1
Atlantic Beach - East (97-102)	6,011	276	384	13	11	10	9	8	7	5
TOTAL	**121,702**									
AVERAGE				**34**	**28**	**15**	**12**	**10**	**6**	**4**

Table 3-29: Estimated Years Until First Round of Projects – Management Reach Basis

Reach	Reach Length (ft)	Management Reach Length (ft)	Preliminary -12 ft Trigger (cy)	-12 ft 2011 Volume (cy)	Years to 25 yr Trigger 50%	Years to 25 yr Trigger 55%	Years to 25 yr Trigger 60%	Years to 25 yr Trigger 65%	Years to 25 yr Trigger 70%	Years to 25 yr Trigger 75%	Years to 25 yr Trigger 85%
Bogue Inlet (1-8)	7,432	11,488	235	349	29	18	13	10	8	7	5
Emerald Isle West - A (9-11)	4,056										
Emerald Isle West - B (12-22)	14,283	18,288	266	297	90	90	90	49	19	11	6
Emerald Isle West - C (23-25)	4,005										
Emerald Isle Central - A (26-32)	10,428	15,802	211	282	45	36	22	16	12	10	7
Emerald Isle Central - B (33-36)	5,374										
Emerald Isle East - A (37-44)	8,814	13,220	221	250	6	5	4	3	3	2	2
Emerald Isle East - B (45-48)	4,406										
Indian Beach/Salter Path - West (49-52)	5,275	12,850	224	284	12	10	8	7	6	5	4
Indian Beach/Salter Path - East (53-58)	7,575										
Pine Knoll Shores - West (59-65)	9,063	23,878	211	253	12	9	7	6	5	4	3
Pine Knoll Shores - East - A (66-70)	6,564										
Pine Knoll Shores East - B (71-76)	8,251										
Atlantic Beach - West (77-81)	5,388	26,176	254	312	9	8	7	6	5	5	4
Atlantic Beach - Central (82-89, 91-96)	13,771										
Atlantic Beach - Circle (90)	1,006										
Atlantic Beach - East (97-102)	6,011										
TOTAL	**121,702**	**121,702**									
AVERAGE			**233**	**288**	**29**	**25**	**22**	**14**	**8**	**6**	**4**
			weighted	weighted							

Based on these above tables, it appears that 5-7 years will pass before various reaches are in need of nourishment from either approach. Please recall that results for the higher % exceedance include storm effects. Based on the proposed management reaches, the Emerald Isle East reach will likely require nourishment first with other reaches following depending on future storm effects. This timing will allow the County and Towns to be proactive in maintaining the required nourishment triggers as well time to replenish over $7 M of local funds that were spent recently for the Post-Irene Renourishment Project. Therefore, this time indicates how long before the “sediment bank” along Bogue Banks can sustain additional erosion or “debits” before additional “credits” or nourishments are needed to maintain the required 25-yr event LoP for the engineered beach.

As for future renourishment intervals and placement areas, a preliminary estimate was made based on past projects, whereas a future re-nourishment placement of 25 cy/ft is assumed and the annualized loss rates for the 50% exceedance (See Chapter 4.0 of Engineering Report) were used to determine how many years would pass before the 25 cy/ft would erode away. This analysis assumes that the "sediment bank" described above has been allowed to reach the 25-yr triggers along Bogue Banks and the County and Towns would then be in a mode of active continuous management. If quiet years or storm years are experienced, the renourishment intervals could be longer or shorter periods of time. However, this approach will be useful from a planning and funding perspective – and should reflect average future long term renourishment intervals – as an assurance that the Master Plan is financially sustainable.

Once the years for the average 25 cy/ft placement rate to erode away were calculated for each reach, it was found that most of the results for the reaches were close to multiples of 3 years (i.e., 3, 6, 9, etc. years). The results were then tabulated and classified into the various 3, 6, and 9 year renourishment cycles and the required volumes calculated. Table 3-30, Figure 3-14, and Figure 3-15 show the results as well as the preliminary proposed projects over the next 50 years. Please note that the nourishment volume approximates the need for background erosion only. It is expected that named storm losses will be handled separately through FEMA reimbursement projects.

Table 3-30: Renourishment Intervals and Preliminary Projects Based on Detailed Subreach and Management Reach Approaches

Year	Detailed Subreach Nourishment Volume (cy)	Management Reach Nourishment Volume (cy)	Nourishment Project (Yr)
2019	640,332	686,067	3
2022	1,686,018	1,839,351	6
2025	1,163,781	967,920	9
2028	1,686,018	1,839,351	6
2031	640,332	686,067	3
2034	2,209,467	2,121,204	6,9
2037	640,332	686,067	3
2040	1,686,018	1,839,351	6
2043	1,163,781	967,920	9
2046	1,686,018	1,839,351	6
2049	640,332	686,067	3
2052	2,209,467	2,121,204	6,9
2055	640,332	686,067	3
2058	1,686,018	1,839,351	6
2061	1,163,781	967,920	9
2064	1,686,018	1,839,351	6
TOTAL	**21,228,045**	**21,612,609**	

Again, it is VERY IMPORTANT to note that the results are based upon average background erosion rates across the island. Storm effects and other factors could DRASTICALLY alter future nourishment requirements. The plan will nourish areas as they reach the nourishment triggers via gradual erosion or in response to future storms which of course cannot be predicted. However, the results presented in Table 3-30, Figure 3-14, and Figure 3-15 are useful for overall long term planning and budgeting purposes.

Figure 3-14: Detailed Subreach Nourishment Plan

Figure 3-15: Management Reach Nourishment Plan

Based on the results above, one can see that some reaches will require more sand than others based on localized and regional erosion patterns. The inlet/dredging effects at Atlantic Beach and Bogue Inlet as well as the hotspots at Pine Knoll Shores-East and Emerald Isle-East are apparent and reflect the greater need for future nourishment, while historically sand receiving areas at Emerald Isle-Central and West will require less sand comparatively. The Management Reach nourishment plan will likely be the one most closely followed in the future, but again, storms and other factors will likely override the above approach in reality. It should also be noted that the results above do not include the storm need volume. It is assumed that these projects will be funded by FEMA once the new nourishment triggers and engineered beach with the 25-year return period event LoP have been accepted by FEMA.

While it is expected that a volumetric trigger will be utilized in the future to determine when nourishment action takes place, plots of the minimum MHW line position based on the volumetric triggers were plotted and can be seen in Appendix B. The maximum expected advance fill templates equating to the min/max range of 25-50 cy/ft is also shown. It is important to note that these lines were generated using the representative profiles and transect specific conditions may be different. None the less, the plots are instructive and useful for permitting purposes.

3.3.3 Construction Window For Preferred Alternative

Carteret County is requesting an allowable construction timeframe extending from November 16 through April 30 for construction of all future projects required for the Bogue Banks Master Beach Nourishment Plan. The request stems from the growing economic burden necessary to provide reasonable buffers against coastal storm and long-term erosional forces. Hopper dredging activities will be required for the majority of work; however, periodic hydraulic pipeline dredging will also occur. The National Marine Fisheries Service (NMFS) and the US Fish and Wildlife Service (FWS) must review the request for determination if the extension may impact any federally listed endangered or threatened species. NMFS will primarily review if the hopper or hydraulic dredging efforts would create substantial risks to endangered species while in federal waters such as the Atlantic Ocean. FWS reviews all land based activities, such as the sand placement, to opine if impacts are likely to endangered or threatened species along the shoreline or on land. The Wilmington District USACE facilitates all coordination efforts for the consultation with the NMFS and FWS relative to Carteret County.

Previous authorizations from the NMFS in 2001 and 2007 allowed hopper dredging for beach nourishment within Carteret County to extend from November 16 through April 30. However, the most recent authorization in 2012 required adherence to a November 16 through March 31 construction window. The currently requested timeframe would match the end date for the 2001 and 2007 authorizations and maintain the previously authorized start dates for the 2001, 2007, and 2012 projects.

Construction costs for coastal restoration efforts have increased substantially since the early 1990's in part as a result of increased equipment demands coupled with restrictive environmental windows. The environmental windows limit construction to the winter months when the most adverse weather conditions typically occur. This creates an economic risk for contractors to meet project completion requirements within the limited construction timeframe. The contractors subsequently pass the risk on to project sponsors in the form of construction costs. The requested construction window would allow additional time for project completion in potentially safer weather conditions, which would provide a more attractive economic scenario for completing the work. Thus, the requested construction window would help reduce the economic burden placed on Carteret County and the additional project sponsor's by allowing a more competitive pricing of the project.

Under typical inflation an annual increase of 3% to 5% could be expected for any consistent order of work. However, Figure 3-16 shows the unit prices ($/CY) for coastal restoration projects occurring in Carteret County have experienced an accelerated inflation rate. The data shown in Figure 3-16 includes hopper and hydraulic pipeline projects involving sand placement for beach nourishment or beneficial re-use from inlet maintenance. The data comes from the North Carolina Beach & Inlet Management Plan and individual project bid documents. All costs include the total bid price for each project, including mob / demob and environmental monitoring. For comparison, Figure 3-16 includes a trend line (red-dashed) to show the observed (best fit) inflation in construction costs. The graph also shows typical annual inflation rates of 3% (blue line) and 5% (orange line). As shown in Figure 3-16, the average annual unit cost for dredge and fill projects increased within the range of 3% to 5% inflation between approximately 1973 and 1992. However, the observed annual inflation rate between 1992 and the most recent sand placement project on Bogue Banks in 2013 equals approximately 9.0%. Prior to 1995 the USACE utilized the Brandt Island spoil area for a sediment source for beach placement. The USACE stock piled channel maintenance material for beneficial re-use on Brandt Island and conducted beach placements on approximate 5 ~ 10 year intervals. Since 1995, Brandt Island along with offshore borrow sources have been considered for beach placement.

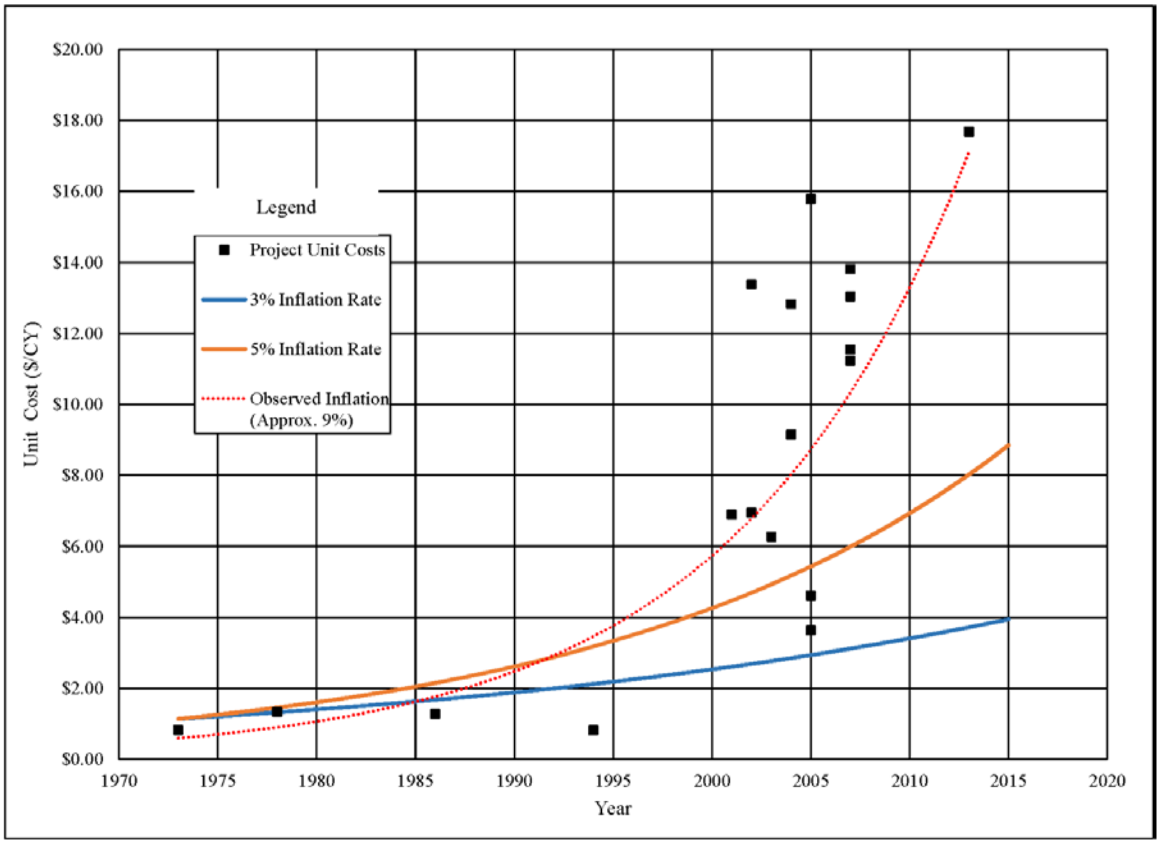

Figure 3-16: Construction Costs for Beach Placement Projects Occuring on Bogue Banks (1973 – 2013)

The ocean bar maintenance projects for the Wilmington Harbor and the Morehead City Harbor provide another relative example of the substantial increase experienced in coastal construction costs. Both the Morehead City and Wilmington Harbor projects have occurred routinely since the early 1990's in a generally consistent manner. Figure 3-17 below shows the construction costs for the projects entailing hopper dredging of the ocean bar located at each harbors entrance. The geographic location of both harbor projects present similar risk factors as the beach placement projects on Bogue Banks, as each project falls either within Carteret County or within reasonable proximity.

Similar to beach placement analysis, Figure 3-17 shows the anticipated range of inflation between 3% (blue line) and 5% (orange line) dating back to the early 1990's for the harbor maintenance projects. The figure also includes an observed, or best fit inflation rate (red line) for comparison. The cost information utilized for the harbor maintenance projects comes from the Wilmington District USACE and also includes the total bid prices for each project, including mob / demob and environmental monitoring. The table excludes two Wilmington Harbor maintenance events occurring in 1994 and 1997 as outliers due to an abnormally high unit cost for their respective time period. The 1994 project provided a unit cost of approximately $8.86 and the 1997 project registered a unit cost of $17.31. The projects were assumed outliers because no other project conducted within the same respective time period registered similar unit costs.

As shown in Figure 3-17, the Wilmington and Morehead City Harbor projects have increased from approximately $1.75/CY in 1993 to approximately $7.00/CY in 2015. This represents an inflation rate of approximately 6.5% across the 22 year period.

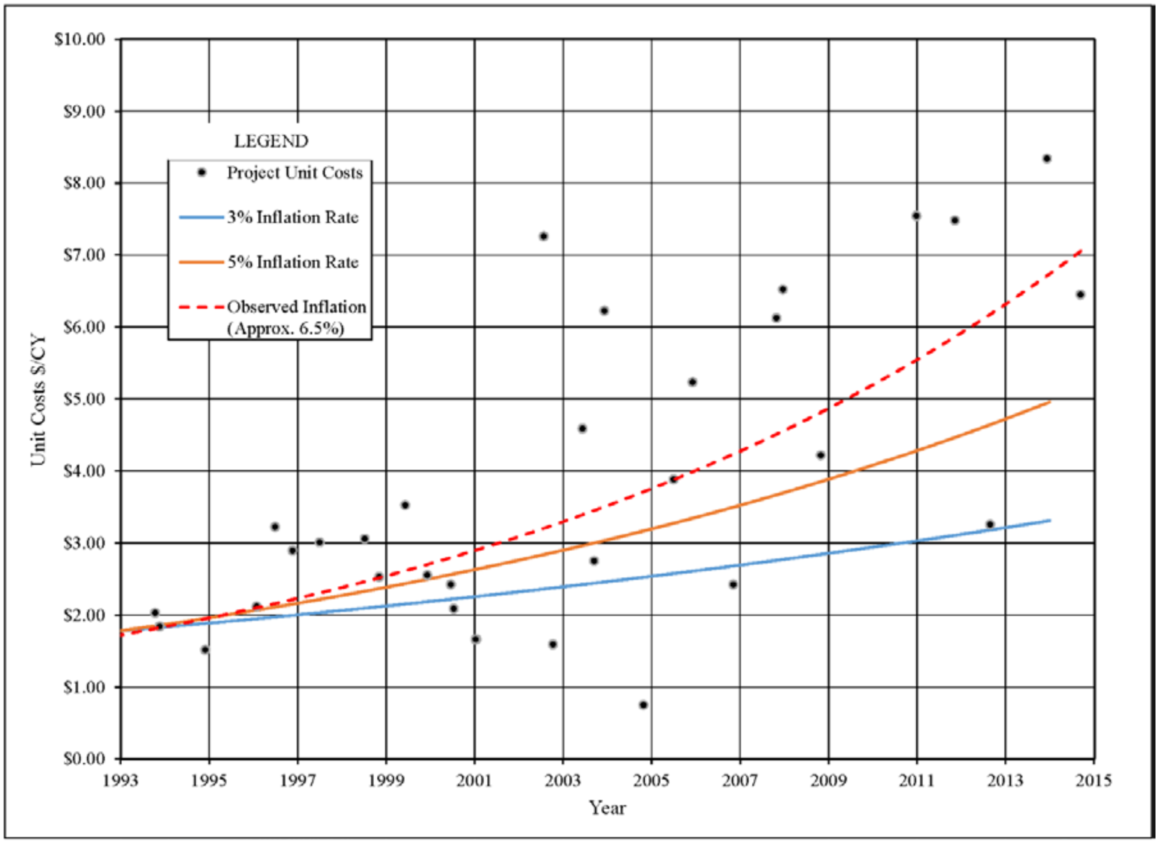

Figure 3-17: Morehead City & Wilmington Harbor Ocean Bar Maintenance Unit Costs (1993 – 2015)

The combined accelerated inflation experienced by the beach placement projects for Bogue Banks and the referenced harbor maintenance projects show a concerning trend for coastal initiatives in Carteret County. **In an effort to mitigate these growing concerns Carteret County is requesting an allowable construction timeframe from November 16 to April 30 to conduct the Bogue Banks project.** The requested allowable construction timeframe from November 16 to April 30 to conduct the Bogue Banks project will help to mitigate these issues by allowing additional time for project construction, removing some of the burden from and consequently preventing them from passing the risk on to sponsors in the form of elevated construction costs. To support the requested construction timeframe, environmental precautions similar to those implemented during the 2013 Post Hurricane Irene Renourishment will most likely be a necessity.

3.3.4 Funding of the Preferred Alternative and Static Line Exception Requirements

With the individual Towns and County funding streams, various scenarios were investigated to determine the long-term financial sustainability of the MBNP. Please see Appendix C for a detailed discussion of the Town and County funding streams – as historically collected from property and occupancy taxes.

First, dredging/placement unit costs were developed from past projects (rates include mob/demob).

- Emerald Isle – Combination of Pipeline and Hopper - $12 - $18/ cy – Avg. = $15/cy
- Indian Beach /Salter Path – All Hopper - $13/cy
- Pine Knoll Shores – All Hopper - $12.25/cy
- Atlantic Beach – Combination of Hopper and Pipeline - $11.50 cy – USACE Project Good To Circle – 60% - Prorated Unit Rate for Entire Volume = $4/cy

Utilizing the annualized volume needs estimated as part of the preferred option and the above unit rates, an annualized estimate of funding need was developed. As can be seen in Table 3-31, utilizing a 25% Town/75% County split would likely not be sustainable for the County fund since annual need would be roughly $3.4 M while $2.4 M is likely to be generated. This scenario also require less cost share overall from the Towns than is currently being generated. However, a scenario with a 33% Town/67% County cost share was also run and the results look much more equitable between the two funding streams. The annualized need versus funds raised for the Towns is quite close to the current funding levels with the exception of Atlantic Beach which does not currently have a dedicated funding source. However, given the possible range of outcomes from the ongoing DMMP, the numbers in this table could become less or more. It appears that it will be important for Atlantic Beach to revisit the idea of a dedicated funding source after the DMMP is finalized. As for the County annual need versus funding level, the need is still higher ($3.1 M vs. $2.4M) but the fund currently has $5.7M in reserve and it is expected that 6 years will pass before the next project is needed. This should allow adequate time for the reserve to build up to a point to where the County fund is also sustainable long-term. The intra-local agreement signed by all the Towns and County also requires them to meet the funding needs even if new taxes or one-time loans are required.

Table 3-31: Annualized Estimate of Funding

				25% Town/75% County Cost Share				33% Town/67% County Cost Share		
Town	Annual Volume Loss (cy)	% of Total Annual Volume Loss	Avg. Placement Unit Cost Per Town	Annual Town Cost ($)	Annual County Cost ($)	% of Total Annual County Cost	Annually Generated Taxes for Beach Nourishment	Annual Town Cost ($)	Annual County Cost ($)	% of Total Annual County Cost
Emerald Isle	139,913	31%	$15.00	$524,674	$1,574,021	46%	$675,000	$692,569	$1,406,126	46%
Indian Beach/Salter Path	62,567	14%	$13.00	$203,343	$610,028	18%	$282,406	$268,412	$544,959	18%
Pine Knoll Shores	84,795	19%	$12.25	$259,685	$779,054	23%	$316,500	$342,784	$695,955	23%
Atlantic Beach	164,945	36%	$4.00	$164,945	$494,835	14%	TBD	$217,727	$442,053	14%
TOTAL	452,220				$3,457,938				$3,089,093	
					Avg. Annual County Tax Generated Over Next 6 Years = $2,440,664					

If the above results were then just multiplied out over the next 50 years, the preferred plan needs would be fairly equal to the current funding levels at the 33% Town/67% County split as summarized below:

- **Annual Total Cost = $4.61 M/yr * 50 yr = $230.5 M**
- **Annual Total Revenue = $3.93 M/yr * 50 yr = $196.6 M**

Thus, if all the variables (dredging/placement costs, tax revenue, etc.) escalate at the same rate, the 50-yr master plan will be 85% funded overall = $196.6M/$230.5M (*assumes Atlantic Beach starts generating taxes and participates in the master plan). If Atlantic Beach declines to participate in the master plan due to adequate sand placement from the Morehead City Harbor Project, the 50-yr master plan will be 94% funded overall = $185.7M/$197.5M.

Of course, the above analysis is simplistic so a more formal cash flow analysis was completed as well. The cash flow analysis utilized the same assumptions as the Static Line Reports submitted to the state in 2010. These assumptions were reviewed and were found to still be valid with recent trends as well (especially with the economic recovery and the Sheraton opening back up).

- Dredging Cost Increases = 2% Annually
- Interest Gained on Accounts = 2% Annually
- Accommodations and Tax Growth = 4% Annually

As can be seen from analyses in Appendix C, the Town and County current funding levels are expected to be sustainable for 20 years into the future.

Again, it is VERY IMPORTANT to note that the results above are based upon average erosion rates across the island. Storm effects and other factors could drastically alter future nourishment requirements. It is also important to note that the all the previous funding analyses are based upon background erosion rates and that FEMA funding is expected to cover the named storm (hurricane) induced erosion as has been done in the past. In summary, the plan will nourish areas as they reach the nourishment triggers as well as in response to future storms which of course cannot be predicted.

Given the preferred plan is sustainable for 20 yrs, the recommendation is to track expenditures over next 5-10 years and adjust then as needed. Finally, it should be noted that all the above analyses does not include any State or Federal funding above that which is expected for the Morehead City Harbor Project and as required to maintain the ICWW near Bogue Inlet. Any additional funds from these sources would extend the long-term sustainability of the project.

3.3.5 Summary of Preferred Alternative

Based on the overall sediment need comprised of background erosion (22.6 Mcy), anticipated storm erosion (22.4 – 27.2 Mcy), and moderate sea level rise (1.8 Mcy), Carteret County is requesting permission to place 46.8 to 51.6 Mcy of material on the beach over the next 50 years using a combination of borrow sources which include offshore sources (Old and Current ODMDS, Area Y, and Area Z), inlets (Bogue Inlet Channel and Morehead City Outer Harbor), and upland sources (sand mines and AIWW disposal areas).

The MBNP and Preferred Alternative include the following elements:

- Renourishment events are expected to be required at 3, 6, and 9 year intervals starting in 2019 - based upon average background erosion rates. Actual renourishment events will be dependent upon actual erosion, and available funding – including FEMA funding in response to future storms for which the timing and severity cannot be reasonably predicted.

- Sand from offshore sources (1st priority), inlet sources (2nd priority) and upland sources (3rd priority) is proposed to be excavated and placed on the beach. These primary sand sources are sufficient to maintain the design beach at a 25-year LoP with advance fill varying from 25 to 50 cubic yards per foot – depending upon actual future erosion rates and available funding.

- Sand obtained from the USACE maintenance dredging of the Morehead City Harbor Channel and Bogue Inlet AIWW "crossings" is proposed to be used as part of the primary sand sources; maintenance dredging is proposed to be performed by the USACE under their permit authority, but USACE dredging and beach-fill placement are assumed to continue and are an integral part of the MBNP.

- If the main channel at Bogue Inlet migrates outside the "safe box", the main channel is proposed to be relocated by the Applicant, Carteret County, to the location constructed in 2005 with the excavated material used to nourish the beach as part of the primary sand sources.

Carteret County is also requesting an allowable construction timeframe extending from November 16 through April 30 for construction of all future projects required for the Bogue Banks Master Beach Nourishment Plan. The request stems from the growing economic burden necessary to provide reasonable buffers against coastal storm and long-term erosional forces. Analysis of historical data shows an accelerated inflation of cost (greater than the typical 3% to 5%) experienced by the beach placement projects for Bogue Banks and harbor maintenance projects which is a concerning trend for coastal initiatives in Carteret County. The requested allowable construction timeframe from November 16 to April 30 to conduct the Bogue Banks project will help to mitigate these issues by allowing additional time for project construction, removing some of the burden from and consequently preventing them from passing the risk on to sponsors in the form of elevated construction costs. To support the requested construction timeframe, environmental precautions similar to those implemented during the 2013 Post Hurricane Irene Renourishment will most likely be a necessity.

moffatt & nichol

1616 EAST MILLBROOK ROAD, SUITE 160 | RALEIGH, NC 27609

P 919. 781. 4626 | F 919. 781. 4869 | WWW.MOFFATTNICHOL.COM