

DEVELOPMENT OF SEDIMENT CRITERIA REGULATIONS FOR BEACH FILL PROJECTS ALONG NORTH CAROLINA'S ATLANTIC COAST

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I. Introduction and Sediment Criteria History

In March of 2002, the North Carolina Coastal Resources Commission's (CRC) Science Panel on Coastal Hazards began discussing concerns associated with the large percentage of coarse-grained shell material and rock cobbles placed on Bogue Banks and Oak Island, respectively, as part of two beach fill projects. Adverse consequences of placing incompatible sediment on the beach range from environmental to economic, and the Panel concluded that it was necessary to address the adequacy of existing standards regulating beach fill and sediment compatibility in North Carolina. For the purpose of this paper, beach fill is the general term given to the emplacement of sediment along the oceanfront shoreline that includes beach nourishment, dredged material disposal, and habitat restoration. The current rule governing sediment compatibility for beach fill projects, Title 15A of the NC Administrative Code, Chapter 7, Subchapter H, Section 308, Subsection (a), Part (3) commonly referred to as 15A NCAC 7H.0308(a)(3), is minimal in its approach regarding sediment compatibility, stating only that nourishment sediment "...shall be compatible with existing grain size and type." The inability to quantify the term "compatible" makes the rule language vague and subjective (Warren, 2005).

The CRC requested input from the Science Panel on sediment compatibility recommendations. To address this task, the Panel reviewed other state's sediment compatibility guidelines, notably those used by Florida, and began exploring potential criteria and data that could be used in North Carolina. Work also began on a major study of the native sediment characteristics of North Carolina beaches based on existing sediment grain size analyses collected by Tracy Rice (Rice, 2003), formerly of the U.S. Fish and Wildlife Service. By September 2002, the Science Panel had expanded their effort to include potential guidelines for excavating sediment from borrow areas and sampling protocols for characterizing the native beach.

It was quickly recognized by the Science Panel that a one-size-fits-all approach to defining compatibility would not work for North Carolina, where native beaches have a wide variation in grain size and mineralogy. Consequently, the Panel recommended compatibility standards that match borrow material to the pre-existing beach within limited grain size thresholds. It follows, then, that the definition of "compatibility" is variable and depends wholly on the existing conditions of the pre-existing, or native, beach. There was also consensus that the focus of the criteria should be on limiting the excessively fine (silt and clay) and coarse (gravel and cobbles) sediment sizes, which are uncommon to North Carolina's beaches, rather than the sand-sized (or compatible) material that makes up the bulk of natural beach sediment.

During subsequent meetings, the Science Panel wrestled with how to effectively define baseline beach conditions (the “native” beach) and the specific coarse and fine sediment grain size thresholds to recommend in the proposed rules. The subcommittee continued to work on potential resolutions for the remaining issues, and at their October 2003 meeting, the Panel concluded that they were close to having a set of recommended guidelines for the CRC to consider.

Dr. John Fisher, then chairman of the CRC Science Panel on Coastal Hazards, presented the final sediment criteria recommendations to the CRC on January 27, 2005 (CRC 05-01). These recommendations were the culmination of more than two years of discussion and technical review aiming to develop an objective definition of sediment compatibility to replace the ambiguous language of 15A NCAC 07H.0308(a)(3). After considering the recommendations, a unanimous vote by the CRC Implementation and Standards (I&S) Committee allowed DCM staff a brief evaluation period to assess the recommendations’ potential impact on the State (Warren, 2005). This period lasted through October 2005 and consisted of continued data acquisition and analysis, technical document review, outreach and dialogue with stakeholder groups, and consultation with engineering firms experienced in beach fill projects.

The result of the evaluation effort was the development of a comprehensive set of sediment criteria to be considered for a new rule entitled “Technical Standards for Beach Fill Projects” (15A NCAC 07H.0312). Draft language is attached as Appendix B. This rule language is based on the initial Science Panel recommendations but also incorporates data gathered during the evaluation period described above. At their request, the Science Panel reviewed the draft rule language on October 31st, and, along with DCM, discussed where it was necessary to deviate from the original recommendations. Many of the Science Panel’s consequent concerns have been addressed in the attached rule language.

Staff presented rule language to the I&S Committee on January 26, 2006 entitled “Technical Standards for Beach Fill Projects” (15A NCAC 07H.0312). At that time, the I&S Committee carried a motion to send the proposed rules to public hearing, and the CRC unanimously approved this recommendation on January 27. The public hearing currently is scheduled to coincide with the CRC meeting in Greenville, NC on June 22 and 23, 2006.

II. Beach Nourishment

Beach fill, most commonly referred to as beach nourishment, is the practice of placing sediment on a beach to mitigate shoreline erosion. By adding sediment directly to the littoral system and altering the local or regional sediment budget, beach fill offers coastal communities a more dynamic, “softer” approach to manage erosion than do “hard” engineering structures, such as breakwaters or groynes, that alter natural geomorphic and hydraulic processes in order to induce sediment deposition. Accordingly, beach fill is viewed as a more environmentally friendly and aesthetic strategy that has been effective in both protecting shoreline development (Rogers, 2000) and maintaining the recreational

beach (NRC, 1995). For instance, after hurricanes Floyd and Dennis in 1999, structures fronted by beach fill projects designed for storm protection experienced a 100% survival rate whereas almost 1,000 buildings were threatened or destroyed outside of these project areas (Rogers, 2000). Types of beach nourishment projects in North Carolina include dredged material disposal (e.g. Atlantic Beach, 2005), storm protection (e.g. Kure Beach, 1998) and habitat restoration (e.g. Oak Island, 2001).

Worldwide, nearly 70% of beaches experience erosion (Bird, 1985). On the east coast of the United States, this number is closer to 80% (Galgano et al., 1998). Given that beaches are a primary tourist destination and support the economies of many coastal communities (Houston, 2002), considerable effort has been made in curbing erosion and maintaining the littoral status quo: since America's first beach nourishment project on Coney Island, NY in 1923 (Dornhelm, 1995), nearly \$1.6 billion has been spent on the east coast of the U.S. alone (PSDS, unpublished data). The growing preference of beach nourishment, coupled with a plethora of other factors including rising sea levels and ongoing long-term beach erosion (Leatherman et al., 2000), short-term storm-related erosion (Zhang et al., 2002), growing coastal populations (Edwards, 1989), and a marked increase in the value of coastal real estate (Houston, 1995), assure that it will be relied upon more frequently in the future.

In North Carolina, state law prohibits oceanfront shoreline armoring, making beach nourishment a primary alternative for erosion control. Between 2004 and 2005, North Carolina spent \$47.1 million on nourishment projects (J. Warren, pers. commun.). Until recently, many projects utilized sediment from the active littoral system, such as from nearby navigation channels or inlet shoals, so that the compatibility of fill material with that of the native beach was not an issue (Benton, 2003). However, the average size of projects in North Carolina has grown, and it is no longer feasible to extract the required sediment volumes from the active beach system without adversely affecting nearshore geomorphic and hydraulic processes. Sediment for most large-scale nourishment undertakings is instead dredged from offshore deposits (NRC, 1995) or excavated and transported to the beach from upland sites (e.g. ATM, 2001). Because neither of these sediment sources are part of the active littoral system, the sediment may be significantly different in size and character from the beach on which it is to be placed (Benton, 2003).

Engineering contractors who carry out nourishment projects do consider sediment compatibility and already match borrow sediment to the native beach (NRC, 1995; USACE, 2003), as grain size plays an important role in beach morphology (Bascom, 1951), ecology (Nordstrom, 2005), and in the lifespan of a nourished beach (NRC, 1995). However, between 2001 and 2005, four privately and federally funded beach nourishment projects placed large quantities of coarse material such as marl cobbles, shell hash, and mudballs on the North Carolina beaches of Oak Island, Pine Knoll Shores, Emerald Isle, and Atlantic Beach (Figure 1). The sediment criteria, as outlined in the preceding section, are designed to preclude such projects and provide a more objective definition of sediment compatibility in North Carolina.

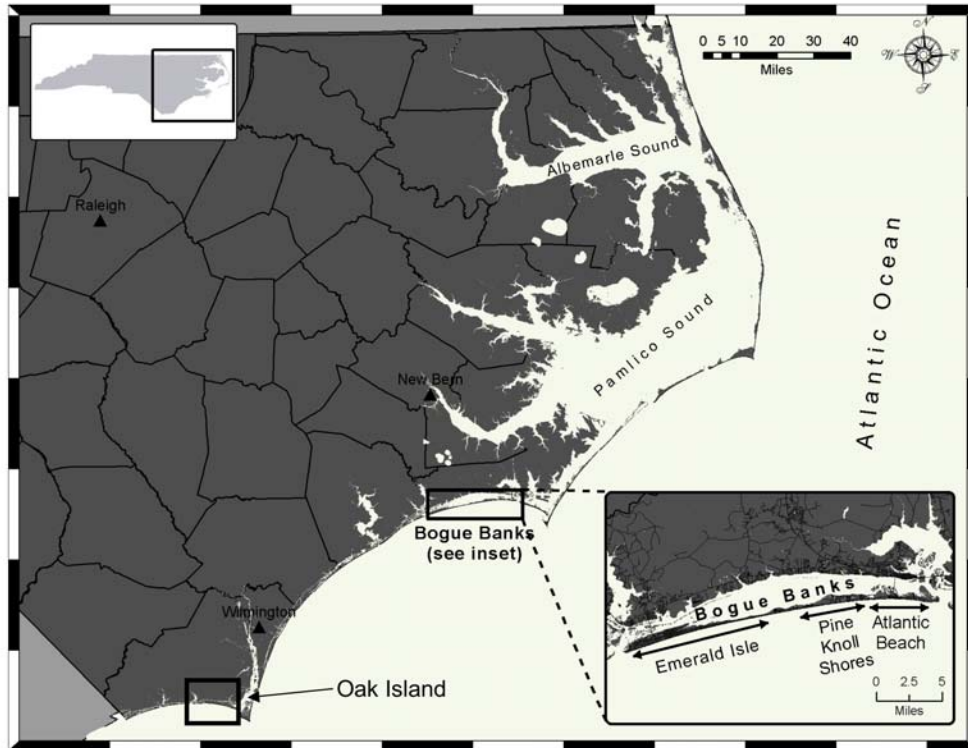


Figure 1. North Carolina location map.

III. Technical Standards for Beach Fill Projects: The Sediment Criteria Explained

The following is a step-by-step explanation of the current *Technical Standards for Beach Fill Projects*. The guide is organized exactly like the technical draft rules, and is divided into four main sections defining the proposed beach fill standards:

1. *Characterizing the beach receiving sediment, or recipient beach, prior to beach fill placement (page 4)*
 2. *Characterizing the borrow sediment, or sediment to be placed on the recipient beach, prior to beach fill placement (page 5)*
 3. *Determining compatibility of the borrow sediment with the recipient beach (page 6)*
 4. *Excavating and place borrow sediment on the recipient beach (page 9)*
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1. *Characterizing the beach receiving sediment, or recipient beach, prior to beach fill placement.* A comprehensive characterization of the recipient beach is required to determine beach fill compatibility. Specific sediment grain size categories used to characterize the beach are defined in section *1(e)* of the draft rules. Based on a combination of geological and engineering grain size scales (Unified Soil Classification System; Wentworth, 1922), the grain size categories are defined as “fine” (<0.0625 mm), “sand” (≥0.0625 mm and <2 mm), “granular” (≥2 mm and <4.76 mm), “gravel” (≥4.76 mm and <76 mm), and a final

broad category of all sediment or shell material greater than 76 mm in diameter (see Figure 4).

Sampling the recipient beach to determine the composite weight percent of each grain size category, except for material greater than 76 mm, and calcium carbonate must occur along at least five evenly spaced shore-perpendicular transects. Transect spacing shall not exceed 5,000 feet and each shall extend from the dune crest seaward to depth of 20 feet. Twelve samples must be taken along all transects and must account for all major morphodynamic zones (Figure 2) because grain size can vary widely in each zone due to the dynamics of depositional processes associated with tides, wind, waves, and storms along the beach profile. For example, the coarsest material is usually found in the high-energy swash zone where the waves break, and the finest sediments are found in the dunes, or moved off the beach to the low-energy offshore areas of the profile. The recipient beach characterization process is designed to best engineering practices so that the unique composition (i.e. grain size and mineralogy) of a given beach can be adequately characterized and serve as a template for compatible beach fill sediment.

After sampling is completed, a composite mean weight percent for gravel, granules, sand, fine material and calcium carbonate is calculated for the entire project area. These “grand means” are used to characterize the overall beach and are the variables to which beach fill sediment must be matched.

The natural background content of sediment and shell material greater than 76 mm in diameter must also be established as part of the native beach characterization. Unlike the previous grain size categories that are calculated along set transects, this material must be physically counted, piece-by-piece, on the beach surface over an area of 50,000 ft². The tabulation is considered to be a representative sample of the entire project area and will establish a baseline by which material greater than 76 mm can be measured in the event that it is placed on the beach during a beach fill project.

Important to note also is an exemption for beach fill sediment excavated from regularly maintained navigation channels. This high-quality compatible sand is a key source of beach fill material for many coastal communities. Because sediment from navigation channels originates from the adjacent beaches it is assumed to be compatible, and a recipient beach characterization is therefore not required.

2. *Characterizing the borrow sediment, or sediment to be placed on the recipient beach, prior to beach fill placement.* The characterization of borrow sediment is accomplished through three main tasks: geophysical imaging of the seafloor surface, geophysical imaging of the seafloor subsurface, and coring. Geophysical imaging of the seafloor surface involves mapping the entire borrow site's bathymetry, or the depth of the ocean and shape of the seafloor, with a SONAR system (Figure 3). Use of SONAR can also provide information regarding the

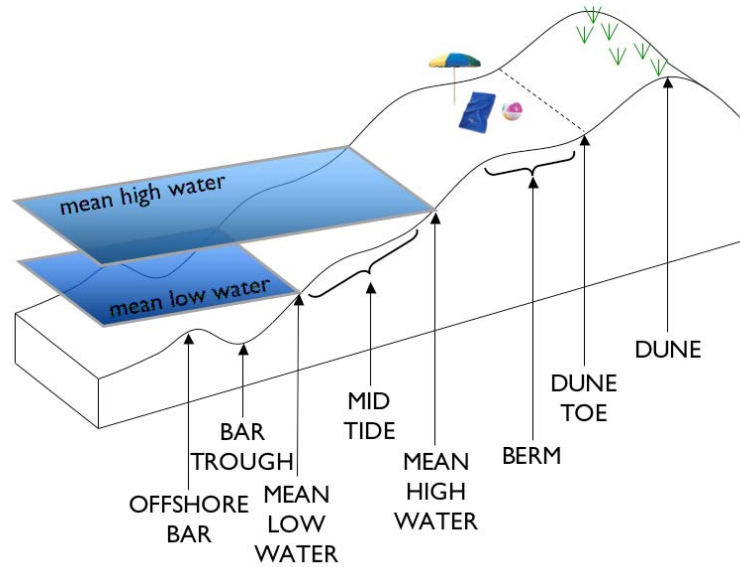


Figure 2: Major beach morphodynamic zones that must be sampled during beach characterization.

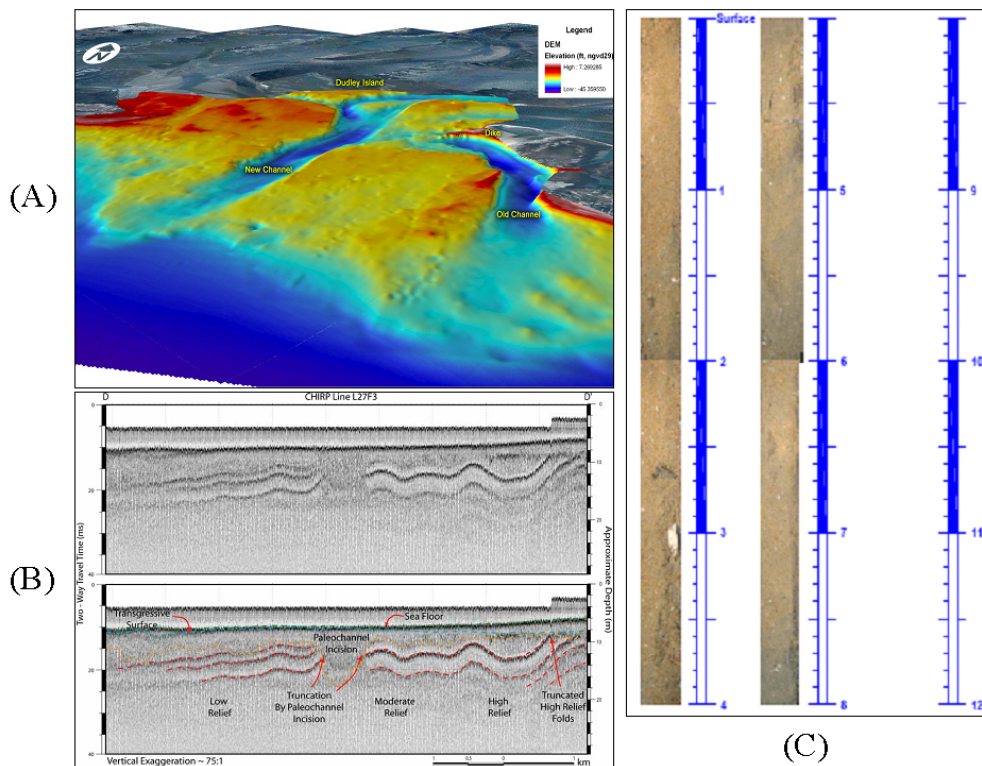


Figure 3: Examples of borrow site characterization techniques. A: Bathymetric imaging of Bogue Inlet with a swath sonar system. B: An interpreted seismic imaging profile. C: Scaled photo of a sediment core.

character of sediment on the seafloor surface. Subsurface geophysical imaging techniques such as seismic profiling (Figure 3) depict the vertical thickness of potential beach fill deposits and other adjacent geologic strata. Finally, physical sampling, such as coring (Figure 3), must be used to ground truth the geophysical data. Grain size and carbonate analyses of core samples must be completed so that the borrow sediment can be accurately matched to the native beach sediment characteristics.

Protocols have been established by the draft rules so that geophysical imaging and physical sampling will be effective in capturing the three-dimensional character of the borrow site. Bathymetric imaging must cover 100% of the borrow site, subsurface imaging must be collected along lines of no greater than 1,000 feet, and at least 10 evenly-spaced cores or one core per ten acres, whichever is greater, must be retrieved utilizing a core barrel of no less than three inches in diameter.

There is an exemption for characterizing borrow sediment excavated from regularly maintained navigation channels for the same reasons before as stated for a recipient beach. Borrow site characterization requires at least five cores with a minimum spacing of 5,000 feet to be taken, and no geophysical imaging is necessary.

- 3. *Determining compatibility of the borrow sediment with the recipient beach.*** In order to determine the thresholds within which beach fill sediment is deemed compatible, it was necessary to examine the natural characteristics and size of native beach sand in North Carolina. This was accomplished through the compilation and analysis of grain size data from Rice (2003) as well as several additional datasets available from the U.S. Army Corps of Engineers. Data used in this study represents all geographic and geomorphic regions of the North Carolina coast from the Virginia border to South Carolina.

In North Carolina, sand is the most common sediment size and accounts for, on average, 96% of all sediment on North Carolina's beaches (Rice, 2003). Therefore, the sediment grain sizes, including gravel, granules and fines, with the highest potential to alter the overall character of a native beach are those that make up the smallest proportion of the total population, on average about 5% (Rice, 2003). The mineralogical composition of beach sediment is primarily silica-based (e.g. quartz and feldspar) with a minor component of calcium carbonate. Shells are made up of calcium carbonate, a chemical compound found naturally as the minerals calcite or aragonite. Shells and shell pieces, many of them sand-sized, make up on average less than 10% of the material found on most North Carolina beaches (see Table 1; Rice, 2003). Significantly changing the amount of calcium carbonate or the grain size on a given beach has the potential to alter its hydraulic behavior (Bascom, 1951; Swart, 1991) and ecology (Milton et al., 1997; McLachlan, 1996).

Statewide compatibility thresholds of 5% for gravel, granules and fine sediment (Figure 4) were established by calculating the natural variation, or standard deviation, of each grain size category on the native beaches of North Carolina. To do this, native beach grain size data from Rice (2003), together with several additional datasets obtained from the U.S. Army Corps of Engineers, was analyzed. Excluding a total of 20 outliers that significantly biased the dataset, standard deviations of 5.3 (n = 980), 5.3 (n = 1,881) and 4.6 (n = 2,269) were calculated for gravel, granules, and fine material, respectively, that represent grain size data from all coastal geographic and geomorphic zones in North Carolina from the Virginia border to South Carolina. Rounded to 5%, these standard deviations represent the natural variation, and accordingly the grain size compatibility thresholds, of each grain size category.

The calcium carbonate threshold was established in a similar way. Statistics illustrating the amount and variability of carbonate in North Carolina beach sediment are shown in Table 1 from data gathered by DCM and Rice (2003). From the maximum standard deviation in Table 1, a threshold of 15% above the native weight percent was established. The beach fill project at Emerald Isle in 2003, noted for its high carbonate content, would have been incompatible seeing as carbonate content of post-project sediment ranged, on average, from 35-43%, or 23-30% above the native content (King, 2004; CSE, 2003).

As discussed in sections (1) and (2), a compatibility exemption exists for sediment from regularly maintained navigation channels. Assuming this sediment is essentially beach-quality, it only has to meet one compatibility threshold: the average percentage by weight of fine sediment must be less than 10%. A second compatibility exemption exists that facilitates the timely infilling of storm-induced barrier island breaches to maintain transportation corridors. Sediment used to initially fill inlet breaches must meet permit requirements, but does not need to meet any compatibility thresholds. However, any subsequent beach fill activities on that site will be considered a beach fill project and must adhere to the Rules.

4. *Excavating and placing borrow sediment on the recipient beach.* Several constraints govern the excavation and placement of beach fill sediment. First, in order to prevent unidentified sediment from being placed on the beach, the sediment excavation depth for all borrow sites shall not exceed the maximum depth of coring. Similarly, the excavation depth for navigation channels shall not exceed their permitted dredge depths. Second, any sediment larger than 76 mm (i.e., cobbles and boulders) placed on the beach during a beach fill project that exceeds the natural background content by a factor of two between mean low water and the dune toe will be considered incompatible. The background content is to be established pre-project during native beach characterization (see *Part I*). The 2001 Oak Island beach fill project in which marl cobbles were placed on the beach would be deemed incompatible under these standards. Lastly, to minimize biological impacts, DCM and other State and Federal agencies must jointly

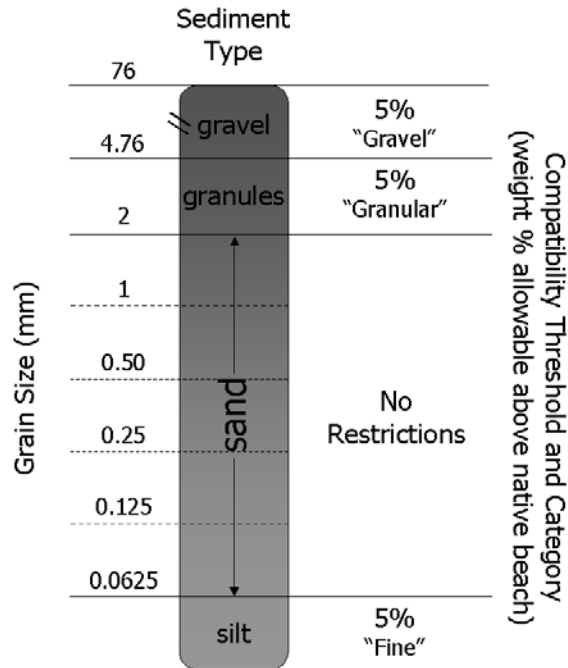


Figure 4: Sediment grain size scale, grain size categories, and compatibility thresholds.

Table 1. Natural Calcium Carbonate Content of North Carolina Beach Sediment (SD: standard deviation; η : number of samples)

Location	η	Mean Weight %	SD	Data Source
Southern Shores	100	1.4	0.9	USACE, unpub. data (2004)
Kitty Hawk	79	3.5	3.4	USACE, unpub. data (2004)
Kill Devil Hills	120	3.2	3.9	USACE, unpub. data (2004)
Nags Head (a)	279	2.8	3.3	USACE, unpub. data (2004)
Nags Head (b)	110	2.8	2.8	CSE (2005)
Cape Hatteras	90	2.1	2.1	USACE, unpub. data (2004)
Ocracoke Island	113	4.3	7.7	USACE (1965) in Rice (2003)
Portsmouth Island	35	3.3	4.3	USACE (1965) in Rice (2003)
South Core Banks	45	10.1	11.7	USACE (1965) in Rice (2003)
Cape Lookout	8	6.7	7.1	USACE (1965) in Rice (2003)
Shackleford Banks	12	22.3	12.8	L. Manning, unpub. data in Rice (2003)
Atlantic Beach	108	11.4	8.1	King (2004)
Emerald Isle	32	12.9	11.3	CSE (2003)
East Emerald Isle	119	12.2	8.0	King (2004)
West Emerald Isle	161	11.0	8.3	King (2004)
Topsail Island	4	23.3	5.4	Rice (2003)
Topsail Island	202	8.4	8.6	USACE, unpub. data (2005)
Ocean Isle	4	2.7	2.9	ATM, Inc., in Rice (2003)

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approve the project to insure that it is not to occur, for instance, in ecologically sensitive habitat or during sea turtle nesting season.

IV. Comparison of the Sediment Criteria with Current Federal Beach Fill Standards

North Carolina's sediment criteria rules share many similarities with current federal beach fill standards followed by the U.S. Army Corps of Engineers (USACE). The USACE has developed numerous protocols for beach and borrow site characterization and as well as beach fill design (e.g., USACE Coastal Engineering Manual Parts III and V, 2003), and enough overlap exists between USACE and North Carolina beach fill standards so that additional costs imposed by the sediment criteria will be minimal as compared to a federal project. However, the USACE does not have a set of universal sediment compatibility rules *per se* since many of these protocols and design standards may be modified, or not used, based on project-specific conditions. North Carolina's grain size compatibility thresholds are unique in that regard. Table 2 shows a comparison between fundamental protocols in the sediment criteria and USACE guidelines.

V. Conclusion

Beach fill has become one of the primary methods of mitigating shoreline erosion in North Carolina, and as coastal development grows, it is important that the integrity of the beach is maintained as well as the development it protects. Impacts of placing incompatible sediment on the beach range from environmental to economic, and the current rule, 15A NCAC 07H.0308(a)(3), provides only a vague and subjective definition of what compatible sediment is. The draft sediment criteria rules presented herein represent a vigorous 3-year-long integration of science and policy, as well as collaboration with many stakeholders (see Appendix B), to define sediment compatibility in a more quantitative and objective manner. Using grain size thresholds based on the natural variation of beach sediment that dynamically match borrow material to the native beach, the sediment criteria will ensure that future beach fill projects will closely mimic the native characteristics of North Carolina's beaches.

Table 2. Comparison of North Carolina Sediment Criteria and USACE Federal Standards

		USACE	North Carolina
Native Beach	Characterization required?	YES	YES
	Beach transect spacing	5,000 ft.	5,000 ft.
	Beach profile sampling	Active beach profile sampled from dune toe to offshore bar; more offshore samples than onshore	≥12 samples along active beach profile at specific morphodynamic zones; half offshore & half onshore
Borrow Site	Bathymetric imaging	YES; variable coverage	YES; 100% coverage
	Subsurface seismic profiling	YES; variable line spacing	YES; 1,000 ft line spacing
	Core density	1,000 ft grid spacing	1,000 ft grid spacing
Sediment Compatibility	Determination of sediment compatibility	Overfill factors (R_A) [†] ; fine sediment may not exceed 10%	Grain size thresholds (“Fine”, “Granular”, and “Gravel”) tied to native beach (Figure 4)
	Carbonate content allowable	Unspecified	≤15% above native content

[†]An overfill factor is a statistical sedimentological comparison between borrow sediment and native beach sediment. For more information, see the USACE Coastal Engineering Manual Part V: <<http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-1100/PartV/PartV.htm>>

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Appendix A. Draft Rule Language Approved for Public Hearing

15A NCAC 07H .0312 is proposed for adoption as follows:

TECHNICAL STANDARDS FOR BEACH FILL PROJECTS

Emplacement of sediment along the oceanfront shoreline shall be referred to in this Rule as beach fill. Beach fill projects including beach nourishment, dredged material disposal, habitat restoration, storm protection, and erosion control may be permitted under the following conditions:

- (1) A characterization of the recipient beach shall be determined according to the following methodology:
 - (a) Characterization of the recipient beach shall not be required for the placement of sediment directly from and completely confined to a regularly maintained navigation channel; and
 - (b) Sediment sampling and analysis designed to acceptable geological and engineering standards shall be used to capture the three-dimensional spatial variability of the sediment characteristics including grain size, sorting and mineralogy within the natural system; and
 - (c) Shore-perpendicular topographic and bathymetric surveying of the recipient beach shall be conducted to determine the beach profile. Topographic and bathymetric surveying shall occur along a minimum of five (5) shore-perpendicular transects evenly spaced throughout the entire project area. Each transect shall extend from the dune crest seaward to a depth of 20 feet (6.1 meters) below sea level. Transect spacing shall not exceed 5,000 feet (1,524 meters) in the shore-parallel direction. Elevation data for all transects shall be referenced to the North American Vertical Datum of 1988 (NAVD 88) and the North American Datum of 1983 (NAD 83); and
 - (d) No less than twelve (12) sediment samples shall be taken along each beach profile transect. At least one (1) sample shall be taken from each of the following morphodynamic zones where present: dune, dune toe, mid berm, mean high water (MHW), mid tide (MT), mean low water (MLW), trough, bar crest and at even depth increments from 6 feet (1.8 meters) below sea level to 20 feet (6.1 meters) below sea level. The total number of samples taken landward of MLW shall equal the total number of samples taken seaward of MLW; and
 - (e) For the purpose of this rule, sediment grain size categories shall be defined as “fine” (<0.0625 mm), “sand” (≥0.0625 mm and <2 mm), “granular” (≥2 mm and <4.76 mm) and “gravel” (≥4.76 mm and <76 mm). Each sediment sample shall report percentage by weight of each of these four (4) grain size categories; and
 - (f) A composite of the simple arithmetic mean for each of the four (4) grain size categories defined in Part (1)(e) of this Rule shall be calculated for each transect. A grand mean shall be established for each of the four (4) grain size categories by summing the mean for each transect and dividing by the total number of transects. The value that characterizes grain size values for the recipient beach shall be the grand mean of percentage by weight for each grain size category defined in Part (1)(e) of this Rule; and
 - (g) Percentage by weight calcium carbonate shall be calculated from a composite of all sediment samples along each transect defined in Part (1)(d) of this Rule. The value that characterizes the carbonate content of the recipient beach shall be a grand mean calculated by summing the percentage by weight calcium carbonate for each transect and dividing by the total number of transects; and
 - (h) The total number of sediments and shell material greater than 3 inches (76 mm) in diameter, observable with the naked eye on the surface of the beach between mean low water (MLW) and the dune toe, shall be calculated for an area of 50,000 square feet (4,645 square meters). This area shall be considered a representative sample of the entire project area and referred to as the “background” value; and
 - (i) Beaches that have received sediment prior to the effective date of this Rule shall be characterized in a way that is consistent with Parts (1)(a) through (1)(g) of this Rule

- and shall use data collected from the recipient beach prior to the addition of beach fill. If such data were not collected or are unattainable, a dataset best reflecting the sediment characteristics of the recipient beach prior to beach fill shall be developed in coordination with the Division of Coastal Management.
- (2) A characterization of sediment to be placed on the recipient beach shall be determined according to the following methodology:
- (a) The characterization of borrow areas including submarine sites, upland sites, and dredged material disposal areas shall be designed to accepted geological and engineering standards to capture the three-dimensional spatial variability of the sediment characteristics including grain size, sorting and mineralogy within the natural system or dredged material disposal area; and
 - (b) The characterization of borrow sites shall include previously acquired data whenever possible; and
 - (c) Geophysical imaging of the seafloor at each submarine borrow site shall provide 100% coverage and use survey-grade swath sonar in accordance with current US Army Corps of Engineers standards for navigation and dredging. All final hydrographic data shall be tide- and motion-corrected and referenced to the North American Vertical Datum of 1988 (NAVD 88) and the North American Datum of 1983 (NAD 83) and conform to standards for accuracy, quality control and quality assurance as set forth either by the US Army Corps of Engineers, the National Oceanic and Atmospheric Administration, or the International Hydrographic Organization; and
 - (d) Geophysical imaging of the subsurface shall be used to characterize each borrow site and shall use survey grids with a line spacing not to exceed 1,000 feet (305 meters). Survey grids shall incorporate at least one (1) tie point per survey line. Subsurface geophysical imaging shall not be required for regularly maintained navigation channels. All final subsurface geophysical data shall use accurate sediment velocity models for time-depth conversions, be tide- and motion-corrected, and be referenced to the North American Vertical Datum of 1988 (NAVD 88) and the North American Datum of 1983 (NAD 83); and
 - (e) Sediment sampling of borrow sites shall use a vertical sampling device no less than 3 inches (76 mm) in diameter. Characterization of each borrow site shall use no less than 10 evenly spaced cores or one (1) core per 10 acres (grid spacing of 1,000 feet or 305 meters), whichever is greater. Characterization of borrow sites completely confined to regularly maintained navigation channels shall use no less than five (5) evenly spaced vertical samples per channel or sample spacing of no more than 5,000 linear feet (1,524 m), whichever is greater, and penetrate to a depth equal to or greater than permitted dredge depth. All sediment samples shall be integrated with geophysical data to constrain the horizontal and vertical extent of lithologic units and determine excavation volumes of compatible sediment as defined in Part 3 of this Rule; and
 - (f) Grain size distributions shall be reported for all sub-samples taken within each vertical sample for each of the four (4) grain size categories defined in Part (1)(e) of this Rule. Weighted averages for each core shall be calculated based on the total number of samples and the thickness of each sampled interval. A simple arithmetic mean of the weighted averages for each grain size category shall be calculated to represent the average grain size values for each borrow site. Vertical samples shall be geo-referenced and digitally imaged using scaled, color-calibrated photography; and
 - (g) Percentage by weight of calcium carbonate shall be calculated from a composite sample of each core. A weighted average of calcium carbonate percentage by weight shall be calculated for each borrow site based on the composite sample thickness of each core.
- (3) Sediment compatibility shall be determined according to the following criteria:

- (a) Sediment completely confined to the permitted dredge depth of a regularly maintained navigation channel shall be considered compatible if the average percentage by weight of fine-grained (<0.0625 mm) sediment is less than 10%; and
 - b) Sediment used solely to establish or strengthen dunes shall not be considered a beach fill project under this Rule; and
 - c) Sediment used solely to re-establish State-maintained transportation corridors across a barrier island breach in a disaster area as declared by the Governor shall not be considered a beach fill project under this Rule; and
 - d) Material other than natural sediment and shell material shall not be considered compatible; and
 - e) The average percentage by weight of fine-grained sediment (<0.0625 mm) in a borrow site shall not exceed the average percentage by weight of fine-grained sediment of the recipient beach characterization plus 5%; and
 - f) The average percentage by weight of granular sediment (≥ 2 mm and <4.76 mm) in a borrow site shall not exceed the average percentage by weight of coarse-sand sediment of the recipient beach characterization plus 5%; and
 - g) The average percentage by weight of gravel (≥ 4.76 mm) in a borrow site shall not exceed the average percentage by weight of gravel-sized sediment for the recipient beach characterization plus 5%; and
 - h) The average percentage by weight of calcium carbonate in a borrow site shall not exceed the average percentage by weight of calcium carbonate of the recipient beach characterization plus 15%; and
 - i) Proposed techniques that are able to use innovative technology to take incompatible sediment within a borrow site or combination of sites and make it compatible with that of the recipient beach characterization shall be considered experimental and evaluated on a case-by-case basis by the Division of Coastal Management.
- (4) Excavation and placement of sediment shall conform to the following criteria:
- (a) Sediment excavation depth from a regularly maintained navigation channel shall not exceed the permitted dredge depth of the channel; and
 - (b) Sediment excavation depths for all borrow sites shall not exceed the maximum depth of recovered core at each coring location; and
 - (c) In order to minimize impacts on biological activity within the project area, no work shall occur without the prior approval of the Division of Coastal Management in consultation with other State and Federal agencies; and,
 - (d) Sediment and shell material with a diameter greater than 3 inches (76 mm) shall be considered incompatible if it has been placed on the beach during the beach fill project, is observed with the naked eye between mean low water and the dune toe, and is in excess of twice the background value of material of the same size along any 50,000-square-foot (4,645 square meter) section of beach.

Appendix B. Stakeholders Solicited for Comment on the Sediment Criteria

EXPLANATION OF SYMBOLS

- ↔ Member(s) of agency/organization attended a DCM sed criteria presentation
- ☎ Sediment criteria outreach and/or request for comments via telephone
- ✉ Sediment criteria outreach and/or request for comments email
- ✉ Sediment criteria outreach and/or request for comments via letter

FEDERAL AGENCIES

- ☎✉↔ US Army Corps of Engineers
- ↔ US Fish and Wildlife Service

STATE AGENCIES AND ORGANIZATIONS




















- ✉ FL Dept of Environmental Protection, Bureau of Beaches and Coastal Systems
- ↔✉ NC Coastal Resources Advisory Council
- ↔✉ NC Coastal Resources Commission
- ↔☎✉ NC Coastal Resources Commission Science Panel on Coastal Hazards
- ↔✉ NC Department of Transportation
- ☎✉ NC Department of Water Resources
- ↔ NC Division of Marine Fisheries
- ↔ NC Division of Water Quality
- ↔ NC Marine Fisheries Commission Habitat and Water Quality Advisory Committee
- ☎✉↔ NC Ports

NON-GOVERNMENTAL ORGANIZATIONS



- ☎✉ Bald Head Island Conservancy
- ✉ BeachHuggers of the Outer Banks
- ☎✉ Business Alliance for a Sound Economy (Wilmington, NC)
- ↔ Eastern Carolina Council of Government
- ☎✉↔ Environmental Defense (Raleigh Regional Office)
- ☎✉ North Carolina Association of Realtors
- ☎✉↔ North Carolina Beach, Inlet and Waterway Association
- ☎✉↔ North Carolina Coastal Federation
- ☎✉ North Carolina League of Municipalities
- ↔ Onslow Bay Saltwater Fishing Club
- ☎✉↔ Program for the Study of Developed Shorelines (Duke University)
- ✉ Sierra Club (North Carolina Chapter)
- ☎✉ Wilmington – Cape Fear Home Builders Association

ENGINEERING AND DREDGING FIRMS

- ☎↔ Applied Technology and Management, Inc. (Charleston, SC)
- ☎✉ Bean Stuyvesant (New Orleans, LA)
- ↔ Catlin Engineers and Scientists (Wilmington, NC)
- ☎✉↔ Clark Group (Wilmington, NC)
- ☎✉ Coastal Planning and Engineering, Inc. (Boca Raton, FL)

-   ⇆ Coastal Science and Engineering (Columbia, SC)
-   Erickson Consulting Engineers (Gainseville, FL)
-   Gahagan and Bryant (Wilmington, DE)
-   Geodynamics Group, LLC (Pine Knoll Shores, NC)
-   Great lakes Dredge and Dock Company (Oak Brook, IL)
-   McKimm and Creed (Wilmington, NC)
-   ⇆ Moffatt and Nichol Engineers (Raleigh, NC)
-   Olsen Associates (Jacksonville, FL)
-  Terracon Consultants, Inc. (Raleigh, NC)
-   Weeks Marine (Cranford, NJ)

COUNTY GOVERNMENTS AND RELATED ORGANIZATIONS

- Beaufort County (Commission Chair, Coop Ext Agent, Mgr, Planner)
- Bertie County (Commission Chair, Coop Ext Agent, Mgr, Econ Dev)
- Brunswick County (Commission Chair, Coop Ext Agent, Mgr, Plan Dir)
- ⇆ Brunswick Beaches Consortium
- Camden County (Commission Chair, Coop Ext Agent, Mgr)
- ⇆ Carteret County (Commission Chair, Coop Ext Agent, Mgr, Planner)
- ⇆ Carteret County Beach Commission
- ⇆   Carteret County Shore Protection Office
- Chowan County (Commission Chair, Coop Ext Agent, Mgr)
- ⇆ Craven County (Commission Chair, Coop Ext Agent, Mgr, Planning Dir)
- ⇆ Coastal Communities Coalition
- Currituck County (Commission Chair, Coop Ext Agent, Mgr, Planner, Econ Dev)
- Dare County (Commission Chair, Coop Ext Agent, Mgr, Planner)
- ⇆ Dare County Board of Commissioners
- Gates County (Commission Chair, Coop Ext Agent, Mgr)
- Hertford County (Commission Chair, Mgr)
- Hyde County (Commission Chair, Coop Ext Agent, Mgr, Planner)
- Jones County (Coop Ext Agent, Mgr)
- Martin County (Commission Chair, Coop Ext Agent, Mgr, Chamber of Comm)
- New Hanover County (Commission Chair, Coop Ext Agent, Mgr, Planning Dir)
- ⇆ North Carolina Beach, Inlet and Waterways Association
- Onslow County (Commission Chair, Coop Ext Agent, Mgr, Community Dev)
- Pamlico County (Commission Chair, Coop Ext Agent, Mgr, Planner)
- Pasquotank County (Commission Chair, Coop Ext Agent, Mgr, Plan Dir)
- Pender County (Commission Chair, Coop Ext Agent, Mgr, Econ Dev)
- Perquimans County (Commission Chair, Coop Ext Agent, Mgr)
- Pitt County (Commission Chair, Coop Ext Agent, Mgr, Plan Dir)
- Tyrrell County (Commission Chair, Coop Ext Agent, Mgr)
- Washington County (Commission Chair, Coop Ext Agent, Mgr)

MUNICIPAL GOVERNMENTS AND RELATED ORGANIZATIONS

- Ahoski (Mayor, Council, Mgr)
- Alliance (Mayor, Commission)
- Arapahoe (Mayor, Commission)
- Askewville (Mayor, Clerk)
- Atkinson (Mayor, Aldermen)
- ⇆ Atlantic Beach (Mayor, Commission, Mgr)
- Aulander (Mayor, Clerk)

- Aurora (Mayor, Commission)
- ↔ Bald Head Island (Mayor, Mgr, Council)
- Bath (Mayor, Commission)
- Bayboro (Mayor, Commission)
- Beaufort (Mayor, Commission, Mgr)
- Belhaven (Mayor, Council, Mgr, Public Utility Dir)
- Belville (Mayor, Clerk)
- Bogue (Mayor, Commission)
- Bolivia (Mayor, Aldermen)
- Bridgeton (Mayor, Commission)
- Burgaw (Mayor, Commission, Planning Dir)
- Calabash (Mayor, Commission)
- Cape Carteret (Mayor, Commission)
- ↔ Carolina Beach (Mayor, Council, Mgr, Planning Dir)
- Carolina Shores (Mayor, Commission)
- ↔ Caswell Beach (Mayor, Commission)
- Cedar Point (Mayor, Commission)
- Chocowinity (Mayor, Commission)
- Cofield (Mayor, Commission)
- Colerain (Mayor, Clerk)
- Columbia (Mayor, Aldermen, Mgr)
- Como (Mayor, Commission)
- Cove City (Mayor, Aldermen)
- Creswell (Mayor, Council)
- Dover (Mayor, Aldermen)
- Duck (Mayor, Council, Mgr, Planning Dir)
- Edenton (Mayor, Commission, Mgr, Dir of Public Utilities)
- Elizabeth City (Mayor, Council, Mgr, Planning Dir)
- ↔ Emerald Isle (Mayor, Commission, Mgr)
- Gatesville (Mayor, Council)
- Grantsboro (Mayor, Council)
- Grimesland (Mayor, Aldermen)
- Harrellsville (Mayor, Commission)
- Havelock (Mayor, Commission, Mgr, Planning Dir, Dir of Public Utilities)
- Hertford (Mayor, Commission, Mgr)
- Holly Ridge (Mayor, Council, Mgr, Public Utility Dir)
- ↔ Holden Beach (Mayor, Commission, Mgr)
- ↔ ↔ Holden Beach Shoreline Protection Committee
- Indian Beach (Mayor, Commission)
- ↔ Jacksonville (Mayor, Council, Mgr, Planning Dir, Public Utility Dir)
- Kill Devil Hills (Mayor, Commission, Mgr, Planning Dir)
- ↔ Kitty Hawk (Mayor, Council, Mgr, Planning Dir)
- Kelford (Mayor, Clerk)
- Kure Beach (Mayor, Commission)
- Leland (Mayor, Council, Mgr)
- Lewiston Woodville (Mayor, Commission)
- Manteo (Mayor, Commission, Mgr, Dir of Public Utilities)
- Mesic (Mayor, Council)
- Minnesott Beach (Mayor, Commission, Mgr)
- ↔ Morehead City (Mayor, Commission, Mgr, Planning Dir, Dir of Public Utilities)
- Murfreesboro (Mayor, Commission)

- ☒↔ Nags Head (Mayor, Commission, Mgr, Planning Dir)
- ☒ Navassa (Mayor, Council)
- ☒ New Bern (Mayor, Aldermen, Mgr, Planning Dir)
- ☒ Newport (Mayor, Council, Mgr)
- ☒↔ North Topsail Beach (Mayor, Aldermen, Mgr)
- ↔ North Topsail Beach Nourishment Committee
- ☒ Northwest (Mayor, Council)
- ☒ Oak Island (Mayor, Commission, Mgr)
- ☒↔ Ocean Isle Beach (Mayor, Commission)
- ☒ Oriental (Mayor, Commission, Mgr)
- ☒ Pantego (Mayor, Commission)
- ☒ Peletier (Mayor, Commission)
- ☒↔ Pine Knoll Shores (Mayor, Commission, Planning Dir)
- ☒ Plymouth (Mayor, Council, Mgr)
- ☒ Powellsville ((Mayor, Clerk)
- ☒ Richlands (Mayor, Aldermen)
- ☒ River Bend (Mayor, Council)
- ☒ Roper (Mayor, Council)
- ☒ Roxobel (Mayor, Clerk)
- ☒ Saint Helena (Mayor, Council)
- ☒ Sandy Creek (Mayor, Council)
- ☒ Shallotte (Mayor, Aldermen, Mgr)
- ☒ Simspon (Mayor, Council)
- ☒ Southern Shores (Mayor, Council, Mgr)
- ☒ Southport (Mayor, Aldermen, Mgr, Public Utility Dir)
- ☒ St James (Mayor, Council)
- ☒ Stonewall (Mayor, Commission)
- ☒↔ Sunset Beach (Mayor)
- ☒↔ Surf City (Mayor, Council, Mgr)
- ↔ Surf City Shore Protection Committee
- ☒ Swansboro (Mayor, Commission, Mgr, Public Utility Dir)
- ☒ Topsail Beach (Mayor, Commission, Mgr)
- ↔ Topsail Beach Shore Protection Committee
- ☒ Trent Woods (Mayor, Commission)
- ☒ Vanceboro (Mayor, Aldermen)
- ☒ Vandemere (Mayor, Commission)
- ☒ Varnamtown (Mayor, Aldermen)
- ☒ Wallace (Mayor, Council, Mgr)
- ☒ Washington (Mayor, Council)
- ☒ Washington Park (Mayor, Commission)
- ☒ Watha (Mayor, Commission)
- ☒↔ Wilmington (Mayor, Council, Mgr, Planning Dir, Comm Develop Dir)
- ☒ Windsor (Mayor, Administrator)
- ☒ Winfall (Mayor, Council)
- ☒ Winton (Mayor, Commission)
- ☒ Wrightsville Beach (Mayor, Aldermen, Mgr, Planning Dir)