Pawcatuck River
Coastal Storm Risk Management
Feasibility Study

Draft Feasibility Report
October 2016

Appendix D

Engineering and Design

Table of Contents

Introduction

1.1 Study Area

The Misquamicut Beach area is located along the southern portion of Rhode Island and is situated about two and one half miles east of the village of Watch Hill, and is wholly in the town of Westerly. The location of the Misquamicut Beach Area is shown in Figure 1.1. The study area consists of approximately three and one eighth miles of shorefront and adjacent backshore areas between Little Maschaug Pond on the west and Weekapaug Breachway on the east. Much of the backshore area is occupied by Winnapaug Pond, a tidewater pond linked to the ocean by the Weekapaug Breachway.

The study area is comprised of mixed commercial and residential structures located along the beachfront. The study area also includes a number of affected residential and commercial structures located on the north side of Atlantic Avenue, the main road that parallels the shoreline. Residential enclaves north of Atlantic Avenue include the Misquamicut neighborhood between Little Maschaug Pond and Winnapaug Pond. Residential and commercial properties in these areas experience damage during coastal storm events.

Most past damages, especially in the recent past, have occurred to the exposed sand dunes and beachfront structures. The continuing beach erosion has made shorefront properties more vulnerable to storms of a given magnitude than they would have in years past. This study reexamines previous shore protection initiatives in this area, including elements of a previous study from the early 1990's. Several alternative plans have been formulated to alleviate damages to the study area.

Figure 1.1 – Location Map

1.2 Existing Shoreline Conditions

Misquamicut Beach is a low-lying narrow sandy beach barrier located near the western limit of the south coast of Rhode Island. The beach, which extends a distance of approximately 5.3 miles east from Watch Hill Point to Weekapaug Point, separates the offshore waters of Block Island Sound from those of several bordering coastal ponds. Winnapaug Pond, the largest of these embayment's, has free communication with Block Island Sound via the Weekapaug Breachway cut through the beach. Although originally present as a small creek, this inlet is now maintained in position by riprap armoring of the channel and two stone jetties. The east jetty was constructed in 1900 and the west jetty in 1954 by the State of Rhode Island. The remaining ponds (Mickill, Maschaug, and Little Maschaug) are effectively isolated from Block Island Sound.

The dune line, backshore, and foreshore of Misquamicut Beach are composed primarily of fine to medium sands interspersed with occasional areas of coarser sands and gravel on the upper foreshore. The bulk of this material is glacial in origin and was supplied primarily by ice advance and meltwater runoff over the Charlestown moraine which borders the inshore limit of the coastal ponds. Erosion and weathering of local till headlands such as Weekapaug Point represent a secondary source.

Misquamicut Beach is typified by sandy beaches, sandy dunes, and stone revetments. The beach berm varies in width from about 50 feet to 150 feet with dune elevations ranging from about +6 feet (NAVD88) to approximately +16 feet (NAVD88). Beach face slopes in the area remain essentially constant. Foreshore slope values range from approximately 1V:15H during the summer to between 1V:20H and 1V:25H during the winter. With increasing energy conditions during the winter, the berm progressively erodes until the upper beach merges uniformly with the intertidal zone. Farther east along the beach, there is no well-developed summer berm and slopes grade uniformly away from the base of the dune line at approximately 1V:30H during the summer to between 1V:20H and 1V:25H in the winter.

1.3 Existing Offshore Bathymetry Conditions

The sea floor immediately adjacent to Misquamicut Beach consists primarily of fine to medium sands with occasional areas of glacial till. These materials are actively eroded and transported by local wind waves and tidal currents resulting in varied and dynamic bathymetric contours (see Figure 1.2). Average depth contours begin essentially shore-parallel in the area adjacent to Watch Hill Point. Proceeding eastward, contours become progressively more irregular in orientation leading to a well-defined shoal in the area offshore of Maschaug and Little Maschaug Ponds. The irregularity associated with this feature extends for about 3,800 feet along the beach. Continuing eastward, contours again become shore-parallel and essentially maintain this orientation until a second major shoal is encountered at a distance of about 2.5 miles east of Watch Hill Point. This feature, associated with a till deposit, is extremely variable in outline and extends alongshore for a distance of approximately 1.6 miles modifying the incident wave field and resultant beach sediment transport. Beyond this shoal contours regain a parallel orientation to the beach which continues to Weekapaug Point.

Beyond the immediate beach area, contours are moderately smooth and regular. Within Block Island Sound, the average depth is about 98 feet with significant variations noted in the vicinity of the submarine ridge extending between Montauk Point and Block Island. This feature, including Montauk Point and Block Island provides significant sheltering for the south coast of Rhode Island serves to substantially modify the character of the wave field propagating shoreward from the adjacent continental shelf. The ridge is cut from north to south by the relict drainage pattern associated with the Block Channel which extends south across the shelf to the Block Canyon. Within Block Island Sound, this drainage pattern consists of two submerged valleys with maximum depths of 180 feet. The northernmost valley directly affects the wave's incident angle on Misquamicut Beach.

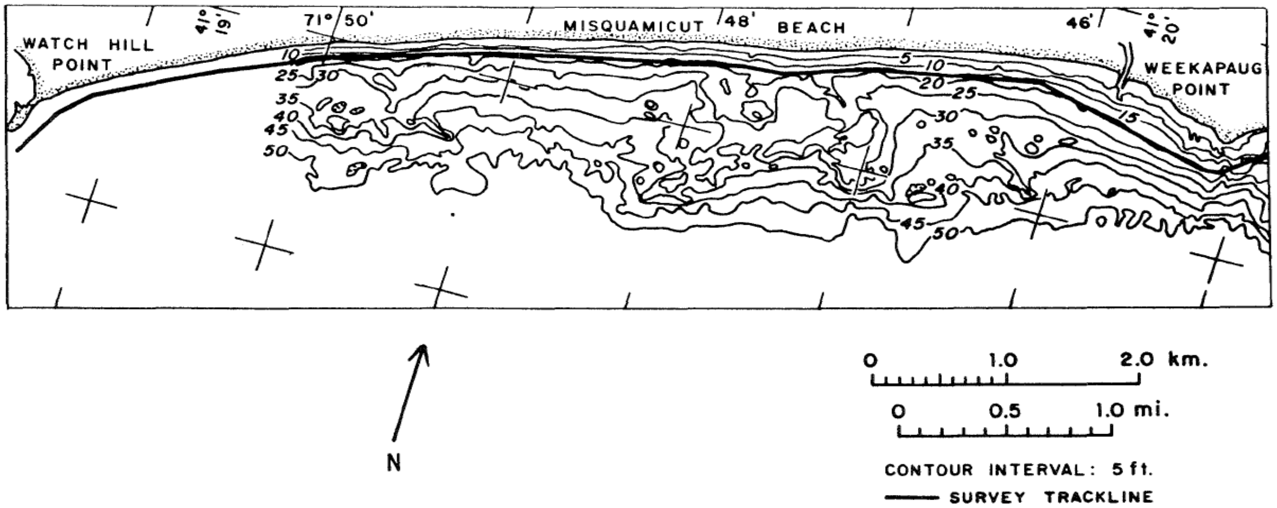


Figure 1.2 – Nearshore Bathymetry adjacent to Misquamicut Beach

Chapter 2: Survey Data

2.1 Topographic Data

Topographic data used for this study was generated through Bentley's InRoads using 2013-2014 USGS Post-Sandy Lidar (MA, NH, RI) obtained from National Oceanic and Atmospheric Administration's (NOAA's) Digital Coast Data Access Viewer. Horizontal data from the survey is referenced to Rhode Island State Plane Coordinate System, NAD 83, US Survey Feet and vertical data is referenced to NAVD88, US Survey Feet.

2.2 Bathymetric Data

Bathymetric data used for this study was generated through Bentley's InRoads using 2010 USACE Topobathy Lidar obtained from National Oceanic and Atmospheric Administration's (NOAA's) Digital Coast Data Access Viewer. Horizontal data from the survey is referenced to Rhode Island Plane Coordinate System, NAD 83, US Survey Feet and vertical data is referenced to NAVD88, US Survey Feet.

Chapter 3: Project Alternatives

Preliminary Alternatives Array

Preliminary alternatives considered for this study include:

3.1 Area 1 - Misquamicut in Westerly (Little Maschaug Pond to Weekapaug Breachway)

Preliminary alternatives considered for this study include:

Alternative 1: No Action Alternative
Alternative 2: 4000 LF of Beach Fill with Dune and 6500 LF of Flood Wall (Misquamicut Village)
Alternative 3: 4000 LF of Beach Fill with Dune (Misquamicut Village)
Alternative 4: 9200 LF of Beach Fill with Dune
Alternative 5: 9200 LF of Beach Fill with Dune, 1900 LF of Flood Wall, and Tide Gate at the Weekapaug Breachway
Alternative 6: Non-Structural Alternative (elevation of structures)

Plans and details of the various alternatives can be found in the "Attachments" at the end of this appendix.

3.1.1 **Alternative 1:** No Action Alternative

This alternative assumes no action for coastal storm damage reduction and does not require civil design input.

3.1.2 **Alternative 2:** 4000 LF of Beach Fill with Dune and 6500 LF of Flood Wall (Misquamicut Village)

This alternative consists of the shoreline being re-nourished with beach fill by installing a 4,000 linear foot beach berm and dune running parallel with the shoreline from the vicinity of the east shore of Little Maschaug Pond to the west end of the Misquamicut State Beach, to include 6,500 linear feet of flood wall. The flood wall is broken up into a westerly flood wall and an easterly flood wall. The west flood wall will run north approximately 1,900 linear feet from a flood gate at Atlantic Avenue past the east shore of Little Maschaug Pond to tie into high ground at approximately elevation +10.5 feet (NAVD88) near the edge of the Misquamicut Club golf course. The east flood wall will run north approximately 4,600 linear feet from a flood gate at Atlantic Avenue past the west shore of Winnapaug Pond to tie into high ground at approximately elevation +10.5 feet (NAVD88) on farmland near Shore Road.

3.1.3 **Alternative 3:** 4000 LF of Beach Fill with Dune (Misquamicut Village)

This alternative consists of the shoreline being re-nourished with beach fill by installing a 4,000 linear foot beach berm and dune running parallel with the shoreline from the vicinity of the east shore of Little Maschaug Pond to the west end of the Misquamicut State Beach.

3.1.4 **Alternative 4:** 9200 LF of Beach Fill with Dune

This alternative consists of the shoreline being re-nourished with beach fill by installing a 9,200 linear foot beach berm running parallel with the shoreline from the vicinity of the east shore of Little Maschaug Pond to 2,100 linear feet east of the easterly end of the Misquamicut State Beach.

3.1.5 **Alternative 5:** 9200 LF of Beach Fill with Dune, 1900 LF of flood wall, and Tide Gate at the Weekapaug Breachway

This alternative consists of the shoreline being re-nourished with beach fill by installing a 9,200 linear foot beach berm running parallel with the shoreline from the vicinity of the east shore of Little Maschaug Pond to 2,100 linear feet east of the easterly end of the Misquamicut State Beach with a west flood wall and tide gate. The west flood wall will run north approximately 1,900 linear feet from a flood gate at Atlantic Avenue past the east shore of Little Maschaug Pond to tie into high ground near the edge of the Misquamicut Club golf course at approximately elevation +10.5 feet (NAVD88). The tide gate will be located at the Weekapaug Breachway.

3.1.6 **Alternative 6:** Non Structural Alternative (elevation and/or acquisition)

This alternative consists of non-structural storm damage reduction features in property buyouts and/or elevating the structures for the most affected properties throughout the study area (coastal flood plain in Westerly, Charlestown, South Kingstown, and Narragansett).

Chapter 4: Beach Fill Design

4.1 Borrow Site

Although no particular borrow site was looked at, it was assumed that a sufficient quantity of upland sand will be available for the project within 6 miles from the project site.

4.2 Volume Calculations

Bentley InRoads surface modeling software was used to develop initial existing and proposed surface models to estimate initial quantities of beach fill for the various alternatives. Bentley InRoads uses the Delaunay triangulation technique to interpolate data and create the surface models. Final estimates of material volumes and surface areas were also calculated using Bentley InRoads.

4.3 Initial Beach Fill Profiles

Beach fill measures consist of placing sand in order to create or expand the beach berm (the flat 'shoreline' part of the beach) or dune (the more elevated portion of the beach landward of the beach berm). Beach fill measures are oftentimes considered preferable to hardened structures (e.g. breakwaters, groins, seawalls, revetments) because beach fill mimics the natural environment and can be shaped to maximize net storm damage reduction benefits. Additionally, a beach fill measure is naturally adaptable to sea level rise. However, the beach fill template would need to be periodically re-nourished throughout the life of the project.

The beach berm reduces coastal storm damages by increasing the distance between structures and the water, thus reducing the potential for erosion related damages, and dampening storm surge and wave heights. It is also the area of the beach that is generally recreated upon. The dune functions as sacrificial line of defense and an additional repository of sand, and can further protect structures from wave attack.

The following beach fill measures were considered:

4.3.1 Beach and Dune Combination Cross Section

The beach and dune combination design template is beach fill consisting of a dune and beach berm with the designed dunes (where applicable) abutting existing dunes and stone revetments on the seaward side; the existing dunes and stone revetments were assumed to remain in place. The design dune template is tied to a control line, which is based on the seaward edge of the proposed dune. The design dune consists of a top width of 10 feet at an elevation ranging from +12 to +14 feet (NAVD88) with landward and seaward slopes at 3 horizontal to 1 vertical (3H:1V). The design beach berm elevation is +9 feet (NAVD88) with a berm width, measured from the toe of the constructed dune seaward, ranging from 30 feet to 50 feet. This was considered our "minimum" design profile. Seaward of the designed beach berm width, the profile closely parallels the existing profile slope of 10 horizontal to 1 vertical (10H:1V) out to a closure depth of –10 to -15 feet (NAVD88). See Figure 4.1.

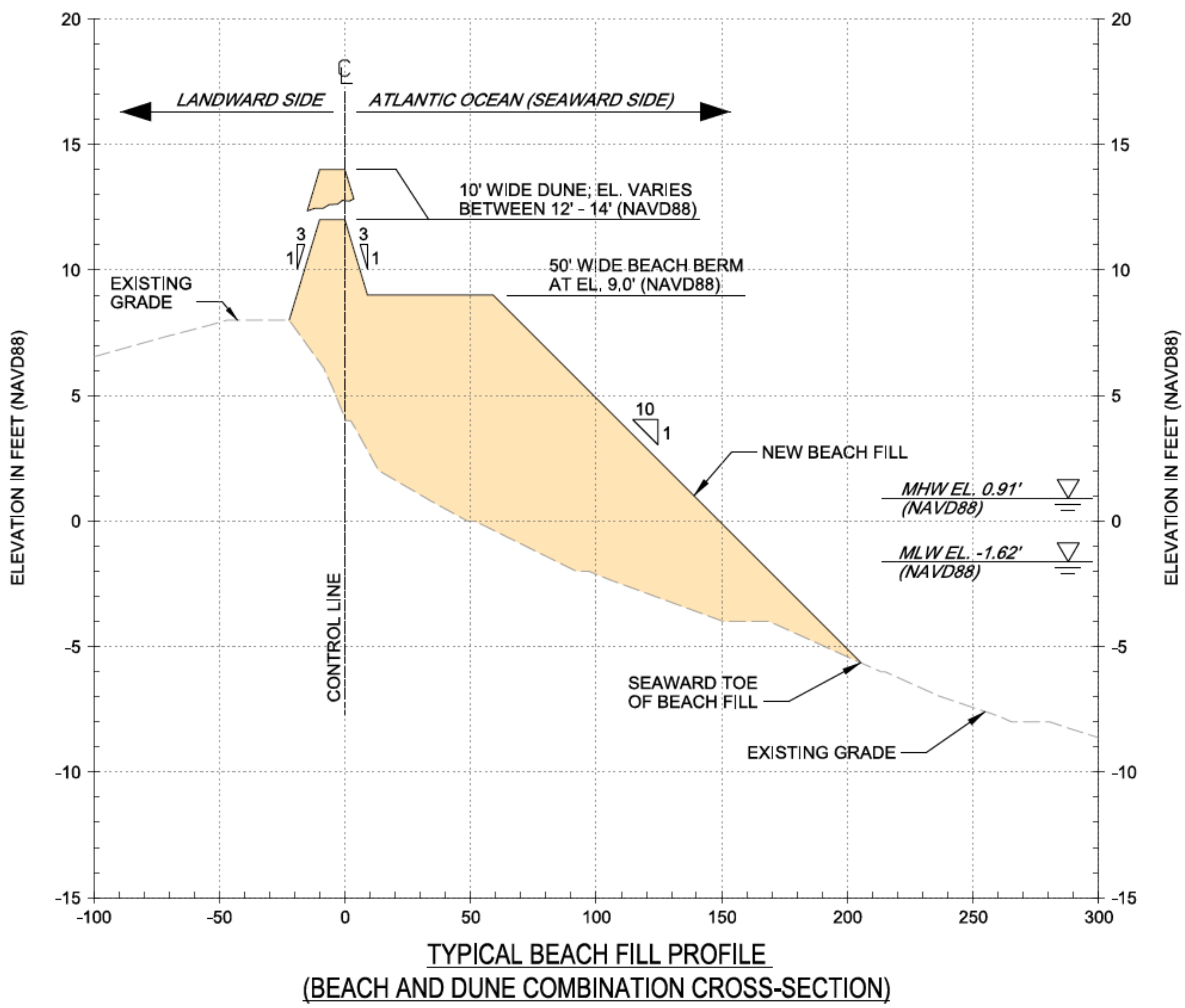


Figure 4.1 – Typical Beach Fill Profile (Beach and Dune Combination Cross-Section)

4.3.2 Beach Berm Only Cross Section

The beach berm only profile applies to the extents of Misquamicut State Beach only. The design template is fill extending seaward from the existing sand dune at an elevation of +9 feet (NAVD88), approximately the elevation of the existing berm along the Misquamicut State Beach portion of the study area. The beach berm width, measured seaward along the top of the berm from the point where the top of proposed berm intersects the existing dune profile, ranges from 100 feet to 120 feet. Seaward of the designed beach berm width, the profile closely parallels the existing profile slope of 10 horizontal to 1 vertical (10H:1V) out to a closure depth of –10 to -15 feet (NAVD88). See Figure 4.2. Beach berm only templates with widths less than 50 feet are not considered practical because they provide very little effective coastal storm protection. This was considered our "maximum" design profile.

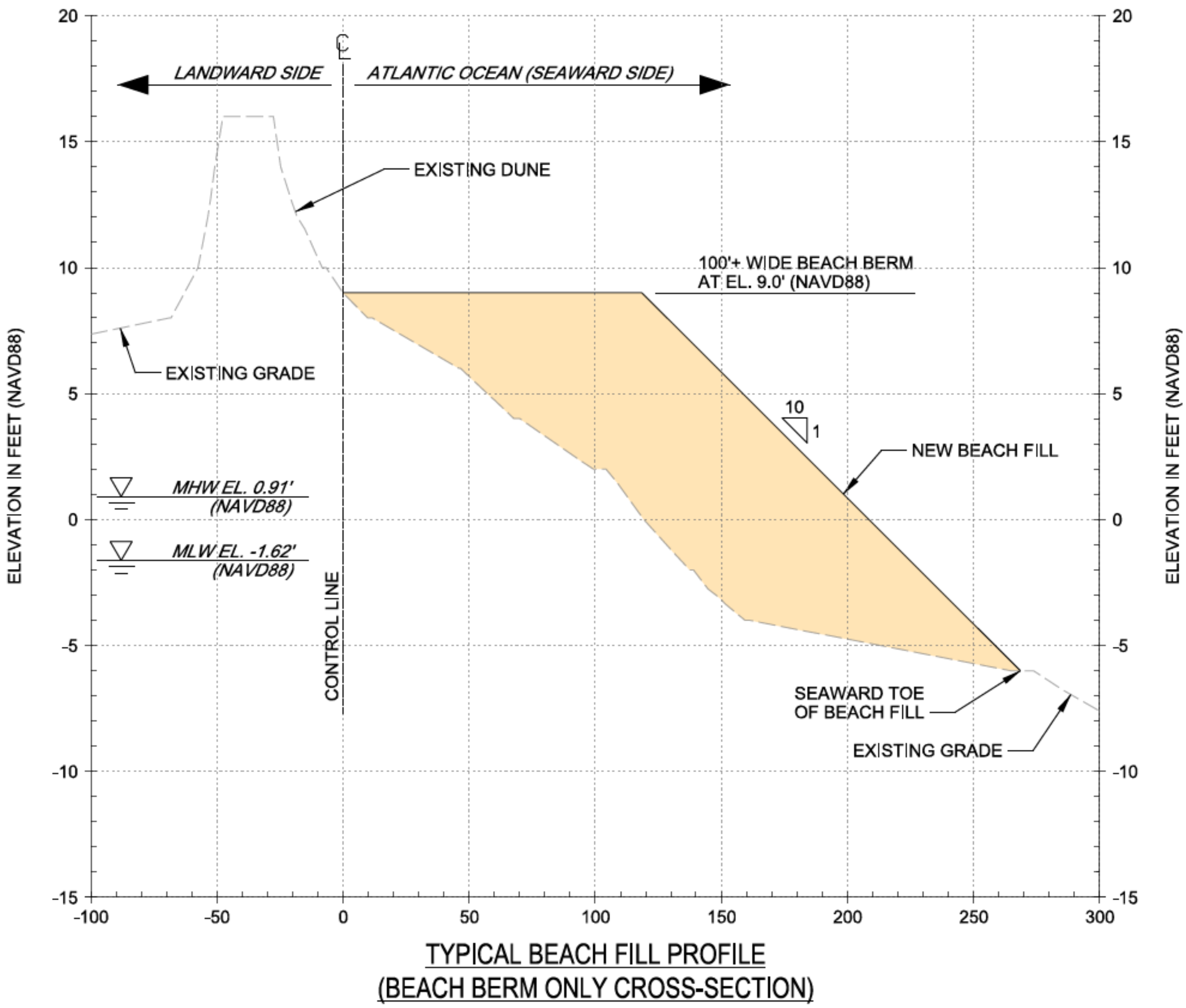


Figure 4.2 – Typical Beach Fill Profile (Beach Berm Only Combination Cross-Section)

Chapter 5: Sheet Pile Wall Design

Two alternatives required floodwall analysis in the Pawcatuck Coastal Study. The walls will be varying in height. For this analysis an assumed 5’- 6” wall and an 8’- 6” wall were analyzed. These heights were analyzed based of level of protection needed in the area. The floodwalls would be constructed of sheet piling with precast concrete fascia panel mounted on the protected side (see Figure 5.1).

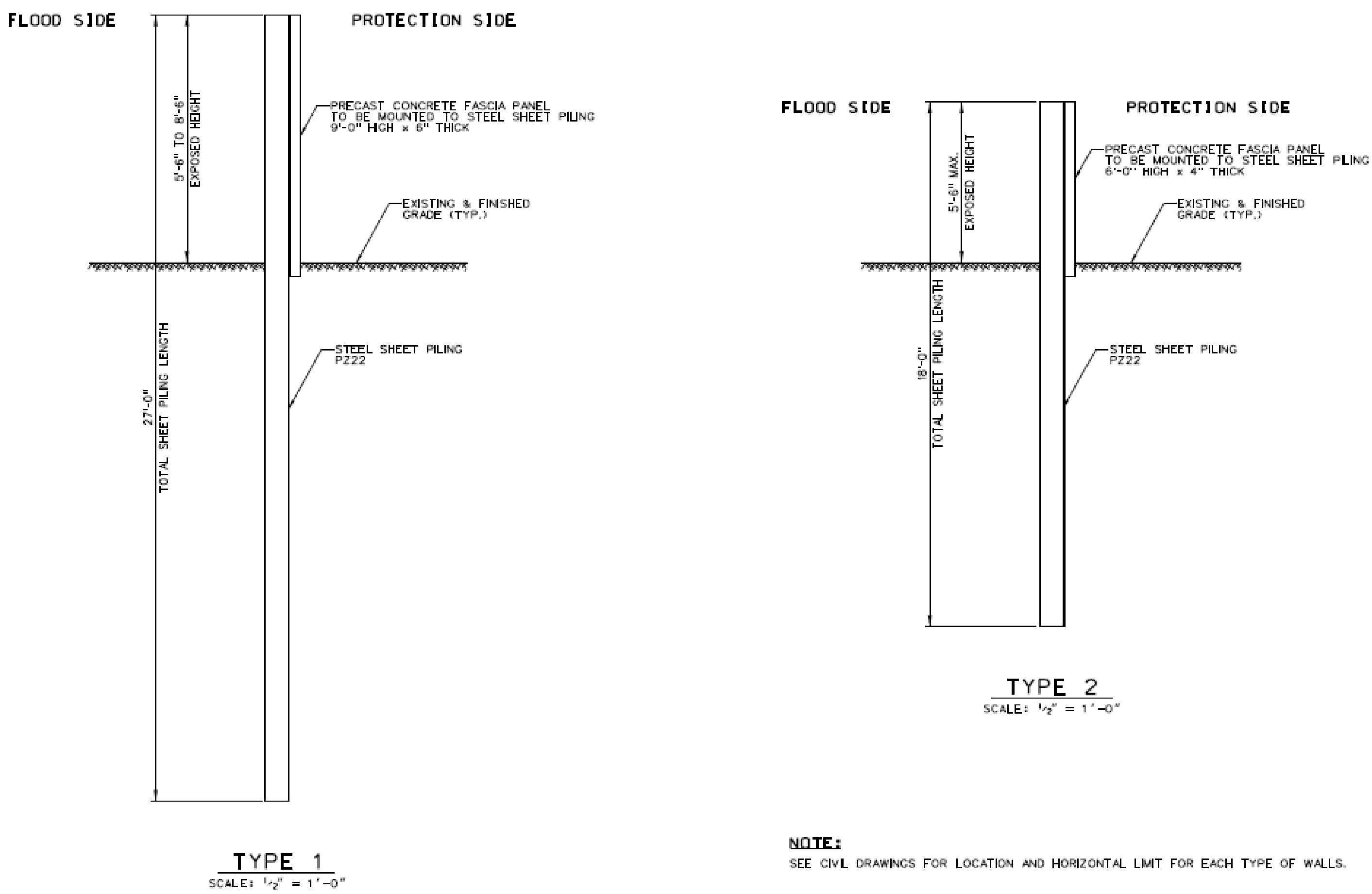


Figure 5.1: Floodwall Design – Type 1: 8’-6” wall; Type 2: 5’-6” wall

Existing foundation borings in the area are limited. Soil properties were assumed for floodwall calculations. Based on the 1967 Surficial Geologic Map and Bedrock Map of the Watch Hill Quadrangle of the Watch Hill Quadrangle Washington County, Rhode Island and New London County, Connecticut, the subsurface was assumed to be a medium to coarse grain sand throughout the area. No subsurface boring information was available in the floodwall area, however, there were borings done in 1993 in the adjacent Winnapaug Pond. There were dense soils found roughly 5-7 feet below the surface in boring FD93-1 and FD93-6 (closest borings to the floodwall area). This information, along with the Geologic Maps, were used to determine the soil properties.

Subsurface investigations will need to be performed prior to final design to refine required wall embedment.

Calculations were done assuming both a 5'-6" foot and 8'-6" foot high floodwall. Due to the height of the wall, the sheet pile penetration will have to be at least twice the depth of the exposed height. During design, once subsurface investigations are complete, a seepage study will also be performed to ensure the sheet pile embedment is adequately designed for to minimize under seepage.

Chapter 6: Tie-Ins

6.1 4,000 LF Beach Fill and Flood Wall End Tie-Ins

6.1.1 **Alternative 2:** 4000 LF of Beach Fill with Dune and 6500 LF of Flood Wall (Misquamicut Village)

Both the west and east ends of the new dune will be tied into the flood wall. The southerly end of both west and east flood walls will be tied into new flood gates located at Atlantic Avenue. Both the west and east ends of the beach berm will be graded from the new beach berm elevation to the existing beach grade.

6.1.2 **Alternative 3:** 4000 LF of Beach Fill with Dune (Misquamicut Village)

Both the west and east ends of the new dune and new beach berm will be graded from their respective elevations to the existing beach grade.

6.2 9,200 LF Beach Fill and Flood Wall End Tie-Ins

6.2.1 **Alternative 4:** 9200 LF of Beach Fill with Dune

Both the west and east ends of the new dune and new beach berm will be graded from their respective elevations to the existing beach grade.

6.2.2 **Alternative 5:** 9200 LF of Beach Fill with Dune, 1900 LF of flood wall, and Tide Gate at the Weekapaug Breachway

The west end of the new dune will be tied into the west flood wall. The southerly end of the west flood wall will be tied into a new westerly flood gate located at Atlantic Avenue. The east ends of both the new dune and new beach berm will be graded from their respective elevations to the existing beach grade. The new tide gate at the Weekapaug Breachway will be tied into the west and east side slopes of the channel.

The 56-foot Tide Gate will be located on the south side of the breachway channel. The Tide Gate System is a Stop-Log Closure Structure which consists of a Concrete "U-Frame" and wing walls supported on piles and sheet piling cutoffs, and the frame will have slots to accommodate the bulkheads.

The stop-log structure was considered to be a multi-bulkhead system. Each bulkhead is composed of two deep steel wide-flange members. These members span the width of the chamber and are connected by intermittent vertical frames to transfer forces between the two. A skin plate creates the impermeable vertical barrier while rubber seals between bulkheads keep water from seeping through. Bulkheads are placed in the chamber by means of a crane system. Tide Gate plans and details can be seen in the attachments of this appendix.

Chapter 7: Access

7.1 Private Property Beach Access

New timber dune walkovers similar to Figure 3.1 will be constructed at two locations along the 4,000 linear foot beach fill and at four locations along the 9,200 linear foot beach fill. The timber dune walkovers will be necessary to allow for continued beach access from the residential and commercial properties along Atlantic Avenue to the ocean side of the beach fill. The preliminary locations of the timber dune walkovers can be seen on the individual alternative site plan.

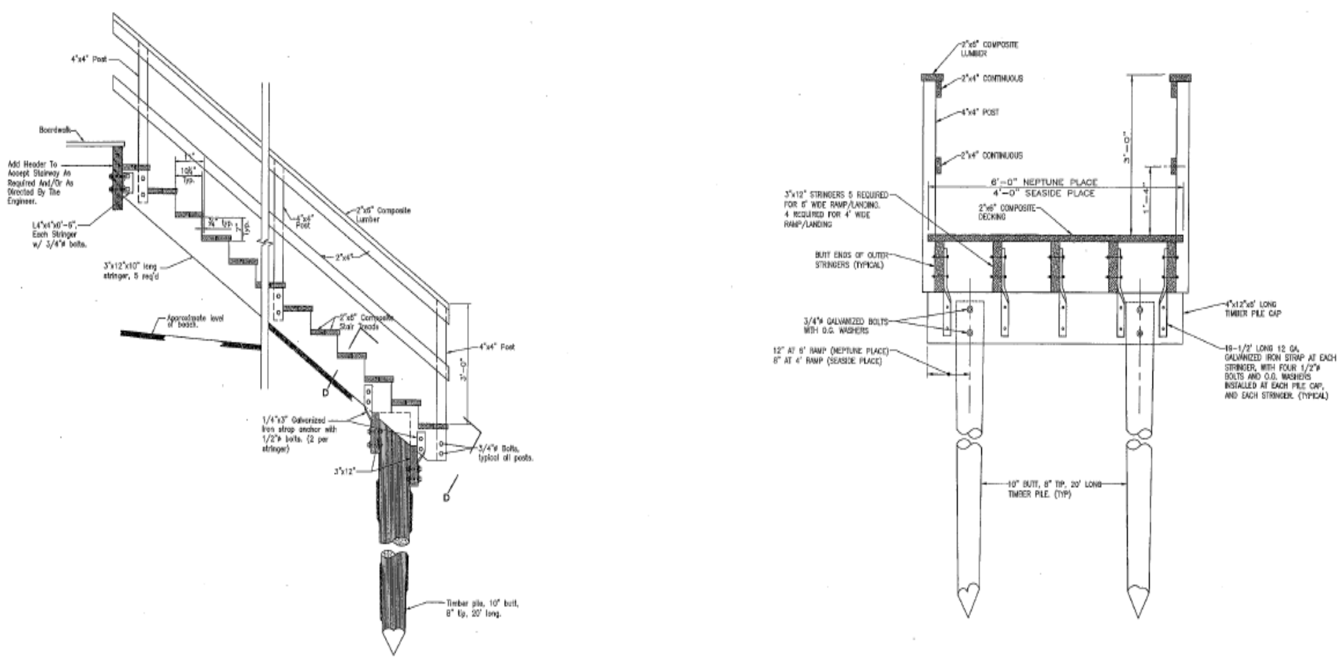


Figure 3.1 – Timber Dune Walkover

7.2 Public Beach Access

The public beach access and parking used for Misquamicut State Beach will remain in place as exists. Except for the placement of beach fill to reestablish the beach berm to elevation +9 feet NAVD88, there will be no new dunes installed between the west and east ends of Misquamicut State Beach.

Chapter 8: Right-of-Way

The proposed alternatives will require acquisition of right-of-ways wide enough to allow for the footprint of all permanent design features as well as enough room for future flood event monitoring, recurring inspection activities, and for operations and maintenance. For the final alternatives array, the following assumptions for right-of-way acquisition were used:

- Permanent easements (Beach Fill): To the extent of the beach fill encompassing the property, i.e. from landward toe of beach fill seaward to rear property line.

- Permanent easements (Sheet Pile Walls): To the extent where the 20 foot wide easement (10 feet on either side of wall) encompassed the property.

- Permanent easements (Tide Gate): For the western side of the tide gate, the area between the channel property line and the existing retaining wall with access from Atlantic Avenue. For the eastern side of the tide gate, a 25-foot easement from Wawaloam Drive to tide gate.

Permanent easements are shown for the alternatives on the Real Estate Plans for each alternative. These easements represent the same area required in each alternative. Contractor storage and staging areas were assumed based on previous construction projects. The actual location(s) for contractor storage and staging will need to be determined during a future phase of the project.

Chapter 9: Utilities

For the beach fill work, it is not anticipated that any utilities will be encountered since the majority of the proposed beach fill will be installed on the seaward side of the existing properties.
There is a stormwater outfall that discharges in Winnapaug Pond from Wawaloam Drive that could present a potential conflict with the east flood wall. Based on preliminary investigations, this outfall could be extended through the to a new rip-rap stabilized outfall as part of Alternative 2.

Chapter 10: Interior Drainage

10.1 Relevant Criteria

Interior areas are the areas protected from direct flooding by levees, floodwalls, or seawalls. One interior drainage analysis was conducted for all alternatives in this study, since the manner of flooding and the consequent protected area are similar in all alternatives. The interior drainage was analyzed in consideration of the following information and guidance:
- EM 1110-2-1413, *Hydrologic Analysis of Interior Areas* (EM 1413);
- ER 1100-2-8162, *Incorporating Sea Level Change in Civil Works Programs,* 2013;
- Town of Westerly E-Code, Stormwater and Storm Sewer standards, Chapters 223 and 224; and

- Rhode Island Department of Environmental Management, Stormwater Best Management Practices.

The interior drainage patterns were compared between the without-project (existing) and the with-project (proposed) conditions. Previous Corps guidance on hydrologic analysis of interior areas relied on the sponsor or local municipality to prepare storm sewer designs. For this project, and due to the unique nature of the proposed protection, however, the possibility was considered that a storm sewer system might be designed here as an integral component of the Local Flood Protection Project. According to EM 1413, the selection of design procedures also includes consideration of local policies and practices. No increase in interior flooding is also desirable.

The Town of Westerly E-code, Part II, General Legislation, was referenced from the website, http://ecode360.com/WE1997?needHash=true. Chapter 223, Storm Sewers, is intended to "regulate contribution of pollutants to municipal separate storm sewer system (MS4)". §223-2 defines "construction" activities as being subject to Rhode Island Pollutant Discharge Elimination System (RIPDES) construction permits. A RIPDES general permit, for example, covers projects with land disturbance greater than one acre. Details were viewed at http://www.dem.ri.gov/pubs/regs/regs/water/ripdesca.pdf. Even if this project were subject to such a permit, it is not anticipated to impact the design because the drainage pattern remains similar. Chapter 224, Stormwater Management, provides performance criteria for proposed development projects. Although §224-10 identifies stormwater performance criteria, this project is not considered subject to these because it is not "land development", it is flood protection. In addition, to note, §224-9 provides for waivers from stormwater requirements. Whether these local requirements are actually applicable can be confirmed in the detailed design phase of this project.

10.2 Description of Existing Drainage System

Much of the landscape between Maplewood and Lawton Avenues of the project study area runs generally downhill from north to south, down to Atlantic Avenue. East of Lawton Avenue, the land drains more in a southeasterly direction, toward Winnapaug Pond. In the short distance between Atlantic Avenue and the ocean is a slight rise in terrain, much of which is occupied by commercial buildings. The area between Maplewood Avenue (to the west) and Winnapaug Road (to the east) is largely residential. Its western edge drains to Little Maschaug Pond; surface runoff from the far eastern edge heads into Winnapaug Pond to the east.

For the majority of this residential area, rainfall runoff drains overland onto the paved streets and downhill toward the flat main thoroughfare, Atlantic Avenue. Catch basin inlets are situated near the downhill ends of the north-south running streets, and along Atlantic Avenue itself. A main storm sewer line on Atlantic Avenue runs easterly and drains into Winnapaug Pond.

10.3 Interior Drainage System Evaluation and Results

Details of the storm sewer system and the overland surface drainage were evaluated to assess impacts from the proposed floodwall and dunes, as well as to compose solutions for any consequent interior flooding. Field visits were made to the project area and observations made of catch basins, storm sewer pipes, and outfall(s). In addition, NAE personnel spoke with

Westerly Town Engineer, Mr. Paul LeBlanc, and gathered reports from residents and online articles. Although the town engineer had mentioned a “pumping station” along Atlantic Avenue, no evidence of this was found in the field. It was thus presumed that the flow is by gravity out into Winnapaug Pond. Although the actual outfall into the pond was not identified in the field, indicators of disturbance on the aerial photography suggest the outfall is near the north edge of the parking lot, on the north side of Atlantic Avenue, across from Paddy’s Beach Club.

Standing water levels were observed in catch basins along Atlantic Avenue. In the last inlet before entering Winnapaug Pond, on Atlantic Avenue just east of the Winnapaug Road/Atlantic Avenue intersection, the observed water level was approximately elevation 2.7’ NAVD88. This is estimated from a depth identified in the field (1’ below grate) and from the project’s base topography map. This observation was made at approximate low tide on July 29, 2015.

Assessment of the existing conditions of surface drainage, then, reveals that Atlantic Avenue floods even in small rainfalls. Daily high tide additionally restricts outflow from Atlantic Avenue into Winnapaug Pond. With the standing water evident in the lowest catch basin in the streamline, it is also likely that the storm sewer pipes contain water at low tide. These factors contribute to the back-bay flooding.

On the eastern edge of the residential area, in the vicinity of Rabbit Run, surface runoff flows amongst houses and across flat slopes vegetated with lawns, shrubs, or woods. Similarly, on the western edge near Maplewood Avenue, runoff flows across lawns and woods into the pond at Misquamicut Club golf course.

In proposed Alternatives 2 through 5, the tops of dunes are higher than the existing topography. This creates a small area that is subject to producing additional rainfall-runoff onto Atlantic Avenue. The potentially contributing area is roughly a 2-foot-wide swath of landside dune for the length of the dunes. Since the vegetated dunes will be constructed of sand and not of low-permeability soil, rainfall is expected to infiltrate. No additional runoff is expected from the dunes to Atlantic Avenue storm sewer in the with-project condition.

On the eastern edge of the residential area, roughly from 2nd Street down to Atlantic Avenue, the proposed floodwall would block the overland flow that presently outlets into Winnapaug Pond. Similarly, the west floodwall would block runoff from the properties situated between Boxwood and Atlantic Avenues that presently outlets into Little Maschaug Pond.

The areas of induced flooding that need remedy, then, are the eastern and western edges and the single-point outlet of the Atlantic Avenue storm sewer line. The blocked overland flow can be relieved with gravity outlets through the floodwalls. Land grading will ensure surface runoff flows to these outlets. The storm sewer line that outlets into Winnapaug Pond will flow through a constructed opening in the floodwall. The outfall will be outfitted with a one-way duckbill valve, such as a Tideflex check valve. No pumping station is therefore needed.

Consideration was also given to modeling surface runoff in HEC-HMS for the project area, and modeling storm sewer flow in the proprietary software, StormCAD. However, with the decision that no pumping station is needed, undertaking these models was deemed not warranted. The interior drainage in the storm sewers is not made worse, therefore determining the flows therein is not needed. For overland flow, the contributing areas are small and runoff into the proposed gravity outlets can be estimated by the Rational Method or TR-55.

10.4 Coincidence of Interior and Exterior Water Levels

The correlation of interior and exterior water levels is used in the economic analysis of damages, such as in riverine settings when a constructed levee blocks outflow of the river. EM 1110-2-1413 identifies methods for evaluating coincidence, from one extreme of no coincidence between the two, to the other extreme when interior and exterior levels are either both high or both low at the same time.

For this coastal setting, the manner and pattern of interior flooding are different than a typical riverine/levee landscape. Influence from coastal waters is deemed the predominant factor in interior water levels for the without-project condition, particularly at low annual chance exceedances (ACE, or frequency). Not only storm surge, wave action, and tides, but the rise in coastal water level as one approaches the existing ridge line at the beach from the ocean, are contributing phenomena. The results of the North Atlantic Coast Comprehensive Coastal Study (NACCS, 2015) include stage-frequency curves. The detailed study of these factors and interactions, as well as specifics on the ADCIRC and STWAVE models, is found in the Coastal Appendix. Back-bay flooding from Winnapaug Pond is also prominent, even when storm surge is not. For these reasons, the interior water surface elevations used for economic analysis were adopted from the coastal studies.

10.5 Sea Level Change

USACE ER 1100-2-8162 stipulates that the potential relative sea level change be evaluated. Effects of sea level change were modeled for this project in the economics model, HEC-FDA, and by ERDC in the model, Beach-fx. The value of 0.6-foot rise over 50 years, the USACE "low rate" value, was adopted. See the Coastal Appendix for further details.

10.6 Summary

Interior drainage in the without-project (existing) conditions was compared to the with-project (proposed) conditions. The assessment reveals that interior flooding, resulting from placement of the floodwalls and dunes, is limited to three sources. Outflow is impeded at the storm sewer outfall at the east end of Atlantic Avenue into Winnapaug Pond, the western edge of the study area draining overland into Little Maschaug Pond, and the eastern edge draining overland into Winnapaug Pond. This flooding is remedied with the following two provisions:

- Install an opening in the floodwall to outlet the storm sewer from Atlantic Avenue into Winnapaug Pond. Include a one-way duckbill valve on the outlet end.
- Install gravity outlets (outlet structures) through the floodwalls to outlet overland flow from the eastern and western edges of the residential areas into the adjacent ponds.

These are considered the "minimum facility", as described in EM 1110-2-1413 Section 3.2c. These measures provide relief from interior flooding by the erection of the floodwall and dunes, to enable the local storm drainage system to function essentially as it did in the without-project condition during low exterior stages.

In the without-project condition, interior flooding results from predominantly coastal effects and back-bay flooding from Winnapaug Pond. Stage-frequency curves and remaining details of that modeling are in the Coastal Appendix.

In the with-project condition, the existing storm sewer system is left in place to continue to function as it does presently. The proposed gravity outlet structures through the floodwall will relieve additional interior flooding from rainfall-runoff.

Chapter 11: Elevation of Structures

11.1 Design Criteria

The Federal Emergency Management Agency (FEMA) is responsible for administering the National Flood Insurance Program (NFIP). The NFIP was established to address issues associated with the flooding of, and subsequent damages incurred by, structures within the 100-year floodplain. All properties within the 100-year floodplain are required to be insured under the NFIP. However, the NFIP recognizes that buildings which are properly floodproofed, or elevated above flood levels, will be much less susceptible to flood damages. Therefore, the NFIP strongly encourages, and in some cases requires, buildings to be elevated or floodproofed according to NFIP criteria. In support of this objective, the U.S. Code of Federal Regulations include building design criteria that is required for all new construction and substantially improved existing buildings within flood-prone areas. These "protected" buildings are also granted significant decreases in flood insurance premiums.

Since all of the houses evaluated for elevation are located within the 100-year floodplain, they are subject to NFIP regulations. Therefore, all of the houses considered in this project will be elevated in accordance with applicable NFIP regulations and other FEMA documents. Additionally, the local building code, and local Zoning Regulations will be adhered to as necessary. Following is a list of the publications used during this feasibility study and for final design:

a. U.S. Code of Federal Regulations, Title 44, Sec. 60.3, "Building Performance Standards of the NFIP".
b. FEJ\1A 54, "Elevated Residential Structures", March 1984.
c. FEMA 114, "Design Manual for Retrofitting Flood-prone Residential Structures", September 1986.
d. FEMA Technical Bulletin 1-93, "Openings in Foundation Walls", April 1993.
e. FEMA Technical Bulletin 2-93, "Flood-Resistant Materials Requirements", April 1993.
f. FEMA Technical Bulletin 5-93, "Free-Of-Obstruction Requirements", April 1993.
g. The Building Officials & Code Administrators (BOCA) Basic Building Code, 1990.

11.2 NFIP Flood Zones

The NFIP separates the coastal floodplain into two major flood zones. The A- Zone is defined as a coastal or riverine flood-prone area that may, or may not, be subject to waves (less than three feet in height). Due to the relatively insignificant wave climate, the NFIP requires structures within the A-Zone to only be protected against the effects of water damage and hydrostatic pressure. The V-Zone is defined as a coastal or riverine flood-prone area which is subject to waves greater than three feet in height. Due to the presence of these waves, the NFIP requires structures in the V- Zone to be protected against the effects of wave attack in addition to the effects of water damage and hydrostatic pressure. Waves of this magnitude apply lateral forces to structures, causing significant damage to or even total failure of the structure. Waves can also carry debris which will impact on a structure and cause more severe damages.

The regulatory Base Flood Elevations (BFE) for the AE and VE zones in the study area, as determined by FEMA, ranges from +11' NAVD88 to +17' NAVD88 (North Atlantic Vertical Datum of 1988). See Appendix C for more information on Base Flood Elevations.

11.3 Elevating Houses in the A-Zone

General: NFIP regulations require houses in the A-Zone to have the lowest habitable floor (hereinafter called the first floor) above the BFE. This, however, is a minimum requirement. State of Rhode Island Building Code requires that the first floors in the A-Zone be elevated to at least one foot above the BFE. NFIP regulations also restrict the use of enclosed areas below the first floor to parking, building access, or limited storage. Uses other than those specified could be construed as making the floor habitable, and the house would then be considered non-compliant with NFIP regulations. After the houses are elevated, assurances must be made to restrict the use of crawl spaces and especially basements.

In the Pawcatuck study area, most of the houses in the A zone are one or two story, single family residences, of timber construction. Many of the houses are rectangular in shape, which because of its simplicity and uniformity is ideal for elevating. Many appear to have been initially constructed as summer cottages, and were later converted into year round residences.

Foundations: The homes in the A-Zone either bear on concrete masonry unit (CMU) foundation walls (w/crawl spaces underneath), are on slabs or have basements of either CMU or reinforced concrete foundations.

Given the age and nature of the construction, as each home is lifted it is anticipated that many of the existing foundations will be demolished and a new foundation constructed with reinforced concrete. Opportunities to extend existing foundations will be analyzed during final design.

NFIP Regulations specify a number of requirements for foundations in flood-prone areas. All building components below the BFE must be constructed of flood-resistant materials. A flood-resistant material is defined as one capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage. NFIP Technical Bulletin 2-93 provides a classification system for flood-resistant materials. All materials below the BFE will be flood-resistant as classified by FEMA.

Foundation walls and other enclosures below the BFE will be subject to the hydrostatic forces of floodwaters. NFIP regulations require foundation walls and enclosures below the BFE to contain openings that will permit the automatic entry and exit of floodwaters. These openings allow floodwaters to reach equal levels on both sides of the walls, thus reducing the potential for damages due to differential hydrostatic pressure. NFIP Technical Bulletin 1-93 provides criteria and guidance for determining the quantity, size, and location of required openings. All foundation walls below the BFE in the A-Zone will be provided with the appropriate area of openings to satisfy NFIP criteria. Those openings will also be equipped with screens that will prevent animals from entering the crawl space or basement, yet will allow the automatic passage of water.

State and local building regulations requires structures in the A- Zone to be anchored to their foundations. This is to prevent the structure from floating off of the foundation during a flood, and to prevent lateral movement of the structure as it is impacted by debris and waves.

<u>Geotechnical Assessment:</u> This geotechnical assessment is based on review of geologic literature and maps as described in Section 5 above. Site specific explorations and laboratory testing were not performed. The subsurface was assumed to be a medium to coarse grain sand throughout the area.

New foundation walls will require footings that are founded on undisturbed beach deposits or undisturbed till. Spread footings will not be founded on topsoil or on-site fill. A design bearing capacity of 3,000 pounds per square foot will typically be used to size the footings. A minimum width of 24 inches will be maintained for isolated footings and 18 inches for continuous footings. The footing bottoms will be buried at least 3.5 feet deep for adequate frost protection, and may be set even deeper in order to protect against scour.

<u>Chimneys/Fireplaces:</u> The presence of masonry chimneys, either with or without fireplaces, creates a particular challenge when elevating a house. These masonry features represent heavy concentrated loads, which are attached to the structure but are not supported by the framework of the structure. When elevating houses with chimneys, the chimney (and fireplace if present) must be elevated along with the house. Therefore, the Contractor must adapt the support/jacking system to accommodate the heavy concentrated loads. In practical terms, the additional effort required to elevate the masonry chimneys and fireplaces translates into somewhat higher construction costs.

<u>Utilities:</u> All of the utilities servicing each house will need to be extended and reconnected after the house is elevated to its final elevation. If any of the electric, gas, or plumbing services are sub-standard according local building codes, they will need to be upgraded.

State and local building code requires all replacement water supply systems to be designed to minimize or eliminate infiltration of floodwaters into the system. These regulations also require all replacement sanitary sewage systems to be designed to minimize or eliminate infiltration of floodwaters into the system, as well as discharge from the system into floodwaters. In the A-Zone, water and sewer lines will enter the house from beneath, within the crawl space. Therefore, the foundation walls will protect these utilities from being damaged by floodwaters and waves carrying debris. Additionally, the water and sewer lines will be insulated to keep them from being damaged by freezing.

Some homes have ductwork located below the first floor. These ducts also need to be raised above the BFE in order to comply with state and local building code. Relocating the ductwork to the attic would most likely require a complete replacement of the heating system, which would be costly. Therefore, those houses with ductwork below the first floor will be elevated an additional amount to bring the existing ductwork above the BFE.

<u>Exits/Stairs:</u> Existing stairs cannot easily be modified to accommodate the new first floor elevation of an elevated house. Many of the existing stairs are constructed of concrete, brick, or CMU and may be abandoned in place. Others are constructed of timber and will be removed. Every exit will be provided with a new set of pressure treated timber stairs, including a landing and railings. Each set of stairs will be securely anchored to the house and to the ground to prevent floatation. Finally, as the elevation of the first floor is increased, the run of the exit stairs is also increased. More space will be required on the lot to accommodate the new stairs. This may require a variance from local zoning regulations. As each exit is different, the new stairs will need to accommodate the layout, geometry, and architecture of the house and the lot.

<u>Porches/Balconies:</u> Many of the homes have enclosed porches attached to the house, open decks, or second story balconies. Balconies will be elevated along with the structure. However, NFIP regulations are not specific concerning decks and enclosed porches. Since enclosed porches are intended for human habitation and are structurally dependent on the house, it is reasonable to expect that they would be considered a part of the house, and would be subject to the first floor elevation requirements of the NFIP. Therefore, all enclosed porches will be elevated along with the house, and the porch flooring will be elevated above the BFE.

Open decks are most often structurally dependent on the adjacent house, and are considered to be part of the house. Since these features are not habitable, they do not appear to be subject to the first floor elevation requirement. However, for the purposes of this study, it was assumed that all open decks would be elevated along with the houses. Additionally, decks must be anchored to the ground and to the house in order to prevent floatation.

<u>Attached Garages:</u> Some homes have garages that are structurally attached to the house. As long as a garage is only used for parking, building access, and limited storage, the garage floor slab is not considered part of the first floor and is not required by NFIP regulations to be elevated above the BFE. Attached garages in the A- Zone will be detached, and then re-attached after the house is elevated to its final location. Although additional carpentry work is required to detach the garage, re-attach the garage, and to finish the exterior between the house and the garage, it is still considered to be more economical than elevating an attached garage structure.

Since an attached garage is considered an enclosure below the BFE, sufficient openings will be provided in the garage walls to satisfy the NFIP regulations concerning hydrostatic pressures (see Technical Bulletin 1-93). Doors are not considered sufficient to comply with NFIP regulations concerning openings below the BFE because they do not allow the automatic passage of water.

Accessory Buildings: Detached garages and sheds are considered accessory buildings. These buildings are separate from residential structures, and are only used for parking and limited storage. The NFIP considers these buildings to be of low value, and their contents to be uninsurable (automobiles are uninsurable for flood damages). Therefore, the NFIP does not cover damages associated with the flooding of accessory buildings in flood-prone areas. Subsequently, the flood proofing of accessory structures within the study area is considered to be outside the authority of this project.

11.4 Elevating Houses in the V-Zone

General: All of the NFIP requirements concerning elevating houses within the A-Zone also pertain to houses within the V-Zone. However, in addition to those general requirements already stated, NFIP regulations contain much more stringent requirements that are specific to elevating houses within the V-Zone. The information contained within this section is intended to be supplemental to that already presented in Section 11.3 of this Appendix.

The NFIP requires that foundations in the V-Zone be designed to allow waves to flow beneath the elevated structure. The result is that waves will transfer only minimal lateral forces to the foundation system, and structural damage to the house and foundation will be minimized. The NFIP further requires that the area beneath an elevated house remains free of any obstructions that would reduce or eliminate the free flow of coastal floodwaters. Any obstructions beneath the BFE can direct coastal floodwaters into the elevated portion of the house or into adjacent buildings, potentially causing structural damage. This "free-of-obstruction" requirement is considered critical to the protection of houses in the V-Zone. See FEMA Technical Bulletin 5-93 for more information on the NFIP free-of-obstruction requirements for houses within the V-Zone. Commensurate with the free-of-obstruction requirement, Sec. 60.3 of the US Code of Federal Regulations requires that "...the bottom of the lowest horizontal structural member of the lowest floor (excluding pilings or columns) is elevated to or above the BFE". This means that not only the first floor, but the first floor joists and support beams must also be elevated above the V-Zone BFE, regardless of whether they are constructed of flood resistant materials or not. For the purposes of this study, it is assumed that the depth of the floor system and support beams is approximately 12 inches. Therefore, the first floors of houses within the V-Zone will be elevated to an elevation of +1 foot above the BFE. This also conforms to State building code requirements.

All of the houses in the V-Zone are one or two story single family residences, of timber construction.

Foundations: The homes in the V-Zone either bear on concrete masonry unit (CMU) foundation walls (w/crawl spaces underneath), are on slabs or have basements of either CMU or reinforced concrete foundations.

Foundation walls constitute an obstruction, and are prohibited due to the free-of-obstruction requirement for buildings in the V-zone. Foundations of this type will need to be entirely removed, and replaced with reinforced concrete columns on spread footings, which are in compliance with the NFIP free-of-obstruction requirement. The new concrete column foundations must be designed to withstand the lateral forces of waves and winds associated with the design storm (a 100-year frequency event). Concrete columns will typically be cast in three lines, one beneath each exterior bearing wall and one down the center of the house. Houses of irregular geometry will require a unique column layout.

Although some of the houses in the V-Zone are currently founded on CMU columns (with or without spread footings), the structural integrity of those columns is questionable. Additionally, there is no way of determining whether the existing column foundations are adequate to withstand the lateral forces associated with the design storm. Extending the existing columns beneath an elevated house would not be prudent without first determining that the foundation is structurally adequate to withstand design loads. Due to the lack of information about these column foundations in the V-Zone, it has been decided to consider them inadequate.

Therefore, all foundations of houses to be elevated in the V- Zone will need to be entirely removed, and replaced with reinforced concrete columns on spread footings. Typically, the reinforced concrete columns will be 18 inches in diameter, and will be supported by spread footings measuring 4 feet by 4 feet by 18 inches thick. The concrete is classified as a flood-resistant material and is in compliance with Technical Bulletin 2-93. Additionally, as required by NFIP regulations, houses in the V-Zone will be anchored to the new foundation to "...resist floatation, collapse, and lateral movement due to the combined effects of wind and water loads acting simultaneously on all building components". The new foundations in the V-zone will also be designed to withstand the effects of scour from waves.

The necessity to replace existing foundations has a significant effect on the cost of elevating houses within the V-Zone. The work of demolition and removal of the existing foundation, and excavation, construction, and backfilling of the new foundation will have to be accomplished beneath the elevated house while it is on temporary supports. Working beneath the elevated house will be cumbersome and will significantly hamper construction schedules. Additionally, in comparison to extending an existing foundation, the construction of a new foundation will require much more materials and labor. All of these factors result in significantly higher costs associated with elevating houses in the V-Zone.

Geotechnical Assessment: This geotechnical assessment is based on review of geologic literature and maps as described in Section 5 above. Site specific explorations and laboratory testing were not performed. The subsurface was assumed to be a medium to coarse grain sand throughout the area.

The construction of spread footings to support columns will be required when elevating residential structures in the V-Zone. The footings will be founded on undisturbed beach deposits or undisturbed till. Spread footings will not be founded on topsoil or on-site fill. A design bearing capacity of 3,000 pounds per square foot will typically be used to size the footings. A minimum width of 24 inches will be maintained for isolated footings and 18 inches for continuous footings. The footing bottoms will be buried at least 3.5 feet deep for adequate frost protection, and may be set even deeper in order to protect against scour.

Chimneys/Fireplaces: As previously stated in Section 11.3, the presence of masonry chimneys, with or without fireplaces, creates particular challenges when elevating a house. In addition to the difficulties of supporting chimneys during the jacking process, a new permanent foundation of reinforced concrete will need to be provided for chimneys within the V-Zone. Existing chimney foundations are constructed of CMU, and may not be adequate to withstand the lateral forces of winds and waves associated with the design storm. Therefore, the existing CMU chimney foundations will be replaced with reinforced concrete. The cost increase associated with replacing the existing chimney foundations, as opposed to extending them, is minimal. Chimney foundations are considered as columns, and are in compliance with NFIP free-of-obstruction requirements.

Enclosures below the BFE: NFIP regulations restrict the use of space below an elevated house to parking of vehicles, building access, and limited storage. Individual homeowners may desire to enclose a portion of that space for reasons of aesthetics, security, or privacy. The NFIP free-of-obstruction requirement allows for such enclosures below the BFE if constructed to strict breakaway standards (See FEMA Technical Bulletin 5-93). Enclosures shall be "...constructed with non-supporting breakaway walls, open wood lattice-work, or insect screening designed to collapse under wind and water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or to the supporting foundation system". Enclosures have no flood proofing benefit, and therefore are beyond the scope of this project and will not be provided.

Utilities: In addition to the requirements previously stated in section 11.3 of this appendix, state and local building code requires that utilities in the V-Zone be protected from potential damage caused by waves that may or may not be carrying debris. To accomplish this, all utilities servicing a house from below the BFE will be protected within a utility chase. The utility chase will be designed to withstand lateral forces associated with the design storm. Water, sewer, and gas lines servicing each house in the V-zone will be contained within a single utility chase which will be attached to one of the foundation columns. The utility chase will be constructed of flood-resistant materials, as required by NFIP regulations, and is commensurate with the free-of-obstruction requirement.

Exits/Stairs: Access stairs will be provided at each exit. Access stairs, either attached to or beneath an elevated house in the V-Zone, are excluded from both the free-of- obstruction and the breakaway requirements of the NFIP. However, access stairs must be constructed of flood-resistant materials. Although access stairs need not comply with the breakaway requirement, the potential loads transferred from these obstructions to the elevated house will need to be considered so as to not jeopardize the structural integrity of the elevated portion of the building.

Attached Garages: Any house within the V-Zone that has an attached garage is subject to the NFIP free-of-obstruction requirement for buildings within the V-Zone. The NFIP does not specifically prohibit attached garages in the V-Zone, but the free-of-obstruction requirement is virtually impossible to comply with. Although an attached garage may conceivably be elevated along with the adjacent house, this would be impractical and expensive. A new garage floor would have to be constructed such that the bottom of the lowest horizontal member is above the BFE. The garage would need to be elevated on concrete columns in order to comply with free-of-obstruction and flood-resistant material requirements. Finally, vehicle access to the garage creates the most difficulty. A ramp constructed on fill is expressly prohibited by NFIP regulations. And a structural ramp would have to be constructed to the NFIP breakaway standards, which would not be able to support the weight of a vehicle.

As in the case with attached garages in the A-Zone, an attached garage in the V-Zone may be detached, and then re-attached after the house has been elevated. The concrete garage floor at ground level complies with free-of-obstruction requirements, and would not be considered as part of the first floor as long as the space is only used for parking, building access, or limited storage. The roof, however, would need to be supported by columns constructed of flood-resistant materials, and designed to withstand the lateral forces of winds and waves associated with the design storm. The garage walls and the garage door below the BFE would have to be constructed according to NFIP breakaway criteria. Since enclosures below the BFE have no floodproofing benefit, they will not be provided as part of this project.

An attached garage could also be detached and made structurally independent from the adjacent house, and therefore not be considered as part of the house. However, as discovered through discussions with representatives of FEMA, the newly detached garage would be considered a "new" building on the property. As stated previously, all new construction within a flood-prone area is subject to NFIP building requirements.

Again, because enclosures below the BFE within the V-Zone have no floodproofing benefits, the walls and doors of an attached garage in the V-Zone will be removed, and the roof will be supported on new columns. In short, attached garages in the V-Zone will be transformed into car ports. In lieu of this alternative, the individual homeowner may opt to do away with the garage altogether. Alternatively, homeowners may request, at no additional cost to the Government, to have the house elevated an additional amount so that vehicles may be parked beneath the house. The additional cost to elevate a house only a few extra feet would be minimal.

Accessory Buildings: The NFIP requires accessory buildings in the V-Zone to be elevated on columns in order to comply with the free-of-obstruction requirement. According to FEMA Technical Bulletin 5-93, "If a building is of significant size and strength to create either a debris impact or a flow diversion problem, it must be elevated ...". Buildings that are small, or of low value, are exempt of this requirement. Since these requirements only apply to new construction and substantially improved existing buildings, and as much as accessory buildings will not be altered in conjunction with this project, accessory buildings in the V-Zone will not be elevated.

11.5 Construction

General: Based on a limited review of the study area, construction access will not be difficult. Access for excavation equipment and equipment for maneuvering lifting beams is adequate in most cases. Access of abutting property to perform the work is not anticipated. Generally, the contractor will have limited space for storage of materials and equipment.

Lifting Process: The process of elevating a house involves a number of steps. Any fences, trees, shrubs, and other plantings that are obstructing the work will need to be removed. Holes will be made within the existing foundation walls to accommodate the lifting beams. Lifting beams (generally made of structural steel) are used to transfer the weight of the house onto pneumatic jacks. Depending on the layout and strength of the structural support system of the house, the lifting beams will carry the house either by the sills and the center beam, or by the floor joists. Additional lifting beams, or secondary beams will be required to support masonry chimneys and fireplaces. If there is insufficient clearance between the bottom of the sill and the adjacent ground surface, small amounts of excavation will be required to insert the lifting beams and to set the jacks. In some cases excavation will be required in a driveway, patio, or a concrete walkway.

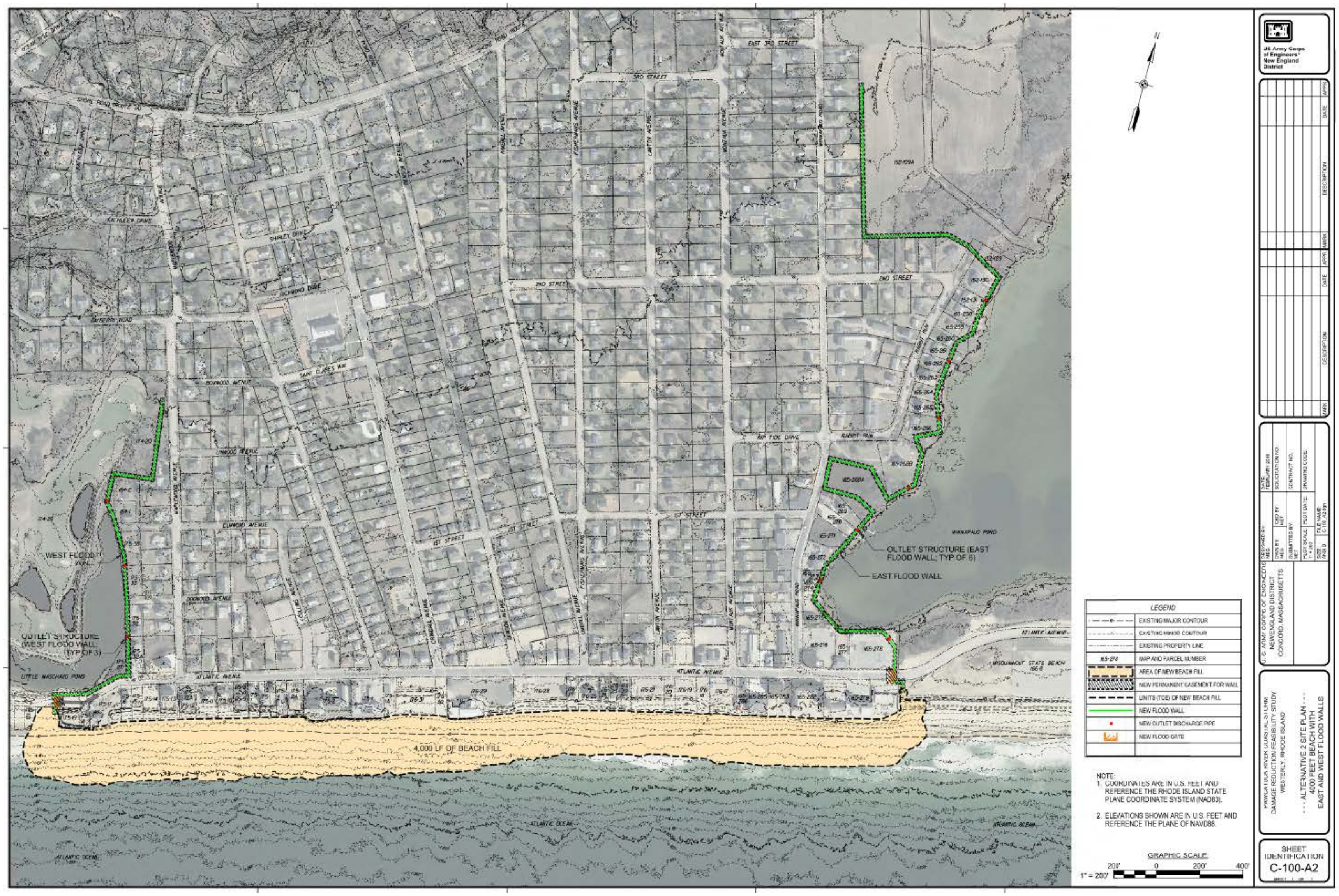
Each house will be elevated by jacking the lifting beams simultaneously. Each lifting beam will be lifted by at least two jacks, depending on the size and strength of the lifting beams and the type and capacity of the jacks. As the jacks become fully extended, the lifting beams will be temporarily supported on timber cribbing. The jacks will be retracted, reset, and the lifting will continue. The house will initially be raised higher than the final elevation, and will be supported on timber cribbing. While the house is in this position, the foundation will either be extended or replaced. The house will then be lowered onto the foundation and anchored in place.

Site Work: All disturbed areas on each lot will be repaired or replaced. Damaged or removed fences will be replaced. All excavations will be backfilled, and where applicable topsoil and seeded. All disturbed driveways, patios and walkways will be replaced in kind. Finally, all removed plantings will either be replanted or replaced.

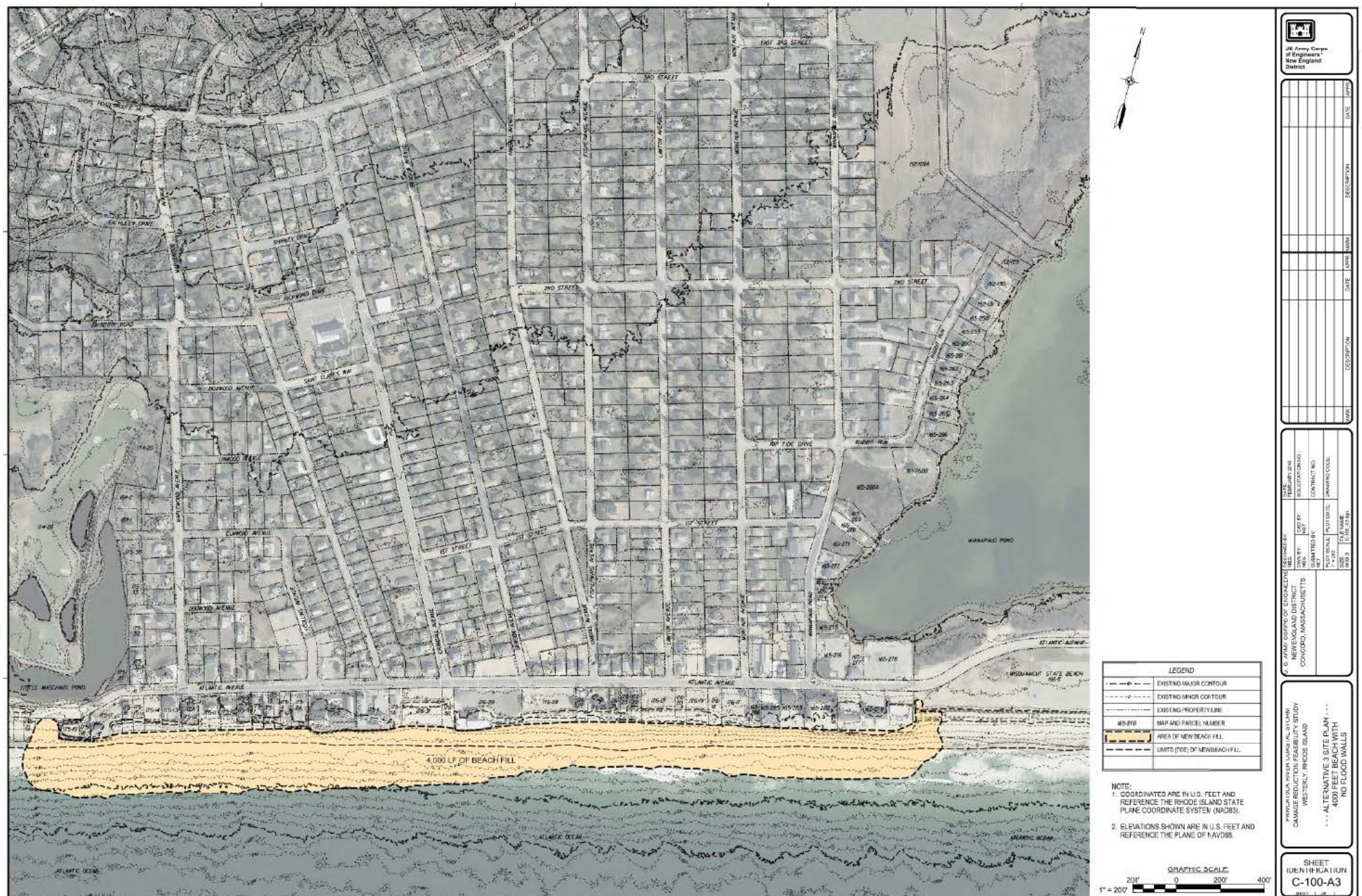
Damages: The elevated structure may become cosmetically damaged. Although many precautions will be taken to prevent damages, plastered walls and ceilings may become cracked, and windows and doors may not close properly. The contractor will be held responsible for all structural damages associated with his work, and will be required to repair/replace all damaged items at no additional cost to the Government or the non-Federal Sponsor. The contractor will not be held responsible for damages to the contents of the house.

Temporary Living Arrangements: It is not anticipated that occupants will be need to leave the home during construction for an extended period of time. The occupant may be asked to leave for a couple of hours when the house is actually being lifted or lowered. Otherwise, temporary stairs and utility connections will ensure the structure can always be lived in. Obviously, fragile contents should be secured during construction.

Attachments



Alternative 2 – 4,000' Beach and Flood Walls



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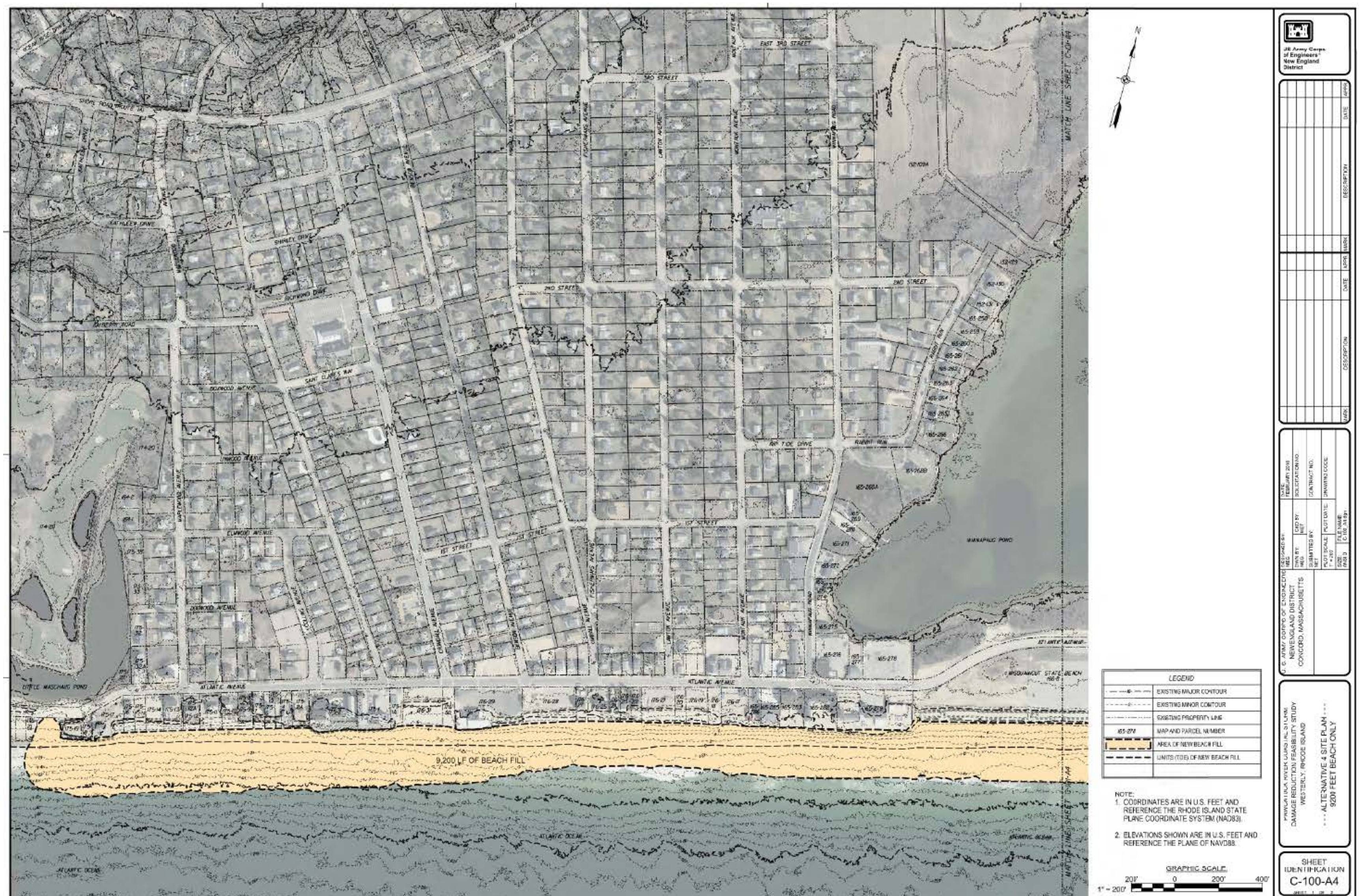
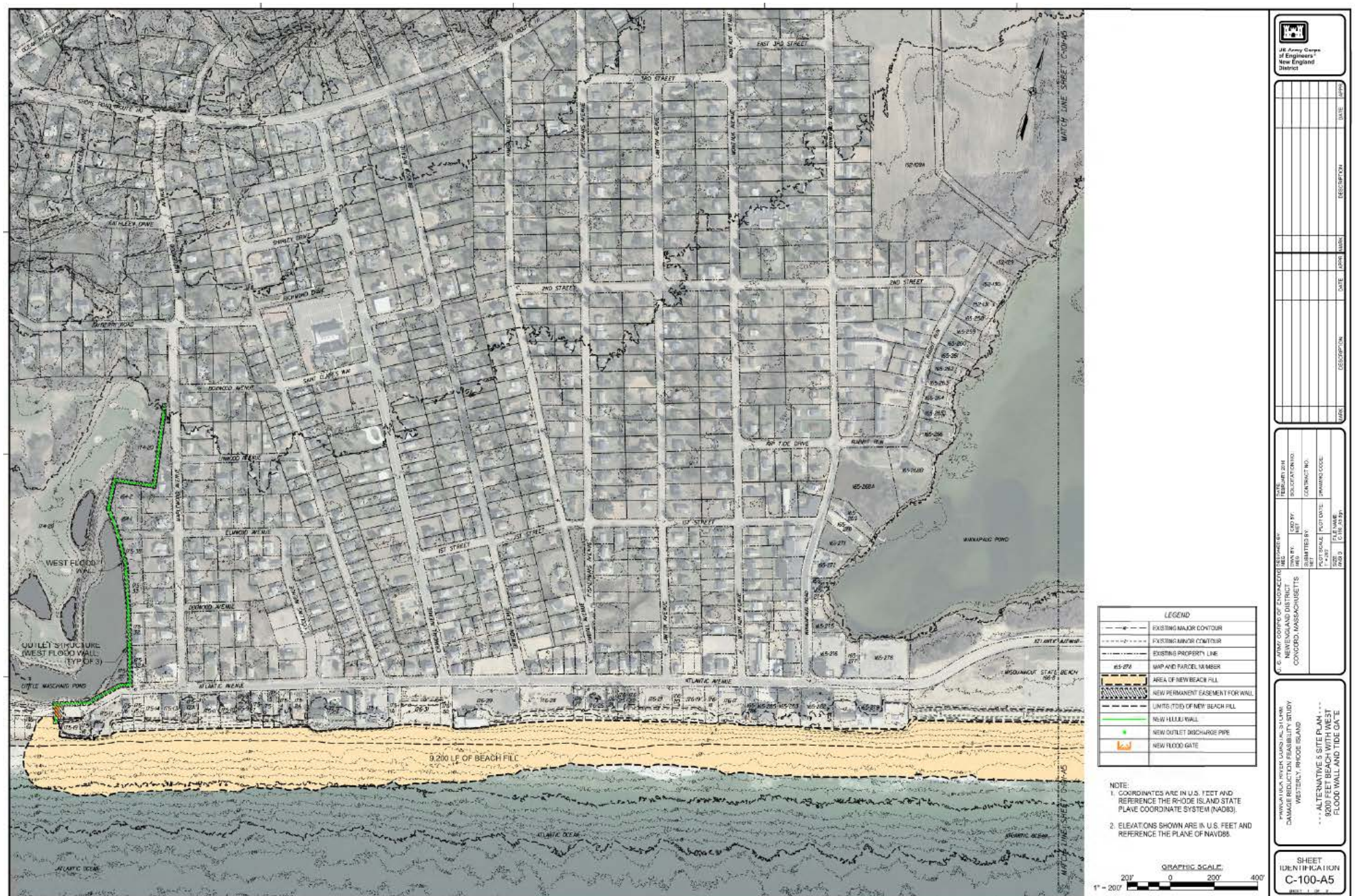


Alternative 4 – 9,000’ Beach (continued on next page)

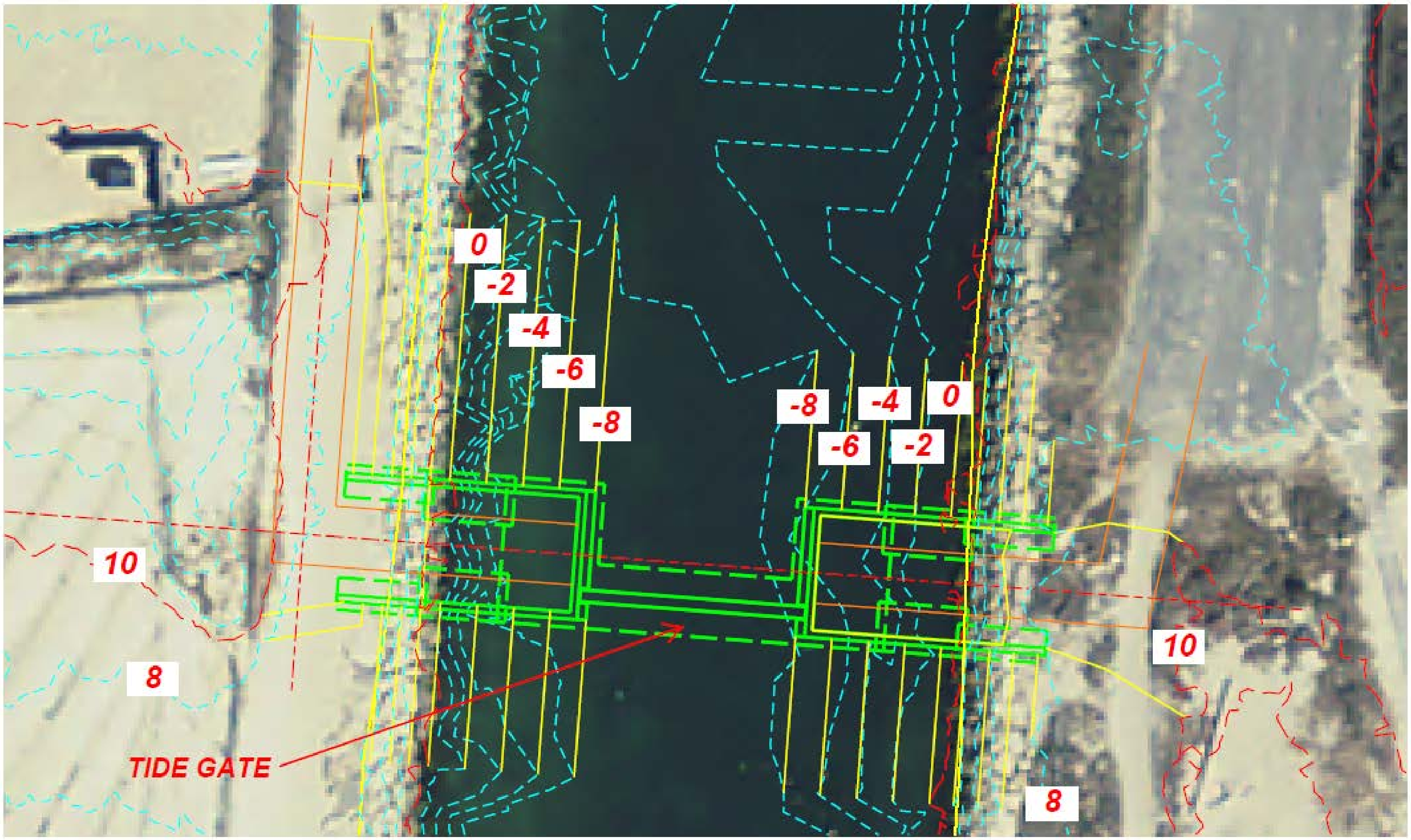
Alternative 4 – 9,000' Beach (continued from previous page)



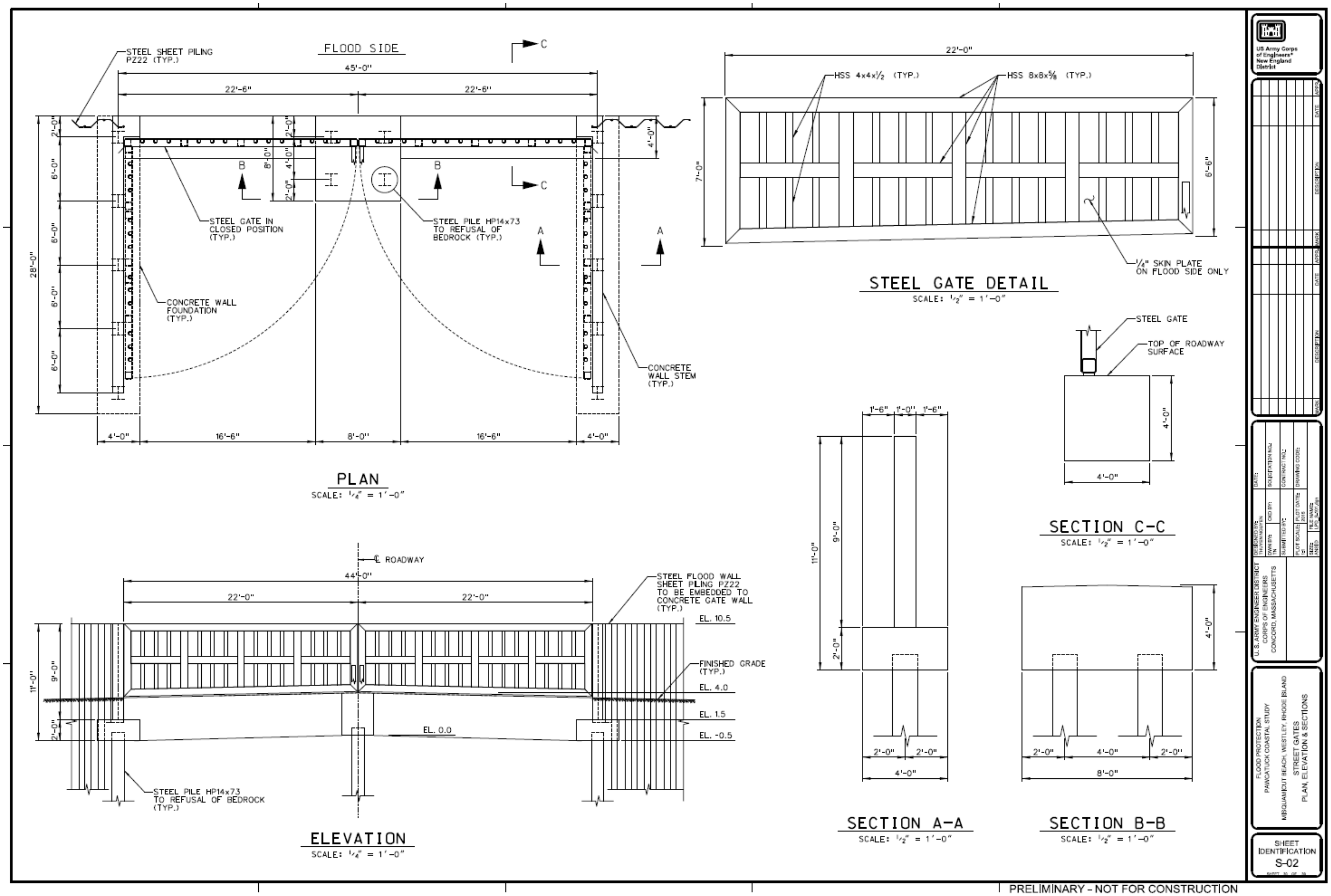
Alternative 5 – 9,000' Beach, West Flood Wall, and Tide Gate (continued on next page)

Alternative 5 – 9,000’ Beach, West Flood Wall, and Tide Gate (continued from previous page)

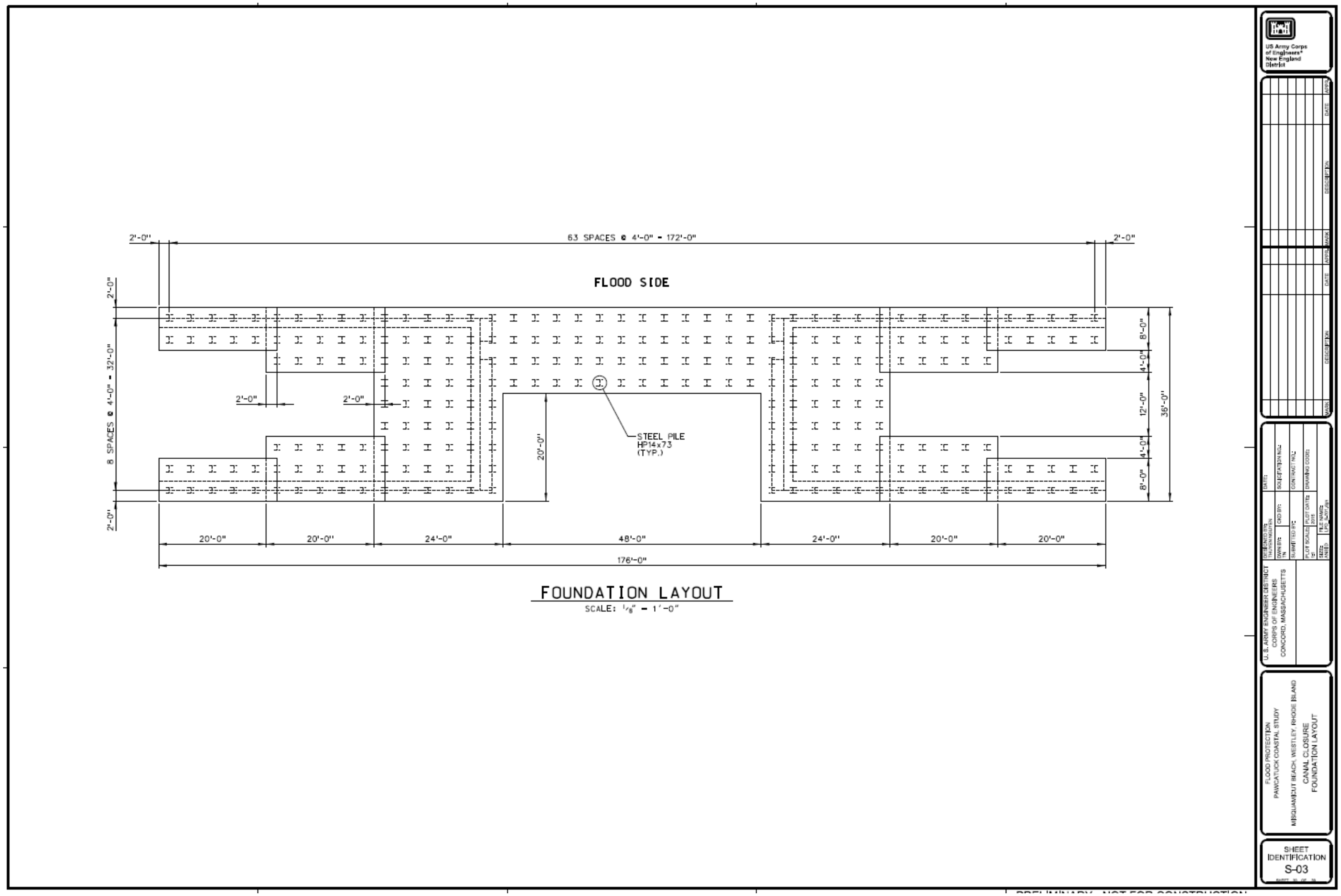
Alternative 5 – 9,000’ Beach, West Flood Wall, and Tide Gate



PLAN VIEW - TIDE GATE
LOCATION
(1" = 40')



Tide Gate Details



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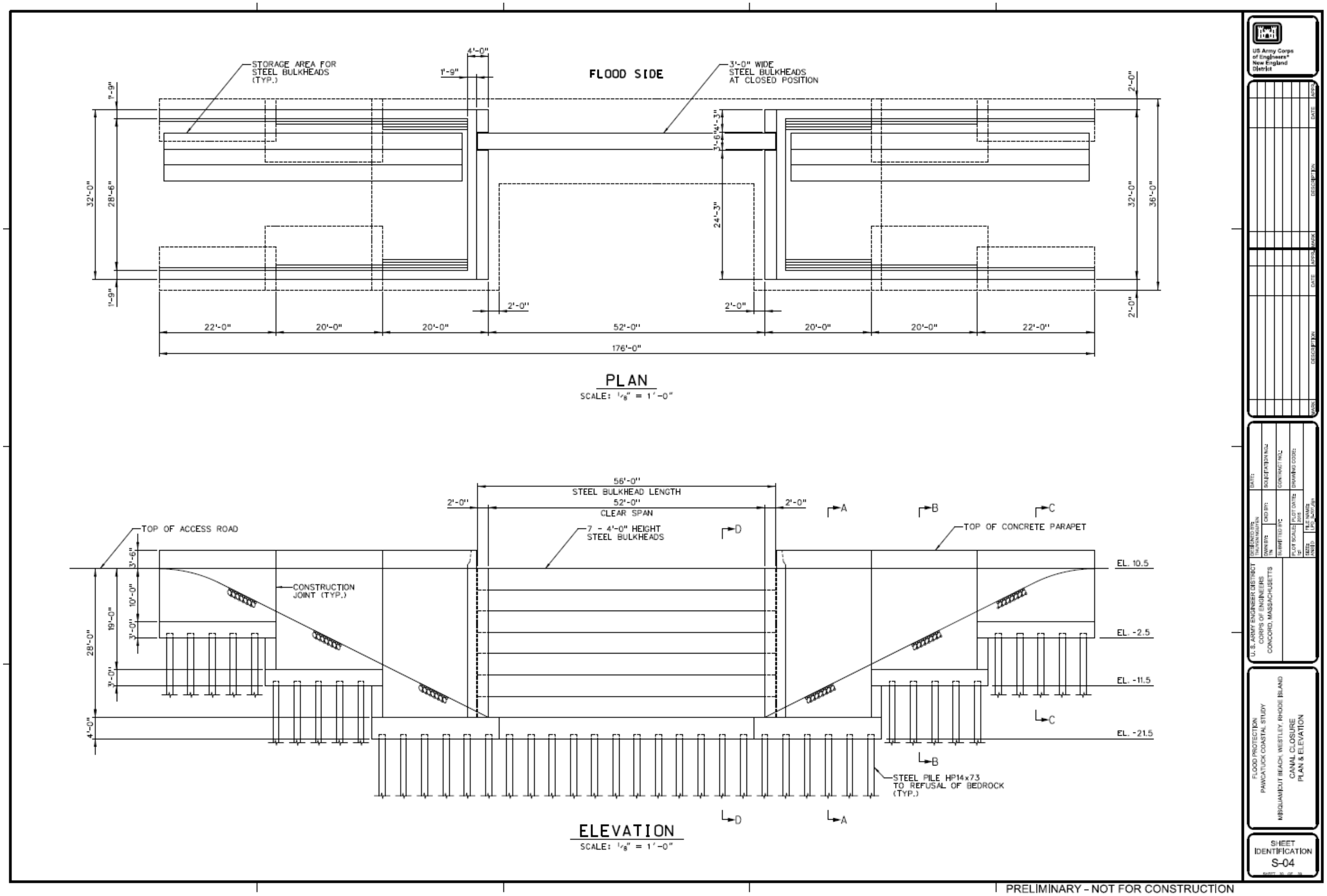
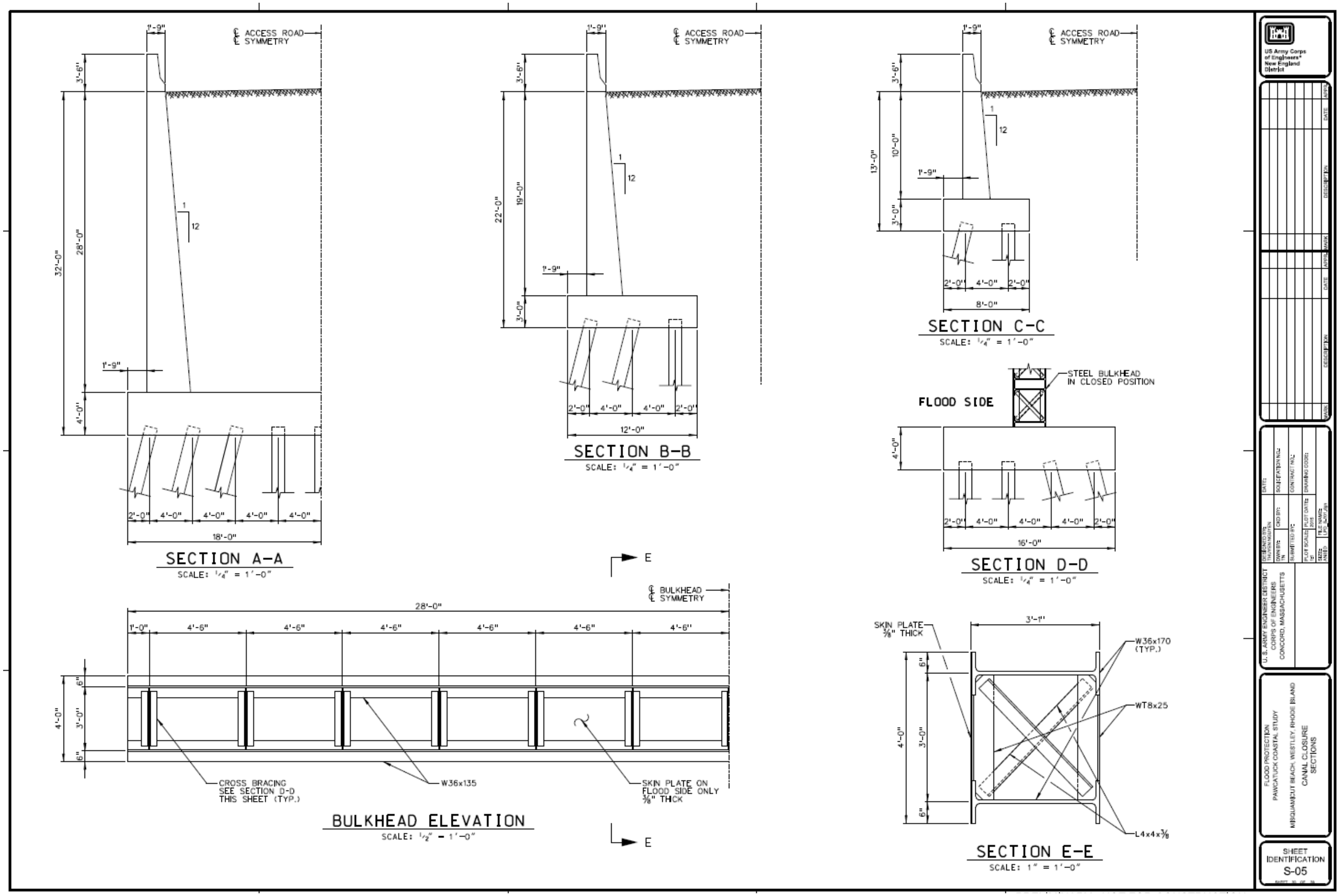


Tide Gate Details



Tide Gate Details