

Raritan Bay and Sandy Hook Bay  
Highlands, New Jersey  
Coastal Storm Risk Management  
Feasibility Study

Feasibility Report  
May 2020

Appendix B1:  
Civil Design

## Raritan Bay and Sandy Hook Bay, Borough of Highlands, New Jersey Coastal Storm Risk Management Feasibility Study

### Appendix B1: Civil Design

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## Chapter 1: Introduction

### 1.1 Study Area

The Borough of Highlands is located in the northeastern section of Monmouth County, New Jersey and is bounded on the north by Sandy Hook Bay and on the east by the Shrewsbury River. The project study area consists of approximately 1/3 of a square mile of 1,500 densely developed marine, commercial, and residential buildings extending approximately 8,000 feet along low-lying coastal areas from Murray Beach at the western end to the NJ-36 Highlands-Sea Bright Bridge at the eastern end. Shore Drive serves as the southern boundary. Highlands topography is flat for approximately 1,500 feet inshore to the base of a steep grade. For analysis purposes, the study area has been divided into four reaches, based on shoreline characteristics and orientation. Reaches 1, 2 and 3 are the bay-fronting sections, and Reach 4 is the river-fronting section. The reach designations can be seen on the plan sheets that follow.

### 1.2 Shoreline Condition

The shoreline of Highlands is composed primarily of bulkheads, which range in elevation from around +6 feet North Geodetic Vertical Datum of 1929 (NGVD29) (approximately +5 feet North American Vertical Datum of 1988, NAVD88) at low points to approximately +10 feet NGVD29 (approximately +9 feet NAVD88) at the highest point. Small marinas, restaurants, and houses characterize the shoreline. Small beaches with public access are also located in the Borough. The existing beaches are relatively stable, but the various types of bulkheads, including timber and exposed steel, are deteriorating and in need of repair or replacement. Based on the Raritan Bay and Sandy Hook Bay, New Jersey Combined Flood Control and Shore Protection, Reconnaissance Study Report (USACE, March, 1993) and New York District site inspection, the existing shoreline and beaches are relatively unchanged due to the hardened condition of the shoreline.

The flat topography of the waterfront fill and low existing bulkhead elevations allow tidal inundation during periods of major storm events. The 100-year (1% annual exceedence probability) tidal flood limit (See Coastal Hydraulics Appendix) would completely submerge Highlands from shoreline to the base of the bluffs, approximately 1,500 feet inland. Most of the town's streets would be below 5 feet of water during a 1% or greater storm event, including Hurricane Sandy of 29 to 30 October 2012. Relatively high frequency storm stage events result in street flooding.

## Chapter 2: Survey Data

### 2.1 Topographic Data

Photogrammetric mapping of the study area is available from the topography that was compiled by stereo photogrammetric methods from the aerial photography flown at 1"=250' in April 2002. The mapping contains planimetric features such as structures, roads, and soundings and was used as a basis to layout project alternatives and develop associated quantities. Surface utilities were located by the surveyor in the field. Underground utility information was obtained by the

surveyor from the various utility companies. The surveyor makes no guarantee that the underground utilities represent all such utilities in the area, either in service or abandoned. The surveyor further does not warrant that the underground utilities are in the exact location indicated and are located as accurately as possible from available information. The surveyor did not physically locate the underground utilities. The following utilities did not provide record information to the surveyor: New Jersey American Water Company and Verizon. Horizontal data from the survey is referenced to New Jersey State Plane Coordinate System, NAD 83, US Survey Feet and vertical data is referenced to NGVD29, US Survey Feet.

## 2.2 Bathymetric Data

Bathymetric profiles of the project area were taken in April 2002 and consist of 21 long range lines, each extending approximately 2,500 feet seaward from near the shoreline, and spaced approximately 500 feet apart. Horizontal data from the survey is referenced to New Jersey State Plane Coordinate System, NAD 83, US Survey Feet and vertical data is referenced to NGVD29, US Survey Feet.

## 2.3 Vertical Datum

Initial project analyses were conducted in reference to the NGVD29 vertical datum. Optimization of the design, as well as future analysis during Pre-Construction Engineering Design (PED) has been and will be conducted in reference to the North American Vertical Datum of 1988 (NAVD88) vertical datum. The tidal bench mark nearest to the Highlands project site is located on the Sandy Hook Spit and has an NGS designation of "853 1680 A TIDAL" (location is shown on Figure 3 of Sub-Appendix B2: Coastal Engineering). The NGS data sheet for this tidal bench mark lists the current NAVD88 elevation as 6.41 feet and the NGVD29 elevation as 7.50 feet. For purposes of this report, it is assumed that conversion of NGVD29 elevations from previous surveys and designs to NAVD88 may be completed by subtracting 1.09 feet from the NGVD29 elevations. Existing elevations in this appendix listed in NAVD88 have been converted using this method. If existing NVGD29 data is to be used in comparison to data collected in NAVD88, a more precise transformation method is recommended. Additional surveys representing current conditions and datums are recommended for the PED phase to further reduce project risks and identify opportunities for cost reduction.

## Chapter 3: Project Alternatives

### 3.1 Preliminary Alternatives Array

During the formulation of preliminary alternatives, the following storm damage reduction features (that include combinations of structural and nonstructural elements) were analyzed:

1. Seawall with closure gates (raised epoxy coated steel sheet pile bulkhead)
  - a) With scour protection
  - b) With a fronting berm

- c) Existing seawall with capping (existing state bulkhead)
2. Offshore closure structure (rubble mound, navigation gate)
3. Reinforced dune (with buried seawall)
4. Removable fabricated floodwall (inland)
5. Non-structural flood features, including combinations of:
  - a) Buyouts (for frequently flooded structures)
  - b) Raising
  - c) Ringwalls/structural peripheral wall
  - d) Flood proofing
6. Beach and dune fill with terminal groins (with buried seawall)
7. Raised road, ground surface, and asphalt areas
8. Setback floodwalls (I-type floodwall)

Various combinations of the above features were included in the selected design approaches. Preliminary alternatives considered for this study include:

- **Alternative 1:** Updated USACE Plan identified in the Pre-Feasibility Study
- **Alternative 2:** Non-Structural Plan
- **Alternative 3:** Offshore Closure Plan
- **Alternative 4:** Beach and Dune Fill Plan
- **Alternative 5:** Environmental Minimization and Avoidance Plan

### 3.1.1 **Alternative 1: Updated USACE Plan identified in the Pre-Feasibility Study**

This alternative is an updated version of Alternative Plan 1 from the Pre-Feasibility Report (May 2000), which was considered to be environmentally and economically feasible. Revisions included adding the capped existing state bulkhead feature to Reach 2, as well as the removable fabricated floodwall and associated additional I-type floodwalls to Reach 4. Crest elevations of the structures were also updated to reflect the wave overtopping analysis.

This alternative includes the construction of epoxy coated steel sheet pile bulkheads with watertight joint sealant, either fronting existing bulkheads or non-bulkheaded frontages, totaling 9,470 linear feet along the Highlands shoreline in all reaches, except for a 1,280 foot portion of existing state bulkhead in Reach 2 which will be capped and in Reach 4 where there would be 1,100 feet of inland removable fabricated floodwall (see plan sheets CS101-CS102). Crest elevations of the raised bulkhead will be set at +15' NGVD in Reach 1, decreasing to elevation +13' NGVD in Reaches 2 and 3, and elevation +12' NGVD in Reach 4. Concrete I-type floodwalls totaling 1,195 linear feet will tie into the existing +11 foot contour at the Highlands/Atlantic Highlands border as the western closure and at Bay Avenue near the Route 36 Bridge as the eastern closure. The raised bulkhead will be located along the high water mark, immediately in front of existing seawalls, passing inboard of piers and rimming the shoreline edges of marina areas. Except in the inside perimeter of marina areas, the bulkheads will be fronted by a stone rubble toe, constructed at the toe of the bulkhead to reduce wave overtopping.

In Reach 2, 1,280 linear feet of the existing State bulkheads would be capped to an elevation of +13' NGVD, for an increase in the bulkhead's existing height of approximately 1 foot. This minimal increase in height is allowable because a parapet of approximately 10 to 15 degrees will be applied to the cap to reduce wave overtopping impacts. Because the increase in height will be relatively small, a fixed, rather than removable, extension is assumed, simplifying the needed structural connection. The landward side of the capped bulkhead (above grade) will need to be structurally reinforced to avoid the potential of exceeding the design loads of the existing bulkhead with the added loads intercepted by the capping. This reinforcement will include a 1.5-foot thick (average) monolithic section of reinforced concrete along the landside of the existing bulkhead, continuing with a 2-foot thick, 10-foot wide monolithic reinforced concrete slab at grade. A 1,460-foot long portion of raised bulkhead will be constructed in front of the marina's existing bulkhead (with no required rubble toe) to tie together the two portions of the capped State bulkhead. The capped bulkhead will connect to a raised bulkhead on both ends of Reach 2 to tie into Reaches 1 and 3. In addition in Reach 3, a seaside restaurant and deck will be raised in place and the restaurant entry will be modified to maintain existing water views and access with the alignment to elevation +12' NGVD.

In Reach 4, 185 feet of concrete I-type floodwall will be constructed from the eastern end of the raised bulkhead in Reach 3 southwest along the Windansea Restaurant's property line towards Shrewsbury Street, starting at elevation +12' NGVD and going down to elevation +11' NGVD near Shrewsbury Street. At Shrewsbury Street, the floodwall will connect to the northwestern end of 1,075 feet of removable fabricated floodwall, installed at a crest elevation of +11' NGVD along the waterside curb of Shrewsbury Street. A second concrete floodwall will connect the southeastern end of the removable fabricated floodwall, extending 125 feet to the northeast at elevation +11' NGVD to a section of raised bulkhead set along the shoreline at elevation +11' NGVD. The alignment's easterly closure will be a concrete I-type floodwall that ties into the +11' NGVD contour, just seaward of Bay Avenue.

It should be noted that the installation alignment of the removable fabricated floodwall leaves 12 residential buildings susceptible to flooding. These are located seaward of Shrewsbury Street, to the southeast of Cornell Street and to the northwest of the park on Bay Avenue. The following structural option for storm damage protection of these 12 structures was considered: an offshore stone dike enclosing the docks and exposed shoreline, including a collinear navigation gate for boating access. This option was determined to be not viable, due to its navigation interference and its very high cost relative to the small amount of shoreline and number of piers and structures actually protected (i.e., the cost could be as much as twice the value of the structures/properties).

Four 25-foot wide closure gates will provide access points through the alignment to boat launch ramps and marina areas along the project's shoreline. As part of the minimum facility costs, ten existing outlets will be updated by placing new flap gates at the outlets. Construction of timber stair walkovers at 27 access points along the raised bulkhead features will allow for continued access to existing piers. These types of access structures can be somewhat unsightly

but can be architecturally treated to improve the aesthetic character. Finally, the temporary (removable) nature of the removable fabricated floodwall in Reach 4 provides for a continuous line of protection when erected just prior to and during storms, but allows for waterfront access at all other times and temporary access during storms via a portable ramp over the removable fabricated floodwall.

This alternative meets the overall project objective of reducing storm damage for the entire Borough of Highlands, except for the buildings located seaward of Shrewsbury Street, to the southeast of Cornell Street and to the northwest of the park on Bay Avenue. In general, as most of the project site's shoreline is being raised from existing elevations, water views will be partially obstructed, but not interrupted.

### 3.1.2 **Alternative 2: Non-Structural Plan**

This alternative consists of non-structural storm damage reduction features up to +11 feet (see plan sheets CS103-CS104). The storm damage reduction features were determined using a structural analysis that applied a generalized computer algorithm to a structure inventory database. The algorithm uses flood levels along with information about each structure (i.e. ground elevation, main floor elevation, type of construction, etc.) to determine the appropriate method of flood protection, and then determines cost for flood proofing each structure. The existing Highlands Structure Inventory Table was used for the analysis. The algorithm flow chart for type of flood proofing to be assumed can be seen in attached drawing CS122.

It should be noted that this was a screening level analysis. Actual determination of the most appropriate types of flood protection for a specific building (and associated costs), including area constraints, will need to be determined by examining individual structures and site specific conditions.

The non-structural storm damage reduction features considered include the following:

1. Evacuating the building from the flood plain (buyout/relocation);
2. Elevating the building (raising);
3. Constructing various types of barriers, which usually surround the building but are not attached (ringwall/berm);
4. Constructing various types of barriers (surface floodwalls) that surround the exterior surface of the structure and provide removable flood shields at structure openings;
5. Using techniques known as "wet" flood proofing where basement utilities are relocated above ground and adjacent to the structure, but the basements are allowed to flood;

6. Using techniques also known as “wet” flood proofing where major basement utilities are protected with barriers where no room exists on the property for an above grade utility shed, but the basement is allowed to flood; and
7. Using techniques known as “dry” waterproofing where exterior wall surface waterproofing is designed to withstand added hydrostatic loading or foundation walls are rebuilt to accommodate extra hydrostatic loading for structures with basements (for low level, above grade, flooding against the structure).

A total of 991 structures are affected, with protection measures including 17 “dry” flood proofings; 65 “wet” flood proofings (for which 50 require barriers to be constructed around the utilities in the basement and 15 require relocation of the utilities in a shed above ground); 861 raisings; 13 structures with surface floodwalls; and 35 structures with ringwall/berms. The average height of raising for buildings is approximately 4.6 feet. The total length of ringwall/berms and structure surface floodwalls required is approximately 12,820 feet.

This alternative does meet the overall project objective of reducing storm damage in the Borough of Highlands. However, as the measures only protect buildings and structures from flooding, considerable residual damage would remain after a storm (i.e. to the infrastructure, cars, landscaping, and basements of “wet” floodproofed structures), and significant emergency personnel activity would be required. The non-structural features will not obstruct any water views, nor will waterfront access need to be modified.

### 3.1.3 **Alternative 3: Offshore Closure Plan**

This alternative combines structural storm damage reduction features in Reach 1 with an offshore breakwater that extends 4,500 linear feet across the Sandy Hook Bay, protecting Reaches 2, 3, and 4 (see plan sheets CS105-CS107).

At the western end of Reach 1, existing ground will be raised using impervious fill to create a raised ground surface totaling 355 square yards at elevation +11’ NGVD that will tie into the existing contour near the end of Shore Drive. The side slopes of the raised ground surface will be approximately 1V:3H and will tie into surrounding areas. The raised ground area will be capped with 6 inches of topsoil and planted with native vegetation. The raised ground will meet a 225 linear feet raised portion of the existing Locust Street. The 225 feet of existing road will be raised to elevation +11’ NGVD; regrading will be necessary for access to private driveways. To match existing grades of both the existing Locust Street to the southeast and the mobile home park parking area to the north, transition road approaches will be constructed at a slope of 1V:10H from each end of the raised road.

Approximately 195 feet of concrete I-type floodwall will be constructed from the eastern end of the raised road northeast along an existing fence line at elevation +11’ NGVD. The northern end of the floodwall will transition up to elevation +13’ NGVD where it will meet the western end

of another 1,276-square yard raised ground surface. This raised ground surface will also be capped with 6 inches of topsoil and planted with native vegetation. It will transition to elevation +13.5' NGVD to meet an reinforced dune constructed along the existing shoreline. The reinforced dune will consist of a buried stone seawall (1V:1.5H) covered with sand (1V:5H) and with an impervious earthen core installed along the backside of the seawall. The dunes will be planted with native dune grass to provide additional stabilization. The reinforced dune will continue at elevation +13.5' NGVD for 290 feet to meet a raised bulkhead.

The raised bulkhead will be located along the set back high water mark, immediately in front of existing seawalls. A parapet of approximately 10 to 15 degrees will be applied to the bulkhead to reduce wave overtopping impacts, allowing for a reduction in elevation in comparison to Alternative 1 of 2 feet. The bulkhead will be 460 feet long at a crest elevation +13.5' NGVD, fronted by a rubble toe, constructed at the toe of the bulkhead to reduce wave overtopping impacts. In addition, the rubble toe will also provide for protection from the isolated historic erosion that is occurring at this location. Another contiguous reinforced dune, again planted with native dune grass, will have a crest elevation of +13.5' NGVD and continue for 305 feet to meet a raised asphalt parking area, 165 feet long. The crest elevation of the raised asphalt area will be at +13.5 feet, with side slopes of 1V:10H, allowing for continued use as a parking area, and for vehicular access to the existing ferry terminal.

Another reinforced dune will continue from the raised parking area along the shoreline for 945 feet at elevation +13.5' NGVD. At the eastern-most pier in Reach 1, the footprint of the reinforced dune will be angled towards the southwestern corner of the existing state bulkhead to allow for continued recreation use of the large existing beach. The dune barrier will transition from elevation +13.5' NGVD to meet a raised bulkhead with a crest elevation of +13' NGVD. The 35-feet of raised bulkhead and its associated rubble toe will be constructed in front of an existing seawall that crosses an existing channel that flows along Snug Harbor Avenue. The raised bulkhead will connect with the existing capped state bulkhead at crest elevation +13' NGVD in Reach 2.

At the eastern end of Reach 1, an offshore breakwater will be tied in to the end of the on-shore dune barrier and run parallel to the existing state bulkhead, continuing across the bay and connecting to high ground on the Sandy Hook Spit. The total breakwater alignment is approximately 4,500 feet, crossing a broad shoal area on the spit side. At the location of the existing navigation channel approximately 500 feet from the state bulkhead, a 135-foot wide navigation sector gate will be installed to allow for a 100-foot clear opening for navigation transit when the gate is in the open position. Prior to potential major storm events, the sector gate will be closed during a period of lower tide, sealing the inner basin, providing additional runoff storage leeward of the barrier and protecting Reaches 2, 3, and 4. No additional storm damage reduction features will be constructed in Reaches 2, 3, and 4.

Mean bay-bottom elevation along the breakwater alignment is roughly -3' NGVD or less, except across the navigation channel where it is an average of -18 to -20' NGVD. The crest of the

breakwater will be set at elevation +13.5' NGVD. The crest elevation was selected to limit the effect of storm waves, reduce overtopping damage to the leeward side of the breakwater, and avoid water buildup from overtopping wave effects. There is insufficient storage leeward of the breakwater to store storm water runoff buildup to below elevation +6' NGVD with the sector gate closed, therefore a pump station will be required. Based on gross approximations, a 4,000 cfs pump station will prevent residual damages from the closed gate.

Mean armor size for the offshore breakwater will be around 2.6 tons with a double-stone thickness of rough angular armor material. The armor stone will be underlain with a double layer of 500 pound stone, which in turn, will overlie the core and bedding stone structure foundation.

The impermeable core will be a steel or composite sheet pile wall to elevation +10.5' NGVD, and penetrated sufficiently below the Sandy Hook Bay bottom for structural stability. Because of the potential for overtopping, the harbor side of the breakwater will also need to be armored with similar sized armor stone. The crest width will be three stones wide (10 feet) and will cover the sheet pile wall. Breakwater side slopes will be 1V:2H.

Two 25-foot wide closure gates will provide access points through the alignment to boat launch ramps and marina areas along the project's shoreline. As part of the minimum facility costs, one existing outlet will be updated by placing new flap gates at the outlet. The reinforced dunes will require earthen dune walkovers to maintain waterfront access at five points. Likewise, construction of a timber stair walkover will be constructed at one access point along the raised bulkhead feature to allow for continued access to an existing pier. These types of access structures can be somewhat unsightly but can be architecturally treated to improve the aesthetic character.

This alternative meets the overall project objective of reducing storm damage for the majority of the Borough of Highlands. There are less waterfront access impacts and partial water view obstructions when compared to Alternatives 4 and 5, as the offshore breakwater excludes the need for any storm damage reduction features along the shoreline of Reaches 2, 3, and 4. However, the offshore breakwater may impact views across the Sandy Hook Bay and Shrewsbury River from both the eastern and western shorelines of the project site.

### 3.1.4 **Alternative 4: Beach and Dune Fill Plan**

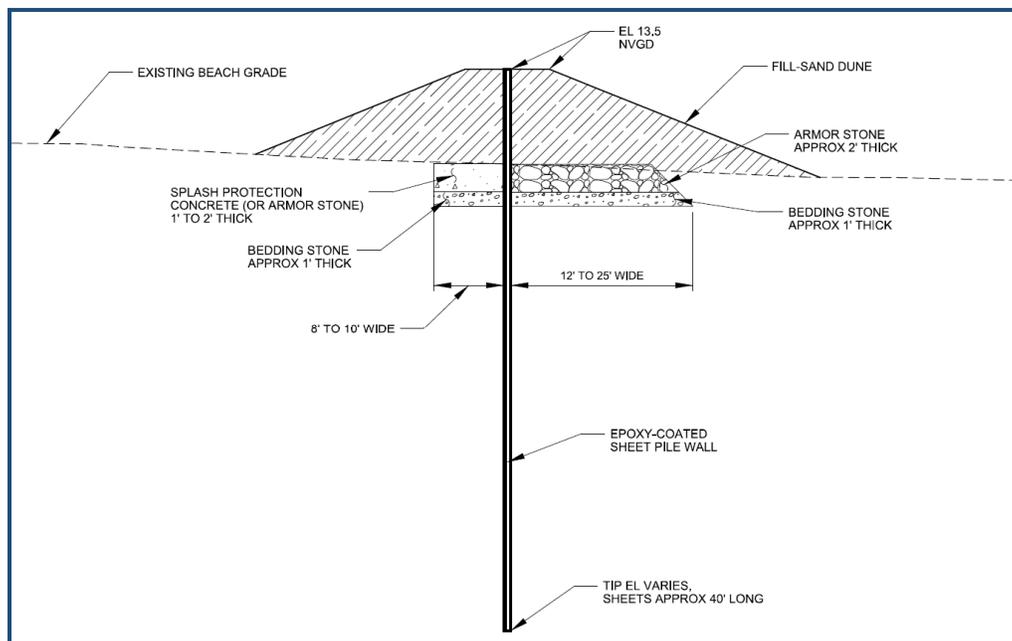
The structural storm damage reduction features in this alternative in Reach 1 are the same as those in Alternative 3—with the substitution of beach and dune fill in a portion of the reach (see Figures CS108-CS109). This is the only area where a beach and dune fill section can be accommodated due to the proximity of the existing navigation channel, piers, and shoreline frontage usage.

At the western end of Reach 1, existing ground will be raised using impervious fill to create a raised ground surface totaling 355 square yards at elevation +11' NGVD that will tie into the

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existing contour near the end of Shore Drive. The side slopes of the raised ground will be approximately 1V:3H and will tie into surrounding areas. The raised ground area will be capped with 6 inches of topsoil and planted with native vegetation. The raised ground will meet a 225 linear feet raised portion of the existing Locust Street. The 225 feet of existing road will be raised to elevation +11' NGVD; regrading will be necessary for access to private driveways. To match existing grades of both the existing Locust Street to the southeast and the mobile home park parking area to the north, transition road approaches will be constructed at a slope of 1V:10H from each end of the raised road.

Approximately 195 feet of concrete I-type floodwall will be constructed from the eastern end of the raised road northeast along an existing fence line at elevation +11' NGVD. The northern end of the floodwall will transition up to elevation +13' NGVD where it will meet the western end



of an L-shaped raised ground surface totaling 2,160 square yards with 1V:3H side slopes tying into surrounding areas. The raised ground area will be capped with 6 inches of topsoil and planted with native vegetation. It will transition from elevation 13' NGVD to 13.5' NGVD to connect to the backside of a beach and dune fill area that extends 1,100-feet long along the shoreline, sized according to crenulate bay theory. The shoreline will be renourished with beach fill, extending the existing waterline seaward approximately 40 feet and mitigating for the isolated historic erosion that is occurring at this location. (The potential seaward projection of the beach fill was limited due to existing functioning pier structures and the existing navigation channel.) The beach fill will be built up to elevation +10' NGVD, meeting the dune fill portion, which will have a crest elevation of +13.5' NGVD. Space limitations and under-seepage concerns did not allow for a wide protective dune; therefore, an inner core consisting of a buried sheet-pile seawall will be located inside the dune approximately flush with dune protection, as shown in Figure B1-1.

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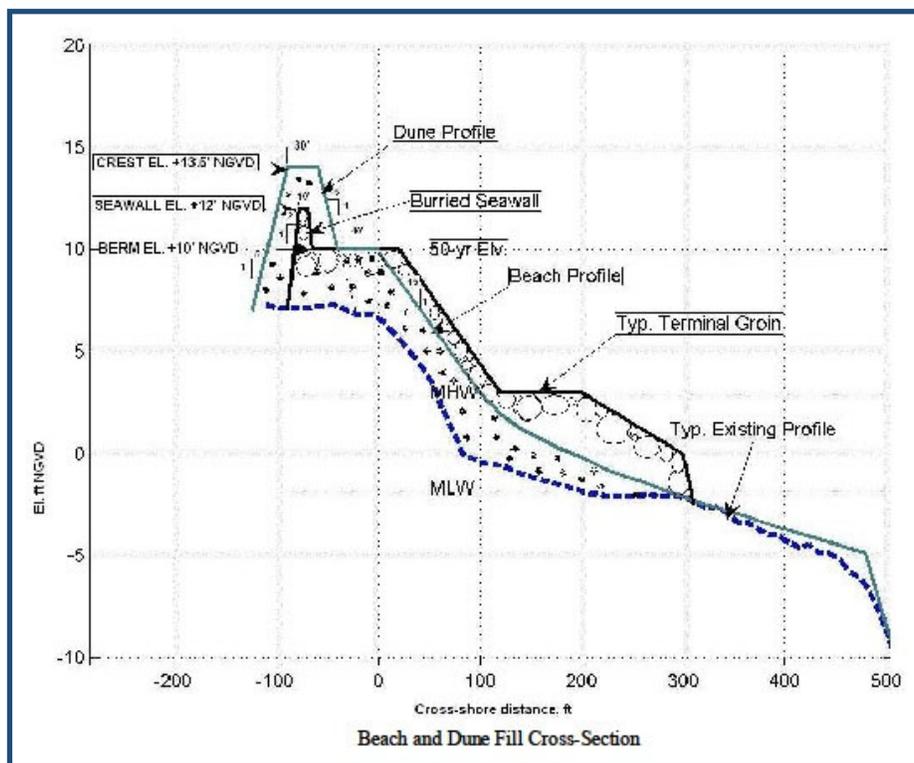
Figure B1-1: Beach and Dune Fill Typical Section.

Figure B1-2: Beach and Dune Fill Typical End Section.

Terminal groins, each approximately 350 feet long will be constructed at either end of the beach and dune fill to create a pocket beach to retain beach fill. Figure B1-2 shows a typical section for the beach and dune fill.

The crest elevation at the eastern end of the dune fill will continue at elevation +13.5' NGVD to connect to a raised asphalt parking area, 165 feet long. The crest elevation of the raised asphalt area will be at +13.5' NGVD, with side slopes of 1V:10H, allowing for continued use as a parking area, and for vehicular access to the existing ferry terminal. A contiguous reinforced dune will be constructed at crest elevation +13.5' NGVD from the raised asphalt area along the existing shoreline for a total of 945 feet. The reinforced dune will consist of a buried stone seawall (1V:1.5H) covered with sand (1V:5H) and with an impervious earthen core installed along the backside of the seawall. The dunes will be planted with native dune grass to provide additional stabilization.

At the eastern-most pier in Reach 1, the footprint of the reinforced dune will be angled



towards the southwestern corner of the existing state bulkhead to allow for continued recreation use of the large existing beach. The dune barrier will transition from elevation +13.5' NGVD to meet a raised bulkhead with a crest elevation of +13' NGVD. The 35-feet of raised bulkhead and its associated rubble toe will be constructed in front of an existing seawall that crosses an existing

channel that flows along Snug Harbor Avenue. The raised bulkhead will connect with the existing capped state bulkhead at crest elevation +13' NGVD in Reach 2.

In Reach 2, 1,280 linear feet of the existing state bulkhead will be capped to an elevation of +13' NGVD, for an increase in the bulkhead's existing height of approximately 1 foot. A parapet of approximately 10 to 15 degrees will be applied to the cap to reduce wave overtopping impacts, allowing for this crest elevation. Because the increase in height will be relatively small, a fixed, rather than removable, extension is assumed, simplifying the needed structural connection. The landward side of the capped bulkhead (above grade) will need to be structurally reinforced to avoid the potential of exceeding the design loads of the existing bulkhead with the added loads intercepted by the capping. This reinforcement will include a 1.5-foot thick (average) monolithic section of reinforced concrete along the landside of the existing bulkhead, continuing with a 2-foot thick, 10-foot wide monolithic reinforced concrete slab at grade. At the center of Reach 2, a buoyant swing gate, similar in design to the "Buoyant Swing Gate" as detailed in the USACE's Leonardo, NJ Hurricane Storm Damage Reduction Feasibility Study: Closure Gate Assessment and Design (Leonardo Report, April 2002), will be installed at the inlet opening to a marina, tying together the two portions of the capped state bulkhead. The entire gate structure will be 70-feet wide, with a 55-foot wide channel available for navigation transit when the gate is in the open position. Prior to potential major storm events, the swing gate will be closed during a period of lower tide, sealing the existing marina and protecting it from flood waters. The capped bulkhead will connect to a raised bulkhead in Reach 3.

In Reach 3, a 430-foot transition section of raised bulkhead will be constructed at a crest elevation of +13' NGVD. The raised bulkhead will be located along the set back high water mark, immediately in front of existing seawalls. The associated rubble toe will only be constructed for 75 feet from the capped state bulkhead, since the remainder of the raised bulkhead runs along the inside perimeter of an existing marina and a rubble toe would interfere with marina operations. To the east, the raised bulkhead will transition to meet a raised asphalt parking area with a crest elevation of +12' NGVD, continuing for 380 feet across the existing parking areas at the end of Atlantic Street. The side slopes of the raised asphalt area will be 1V:10H, allowing for continued use as parking areas and continued access to the existing marina. Another reinforced dune, again planted with native dune grass, will continue at elevation +12' NGVD for 145 feet from the raised asphalt area along the existing shoreline. This reinforced dune will then connect to another raised bulkhead, which continues at a crest elevation of +12' NGVD. This raised bulkhead and its associated rubble toe will be constructed for 510 feet. Another 850 feet of contiguous reinforced dune will be constructed at a crest elevation of +12' NGVD and connect to another section of raised bulkhead, also at crest elevation +12' NGVD. The raised bulkhead and its associated rubble toe will be constructed in front of existing seawall for 635 feet, connecting to a concrete I-type floodwall in Reach 4. A seaside restaurant and deck will be raised in place and the restaurant entry will be modified to maintain existing water views and access with the alignment to elevation +12' NGVD.

In Reach 4, 140 feet of concrete I-type floodwall will be constructed from the eastern end of the raised bulkhead in Reach 3 southwest along the Windansea Restaurant's property line towards Shrewsbury Street, transitioning from elevation +12' NGVD to elevation +11' NGVD. The I-type floodwall will connect to the northwestern end of 1,075 feet of removable fabricated floodwall, installed at a crest elevation of +11' NGVD along the waterside curb of Shrewsbury Street. The removable fabricated floodwall will connect to the northwestern end of another raised ground surface. The crest will continue at elevation +11' NGVD. The footprint of this raised ground covers 5,650 square yards of an existing public park located to the north of Bay Avenue. The raised surface will duplicate the existing park features and surfacing, including the raising of a monument at the entrance to the park. The raised ground area will be capped with 6 inches of topsoil and planted with native vegetation. At the southeastern end of this area, the crest elevation of the raised ground will continue at elevation +11' NGVD and meet a 415- linear foot raised portion of the existing Bay Avenue to tie into the +11' NGVD contour along Bay Avenue at the eastern closure of the project. The 415 feet of existing road will be raised to elevation +11' NGVD; regrading will be necessary for access to driveways and walks. To match existing grades of the existing Bay Avenue to the northwest and close the alignment at the eastern end of the project site, a transition road approach will be constructed at a slope of 1V:10H from the northwestern end of the raised road.

The recommended type of removable fabricated floodwall is the same as that for Alternative 1. It should be noted that the installation alignment of the removable fabricated floodwall leaves the 12 residential buildings located seaward of Shrewsbury Street, to the southeast of Cornell Street and to the northwest of the park on Bay Avenue, susceptible to flooding. The following structural option for storm damage protection of these 12 structures was considered: an offshore stone dike enclosing the docks and exposed shoreline, including a collinear navigation gate for boating access. This option was determined to be not viable, due to its navigation interference and its very high cost relative to the small amount of shoreline and number of piers and structures actually protected (i.e., the cost could be as much as twice the value of the structures/properties).

Three 25-foot wide closure gates will provide access points through the alignment to boat launch ramps and marina areas along the project's shoreline. As part of the minimum facility costs, four existing outlets will be updated by placing new flap gates at the outlets. The reinforced dunes will require earthen dune walkovers to maintain waterfront access at eight points. Likewise, construction of timber stair walkovers will be constructed at nine access points along the raised bulkhead features to allow for continued access to existing piers. These types of access structures can be somewhat unsightly but can be architecturally treated to improve the aesthetic character. The inclusion of the buoyant swing gate will allow for continued access to the marina in Reach 2. The gently sloped (1V:10H) raised parking areas will allow for the continued access to the adjacent waterfront structures. Finally, the temporary (removable) nature of the removable fabricated floodwall in Reach 4 provides for a continuous alignment when erected just prior to and during storms, but allows for waterfront access at all other times and temporary access during storms via a portable ramp over the removable fabricated floodwall.

This alternative meets the overall project objective of reducing storm damage for the majority of the Borough of Highlands, except for the buildings located seaward of Shrewsbury Street, to the southeast of Cornell Street and to the northwest of the park on Bay Avenue. In general, as most of the project site's shoreline is being raised from existing elevations, water views will be partially obstructed but not interrupted.

### 3.1.5 **Alternative 5: Environmental Minimization and Avoidance Plan**

This alternative (as shown on plan sheets CS110-CS111) is considered to be the environmental minimization and avoidance alternative. It combines the same alignment as Alternative 3 for Reach 1 with the same alignment as Alternative 4 for Reaches 2, 3, and 4.

At the western end of Reach 1, existing ground will be raised using impervious fill to create a raised ground surface totaling 355 square yards at elevation +11' NGVD that will tie into the existing contour near the end of Shore Drive. The side slopes of the raised ground surface will be approximately 1V:3H and will tie into surrounding areas. The raised ground area will be capped with 6 inches of topsoil and planted with native vegetation. The raised ground will meet a 225 linear feet raised portion of the existing Locust Street. The 225 feet of existing road will be raised to elevation +11' NGVD; regrading will be necessary for access to private driveways. To match existing grades of both the existing Locust Street to the southeast and the mobile home park parking area to the north, transition road approaches will be constructed at a slope of 1V:10H from each end of the raised road.

Approximately 195 feet of concrete I-type floodwall will be constructed from the eastern end of the raised road northeast along an existing fence line at elevation +11' NGVD. The northern end of the floodwall will transition up to elevation +13' NGVD where it will meet the western end of another 1,276-square yard raised ground surface. This raised ground surface will also be capped with 6 inches of topsoil and planted with native vegetation. It will transition to elevation +13.5' NGVD to meet a reinforced dune constructed along the existing shoreline. The reinforced dune will consist of a buried stone seawall (1V:1.5H) covered with sand (1V:5H) and with an impervious earthen core installed along the backside of the seawall. The dunes will be planted with native dune grass to provide additional stabilization. The reinforced dune will continue at elevation +13.5' NGVD for 290 feet to meet a raised bulkhead.

The raised bulkhead will be located along the set back high water mark, immediately in front of existing seawalls. A parapet of approximately 10 to 15 degrees will be applied to the bulkhead to reduce wave overtopping impacts, allowing for a reduction in elevation in comparison to Alternative 1 of 2 feet. The bulkhead will be 460 feet long at a crest elevation +13.5' NGVD, fronted by a rubble toe, constructed at the toe of the bulkhead to reduce wave overtopping impacts. In addition, the rubble toe will also provide for protection from the isolated historic erosion that is occurring at this location. Another contiguous reinforced dune, again planted with native dune grass, will have a crest elevation of +13.5' NGVD and continue for 305 feet to meet a

raised asphalt parking area, 165 feet long. The crest elevation of the raised asphalt area will be at +13.5 feet, with side slopes of 1V:10H, allowing for continued use as a parking area, and for vehicular access to the existing ferry terminal.

Another reinforced dune will continue from the raised parking area along the shoreline for 945 feet at elevation +13.5' NGVD. At the eastern-most pier in Reach 1 the footprint of the reinforced dune will be angled towards the southwestern corner of the existing state bulkhead to allow for continued recreation use of the large existing beach. The dune barrier will transition from elevation +13.5' NGVD to meet a raised bulkhead with a crest elevation of +13' NGVD. The 35-foot of raised bulkhead and its associated rubble toe will be constructed in front of an existing seawall that crosses an existing channel that flows along Snug Harbor Avenue. The raised bulkhead will connect with the existing capped state bulkhead at crest elevation +13' NGVD in Reach 2.

In Reach 2, 1,415 linear feet of the existing state bulkhead will be capped to an elevation of +13' NGVD, for an increase in the bulkhead's existing height of approximately 1 foot. A parapet of approximately 10 to 15 degrees will be applied to the cap to reduce wave overtopping impacts, allowing for a crest elevation +13' NGVD. Because the increase in height will be relatively small, a fixed, rather than removable, extension is assumed, simplifying the needed structural connection. The landward side of the capped bulkhead (above grade) will need to be structurally reinforced to avoid the potential of exceeding the design loads of the existing bulkhead with the added loads intercepted by the capping. This reinforcement will include a 1.5-foot thick (average) monolithic section of reinforced concrete along the landside of the existing bulkhead, continuing with a 2-foot thick, 10-foot wide monolithic reinforced concrete slab at grade. At the center of Reach 2, a buoyant swing gate, similar in design to the "Buoyant Swing Gate" as detailed in the USACE's Leonardo, NJ Hurricane Storm Damage Reduction Feasibility Study: Closure Gate Assessment and Design (Leonardo Report, April 2002), will be installed at the inlet opening to a marina, tying together the two portions of the capped state bulkhead. The entire gate structure will be 70-foot wide, with a 55-foot wide channel available for navigation transit when the gate is in the open position. Prior to potential major storm events, the swing gate will be closed during a period of lower tide, sealing the existing marina and protecting it from flood waters. The capped bulkhead will connect to a raised bulkhead in Reach 3.

In Reach 3, a 430-foot transition section of raised bulkhead will be constructed at a crest elevation of +13' NGVD. The raised bulkhead will be located along the set back high water mark, immediately in front of existing seawalls. The associated rubble toe will only be constructed for 75 feet from the capped state bulkhead, since the remainder of the raised bulkhead runs along the inside perimeter of an existing marina and a rubble toe would interfere with marina operations. To the east, the raised bulkhead will transition to meet a raised asphalt parking area with a crest elevation of +12' NGVD, continuing for 380 feet across the existing parking areas at the end of Atlantic Street. The side slopes of the raised asphalt area will be 1V:10H, allowing for continued use as parking areas and continued access to the existing marina. Another reinforced dune, again planted with native dune grass, will continue at elevation +12' NGVD for 145 feet from the raised

asphalt area along the existing shoreline. This reinforced dune will then connect to another raised bulkhead, which continues at a crest elevation of +12' NGVD. This raised bulkhead and its associated rubble toe will be constructed for 510 feet. Another 850 feet of contiguous reinforced dune will be constructed at a crest elevation of +12' NGVD and connect to another section of raised bulkhead, also at crest elevation +12' NGVD. The raised bulkhead and its associated rubble toe will be constructed in front of existing seawall for 635 feet, connecting to a concrete I-type floodwall in Reach 4. A seaside restaurant and deck will be raised in place and the restaurant entry will be modified to maintain existing water views and access with the alignment to elevation +12' NGVD.

In Reach 4, 140 feet of concrete I-type floodwall will be constructed from the eastern end of the raised bulkhead in Reach 3 southwest along the Windansea Restaurant's property line towards Shrewsbury Street, transitioning from elevation +12' NGVD to elevation +11' NGVD. The I-type floodwall will connect to the northwestern end of 1,075 feet of removable fabricated floodwall, installed at a crest elevation of +11' NGVD along the waterside curb of Shrewsbury Street. The removable fabricated floodwall will connect to the northwestern end of another raised ground surface. The crest will continue at elevation +11' NGVD. The footprint of this raised ground covers 5,650 square yards of an existing public park located to the north of Bay Avenue. The raised surface will duplicate the existing park features and surfacing, including the raising of a monument at the entrance to the park. The raised ground area will be capped with 6 inches of topsoil and planted with native vegetation. At the southeastern end of this area, the crest elevation of the raised ground will continue at elevation +11' NGVD and meet a 415- linear foot raised portion of the existing Bay Avenue to tie into the +11' NGVD contour along Bay Avenue at the eastern closure of the project. The 415 feet of existing road will be raised to elevation +11' NGVD; regrading will be necessary for access to driveways and walks. To match existing grades of the existing Bay Avenue to the northwest and close the alignment at the eastern end of the project site, a transition road approach will be constructed at a slope of 1V:10H from the northwestern end of the raised road.

The recommended type of removable fabricated floodwall is the same as that for Alternative 1. It should be noted that the installation alignment of the removable fabricated floodwall leaves the 12 residential buildings located seaward of Shrewsbury Street, to the southeast of Cornell Street, and to the northwest of the park on Bay Avenue, susceptible to flooding. The following structural option for storm damage protection of these 12 structures was considered: an offshore stone dike enclosing the docks and exposed shoreline, including a collinear navigation gate for boating access. This option was determined to be not viable, due to its navigation interference and its very high cost relative to the small amount of shoreline and number of piers and structures actually protected (i.e., the cost could be as much as twice the value of the structures/properties).

Three 25-foot wide closure gates will provide access points through the alignment to boat launch ramps and marina areas along the project's shoreline. In addition, three existing outlets will be replaced by new tide gates as part of minimum facility costs. The reinforced dunes will

require earthen dune walkovers to maintain waterfront access at ten points. Likewise, construction of timber stair walkovers will be constructed at ten access points along the raised bulkhead features to allow for continued access to existing piers. These types of access structures can be somewhat unsightly but can be architecturally treated to improve the aesthetic character. The inclusion of the buoyant swing gate will allow for continued access to the marina in Reach 2. The gently sloped (1V:10H) raised parking areas will allow for the continued access to the adjacent waterfront structures. Finally, the temporary nature of the removable fabricated floodwall in Reach 4 provides for a continuous alignment when erected just prior to and during storms, but allows for waterfront access at all other times and temporary access during storms via a portable ramp over the removable fabricated floodwall.

This alternative meets the overall project objective of reducing storm damage for the majority of the Borough of Highlands, except for the buildings located seaward of Shrewsbury Street, to the southeast of Cornell Street, and to the northwest of the park on Bay Avenue. In general, as most of the project site's shoreline is being raised from existing elevations, water views will be partially obstructed, but not interrupted.

## 3.2 Primary Alternatives Array

Alternative 1 (the pre-feasibility plan), Alternative 4 (the dune and beachfill plan), and Alternative 5 (the environmental impact minimization and avoidance plan) were considered. Of the three alternatives, Alternative 5 had the highest BCR and the highest net benefits. Accordingly, Alternative 5 was developed further into five variants, Alternatives 5A to 5E.

- **Alternative 5A:** Alternative 5 with Perimeter Bulkhead in lieu of Buoyant Swing Gate
- **Alternative 5B:** Alternative 5 with Raised Bulkhead and Non-Structural Measures in lieu of Removable Flood Wall, Target Elevation of 12 feet NGVD
- **Alternative 5C:** Alternative 5 with Raised Bulkheads and Non-Structural Measures in lieu of Removable Flood Wall, Target Elevation of 13.2 feet NGVD
- **Alternative 5D:** Alternative 5 with Raised Bulkheads in lieu of Removable Flood Wall, Target Elevation of 13.9 feet NGVD
- **Alternative 5E:** Alternative 5A and Alternative 5D Combined

The alignments for Alternative 5A-5E have been further refined to match the existing topographic features from the 2002 survey. In addition, features in various locations have been modified based on input received at multiple public meetings conducted between March and May 2014.

### 3.2.1 Alternative 5A: Alternative 5 with Perimeter Bulkhead in lieu of Buoyant Swing Gate

This alternative is shown on plan sheets CS112-CS113.

For features in Reach 1, the design elevation is set at 13.5 ft. NGVD. See paragraph 4.1 for information on the western tie-in and the private development that has been proposed for the area referred to as the Bollerman property. This private development is assumed to serve as the western end of the project alignment and the raised bulkhead for Reach 1 is assumed to begin at the eastern edge of the development. Raised bulkheads are proposed throughout Reach 1 and will include a stone rubble toe and concrete splash pad along the entire length. The seaside rock berm will provide toe protection against erosion and will act as a rubble toe to reduce wave action. The rubble toe is 12 ft. wide and 2 ft. thick and will be placed on top of a 6 in. layer of bedding material on geotextile. The concrete splash pad will be placed on the landside to protect against erosion from overtopping. The splash pad is 10 ft. wide and 2 ft. thick and will be placed on top of a 1 ft layer of bedding material on geotextile. At two locations in Reach 1, sand fill will be placed over the raised bulkhead to improve the aesthetics since they are located along existing beach areas. The sand fill is 12 ft wide at the crown with 1V:5H side slopes to tie into the surrounding area. The dune fills will be planted with native vegetation to help protect against erosion.

For features in Reach 2, the design elevation is set at 13 ft. NGVD. Refer to the description from Alternative 5 for details on the capping of the existing state bulkhead. In lieu of a buoyant swing gate across the opening of the Captain's Cove Marina, this alternative proposes a raised bulkhead that is setback on the landward side of the existing perimeter bulkhead. No rubble toe is proposed for the setback wall as wave action is reduced within the marina and toe protection will be provided by the existing wall that is left in place. A concrete splash pad is included on the landside of the setback wall to protect against erosion from overtopping.

A raised bulkhead installed in front of the existing marina wall (as assumed for Alternative 1) was considered but was determined to be undesirable after discussions with the owner. The existing marina is very narrow and interior bulkheads would further reduce the available wet footprint. In addition, due to the increased wall height, walkways would be needed along the interior perimeter and would again reduce the operating width of the marina. Instead, the proposed bulkhead has been setback on the landward side to minimize impacts to the marina. One existing residential structure on the east side of the marina is located too close for a setback wall to be feasible. Consequently, at this location, approximately 100 lf of the raised bulkhead will be installed inside the existing marina wall. Also, due to the setback, traffic along Washington Avenue will likely need to be converted to one direction only; however, roadside parking will remain.

For features in Reach 3, the design elevation is set at 12 ft. NGVD. Raised bulkheads are proposed throughout Reach 3 and will include a stone rubble toe and concrete splash pad along the entire length. At two locations in Reach 3, sand fill will be placed over the raised bulkhead to improve the aesthetics since they are located along existing beach areas. The dune fills will be planted with native vegetation to help protect against erosion. In addition, a boat launch facility that utilizes a 35 ton travel lift will need to be raised in place to the new design elevation and will require the construction of an approach ramp to tie into the existing parking lot. Also, the Inlet

Café Restaurant and the seaside deck of the Windandsea restaurant will be raised in place to mitigate viewshed impacts to their dining areas.

For features in Reach 4, the design elevation is set at 11 ft. NGVD. Refer to the description from Alternative 5 for details on the removable flood wall. The Eastern Tie-In will consist of sea wall tying in the edge of the Veteran's Memorial Park to high ground at the bluff. A steel and reinforced concrete closure structure and hydraulic gate or gates will be required to allow access along Bay Avenue while maintaining the alignment. This tie-in was selected as the most economical option and reducing the number of conflicts with landowners, including the Twin Lights and Gateway Marinas.

The reinforced dunes will require earthen dune walkovers to maintain waterfront access at seven points. Likewise, construction of timber stair walkovers will be constructed at access points along the raised bulkhead features to allow for continued access to existing piers.

### 3.2.2 **Alternative 5B: Alternative 5 with Raised Bulkhead and Non-Structural Measures in lieu of Removable Flood Wall, Target Elevation of 12 feet NGVD**

This alternative is shown on plan sheets CS114-CS115.

This alternative consists of the same storm damage reduction features and access features as Alternative 5A, except the buoyant swing gate is used at Captain's Cove Marina in Reach 2 and the fabricated floodwall is removed in Reach 4. In lieu of the fabricated floodwall, protection is provided by the following features: bulkheading to elevation 12.0 ft. NGVD along the existing shoreline in Reach 4 and raising of the 16 structures landward of the bulkhead with reinforced concrete foundations. The reinforced raised foundations are necessary to withstand the wave overtopping forces possible with a 12.0 ft. NGVD elevation bulkhead.

The reinforced dunes will require earthen dune walkovers to maintain waterfront access at seven points. Likewise, construction of timber stair walkovers will be constructed at access points along the raised bulkhead features to allow for continued access to existing piers.

### 3.2.3 **Alternative 5C: Alternative 5 with Raised Bulkheads and Non-Structural Measures in lieu of Removable Flood Wall, Target Elevation of 13.2 feet NGVD**

This alternative is shown on plan sheets CS116-CS117.

This alternative consists of the same storm damage reduction features and access features as Alternative 5A, except the buoyant swing gate is used at Captain's Cove Marina in Reach 2 and the fabricated floodwall is removed in Reach 4. In lieu of the fabricated floodwall, protection is provided by the following features: bulkheading to elevation 13.2 ft. NGVD along the existing shoreline in Reach 4 and raising of the 16 structures landward of the bulkhead with standard block

foundations. The raised standard block foundations are adequate to withstand the wave overtopping forces possible with a 13.2 ft. NGVD elevation bulkhead.

The reinforced dunes will require earthen dune walkovers to maintain waterfront access at seven points. Likewise, construction of timber stair walkovers will be constructed at access points along the raised bulkhead features to allow for continued access to existing piers.

### 3.2.4 **Alternative 5D: Alternative 5 with Raised Bulkheads in lieu of Removable Flood Wall, Target Elevation of 13.9 feet NGVD**

This alternative is shown on plan sheets CS118-CS119.

This alternative consists of the same storm damage reduction features and access features as Alternative 5A, except the buoyant swing gate is used at Captain's Cove Marina in Reach 2 and the fabricated floodwall is removed in Reach 4. In lieu of the fabricated floodwall, protection is provided by the following features: bulkheading to elevation 13.9 ft. NGVD along the existing shoreline in Reach 4. The existing foundations of structures landward of the bulkhead are adequate to withstand the wave overtopping forces possible with a 13.9 ft. NGVD elevation bulkhead.

The reinforced dunes will require earthen dune walkovers to maintain waterfront access at seven points. Likewise, construction of timber stair walkovers will be constructed at access points along the raised bulkhead features to allow for continued access to existing piers.

### 3.2.5 **Alternative 5E: Alternative 5A and Alternative 5D Combined**

This alternative is shown on plan sheets CS120-CS121.

This alternative consists of the same storm damage reduction features and access features as Alternative 5A combined with Alternative 5D. In lieu of a buoyant swing gate across the opening of the Captain's Cove Marina in Reach 2, protection is provided by a raised bulkhead that is setback on the landward side of the existing perimeter bulkhead. In lieu of the fabricated floodwall in Reach 4, protection is provided by bulkheading to elevation 13.9 ft. NGVD along the existing shoreline. As noted above, the existing foundations of structures landward of the bulkhead are adequate to withstand the wave overtopping forces possible with a 13.9 ft. NGVD elevation bulkhead.

The reinforced dunes will require earthen dune walkovers to maintain waterfront access at seven points. Likewise, construction of timber stair walkovers will be constructed at access points along the raised bulkhead features to allow for continued access to existing piers.

## **Chapter 4: Optimization of Tentatively Selected Plan**

## 4.1 Changes from Alternative 5E

Alternative 5E was tentatively selected as the National Economic Development (NED) Plan, to be further studied and refined in a process referred to as Optimization. Alternative 5E assumed a continuous I-Wall composed of driven or vibrated sheetpile with various options for dune fill and a limited section of Toe Stone. During Optimization, three wall profiles were considered for comparison of their net benefits and benefit-cost ratio, referred to as Small, Medium and Large, or Low, Medium and High Plans.

Prior to the beginning of Optimization, but after the TSP Report, EC 1110-2-6066 was published limiting the applicability of sheetpile and other forms of I-Wall base on the soil type and the vertical height above grade (sometimes referred to as “stick-up”). Alternative 5E quantities and initial analysis did not take into account these limitations, and assumed a sheetpile I-Wall would be used throughout the project. In all three of the profiles considered in Optimization, a significant portion of the flood wall system would require reinforced concrete T-Walls. Furthermore, in previous alternatives, it was assumed that the State Bulkhead in Reach 2 was of sufficient condition that it could be used within each of the two lower profiles (left as-is for the Small/Low profile, capped in the Medium profile), however, recent spot inspections revealed significant corrosion and damage, invalidating this assumption.

To reduce wave forces and level out the induced flood elevations in Reaches 1 and 3, a stone rubble toe feature was added (wall is located in the breaking zone in these reaches, and in deeper water for Reaches 2 and 4). The rubble toe will be constructed of 7T Armor Stone for Reach 1 and 1T Armor Stone for Reach 3, placed against the wall at the assumed angle of repose, 1V:1.5H in both reaches, founded on approx. 1’ of bedding stone with bottom elevation at -3.0. In all Reaches, approximately 1’ thickness of plain concrete over bedding stone will be placed landward of the walls as Splash Protection. Table B1-1 shows a comparison of the three plan profiles for stone and top-of-wall.

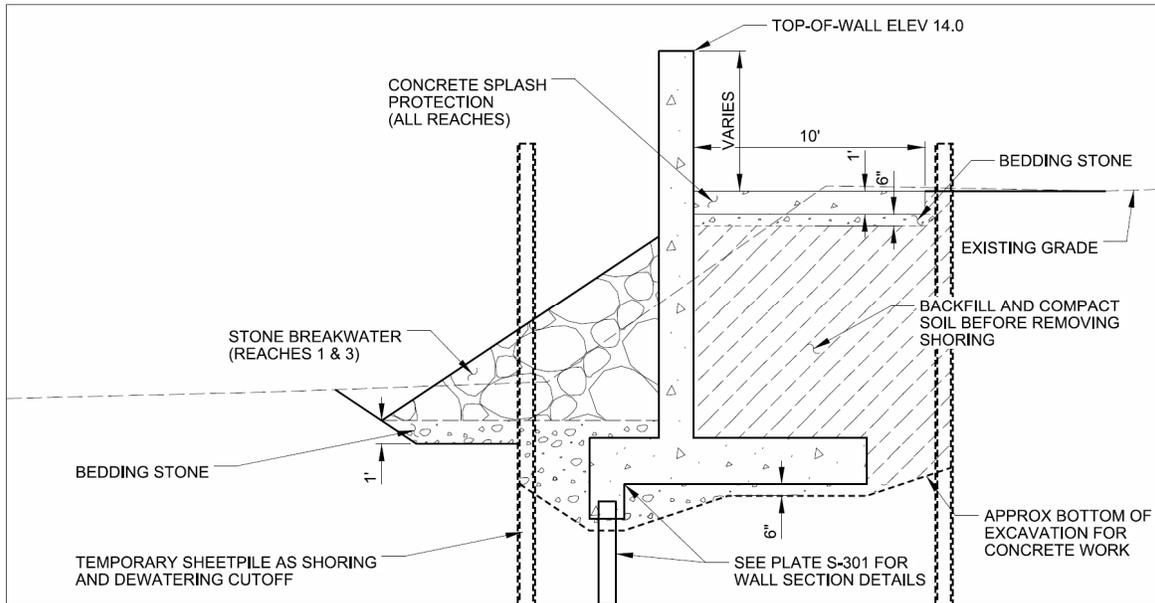
**Table B1-1: Optimization Profile Comparisons**

Reach	Small Plan			Medium Plan			High Plan		
	Top-of-Wall Elev.	Top-of-Stone Elev.	Stone Height	Top-of-Wall Elev.	Top-of-Stone Elev.	Stone Height	Top-of-Wall Elev.	Top-of-Stone Elev.	Stone Height
1	11.0	11.0	13.0	12.5	12.0	14.0	14.0	14.0	16.0
2	11.0	-	-	13.0	-	-	14.0	-	-
3	11.0	4.0	6.0	12.0	5.0	7.0	14.0	6.0	8.0
4	11.0	-	-	13.0	-	-	14.0	-	-

All Elevations listed in NAVD88, all units of Survey Feet

## 4.2 Optimized Profile Description – High Plan

Based on economic analysis of the three plans, the High Plan provided the highest Benefit-Cost Ratio, and was selected as the Optimized Plan. This profile is composed primarily of Reinforced Concrete T-Wall, with small sections of Sheetpile I-Wall interspersed throughout. Figure B1-3 shows a sample T-Wall Section (as discussed in the Structural Appendix) from Reach 1.



**Figure B1-3: T-Wall and Piles Section – Reach 1**

## 4.3 Constructability

### 4.3.1 Shoring and Dewatering

In order to construct T-Wall sections, temporary sheetpile bulkheads are proposed, with pump systems used to dewater the construction zone. The sheetpile system will require additional design consideration to ensure that it functions both as bulkhead to reduce water intrusion into the construction location, as well as a temporary retaining wall for the remaining soil behind. Dewatering will likely be achieved through submersible pumps placed at low portions of the excavation.

### 4.3.2 Floating and Land-Based Operations

Excavation and other construction phases may require floating plant at some locations due to the density of nearby structures. Other areas may be accessible by land-based equipment, using public roads and parking areas for access and staging. Additional site selection for access and staging will be necessary during the PED Phase of Design.

### 4.3.3 Removals

The existing protection, where present, consists of a variety of bulkhead materials (timber, vinyl, concrete, steel, etc., and often a combination thereof) and configurations, buried to varying depths with little or no documentation to represent as-built conditions (Figure B1-4). These bulkheads may slow construction and require varying methods of removal, including torch-cutting, pneumatic hammer breaking, chainsaw cutting, etc. Many of the materials may be unrecoverable, and must be disposed of, while others may be reusable or recyclable.

Additionally, the construction area may coincide with the buried foundations of docks, buildings and other past infrastructure that cannot be determined accurately prior to construction, increasing the schedule risk for construction.

For this level of design, it is assumed that all bulkheads will be contained by the temporary shoring, and will be removed as part of the excavation phase for T-Walls. Sheetpile I-Wall is assumed to be driven slightly seaward of the existing bulkheads prior to their removal. Removal of such will be limited to removing the portions that will interfere with the installation of splash protection, Interior Drainage Facilities, and other features as applicable.

## 4.4 Value Engineering Study Recommendations

A Value Engineering (VE) Study was conducted in 2016 to review the project concept and features to recommend potential cost-saving measures. The VE Team presented the Design Team with three Proposals and 11 Comments. In Memoranda for Record dated May 31<sup>st</sup>, 2016 and July 5<sup>th</sup>, 2016, the Design Team summarized its responses to the Proposals and Comments, Respectively.

## Chapter 5: Other Project Features

### 5.1 Western Tie-In

During the final alternative design phase of this study, a private developer submitted preliminary plans to the Borough of Highlands that proposes a new development at the western end of the project area (approximately 600 linear feet). This are, known as Harborside at Hudson's Ferry, is under construction. The plan includes a multi-use development consisting of 49 residential units located in 11 buildings, a 5,735 square foot restaurant, a 590-square-foot office space, and reconstructs the existing marina to include 129 slips. A combination of raised ground

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surfaces and new bulkheads are proposed as part of the development to serve as the alignment against flooding. For the final alternative analysis, it was assumed that this private development will serve as the western tie into high ground and will prevent flood water from flanking around the overall alignment. During PED, the Harborside development will need to be reexamined to ensure that a continuous and complete alignment is provided at the western tie-in. The preliminary grading plan for the development has been included as an attachment.



**Figure B1-4: Highlands Bulkhead Photos from 2013 and 2014 Inspections**

## 5.2 Eastern Tie-In

The Eastern Tie-In will consist of an epoxy-coated sheet pile sea wall from the alignment along the center of Veteran's Memorial Park to high ground at the bluff. A steel and reinforced concrete closure structure and hydraulic gate or gates will be required to allow access along Bay Avenue while maintaining the alignment. This tie-in was selected as the most economical option and reduced the number of conflicts with landowners, including the Twin Lights and Gateway Marinas.

## 5.3 Ancillary Access

Along raised bulkhead features, public and private access will be blocked, requiring access methods to be constructed. Initially, it was assumed that access would be provided as a project feature, but after an Office of Counsel and Real Estate Review, the determination was made that ancillary access (including all but the Bay Ave. Closure Gate) would be handled as Real Estate requirements, and not as project features. The following discuss the various types and previous recommendations for continuity of access.

### 5.3.1 Marina Access

There are several privately owned and operated marinas within the project area, currently using a variety of methods for removing and restoring the private pleasure and fishing craft from and to the Sandy Hook Bay. These methods include swing-arm cranes, gantry cranes, and the use of wheeled handling equipment, such as forklifts (Figure B1-5). During development of the primary alternatives, various ideas were collected to find ways to reduce or eliminate disruption of marina access, including construction of raised embankments for wheeled vehicle access, use of after-market or off-the-shelf static lift equipment, and design of custom travelling lift systems.

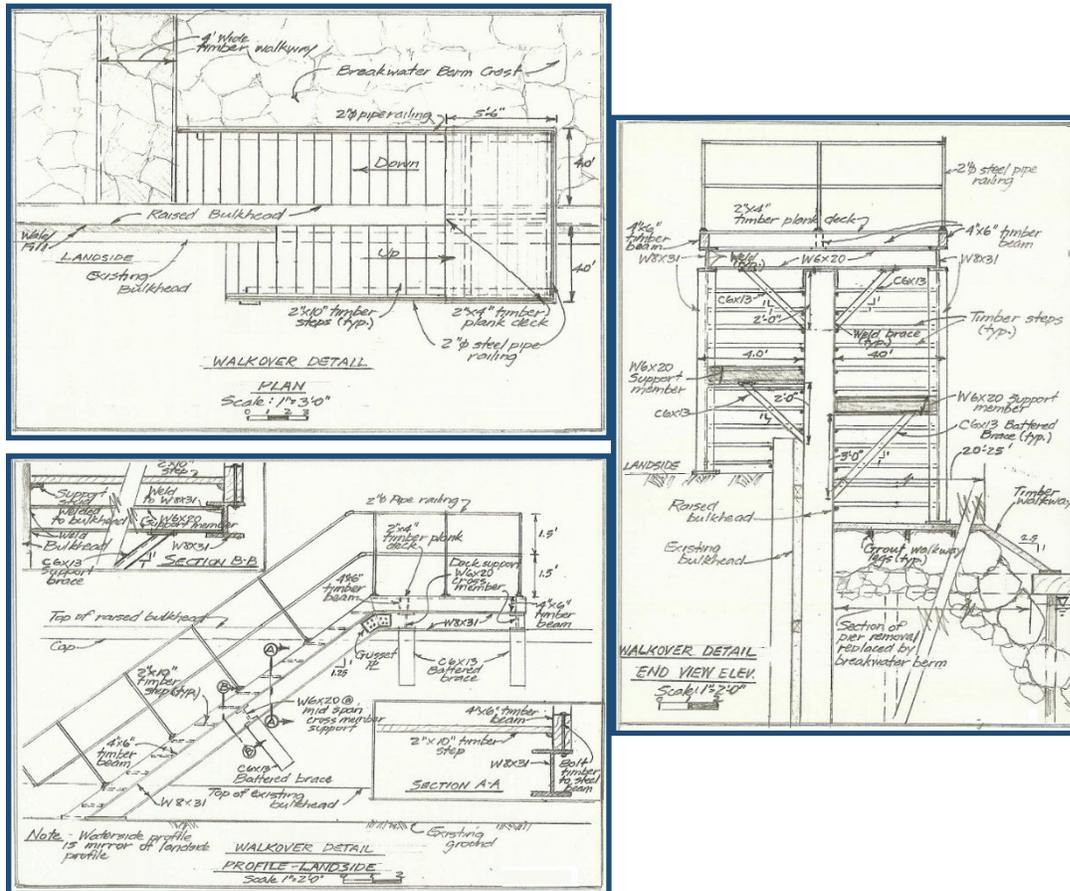


**Figure B1-5: Existing Marina Access Methods**

Before these options could be fully studied, the determination was made that the USACE project would pay for this option as a Real Estate Interest, and not include them as part of the design. During the brainstorming phase, however, it was found that no common travelling lift equipment would be able to lower the boats the necessary distance below the wheel base, eliminating the embankment option, and no after-market or off-the-shelf systems appeared to handle the wide variety of craft at the necessary heights to work in concert with the wall elevations, likely eliminating that option from consideration. It is likely that custom travelling gantry crane systems will be the preferred method of marinas not accepting a buyout in lieu of a continued access agreement.

### 5.3.2 Timber Stair Walkovers

The preliminary location of timber stair walkovers can be seen on the individual alternative plan sheets. Figure B1-6 show different views of a typical timber stair walkover for the project.



**Figure B1-6: Typical Timber Stair Walkover Details**

### 5.3.3 Earthen Ramp Walkover

Along reinforced dune features - if other organizations or individuals would choose to place sand fill over the constructed flood wall system - construction of earthen ramp walkovers will be necessary to allow for continued access to seaside beaches. Figure B1-7 shows a typical earthen ramp walkover for the project.

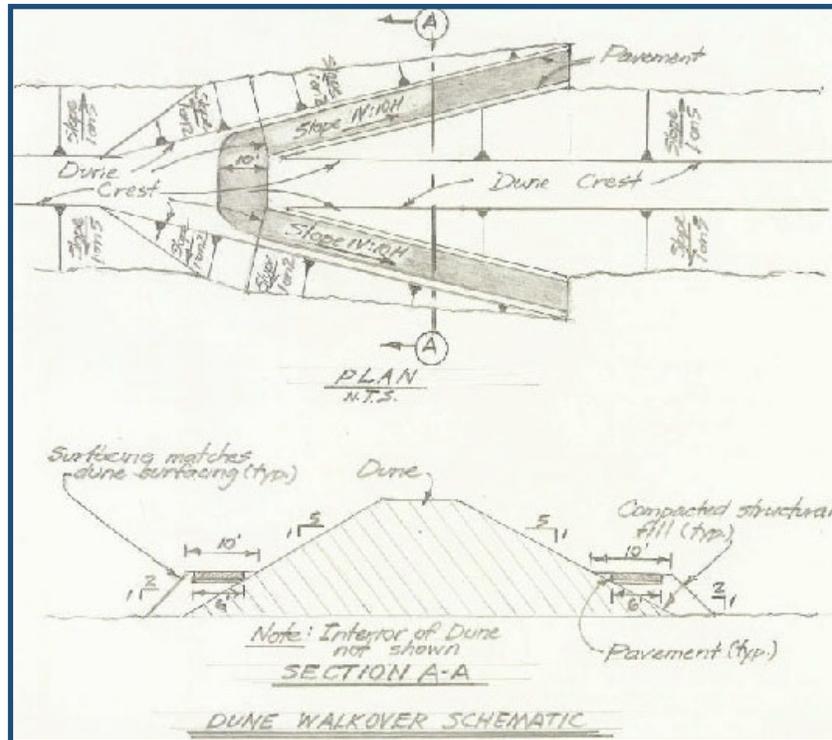


Figure B1-7: Typical Earthen Ramp Walkover Details

## Chapter 6: Construction Coordination

### 6.1 Rights-of-Way

The proposed plan will require acquisition of a right-of-way corridor wide enough to allow for the footprint of all permanent design features as well as enough room for future flood event monitoring and recurring inspection activities. The following assumptions for right-of-way acquisition layout were used:

- Permanent easement: 15 feet from centerline of floodwall, and 5 feet, minimum, from the outside edge of any permanent design feature.
- Temporary easement: For Construction Limits, 25 feet of the centerline of floodwall, and 5 feet from the permanent easement for other features.

Additionally, two acres for contractor staging were assumed. The actual location(s) for contractor staging will need to be determined during the PED phase of the project. See Appendix D, Real Estate Plan for additional right-of-way details.

### 6.2 Utilities

Utility costs at this point in the study have been captured in the items associated with the Interior Drainage Features. This design calls for the extension or modification of existing outlets; see Appendix B4, Hydrology and Hydraulics for additional details on the Interior Drainage Features.

It is not anticipated that many conflicts with utilities will be encountered since the majority of the proposed design features will be installed on the seaward side of the existing protection. However, as the design of the T-Wall system and Interior Drainage Features is further refined during the course of PED, areas of potential conflict with existing utilities will need to be identified.