SECTION 3.0 – PROJECT ALTERNATIVES

3.1 SCREENING OF ALTERNATIVES

Based upon the stated project purpose and need, the USACE, in consultation with the Project Review Team (PRT), developed a range of alternatives to be considered in the EIS. The range of alternatives includes considerations of various means by which to respond to the project need and associated objectives. The preliminary list of alternatives was screened via the scoping process and PRT input. An initial alternative identified during scoping, but not advanced further in the EIS analysis included consideration of construction of a terminal groin without beach nourishment. As this alternative is not compliant with the provisions of SB 151 and is not preferred from an engineering standpoint, it has been eliminated from further consideration. The remaining alternatives evaluated within this document are identified in Table 3.1 below.

Table 3.1. List of Project Alternatives

Alternative #1	**No-Action (includes component of Status-Quo)**
Alternative #2	**Retreat**
Alternative #3	**Beach Nourishment/Disposal with Existing Sand Tube Groinfield to Remain in Place**
Alternative #4	**Beach Nourishment/Beach Disposal and Sand Tube Groinfield Removal**
Alternative #5	**Terminal Groin with Beach Nourishment/Beach Disposal (Sand Tube Groinfield Remaining)**
Alternative #6	**Terminal Groin with Beach Nourishment/Disposal (Removal of Sand Tube Groinfield)**

3.2 DESCRIPTION OF ALTERNATIVES

3.2.1 No Action/Status Quo Alternative (Alternative #1)

Under the No-Action Alternative, the Village would not implement any comprehensive action (or actions) to offset the on-going erosion of the western end of South Beach. The No-Action Alternative takes into consideration the existing or status quo condition. As such, disposal events occurring under the existing Wilmington Harbor Sand Management Plan (SMP) may occur. The current SMP calls for the sand from Bald Head Shoal Reaches 1 and 2 and Smith Island Reach to be placed on Bald Head Island in two out of every three channel dredging cycles. These cycles are scheduled to occur every other year if conditions, funding, and navigation priorities permit. Under the No-Action Alternative, short-term stabilization measures such as the placement of emergency sand-bags for protection of structures imminently threatened by erosion (in compliance with current state regulations) and the maintenance of the existing sand-tube groinfield would occur (as they have over the last decade or more). Furthermore, the no-action or status quo alternative would include use of beach scraping during the winter months to help rebuild and stabilize foredunes in critically-eroded areas. In similar regard, the Village would continue its program of sand fencing to promote dune formation and stabilization.

3.2.2 Retreat (Alternative #2)

Under the Retreat Alternative, the Village would identify high-risk areas for the development and implementation of a Managed Shoreline Retreat Plan that would ultimately provide for the unimpeded recession of the shoreline. The Plan would provide for the systematic removal of the sand tube groinfield and the demolition or relocation of residences, roads, and infrastructure, if land and funds are available, in advance of the shoreline recession. Thresholds would be identified to trigger the demolition or relocation of specific structures. As part of the retreat strategy, undeveloped lots of the interior sections of Bald Head Island would be identified and acquired for the explicit use of relocating homes. Unimproved lots potentially available for acquisition and structure relocation have been identified (refer to

Figure 3.1). These lots were identified based upon several factors, including: distance from nine-year predicted shoreline position under the Retreat Alternative; condition of lot (i.e. unimproved); and relocation logistics (e.g. avoiding areas in maritime forest that would require additional clearing along narrow right-of-ways for structure transport).

Based upon Delft 3D modeling results (described in Section 5.0), relocation efforts would need to be initiated rather quickly, as roads and several residences would be susceptible to loss within the first three years. Much of the demolition and relocation would need to be completed by Year 9 of the implementation of this alternative (refer to Section 5.2 for predicted shoreline positions). It can be expected that retreat measures would need to be implemented over the 30-year period under consideration. Where necessary and feasible, new right-of-way corridors would be acquired for the relocation of roads and utilities. It is expected that all or portions of secondary right of ways in the permit area (including Sandpiper Trail, Water Thrush Court, and Cape Fear Trail) would need to be abandoned, while the primary route along South Beach (South Bald Head Wynd) would need to be relocated. Detailed information regarding the number of lots (both improved and unimproved) and the specific right of ways and infrastructure that would be subject to relocation or demolition is provided in Section 5.0.

As part of the overall strategy, temporary stabilization methods may be employed to prolong the life of homes, buildings, roads, and infrastructure to provide adequate time for relocation or demolition. For instance, placement of temporary sand bags in accordance with state regulations may be utilized seaward of imminently threatened structures. Use of sand bags would be for a defined period to provide for adequate planning and implementation of retreat measures. In a similar manner, it is expected that the existing sand tube groinfield would be left in place until such time as sufficient retreat measures (e.g. demolition or relocation of infrastructure and homes) have been employed to minimize the risk of potential environmental and safety hazards associated with rapid shoreline recession.

Upon completion of the necessary retreat measures, the sand tube groinfield would be removed at a cost to the Village.

While not relied upon to prolong the life of any structure, it is assumed that under the Retreat Alternative sand disposal would continue to occur per the federal SMP and contingent upon federal funding. However, it is likely that removal of the sand tube groinfield would influence the location and extent of future federal sand disposal on South Beach.

3.2.3 Beach Nourishment/Disposal with Existing Sand Tube Groinfield to Remain in Place (Alternative #3)

Under Alternative #3, it is assumed that beach disposal would continue per the terms of the existing SMP. The Village would continue to design and implement independently-sponsored beach nourishment and beach disposal projects on an as-needed basis. While FEMA funds may be available to the Village to address sand losses subsequent to a declared disaster, FEMA support is not available for scheduled renourishment events. Note that the levels of federal and/or state contribution for prior disposal and nourishment events on Bald Head Island are identified in Table 1.2 (Section 1.0). As described further in Section 5.0, costs associated for Village-sponsored nourishment under this alternative are considered to be borne wholly by the Village.

In light of calculated volumetric losses provided by the Applicant (see Section 5.0), it is anticipated that the volume and frequency of Village-sponsored nourishment/disposal events required to reduce the risk of further shoreline erosion is on the order of magnitude of 1.5 Mcy of sand beginning at Year 3 post federal SMP disposal and continuing every nine years for the life of the project (30 years). The sand tube groinfield would be maintained so as to continue its beneficial effect on sand losses which are most evident for two years after a large scale sand placement event.

Potential sand sources that may be considered under this alternative are described below. Note that the locations of each of the potential sand source sites are depicted in Figure 3.2.

3.2.3.1 Wilmington Harbor Entrance Channel

Prior federal channel maintenance and disposal events conducted under the Wilmington Harbor SMP have demonstrated that the innermost segment of the Ocean Entrance Channel is a suitable source of beach-compatible material. Navigation channel surveys for three channel reaches (Smith Island Range, Baldhead Shoal Reach 1, and Baldhead Shoal Reach 2) continue to be conducted on bi-monthly intervals. Condition surveys performed in 2012, preceding the Spring 2013 maintenance dredging contract, indicate the occurrence of continued shoaling in the western side of the Smith Island Channel and the eastern side of Baldhead Shoal Reach 1 and 2. The most recent pre-dredging hydrographic surveys for these channel reaches are provided for reference in Appendix E. Areas of pronounced decreases in channel depth resulting from shoaling represent suitable high quality sources for beach nourishment material.

Per the Wilmington Harbor Dredged Material Management Plan (USACE 1996) and the SMP (USACE 2000), beach quality sand can be found within the interior reaches north of the Smith Island Channel. According to sediment composition data, dredged material from Horseshoe Shoal and Reaves Point contained 98% sand and 99% sand, respectively (USACE 1996). The SMP contains a section dedicated to the management of sediments dredged from the Inner Harbor channels (Snows Marsh and Horseshoe Shoals channels). Based upon investigations conducted in support of the development of the SMP, it was estimated that 0.6 Mcy of beach quality material would be removed from these channels as part of the proposed Wilmington Harbor Deepening Project. Prior to 2000, maintenance dredging operations for these reaches utilized the ODMDS. Subsequent to the development and implementation of the SMP, placement of dredged material from these reaches may occur on adjacent beaches including Carolina Beach, Kure Beach, the Fort Fisher area, Bald Head Island, or Caswell Beach (when such options are deemed the least costly and

environmentally acceptable alternatives that are consistent with the engineering requirements of the project) (USACE 2000).

3.2.3.2 Jay Bird Shoals

Jay Bird Shoals is a linear, ebb tidal feature of the Cape Fear River and is situated immediately west of the confluence of the current Wilmington Harbor entrance channel and the former, abandoned channel. Suitable sediment (i.e. beach compatible by North Carolina sediment standard criteria) has been previously identified throughout much of the shoal feature to an average depth of -22 ft National Geodetic Vertical Datum (NGVD). In 2009, the Village of Bald Head Island received federal and state authorizations (Department of Army (DA) Permit No. 2007-02699 and CAMA Major Permit No. 67-09, respectively) to dredge up to 2 Mcy of material from Jay Bird Shoals. The permitted borrow site was approximately 158 acres and was located at the seaward end of the shoal. Prior to authorization of the final borrow site footprint, boundaries were refined to avoid and minimize disturbance to potential cultural and environmental resources. For instance, a 200-ft buffer was maintained around two groupings of magnetic anomalies exhibiting signatures consistent with potential shipwreck material. In addition, the final authorized borrow limits avoided shallow subtidal and intertidal habitat (Land Management Group, 2009).

Approximately 1.85 Mcy of material (measured volume from borrow site) was excavated and pumped to South Beach and West Beach during the Village-sponsored 2009/2010 Beach Restoration Project at a Village cost of approximately $17M. As indicated in Section 1.0, this project was funded entirely by the Village with no federal or state contribution. Note that the contract pay volume measured on the beach via as-built survey was 1.55 Mcy. Based upon geotechnical evaluations completed in 2007, the Jay Bird Shoals borrow area that was investigated contained over 3 Mcy of beach quality material (Olsen 2007). However, as indicated above the final volume permitted for the 2009/2010 project was 2 Mcy for a one-time nourishment event. Nonetheless, geotechnical, cultural, and environmental resource

investigations were completed for the larger shoal formation as part of the Environmental Assessment (EA) prepared by the Village at that time.

3.2.3.3 Bald Head Creek Shoals

The depositional shoal feature located at the mouth of Bald Head Creek (BHC) represents a smaller volume sand source in the immediate vicinity of the Island. The creek mouth is located approximately 1600 lf north of the entrance to Bald Head Marina. BHC, itself, is a relatively small saltwater creek system (approximately 3.5 km from headwaters to mouth) subject to semidiurnal tidal flows. It is bordered to the south by Bald Head Island and to the north by Middle Island.

In November 2010, the Village received federal and state authorization (DA Permit No. 198000291 and CAMA Major Permit No. 139-10, respectively) to dredge 100,000 cy of material from an approximate 21-acre borrow site at the mouth of BHC for the purpose of providing supplemental sand to a severely eroded segment of western South Beach. The permit was subsequently modified to allow for up to 140,000 cy of material to be excavated. The Village completed the dredge and nourishment work in March 2012 at a Village cost of approximately $1.25M. The total amount dredged at that time was 137,990 cy. Physical and biological monitoring of the borrow site was conducted for 3 years post-construction. Biological monitoring has indicated rapid recovery of characteristic benthic infauna within the borrow site. Based upon Year 1 and Year 2 post-construction monitoring, species diversity and richness were both significantly greater at the borrow site than at the reference sites (LMG 2013 and 2014). Physical monitoring surveys of the excavated area has shown only limited shoaling (or recovery) resulting from sediment transport from Bald Head Creek, the Row Boat Row shorefront, and the adjustment of side slopes. As a result, the Applicant's engineer has recommended the expansion of the prospective borrow site to the north.

The entire Bald Head Creek shoal borrow site delineated by the Applicant's engineer is 65.1 acres (refer to Appendix F). Of this, the 21.3-acre borrow site excavated in 2012 and its adjacent side slopes will remain undisturbed over the near term and will be allowed to physically recover over time. Agency consent would be sought for purposes of its future reuse as a sand source for use by the Village. In the near term, an undredged 37.6-acre area is identified as a prospective source site. Geotechnical analysis and a Phase I archaeological survey has been completed for the proposed borrow area expansion (refer to Appendix F and G, respectively). Based upon the geotechnical analysis, all the material within the 37.6-acre site meets the State of North Carolina's standards for borrow site compatibility relative to the recipient beaches (i.e. the west end of South Beach and West Beach). More detailed information regarding the existing conditions of the Bald Head Creek borrow site are provided in Section 4.0 of the FEIS and respective appendices (Appendix F and Appendix G).

3.2.3.4 Frying Pan Shoals

Frying Pan Shoals is a submerged extension of a cuspate foreland (i.e. accretional feature formed by processes of longshore drift and prevailing wind and wave conditions). The shoals extend nearly 20 miles offshore from the eastern end of Bald Head Island. Early reconnaissance level sand resource evaluations conducted for the Cape Fear Region (Meisburger 1977) identified that "modern sediment accretion on the inner shelf appears to be largely restricted to the shoal fields off Cape Lookout and Cape Fear, and to inlet shoals along the coast." It included exploratory density type seismic lines, as well as a limited number of cores and surficial grab samples. Based upon sediment core data collected as part of this study, the most appropriate beach quality sand identified within the Cape Fear shoal field was some sixteen (16) nautical miles offshore of Bald Head Island. It should be noted that sediment sampling for the study was relatively limited given the expansive area of Frying Pan Shoals. Other suitable borrow areas have been tentatively identified closer to shore.

More recent evaluations conducted by the USACE as part of the General Reevaluation Report (GRR) for the Brunswick County Beaches Coastal Storm Damage Reduction Project indicate the presence of substantial volumes of "beach-compatible" material. A Notice of Intent (NOI) to prepare an EIS for the project was published in the Federal Register on February 24, 2012. The USACE has identified Frying Pan Shoals as a potential sand source for this 50-year project. Updated geotechnical information from recent USACE site investigations is provided in Section 4.0 of this document.

3.2.4 Beach Nourishment/Beach Disposal and Sand Tube Groinfield Removal (Alternative #4)

Under this alternative, beach disposal would continue per the terms of the existing SMP, and the Village would implement supplementary beach nourishment and/or beach disposal projects on intervals sufficient to accomplish the stated Purpose and Need. In addition, the Village would terminate maintenance of the sixteen (16) sand-filled tube groinfield or seek means by which it would be removed. Note that information regarding the existing sand-tube groinfield (including dates of installation and replacement) is provided in Section 1.0 of the EIS.

Removal of the sand-filled geotextile tubes and associated underlayments would require excavation with heavy machinery and sand tube clearing via hydraulic means (*i.e.* washing of sand from each tube structure). Although solid in appearance when full, the geotubes have no integral strength due to the limited strength of the geotextile fabric of which they are comprised. As a result they cannot be lifted, and the sand must be emptied in place. The tubes can be physically removed relatively easily, as demonstrated in previous sand tube groin reconstruction projects, where tube removal occurred before replacement. Sand tube removal can occur only subsequent to a beach fill operation in order to ensure a sandy shorefront immediately upon removal. Similarly, excavation of the structures – essentially in the "dry" after a fill project – ensures both complete and relatively cost-effective removal.

The residual shoreline after groin removal would be subject to littoral transport rates unaffected by stabilizing structures. In doing so, the frequency and extent of Village-sponsored sand placement events will likely be greater than that of Alternative #3, as substantiated by the applicant's Delft 3D modeling results discussed in Section 5.0.

The potential sand sources required for this Alternative are the same as those identified under Alternative #3.

3.2.5 Terminal Groin with Beach Nourishment/Beach Disposal (Sand Tube Groinfield Remaining) (Alternative #5)

3.2.5.1 Description of Alternative #5 (Applicant's Proposed Action)

Alternative #5 includes the construction of a 1,900 lf terminal groin to be constructed in two phases. Phase I consists of a 1,300 lf structure to be constructed immediately subsequent to the next federal beach disposal operation on Bald Head Island. Any extension beyond the 1,300 lf structure would be based principally on the results of physical monitoring for a period of two (2) or more years following initial construction. The various elements of the proposed construction phasing are described further below. Note that design drawings of the proposed terminal groin are provided in Appendix H. The structure would serve as a "template" for fill material placed eastward thereof. In other words, the structure would help to form the three-dimensional limits (length, width, and height) of the sand placement or updrift fillet. Note that federal beach disposal activities on South Beach generally proceed from west to east. The typical westernmost limit of direct federal beach disposal in proximity to the channel (by design specification) is South Beach baseline station 44+00 (refer to Sheet 7 of Appendix H for station location relative to the proposed structure).

The primary function of a permanent terminal structure is to limit the rapid loss of fill material. Over the long-term, such an approach is anticipated to reduce erosion at the westernmost segment of South Beach (an identified hot spot for erosion). The placement of

beach quality sand with concurrent installation of a groin structure is anticipated to reduce the volume of material otherwise lost via longshore drift and tidal currents. The extent to which this may occur is discussed in greater detail in Section 5.0.

According to the applicant's engineer, an advantage of a singular, relatively long terminal structure should be its ability to reorient the South Beach shoreline (through updrift impoundment, or sand retention) closest to the Cape Fear River navigation channel so as to reduce the rate of transport of beach sand from the island. This is a design goal that has been modeled (results of which are discussed in Section 5.0 of this document). The applicant's engineer states that a single terminal groin is intended to do what the existing sand tube groinfield cannot satisfactorily accomplish due to its limited scope, configuration and composition, that is to control sand losses in a more effective manner. As indicated above, the terminal structure is to serve as a "template" for comprehensive sand fill projects placed eastward thereof. The design goal is to reduce inlet-directed sand loss (both short-term and long-term) and to allow for a more stable condition (particularly post sand placement).

As required by current North Carolina General Statute, the construction of a terminal groin would necessarily involve the placement and maintenance of a concurrent beach fillet (NC Session Law 2013-384, G.S. 113A-115.1(f)(3)). The proposed 1,300-lf Phase I structure would utilize the sand placement from the federal beach disposal project that would occur immediately prior to groin construction. Sand from the federal placement is anticipated to be rapidly impounded by the Phase I groin structure as it is constructed. Should this not occur to a satisfactory level, the Applicant would place sand hydraulically from an alternate borrow source. The Applicant's preferred borrow source would be the remaining, undredged portions of the Jay Bird Shoals borrow site (previously authorized in 2009). Groin construction would be initiated immediately following the federal beach disposal project. Should the federal project be delayed (for funding or any other reason), the initiation of the Phase I groin construction would be similarly delayed. For the full 1,900-ft structure, a

concurrent beach fillet would be achieved via disposal from the identified Jay Bird Shoals borrow site. Sand source sites identified for fillet creation or maintenance as well as future Village-sponsored nourishment are: (1) Jay Bird Shoals; (2) reaches of the Wilmington Harbor Channel demonstrated to contain beach-compatible material (i.e. Baldhead Shoal Reach 1, Baldhead Shoal Reach 2, and Smith Island Range); (3) Bald Head Creek Shoals; and (4) Frying Pan Shoals. The extents of the proposed borrow sites for Jay Bird Shoals, reaches of the Wilmington Harbor Channel, and Bald Head Creek Shoals are depicted in Appendix H (Sheets 15-19).

The expanded borrow site at Bald Head Creek Shoals is the applicant's proposed site to be utilized to comply with the terms and conditions of SB 151 which requires a plan to mitigate for any potential adverse downdrift effects of the terminal groin and to provide for a plan to address groin fillet maintenance. The entire delineated borrow site (including the area dredged in 2012) is 65.1 acres. Of this, the 21.3-acre borrow site excavated in 2012 and its adjacent side slopes will remain undisturbed over the near term and will be allowed to physically recover over time. Agency consent would be sought for purposes of its future reuse as a sand source for fillet maintenance or nourishment on West Beach (downdrift of the proposed groin). In the near term, an undredged 37.6-acre area is identified as a prospective source site for terminal groin mitigation or fillet maintenance. As indicated above, geotechnical analysis and a Phase I archaeological survey has been completed for the proposed borrow area expansion (refer to Appendix F and G, respectively). More detailed information regarding the existing conditions of the Bald Head Creek borrow site are provided in Section 4.0 of the FEIS and respective appendices (Appendix F and Appendix G).

Under this alternative, the existing sand tube groinfield would essentially remain in place. It is predicted that some of the sand tubes will be located in the upland portion of the sand fillet created by the terminal groin and therefore essentially become non-functional. The anticipated maximum extent of that phenomenon is the westernmost six (6) groins. Eastward thereof, the remaining sand tube groins may provide benefit during some portion

of the life cycle of each sand placement operation (presently assumed to vary from two to three years). Periodic maintenance and modification to the groinfield would be anticipated (as it has over its existence to date). Example maintenance activities would include the replacement of damaged sand tubes or repair to the field via sand placement around tubes susceptible to flanking. Example of modification activities would include the relocation of one or more sand tubes. Groinfield modification may also include the removal of one or more sand tubes while leaving a majority of the field intact and functional. Sand tubes demonstrated to be non-functional via long-term burial, and as verified through a minimum of three years of monitoring, may be removed. Alternative 6 (below) considers the scenario of the removal of the entire sand tube groinfield in conjunction with, or subsequent to, the installation of a terminal structure.

A number of design and construction measures have been identified to avoid and minimize potential adverse effects of Alternative #5 on natural resources. Many of these measures are outlined as part of the project description below and in Section 6.0 (Avoidance, Minimization and Mitigative Measures).

Construction Phasing: In order to expedite beneficial post-groin shoreline equilibration conditions (both updrift and downdrift of the structure, and including formation of the sand fillet), the applicant proposes that the terminal groin would be constructed in two phases. Phase I would involve the construction of an approximate 1,300-lf structure (approximately 2/3 of the structure's overall design length) to occur immediately subsequent to the federal disposal of sand on South Beach. Based upon coordination with the USACE Wilmington District Navigation Branch, the Village will not perform any groin construction activities on South Beach until the USACE dredging contractor has completed the federal channel maintenance disposal project and has demobilized all equipment and pipeline from that location. As a result, actual groin construction is expected to begin April 2015 and continue for four to six months (pending weather conditions and the specific method of construction employed by the contractor). The start of groin construction immediately following federal

disposal will theoretically allow for sand to be transported westward toward the structure and will help minimize its lee side effects.

If implemented in concert with the federal disposal, the Phase I structure may not require additional sand from a supplemental source site (i.e. Jay Bird Shoals or, as appropriate, a sufficient quantity of borrow material within the federal channel). A Phase I structure is expected to reduce both the initial volume of sand required, as well as to potentially delay the timing of updrift fillet enhancement (if necessary) by approximately six months to one year. Should the updrift fillet require additional sand, dredging and disposal for such would occur during the winter months (and outside the sea turtle nesting moratorium). The location and extent of the Phase I structure relative to the applicant's expected beach condition subsequent to federal disposal is depicted in Sheet 9 of Appendix H.

It is likely that a Phase I groin construction operation can benefit from the creation of sand work pads on the structure's updrift side with the source of sand being the federal disposal berm. The purpose of the work pads is to minimize, or ideally eliminate, the need for a construction trestle. Any work pad sand placement likewise beneficially contributes to the expedited formation of an updrift fillet. Construction activities during the summer months would include material staging on the northern and western riverfront shoreline (north of the Point); transport of rock between the material storage area and groin location by 4WD trucks; excavation of sand for placement of rock in post-disposal berm; individual placement of armor stone (with optional, potential use of construction trestle); and excavation of sand in post-disposal berm for use in forming construction pads. Specific work zones and construction activities are graphically depicted in Figure 3.3. Construction practices designed to minimize potential adverse effects to environmental resources are described in Section 6.0.

The approximate proposed maximum physical extent of an updrift fillet for both the Phase I and Phase II structure, constructed through sand placement from an appropriate borrow

site, is depicted by Sheet 7 (Appendix H). Phase II would extend the seaward end of the structure to complete the structure's overall design length (1,900 lf). Refer to Sheet 8 of the design drawings (Appendix H) for the proposed phases. The timing of the Phase II groin construction would be based upon an estimated two or more years of performance monitoring. The implementation of Phase II would be coordinated with resource agencies subsequent to the submittal of physical monitoring data. Physical monitoring is described in more detail in Section 6.0.

3.2.5.2 Terminal Groin Design Goals and Precepts

A number of design parameters influence the effectiveness of a terminal structure. Under this alternative, varying options related to structure length and permeability have been evaluated to determine the level of performance relative to the project objectives (see Appendix I.

Specific design goals and precepts are identified below.

Terminal Groin Design Goals:

The following is a list of the design goals developed to evaluate predicted performance:

(1) Reduce sediment transport rates from the westernmost segment of South Beach to the Cape Fear River;
(2) Minimize the potential for adverse impacts to a downdrift shoreline (e.g. West Beach) which is presently both highly dynamic and erosional;
(3) Establish an updrift (easterly) impoundment fillet with the goal of protecting currently threatened residential structures and public infrastructure (water, sewer, roads, etc.);
(4) Protect an important upland evacuation route which parallels South Beach;
(5) Protect and stabilize beachfront along the western end of South Beach ;
(6) Provide potential benefits to an adjacent navigation project via reduced shoaling;
(7) Preclude impacts to other coastal barrier islands;

(8) Require little to no structural maintenance;

(9) Minimize or reduce future maintenance requirements for portions of an existing sand tube groinfield located along South Beach;

(10) Provide an improved beach condition conducive to the facilitation of future federally-constructed beach disposal projects; and

(11) Extend the effective life and benefit level associated with future beach improvement projects (updrift of the structure).

Terminal Groin Design Precepts: In order to achieve the design goals as outlined above, the following design precepts have been considered and evaluated:

(1) Porosity – the structure should be sufficiently permeable (or "leaky") as to limit its effectiveness in the long-term impoundment of sand.

(2) Template (length and width) – the direct, as well as synergistic effects of the groin structure should provide an equilibrated profile or template for the stabilization of the updrift South Beach shoreline sufficient to last between federal beach disposal events, *i.e*., nominally two to three years. The beach profile is expected to progressively reduce in size between sand placement events.

(3) Elevation – portions of the groin should be sufficiently low such that wave overtopping and resultant sediment transport can occur past the structure during periods of energetic wave conditions.

(4) Settlement – the structure should have a foundation designed to be highly resistant to long-term settlement so as to substantially reduce future maintenance requirements.

(5) Adjustment – the structure should be capable of post-construction "tuning" if deemed necessary to refine performance characteristics.

(6) Constructability – the structure should be adequately robust so as to resist damage during low probability storm events, but at the same time sufficiently straight forward in design to assure cost-effective constructability in a highly energetic and dynamic environment.

The precepts above have been used by the applicant's engineer to develop a structural design that meets the applicant's goals regarding optimal performance. The proposed groin is designed as a low-crested, semi-permeable (i.e. "leaky") structure so as to not totally disrupt sand transport to either the "Point" or West Beach. In order to foster structure permeability, the cross-section and crest of a terminal groin would be constructed with a large (and atypical) void ratio. This is accomplished through the use of large and relatively uniformed-diameter quarried granite stone. No core stone is specified, and the use of any mix of stones is discouraged. As a result, the uppermost one meter (or more) of the rock terminal structure will be subject to some level of sediment transport through the section during occasions of wave wash. For illustrative purposes, oblique aerial photography of a permeable groin of similar design to that of the proposed structure on Bald Head Island is provided in Appendix J. The photographs depict a chronology of shoreline conditions on South Amelia Island (at Amelia Island State Park in Nassau County, Florida) from construction (August 2004) to two years post construction (March 2006).

An important design characteristic of a permeable terminal groin structure is the continued opportunity for spit formation on its downdrift (channel facing) side. The applicant's engineer believes that the latter feature would be conducive for continued northward sand transport along the Point toward West Beach. It should be noted however that since the Point shoreline and West Beach shorefront are both highly erosive and dynamic, the forces which control those processes would be expected to result in a shoreline and spit configuration which may be different from those of the past. That is to say, the terminal structure is *not* expected to necessarily resolve ongoing erosion issues on its downdrift side. As noted previously, a design goal is to neither exacerbate existing erosion trends nor result in a condition which cannot be remediated in a manner similar to the pre-project condition – which in this instance is direct sand placement along the affected West Beach shorefront on an as-needed basis. Detailed engineering analyses of post-project conditions within and adjacent to the project area are provided in the Applicant's engineering report entitled "*Shoreline Stabilization Analysis (July 2013)*" (Olsen 2013). Inclusive in this report is the

prediction of any potential increase in erosion on West Beach due to the maximum length of the proposed groin. According to the Applicant's engineer, the total predicted difference is estimated to be -5200 cy/yr over nine years. The analyses in this report are the professional engineering opinions of the Applicant's engineer, and have not been independently reviewed or verifed. Mitigative measures for potential down-drift effects (including thresholds for mitigative action) are further described in the Inlet Management Plan prepared by the Applicant (Appendix B).

The design process itself considers various structural characteristics that ultimately define performance relative to the design goals. Evaluations of design characteristics such as permeability and length are described in Appendix I and within the Engineering Report (Olsen 2013).

3.2.5.3 Terminal Groin Design Details

Design drawings are provided in Appendix H. The terminal groin can be defined by three principal sections: (1) the upland tieback; (2) the groin stem; and (3) the structure head. The latter segment is generally more robust structurally since it experiences the highest levels of incident wave energy (particularly during storms). The stem comprises the majority of the structure and is typically the segment of greatest sediment transmissivity above a certain elevation. The tieback is defined herein as the "root" of the structure higher in elevation and therefore not necessarily subject to sand loss due to daily or monthly tide and wave conditions. It therefore defines the template for the minimum level of updrift beach impoundment and resultant beneficial shoreline alignment (due to its relative non-permeability and higher crest elevation).

Note that Sheet 3 of the design drawings (Appendix H) depicts a "no-construction" area associated with a 150-ft buffer located around the remains of a wooden sailing vessel considered to be from the late 19th or early 20th century. The shipwreck was located and documented by Tidewater Atlantic Research, Inc. (T.A.R) under contract to the Village of

Bald Head Island. The investigation carried out by T.A.R. was part of the design due-diligence associated with the siting of the proposed terminal structure seaward of the westernmost segment of South Beach shoreline. Following consultation with NC Department of Cultural Resources (NCDCR) personnel at Fort Fisher it has been determined that the shipwreck is potentially significant and eligible for nomination to the National Register of Historic Places (NRHP). NCDCR recommended a 150-ft buffer to protect the wreck. In order to accommodate a 150-ft buffer, the original conceptual design for the terminal structure was modified as to both its footprint and its orientation. In addition, the identified wreck is located updrift of the proposed structure. It is the intent of the design engineer for accreting sediment to afford some protection for the surviving hull remains. Per the findings of the T.A.R. archaeological study, burial of the remains as a result of the accretion updrift of the structure would be considered a positive impact. The final report of findings of the archaeological survey and shipwreck assessment prepared by T.A.R. is enclosed (refer to Appendix K).

Sheet 4 (Appendix H) depicts the spatial footprint or "plan" of the proposed groin structure relative to a May 2012 survey and aerial photography. Hence, the shoreline shown relative to the groin is in an eroded condition. All survey information is relative to NGVD 29. As shown, the present-day elevation of the seabed near the terminus of the groin is -10 ft NGVD. The approximate 1900-lf structure has a curvilinear orientation toward the east in order to account for the proximity of the depths associated with the navigational project channel to the west and the existence of a shore-attached shoal formation extending southward from the existing shoreline in the vicinity of the terminal structure's root. The current groin structure and fillet location is intended to avoid the shoal feature (i.e. the shoal will remain outside or westward of the groin). Although the overall structure length is 1,900 ft, its terminus is only 700 ft offshore (or southward) of the 2012 MLW location. Subsequent to filling of the structure through sand placement, the post-fill location of the MLW will initially be at, or in the proximity of, the structure head. The latter condition would likely represent the maximum level of sand impoundment by the structure.

Sheet 5 (Appendix H) depicts the design characteristics of the three (3) typical structural sections associated with the proposed rock structure. The general locations of the cross sections are noted on Sheet 4. Similarly, the general profile of the terminal groin is presented on Sheet 6. As shown, the *specified elevation* of the crest (top of stones) for the section of the groin conducive to westward sand transport is +4.5 ft NGVD. Due to the resultant formation of large voids (between large similarly sized armor stone), the "effective" crest elevation will typically be about one-third to one-half an armor stone diameter below the specified elevation. In the present case, the specified crest elevation is +4.5 ft NGVD and the requisite cap stones average 3 to 5 ft in diameter.

The terminal structure under this alternative is not intended to eliminate the need for nourishment events on West Beach. West Beach (downdrift of the proposed terminal structure) is not presently in a stable condition and will remain prone to sand losses, which may be exacerbated by the presence of the groin structure.

Predicted shorelines and physical conditions resulting from the terminal groin (and its associated design characteristics) are discussed further in Section 5.0 of this EIS.

3.2.5.4 Terminal Groin Construction Methods

Rock-filled marine mattresses would be utilized as a foundation for the seawardmost section of the rock groin structure so that long-term settlement would be minimized and that the project's design intent and unique performance characteristics would be maintained over time. In the more landward section of the rock groin, a composite geogrid/geotextile fabric would in all probability be used as an underlayment (where settlement is less of an issue).

The terminal groin would be constructed of relatively large granite armor rock of varying size (weight and dimensions). Rock would be transported to Bald Head Island by barge from an upland location. Typically rock is transported from the quarry to the waterside transfer site

by rail and/or truck. Placement of the foundation mattresses and rock is generally by crane from a barge, from the upland and/or from a temporary trestle or pier constructed in close proximity to the groin structure. Such a pier is typically pile-supported and necessitates the driving or jetting of steel pile which are later retracted and removed from the site once the rock structure is completed. Note that for construction of Phase 1, use of a temporary trestle may be minimized or avoided entirely. Instead, equipment may be operated from sand work pads on the updrift side of the structure (with the applicant's preferred source of the sand being the federal disposal). Upland portions of the structure tieback necessitate excavation and backfilling of beach sand in order to place the groin foundation and rock at their prescribed elevations (normally below existing grade). Since the construction of the structure is best performed subsequent to sand placement (via either federal disposal of Village-sponsored nourishment), groin construction itself is planned to begin April 2015 and would extend into environmental moratorium periods (including periods of sea turtle nesting). Hydraulic dredging and filling for fillet enhancement (if necessary) would be expected to occur the following winter (outside of the environmental moratoriums). The effects of these proposed actions are further described in Section 5.0.

3.2.5.5 Post-Construction Mitigative Actions

Mitigative actions for any potential adverse effects of the proposed action are outlined in Section 6.0 with more detailed descriptions of the proposed post-construction monitoring, thresholds for implementation of mitigative measures, and mitigative measures that may be implemented included within the Applicant's Inlet Management Plan (Appendix B). A brief description of some of these measures is described below.

Priority for any required mitigation on West Beach would be alongshore sand placement sufficient to protect endangered residential structures and the total loss of protective dune formations. The timing of a mitigative sand placement, however, may be adversely affected by factors such as design document formulation, dredge availability, and public project bid requirements. As a result, the following interim actions may likewise need to be considered:

(1) sand bag revetment construction along the section of shorefront where threatened structures exist; (2) temporary borrowing of sand mechanically from the updrift impoundment fillet of the terminal groin and placement along the affected shorefront; or (3) both actions. Note that any proposal to borrow small volumes of sand from the terminal groin fillet would be predicated upon the existence of an emergency condition only (where sand was required seaward of a building endangered by erosion and where such a condition could not be remedied in sufficient time through hydraulic sand placement). It is estimated that any updrift fillet eastward of the terminal groin would readily hold 250,000 to 500,000 cy of sand. According to the Applicant's engineer, the borrowing of small emergency volumes (e.g. 5,000 to 10,000 cy) would have no measureable effect on the spatial extent of the updrift fillet or the performance of the terminal structure.

As discussed above, the proposed terminal groin is to be constructed as a "leaky" structure with some level of reduced sediment transport continuing to occur either through and/or over the structure crest. As a rubble mound structure, sand permeability can be physically increased through the removal of stones. Any reduction in effective structural elevation will increase sediment transport across the groin. Increased transport would be conducive to spit or dry beach growth on the downdrift side of the structure which, in effect, would be expected to increase sediment transport to West Beach. Such "tuning" of a permeable structure is often desirable with respect to achieving the desired performance goals even if mitigation is not required. Normally, tuning would not occur without the benefit of significant post-construction monitoring, since the transmissivity of such a structure varies over time – dependent upon the condition (*i.e.* size and elevation) of the updrift sand fillet, seasonal wave climatology, storm effects and other site specific factors. In an extreme circumstance, and absent more reasonable, cost-effective alternatives, effective "removal" or major dismantling of the structure may be required.

The effective height of the structure can also be adjusted by the addition of rock to the structure crest should physical monitoring demonstrate that it is not achieving the updrift

design goals, or as needed in the future if it is deemed necessary to address the effects of sea-level rise. Any such proposal for modification would need to be reviewed and authorized by the appropriate state and federal regulatory agencies upon review of sufficient monitoring data and in consultation with resource agencies.

3.2.6 Terminal Groin with Beach Nourishment/Disposal and Removal of Sand Tube Groinfield (Alternative #6)

Alternative #6 would involve the construction of a single, low-profile terminal groin as described in Alternative #5 above. However, upon completion of the installation of the terminal groin, the Village would begin the systematic removal of the existing sand-tube groinfield on South Beach. Sand placement via Village-sponsored nourishment projects and federal beach disposal would continue on periodic intervals. As with Alternative #5, the proposed structure would utilize the sand placement from the federal beach disposal project occurring immediately prior to the groin construction. Sand from the federal placement would be rapidly impounded by the groin structure as it is constructed. . Should this not occur to a satisfactory level, the Applicant would place sand hydraulically from an alternate borrow source. The Applicant's preferred borrow source would be the remaining, undredged portions of the Jay Bird Shoals borrow site (previously authorized in 2009). Groin construction would occur immediately following the completion of the federal beach disposal project. Should the federal project be delayed (for funding or any other reason), the initiation of the groin construction would be similarly delayed. For the full 1,900-ft structure, a concurrent beach fillet would be achieved via disposal from the identified Jay Bird Shoals borrow site. Sand source sites identified for fillet creation or maintenance as well as future Village-sponsored nourishment are the same as those identified for Alternative #5.

Note that to accurately characterize potential costs and environmental consequences of this alternative, it is anticipated that nourishment would occur on a greater frequency than that

of Alternative #5. The Delft 3D modeling results associated with future physical performance are further discussed in the applicant's Engineering Report (Olsen Associates 2013). The engineering report provides detailed analyses on post-project conditions of the project area including potential adverse effects to the down-drift shoreline (i.e. West Beach). Potential adverse effects are described in Section 5.0 of the EIS.

Mitigative actions for Alternative #6 would be similar to those described for Alternative #5. These actions are further described in Section 6.0 and within the Applicant's Inlet Management Plan (Appendix B).