HISTORIC FORT DUPONT NATURE TRAIL

discover the beauty of hidden history

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UNIVERSITY OF DELAWARE BSLA SENIOR CAPSTONE

CONTENTS

INTRODUCTION

PROJECT: Fort DuPont Nature Trail

SITE: Fort DuPont State Park
Wilmington Avenue
Delaware City, Delaware 19706

ECOREGION: EPA Level III, Coastal Plain

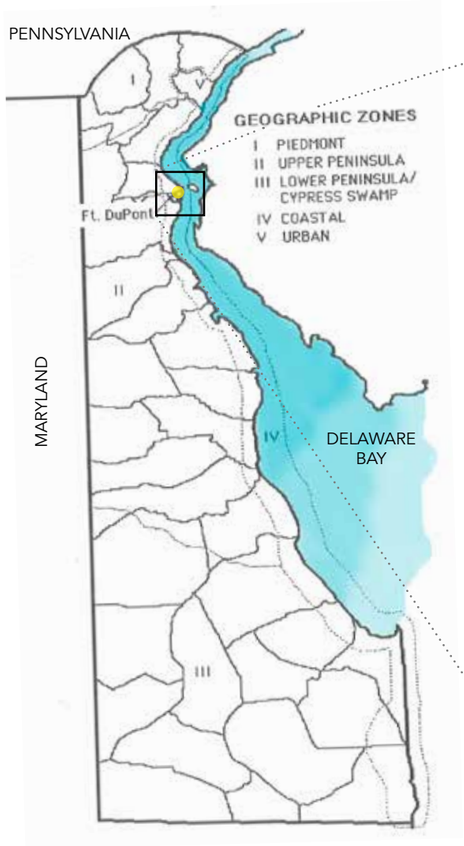


Figure 1. Fort DuPont location within the geographic zones of Delaware.

Adapted from Ames, D., Doerrfeld, D., Elterich, A., Fisher, C. and Siders (Sheppard), R. (June 1994). *Fort DuPont, Delaware: An Architectural Survey and Evaluation* [PDF file]. University of Delaware Center for Historic Architecture and Engineering, pp. 8.

Figure 2. Fort DuPont is located in Delaware City and is located along the Delware River, which separates Delaware and New Jersey.
Adapted from *Google Maps*.

Figure 3. Fort DuPont parcel extents shown in green and coastal area of study highlighted in pink.
Adapted from *Google Maps*.

I grew up walking the rip-rap coastline of the eastern shore of Maryland and exploring the rivers that feed into the Chesapeake Bay. I remember catching rockfish and blue crabs and seeing the marshy extensions of vegetation grow out into the water from the shoreline. Over the years, I watched as the green hugging the shore receded: habitat transformed into a lifeless muddy bottom.

Connecting with this environnment has instilled in me a value for environmental stewardship. Since I began studying Landscape Architecture at the University of Delaware, I have interacted with landscape applications that promote stewardship and sustainability through design. During an internship documenting the sustainable practices of a designed wetland and bioswale in southern Delaware, I learned the positive impact green infrastructure systems can provide. Seeing the value in these systems both environmentally and socially, I wanted to focus my capstone research on how landscape architects might implement green infrastructure in a way that protects shoreline ecosystems, mitigates effects of climate change, provides habitat for wildlife, and encourages environmental stewardship.

The Delaware River coastline became an ideal site to study given my interests in coastal resilience, habitat, and stewardship. The site I am studying is the Fort DuPont coastline - a portion of a historic military site located on the Delaware River in Delaware City. Situated just above the outlet of the Chesapeake and Delaware Canal, the site was once a pivotal place for maritime monitoring and coastal defense. A portion of property nearest the coastline, including a small forested area, is now public park. With the site's rich cultural history and scenic river views, I focused this plan on connecting people to a healthy living shoreline with opportunities for ecological interpretation, fostering a sense of stewardship and discovering the beauty of hidden history.

OBJECTIVES

The scope of this project focused on designing for 5 objectives, listed in priority order:

1. **Promote human connectivity** to the Delaware River and to the amenities of Fort DuPont's natural and cultural history.
2. Provide **design solutions for coastal change** associated with the degradation of marshland and predicted sea level rise.
3. **Enhance habitat** for emergent tidal wetland plants and animals.
4. Interpret and **protect the cultural history of Fort DuPont** and its coastal historic structures.
5. **Improve the quality of stormwater runoff** from developmental projects at Fort DuPont through the creation of a riparian buffer and a bioswale.

EXISTING CONDITIONS

Fort DuPont is a historic military site located in Delaware City, just south of New Castle in New Castle County, DE. Historically, the property was used for military operation due to its strategic location along the Delaware River in order to protect the port cities of Wilmington and Philadelphia (DNREC, 2013). The property is bounded by the Delaware City Branch Canal to the North, the Delaware River to the East, the St. Augustine wildlife area as well as the C&D Canal to the south, and route 9 to the west.

As of 2016, the Fort DuPont Redevelopment and Preservation Corporation Current oversees the management, preservation and development of the property (Fort DuPont Redev. & Preserv. Corp., 2019). Current plans are underway to redevelop much of the inland portion of the site for new housing and mixed use development. The focus of this study is limited to the coastline area and the site's connection to the Delaware River.

DELAWARE RIVER

TO PEA PATCH ISLAND

WHARF RUINS

DEGRADED BULKHEAD

NEW CASTLE COUNTY WATER TREATMENT FACILITY

PROPOSED MARINA

DELAWARE CITY BRANCH CANAL

PROPOSED BRIDGE

EXISTING MARSH / WETLAND

BATTERY ELDER

EXISTING FOREST

MORTAR BATTERY

BATTERIES REED & GIBSON

TWENTY GUN BATTERY

PROPOSED MIXED USE RESEARCH, EDUCATION, AND RESIDENTIAL NEIGHBORHOOD

PROPOSED RESIDENTIAL NEIGHBORHOOD

ROUTE 9

KEY

- AREA OF INTEREST
- PROPOSED 2013 MASTER PLAN
- WATER ACCESS
- EXISTING MARSH / WETLAND
- EXISTING FOREST

LARC450 - SENIOR DESIGN
PROFESSOR JULES BRUCK

EMMA RUGGIERO
UNIVERSITY OF DELAWARE

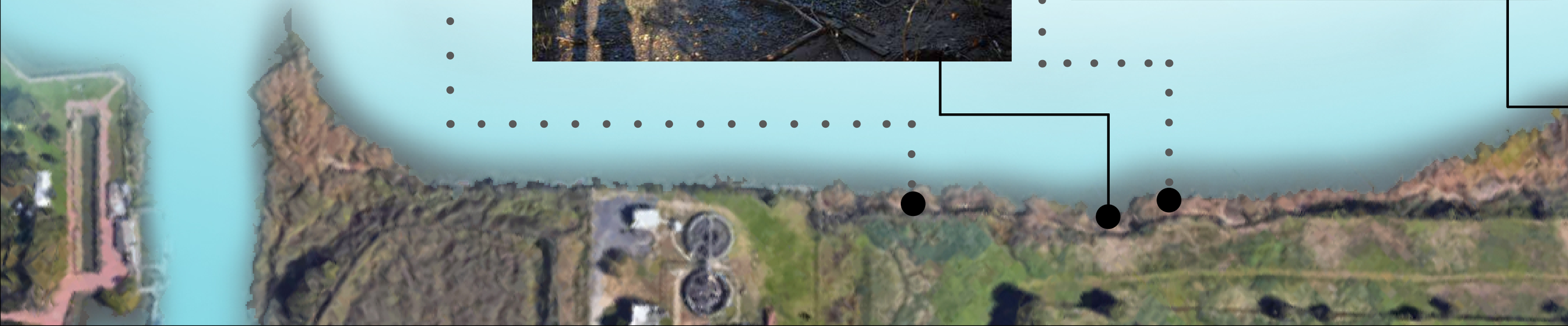
EXISTING CONDITIONS PLAN

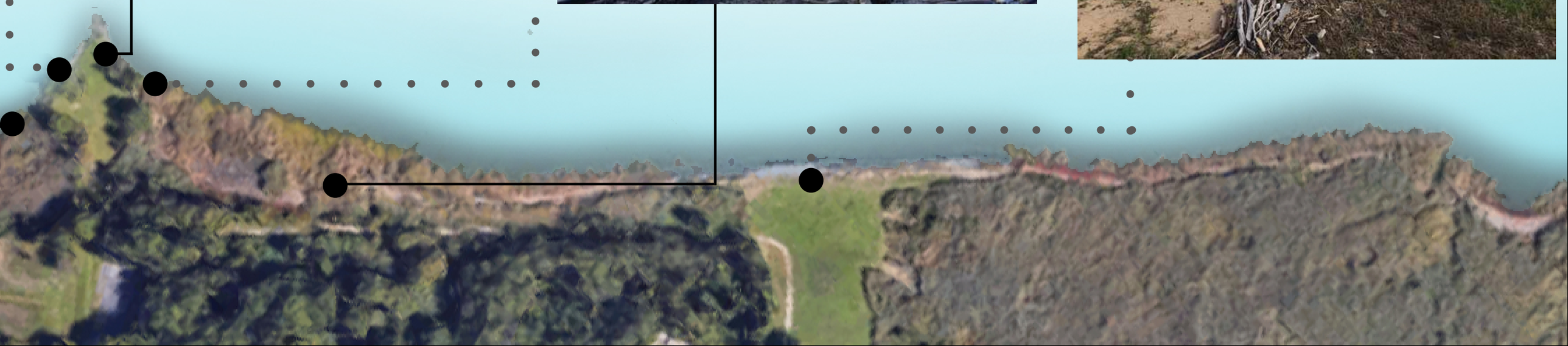
DATE: 04 JANUARY 2019

SCALE: 1" = 150'-0"

0 75' 150' 300'
0" 1" 2"

N





HISTORIC CONTEXT

Land Use

Structures

The Fort DuPont Historical District in Delaware City is comprised of 320+ acres of historic land originally established as a military base used for defense, storage and deployment as early as the mid-nineteenth century during the Civil War. This site was commissioned as Fort DuPont in 1899 as part of the nation's coastal defense system, intending to defend the Delaware River, Wilmington, and Philadelphia from naval attack. Construction of the fort took place from 1899 until 1915, and displayed revolutionary advances in long range artillery. In 1922, the site was decommissioned and became the base of the Engineer's Regiment until 1939. Fort DuPont was then used as a training facility during WWII (Ames, et. al., 1994). In 1947, the fort was again decommissioned and turned over to the state of Delaware. The Governor Bacon Health Center was established and became a long term health facility that is still in operation. Green space nearest the coast was designated as a State Park in 1992 (Delaware State Parks, n.d.). Today, Fort DuPont is on the National Register of Historic Places.

Much of the historic integrity of the land has remained in tact, as can be seen in the aerial images (page adjacent) from 1937 and 2017. Unfortunately, many structures today are unused and some degrading. 273 structures existed in a 1943 plan, of which 63 remain (Andrzejewski et. al., 1999). The remaining structures nearest the coast include a pump house near the point, battery elder, batteries Read and gibson, and remnants of a bulkhead, a mortar battery, two warehouses and remnants of a wharf off of the point.

The historic wharf was used for transportation, which is today in ruins that become exposed during low tide and hidden during high tide. The point became a focal piece of my design for its historical intrigue and strong connection to the coast.

HISTORIC LAND USE

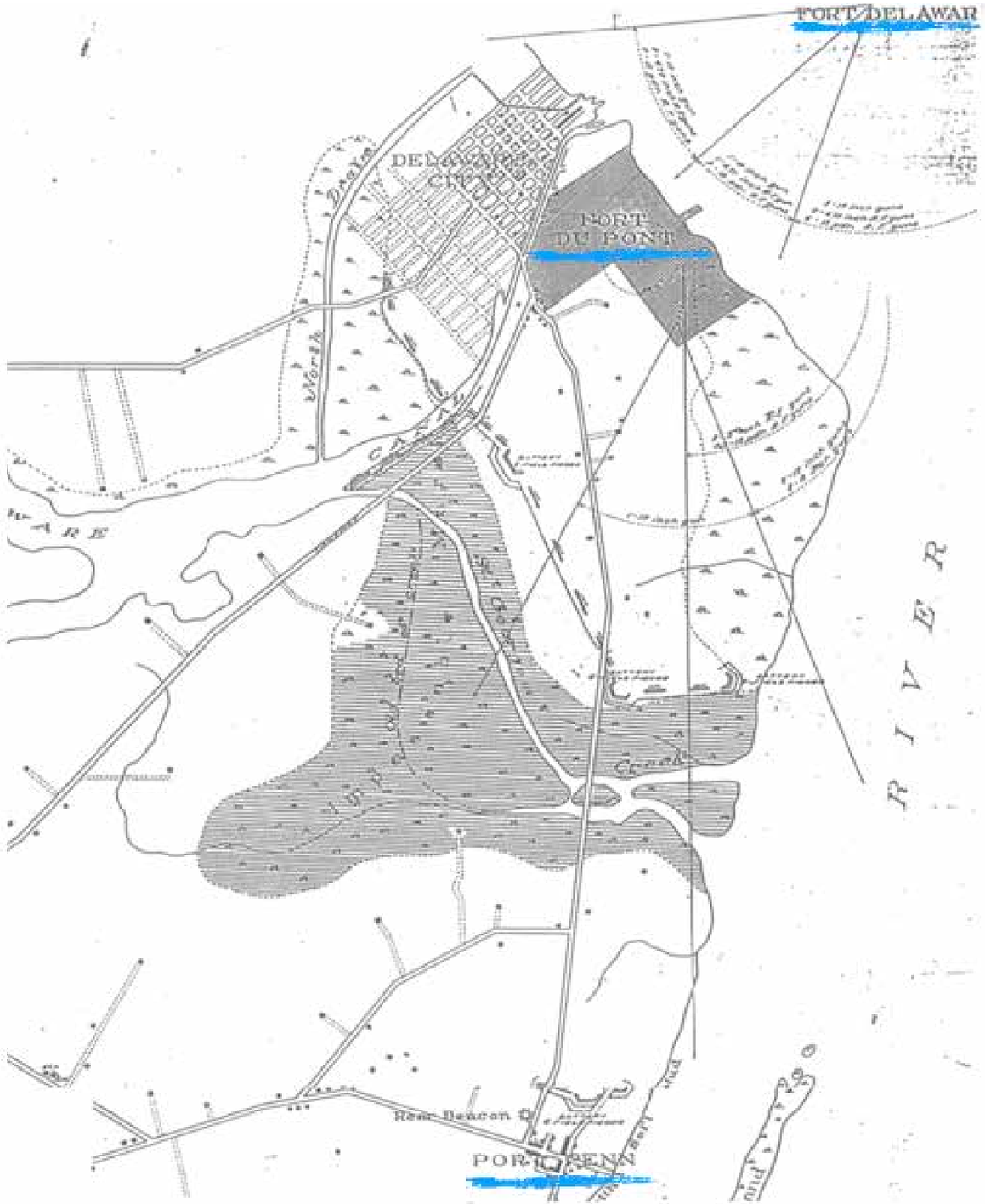


Figure 6. National Archives 1903 map showing trategic placement of Fort DuPont across the river from Fort Delaware (on Pea Patch Island) and within short distance of Port Penn.

Figures 4, 6, 8: Adapted from Ames, D., Doerrfeld, D., Elterich, A., Fisher, C. and Siders (Sheppard), R. (1994). *Fort DuPont, Delaware: An Architectural Survey and Evaluation* [PDF file]. University of Delaware Center for Historic Architecture and Engineering, pp. 49, 51, 68, 81. Retrieved from http://udspace.udel.edu/handle/19716/1516.

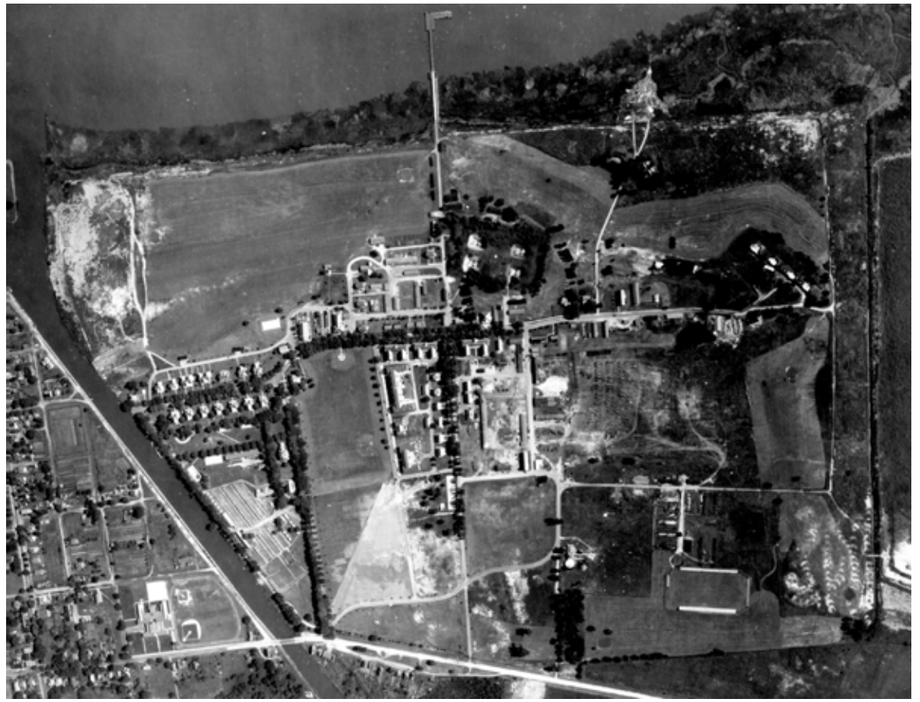


Figure 4. An aerial photograph of Fort DuPont from the CDSG Digital Library NARA Aerial Photographs Collection, 1940, shows the preserved historic integrity of the land.

Figure 5. An aerial image of Fort DuPont, 2016, shows little change to pathways, yet 63 of 273 historic structures remain intact. Adapted from *Google Maps*.

HISTORIC STRUCTURES

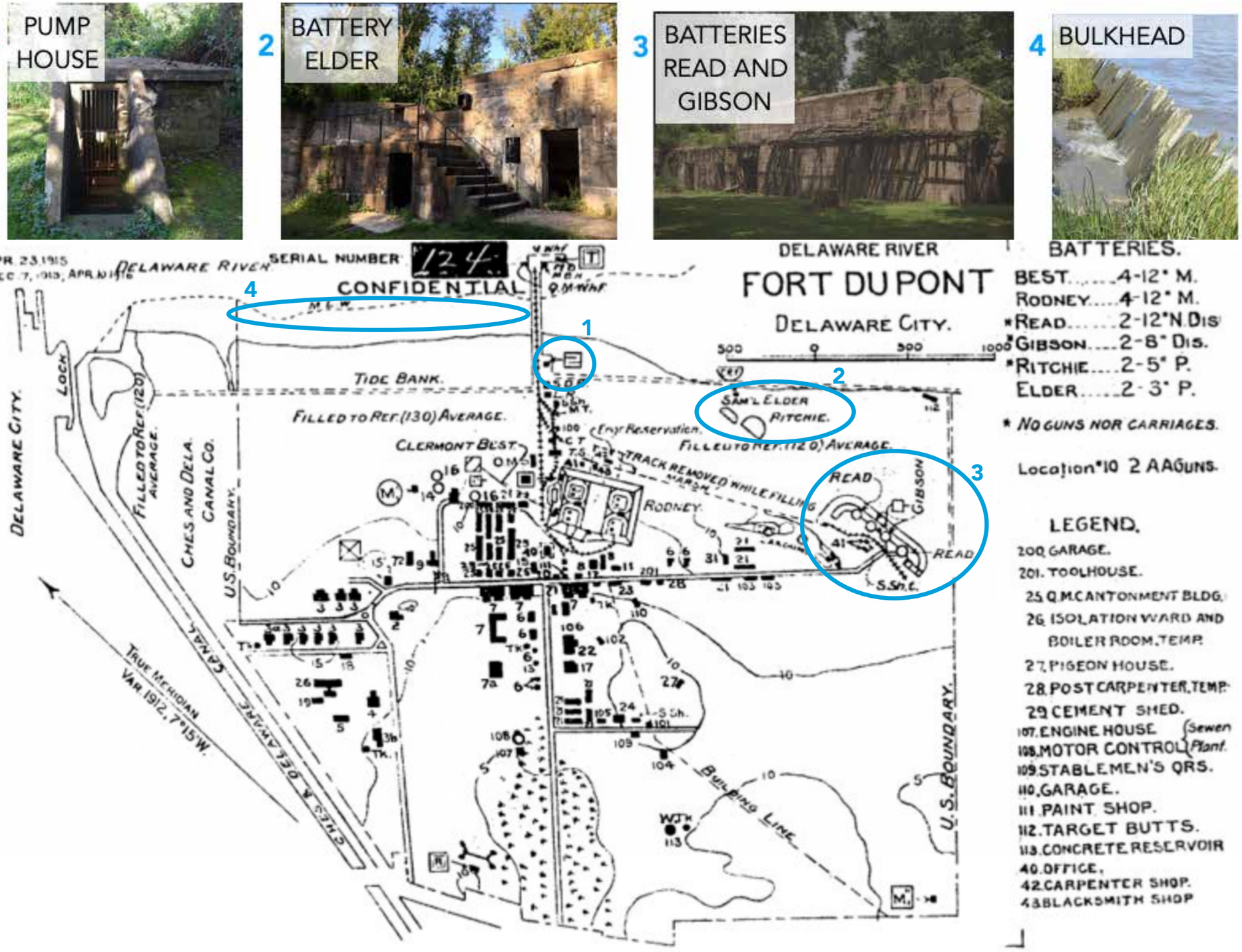


Figure 7. Map of Fort Dupont, 1915, showing the location of several historic infrastructure points of interest. Adapted from National Archives and Records Administration. (n.d.). *Fort DuPont Plan*. Retrieved from http://www.fortwiki.com/File:Fort_DuPont_Plan.jpg.

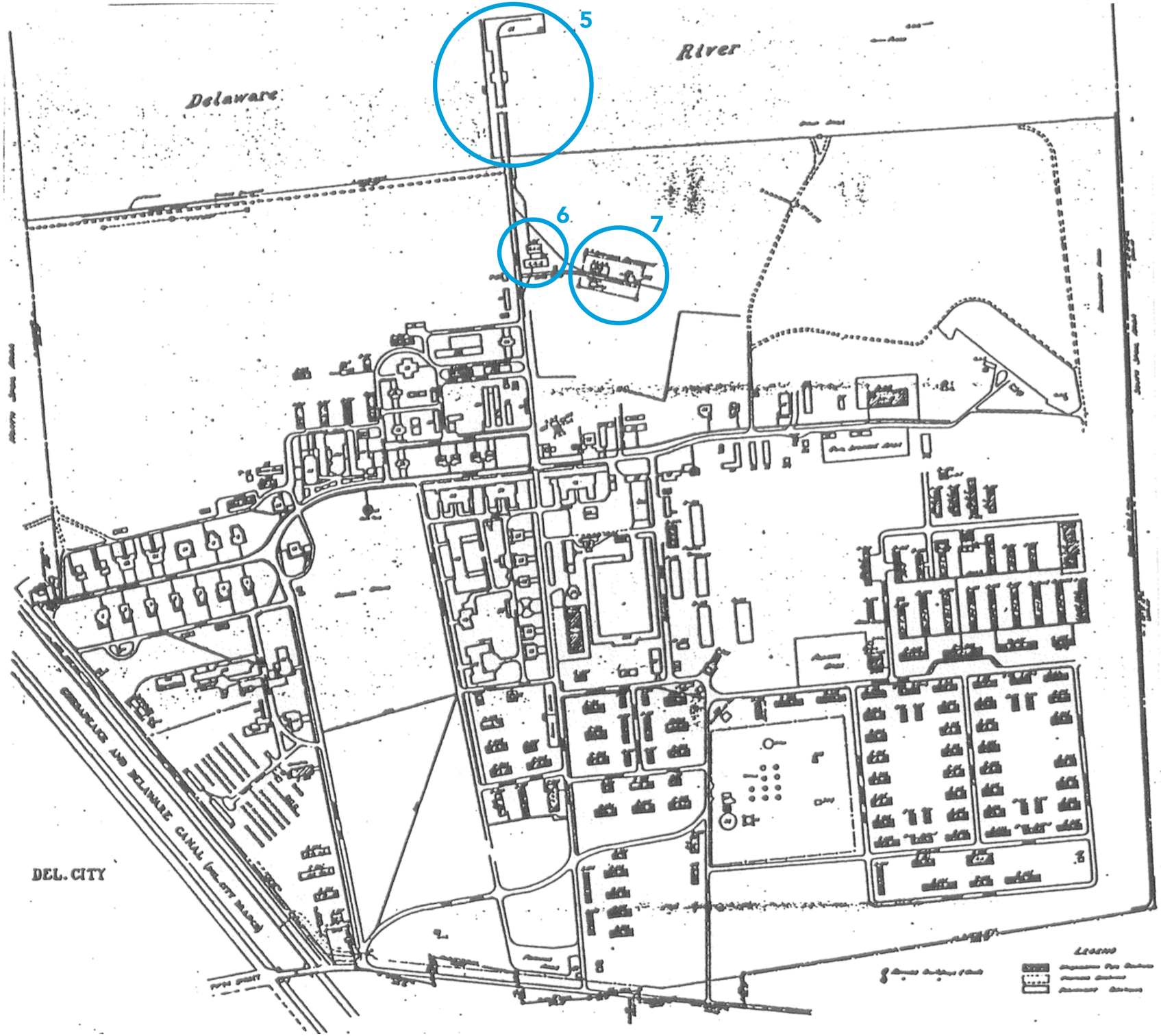


Figure 8. National Archives 1943 map of Fort Dupont detailing historic structures including the wharf form and size, as well as a "dumping area" at the coast.

5 - Wharf

6 - Warehouses

7 - Mortar Battery

PRECEDENT STUDY

SCAPE Living Breakwaters

SCAPE Ohio Creek Watershed Resilience

Biohabitats Drainage Retrofit and Living Shorelines

The following projects implemented green infrastructure or coastal protection in designs aimed at ecological and people-oriented resilience. Using a scale of innovation, I was able to rank each precedent study for its use of creative design solutions. I incorporated inspiration from researching these precedent studies into my final design.

LIVING BREAKWATERS

SCAPE / Landscape Architecture

LIVING BREAKWATERS
Staten Island, NY

INNOVATION LEVEL: I
(highest)

In a response to the U.S. Department of Housing and Urban Development's Rebuild by Design (RBD) Initiative after the destruction caused by Hurricane Sandy in 2012, SCAPE proposed a plan for **long-term shoreline protection and rehabilitation**. The project, Living Breakwaters, employs coastal resiliency infrastructure in the form of designed breakwaters and constructed reefs to promote the accretion of beach and wildlife habitat in the Staten Island Raritan Bay area.

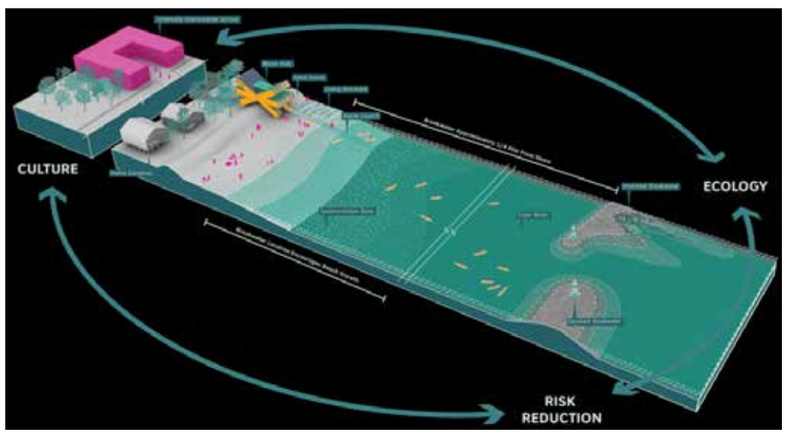
Infrastructure treatments are designed to encourage biodiversity by **creating niche space**, including reef space for oyster growth. Oyster harvesting is historically and culturally significant to the Raritan Bay. The treatments are also designed to **reduce risk associated with sea level rise** and storm events by protecting the shoreline and the surrounding community.

In addition to the focus on habitat and coastal resiliency, this project aims to **strengthen environmental stewardship**, water-based economy, and social resilience. Water hubs will connect schools with the coastline, allowing for further interaction with and education of the ecosystem. Hubs will encourage recreation along the waterway and preserve the region's historical coastal connection for future generations.

I chose to study this precedent site for it's innovative and engaging design approach. There is a clear focus on reclaiming historically significant habitat and ecological health in order to promote the resiliency of the coast from both an ecosystem service and social perspective.

Innovative Practices

- Study of landscape topology of shallow water zones
- Use of various materials in breakwater design to increase biodiversity
- Computer modeling of tide and wave action to select optimal placement of breakwaters



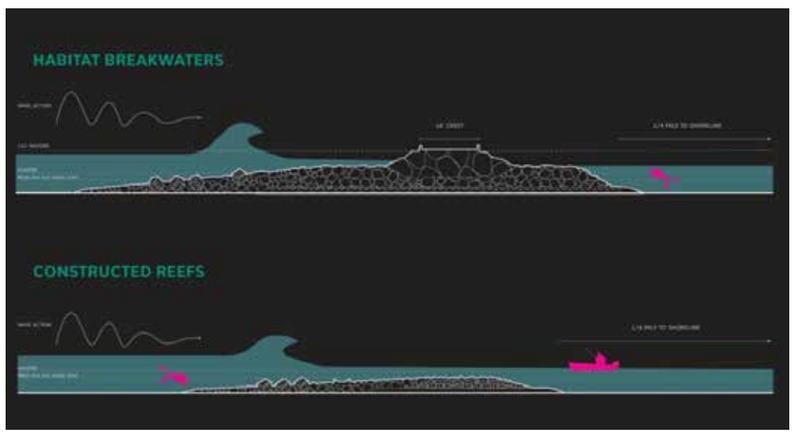


Figure 9. Use of eco-materials in breakwaters supports a variety of niches so that biodiversity may flourish.

Figure 10. Visualization of water hubs to promote community interaction, including recreation and education.

Figure 11 (far left). Connection of the infrastructure components and their ecology to the shore and culture.

Figure 12 (near left). Attenuation of waves by breakwaters and constructed reefs, as formed by study of landscape topology and computer modeling.

SCAPE

SCAPE Landscape Architecture. (2015). *Living Breakwaters Rebuild By Design Competition*. Retrieved from https://www.scapestudio.com/projects/living-breakwaters-competition/.

OHIO CREEK WATERSHED RESILIENCE

SCAPE / Landscape Architecture **INNOVATION LEVEL: II**

OHIO CREEK WATERSHED RESILIENCE PROJECT

Norfolk, VA

In a comprehensive watershed-sized approach, SCAPE is addressing sea level rise, storm surge, and flooding due to stormwater in the developed area of Norfolk, Virginia along the Elizabeth River. The health of the river has been historically compromised by significant industrial pollution that remains to this day. SCAPE has outlined three goals to achieve as part of this design focused on resilience:

"1) Designing the coastal community of the future,

2) creating economic opportunity by advancing efforts to grow existing and new industry sectors, and

3) advancing initiatives to connect communities, deconcentrate poverty, and strengthen neighborhoods"

The current focus is on the design of an open park space between two residential neighborhoods that face risk related to flood. The designs propose green infrastructure elements such as a flood berm, an open pond, and a wetland. In addition to **managing stormwater and surge**, the park aims to provide a space that promotes connectivity and health among the adjacent communities and into the watershed. Several walking, biking and kayaking loops establish a **sense of connectivity to the watershed**. The park will connect the community to the river through elements such as an educational center and coastal infrastructure (a pier, a pump station and a kayak launch).

This precedent site considers the implementation of green infrastructure practices along a river in the lower Chesapeake Bay area that experiences degraded health from industrial pollution, while also addressing large scale concerns stemming from an entire watershed. Because the Delaware River flows from large cities such as Philadelphia and Wilmington past my coastal study site, this site offers a comparison for coastal resiliency and river health.

Innovative Practices

- Study of detritus build up in high zones along the Elizabeth River to provide basis for planting in the wetland area
- Designing a flood berm to reduce risk related to flooding versus hard infrastructure such as a levee
- Connecting communities and elements within a watershed as opposed to infrastructural boundaries

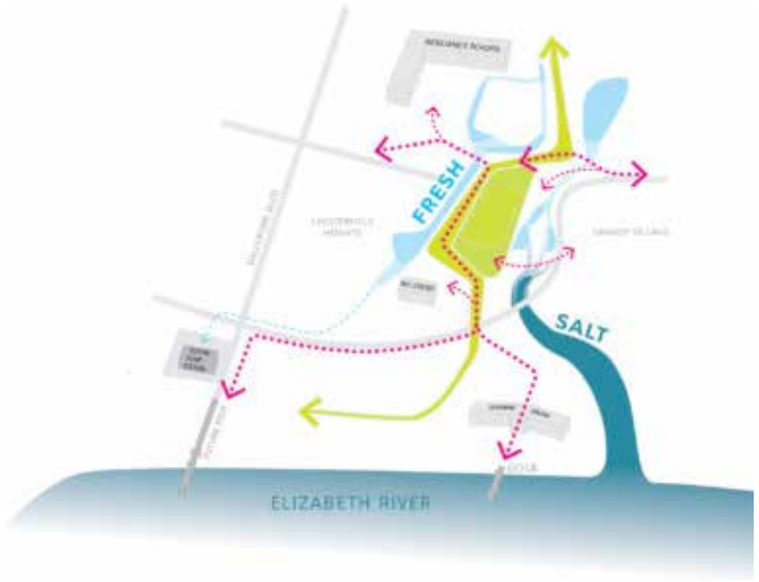


Figure 13. Connection of freshwater ecosystem to brackish ecosystem through public park space.

Figure 14. Connection of bike, walking and kayaking pathways within the watershed.

Figure 15 (left). Open park space design including stormwater management infrastructure such as a wetland and bioswales.

Figure 16 (right). Sources of pollution surrounding the Elizabeth River.

SCAPE Landscape Architecture. (2019). *Ohio Creek Watershed Resilience Project.* Retrieved from https://www.scapestudio.com/projects/ohio-creek-watershed/.

DRAINAGE RETROFIT AND LIVING SHORELINE

BIOHABITATS

INNOVATION LEVEL: III

ARUNDEL-ON-THE-BAY LID AND LIVING SHORELINE

Annapolis, MD

With a focus on regenerative design, the Arundel-on-the-Bay Living Shoreline addresses poor drainage and flooding issues for a 300-acre community in the Chesapeake and Delaware Bays area. The design for one 40-acre area, where untreated stormwater drains into Fishing Creek and significant flooding occurs, focuses on the implementation of two roadside swales and a living shoreline. By retrofitting ditches that were already established into flat swales, the design takes advantage of **cost-effective and low-impact** solutionsWW. The green infrastructure systems are incorporated into a community park where flood water accumulates.

The goals of implementing the green infrastructure techniques are to:

1) Provide storage for stormwater
2) Reduce pollution by drainage into waterways
3) Address flooding issues in the community

Innovative Practices

- Focus on LID (low impact development) to increase biological function of living systems
- Retrofitting drainage elements into coastal swales to increase their functionality in the landscape
- Opening previously filled tidal marsh and bulkhead to provide habitat

Figure 17. Establishment of a tidal marsh habitat that supports increased wildlife value.
Underwood and Associates. (2016). *Arundel on the Bay*. Retrieved from http://ecosystemrestoration.com/arundel-on-the-bay/.

Figure 18. A natural gradient was created for the living shoreline by using a range of materials: fine sand to pea gravel to cobble stone to boulders.
Arundel Rivers Federation. (2019). Arundel on the Bay Stormwater Wetlands. Retrieved from http://www.arundelrivers.org/restoration/stream-wetlands/atob/.

Figure 19. A retrofitted ditch becomes a roadside swale with riffle grade controls & pools - an aesthetic mimicing a natural streambed.
Biohabitats. (n.d.). Arundel-on-the-Bay LID and Living Shoreline. Retrieved from https://www.biohabitats.com/wp-content/uploads/Arundel-on-the-Bay-2.pdf.

SITE ANALYSIS

Floodplain & Waterways

Coastal Erosion & Orthophotography

Sea Level Rise Projection

Bathymetry & Ship Traffic

Soil Composition & Boring Data

Natural Assets

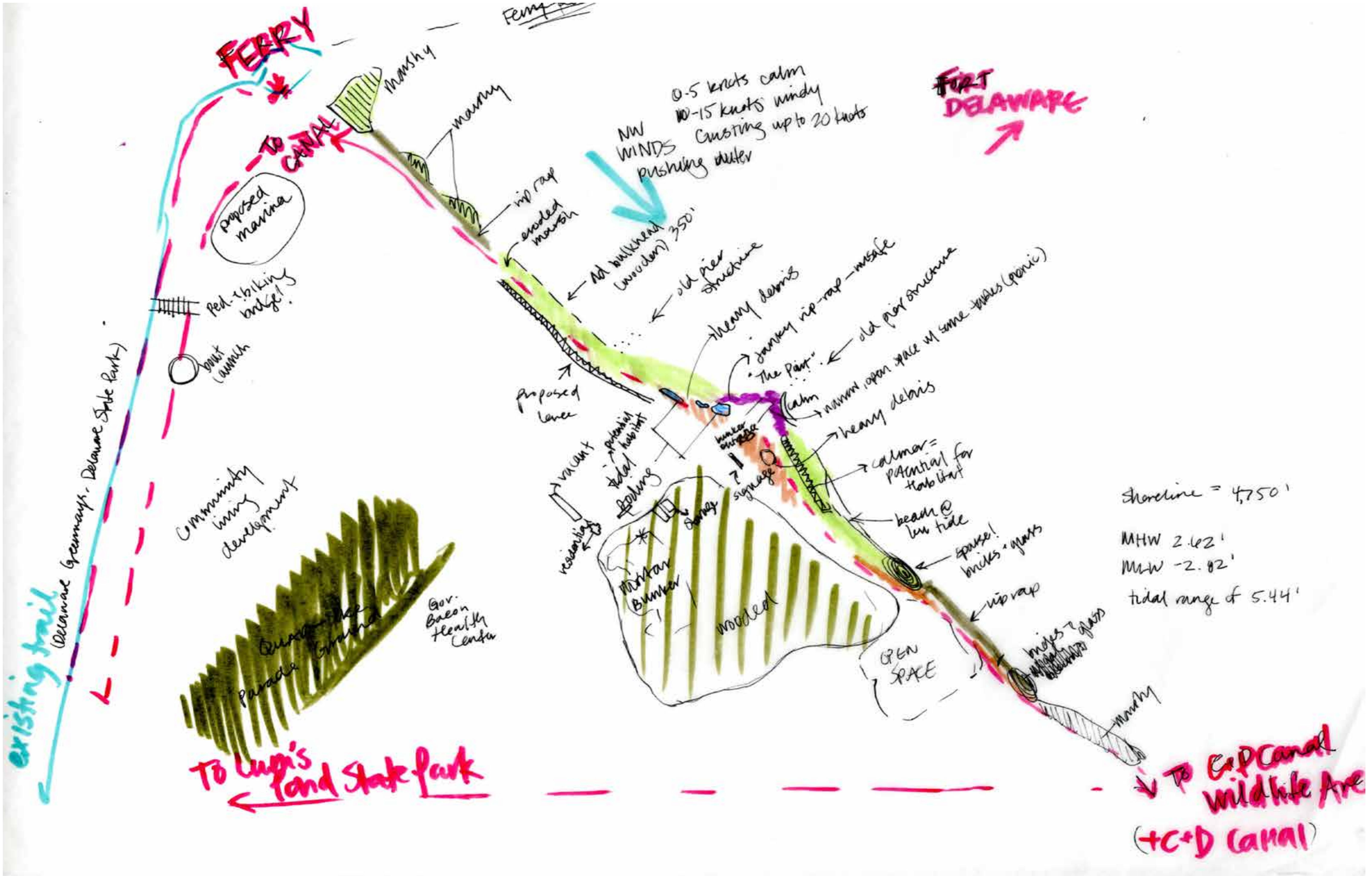
Connectivity

Wildlife

Plant Community & Invasive Pressure

Topography

Instagram Analysis



FERRY
Ferry
marshy
TO CANAL
proposed marina
0-5 knots calm
10-15 knots windy
Gusting up to 20 knots
NW WINDS pushing water
FORT DELAWARE
rip rap
eroded marsh
Old bulkhead (wooden) 350'
old pier structure
heavy debris
janky rip-rap - unsafe
"The Point"
old pier structure
narrow open space w/ some tables (picnic)
calm
heavy debris
calmer = potential for habitat
beach @ low tide
sparse! bricks + glass
rip rap
marshy
ped + biking bridge!
boat launch
proposed levee
potential habitat
tidal
vacant
signage
Mortar Bunker
wooded
OPEN SPACE
community living development
Parade Ground
Gov. Bacon Health Center
existing trail (Delaware Greenways - Delaware State Park)
Shoreline = 4,750'
MHW 2.62'
MLW -2.82'
tidal range of 5.44'
To Lums Pond State Park
To C+D Canal Wildlife Area (+C+D Canal)

COASTAL EROSION & ORTHOPHOTOGRAPHY

By overlaying several aerial photographs spanning the years 1937 to 2017, the effects of global change on coastal structures and marsh ecosystems become clear. Mapping the edge of tidal marsh indicates the loss of up to 100 foot extensions of plant life into the river along this coastline in the past 80 years.

1937

1954

1992

2017

N

Scale: 1″ = 500′ - 0″

Figure 21. Erosion along the coast from 1937-2017.

Delaware Archives, National Archives and USDA Agricultural Stabilization and Conservation Service. (1937). Delaware 1937, 1954, 1992, 2017 Orthophotography [Data file]. Retrieved from http://firstmap.gis.delaware.gov/arcgis/rest/services/DE_Imagery.

FLOODPLAIN & WATERWAYS

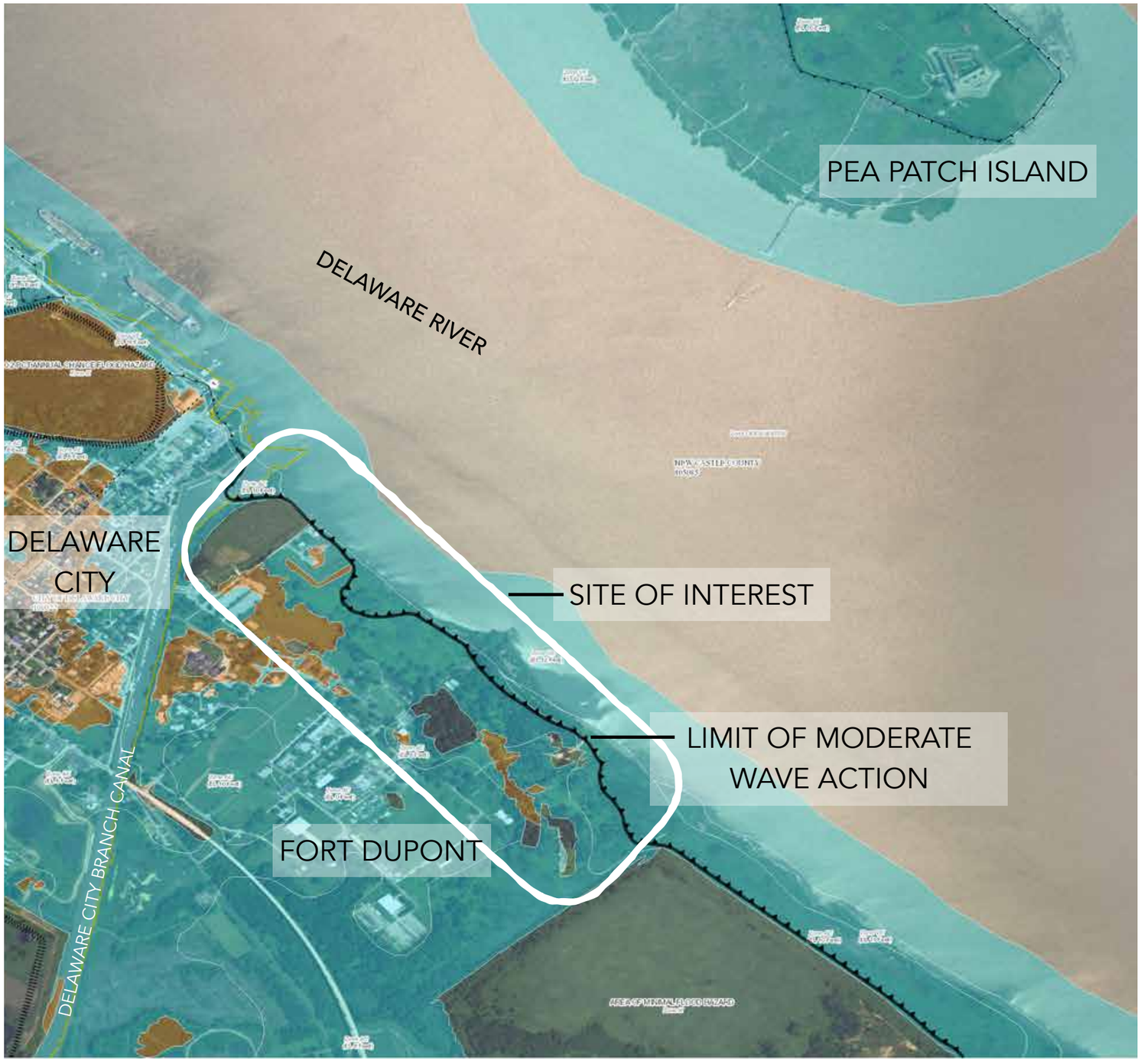


Figure 20. FEMA flood map showing flood prone areas and the limit of moderate wave action along the coast.
FEMA. (2017). National Flood Hazard Layer (NFHL) Viewer [Online Map Viewer]. Using: Esri ArcGIS [GIS software].Retrieved from https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html.

Fort DuPont in Delaware City is located in a coastal zone along the Delaware River. The Delaware River flows along Delaware's northern coast, to the Delaware Bay and out to the Atlantic Ocean. The site of interest includes the coast and of Fort DuPont is designated as state protected land.

The Delaware City Branch Canal is located to the west of the site, and the Chesapeake and Delaware (C&D) canal to the southeast of the site. The site is located within the C&D Canal East Watershed, and most runoff drains first to the C&D Canal, eventually meeting the Delaware River.

The adjacent map generated by FEMA displays areas of inundation in the case of the **100-year storm event in blue** and the **500-year storm flood areas in orange**.

The high risk of flooding at Fort DuPont will be addressed in the design solution. Strategies focusing on adaptative coastal structure combined with protective earthwork have the ability to protect upshore areas and preserve historical features.

By emphasizing the **limit of moderate wave action** (shown in black) through a strategic placement of pathways that follow its form, connectivity both relates to the natural environment and provides the opportunity for interpretation of the coastline with indicating signage.

KEY

100-YR FLOOD

500-YR FLOOD

LIMIT OF MODERATE WAVE ACTION

SCALE **1" = 1000'-0"**

0 500 1000 2000

N

SEA LEVEL RISE PROJECTIONS

Figure 22. Areas that experience high tide flooding are shown in red along the coast and inland from the canal.

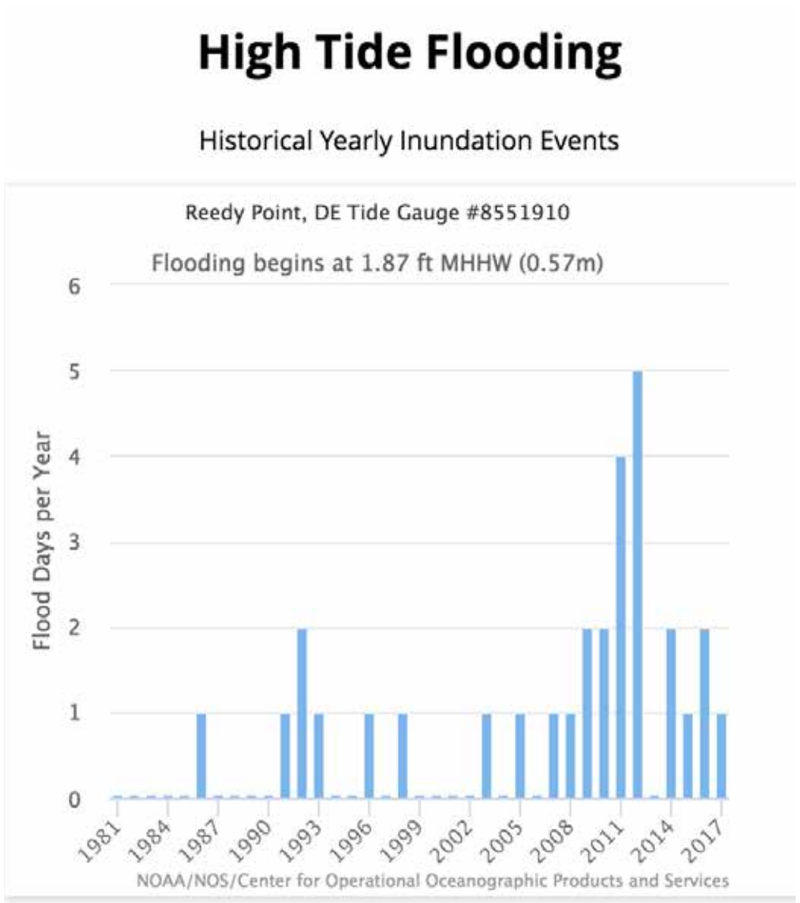


Figure 23. The incidence of high tide flooding at the nearby Reedy Point tide gauge is on trend for many U.S. coastal zones, with more frequent historical yearly inundation events in recent years.

Data from the National Oceanic and Atmospheric Administration (NOAA) shows the Fort DuPont coastline is subject to tidal flooding also known as "reccurent or nuisance flooding". Tidal flooding is defined by repeated significant inundation events that "exceed local thresholds for minor impacts to infrastructure". NOAA states that these flooding events "have increased 5- to 10-fold since the 1960's in several U.S. coastal cities" (NOAA Office for Coastal Management). Areas that experience reccurrent high tide flooding are good indicators of areas susceptible to the impact of sea level rise in coastal areas. With an intermediate level projection for sea level rise, there will be both significant permanent flooding of the coastal region of the site and increased tidal flooding by the year 2060, as shown in the maps above. Design solutions will plan for increased tidal flooding and the idea that habitat will need to migrate with the changing climate.

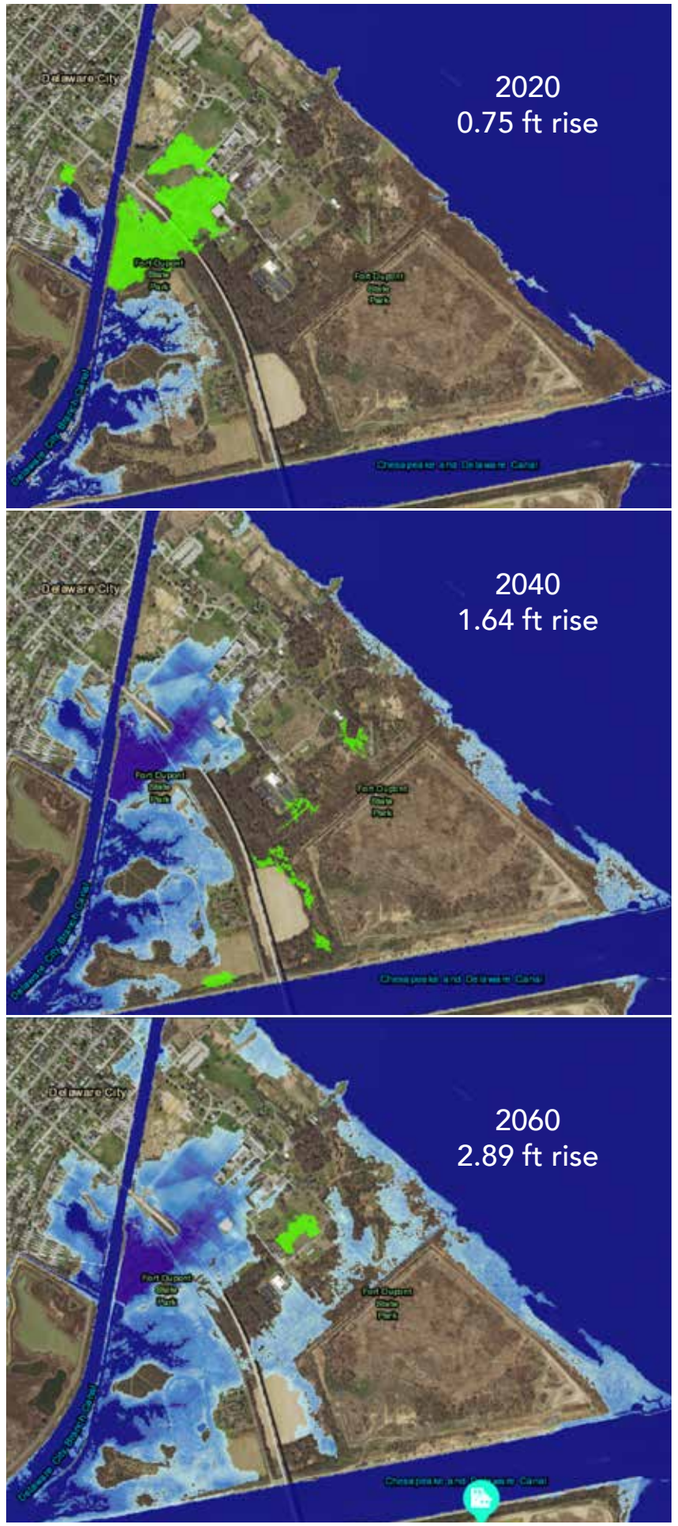


Figure 24 (right). Intermediate scenario prediction for 0.75 ft (year 2020), 1.64 ft (year 2040), and 2.89 ft (year 2060) sea level rise increase from current MHHW.

Figures 22-24 adapted from NOAA Office for Coastal Management. (2019). Sea Level Rise Viewer [Online Map].Retrieved from https://coast.noaa.gov/slr/.

BATHYMETRY & SHIP TRAFFIC

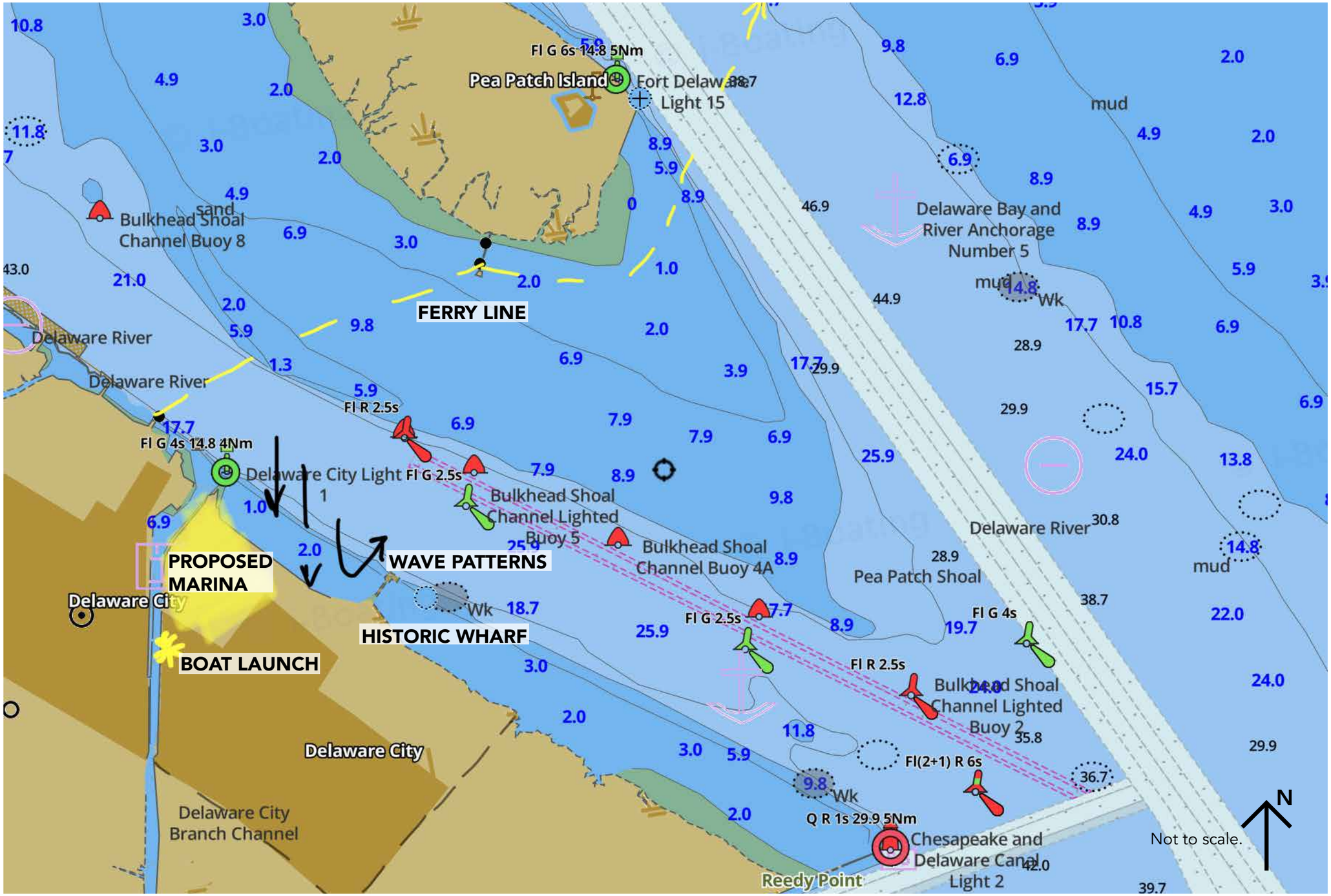


Figure 25. Channels, ship traffic, and wave flow patterns as observed on site.
GPS Nautical Charts. (2014). Delaware River Marine Chart [Online Map]. Retrieved from fishing-app.gpsnauticalcharts.com.

Residents and visitors may access the river from Fort DuPont at the boat launch or dock their boats within the Delaware City Branch Canal.

Site-adjacent channels are used for recreation, fishing and as passage for shipping. Large ships and barges pass to either side of Pea Patch Island, and effect a small yet consistent wake.

The Fort Delaware Ferry runs seasonally to from Delaware City to Pea Patch Island and across to Fort Mott in New Jersey.

With the implementation of a proposed marina in the 2013 Fort DuPont Master Plan, it is likely that the coastline will recieve increased wave action from shipwake in the future.

Considering offshore bathymetry and understanding ship traffic patterns and impact aided in the design and positioning of designed breakwaters to offer protection.

SOIL COMPOSITION & BORING DATA

The dominant soils nearest the shoreline have properties of both natural and disturbed envrionments. Broadkill mucky peat (MuB) is a typical soil for consistently inundated and tidally flooded areas. MuB has characteristics of urban infill, due to degradation from development (Soil Survey, n.d.). Development of this site began as early as 1861 during the American Civil War.

Due to the historic military use of the site, several areas were exposed to contamination and have undergone investigation since the 1980's. Four sites have been remediated or are in the process of being remediated.

The first of these sites was used historically as a landfill is located in open space along the coastline. This area was once used as a landfill, and marked as such in historic maps as a "dumping area". An EPA removal action was performed here to remove PCB contamination in the soil, and the area was filled with one foot of new soil.

The second site of contamination is a SIRB site currently undergoing remediation where marina spoils were piled, at the outlet of the Delaware City Branch Canal.

The third contamination site falls outside of the study boundary, along the Branch Canal, where there are plans for residential development. Here, a brownfield investigation deemed no remediation plans neccesary because contaminents do not exceed threshold levels.

The final contamination site exists at the Mortar Bunker, where remediation of soil contaminants has been completed with a limited soil excavation. The remediation eliminates potential risk to visitors and residents, though the use of groundwater in the area is prohibited (DNREC, 2018).

COASTAL SOILS

MuB - Mattapex-Urban land complex, 0 to 5 percent slopes

Br - Broadkill mucky peat, very frequently flooded, tidal

OTHER SOILS OF INTEREST

UzC - Udorthents, 0 to 10 percent slopes

Soil Remediation Site

Off-Site Areas

Figure 26 (right). Soil map created with Web Soil Survey.
Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey [Online map]. Retrieved from https://websoilsurvey.sc.egov.usda.gov/. Accessed November 2018.

NATURAL ASSETS

Figure 27. Forest cover, wetland, and marsh at Fort Dupont.
New Castle County GIS Services. (2017). "Explore New Castle County" [online map viewer]. Using: Esri ArcGIS [GIS software]. Retrieved from https://nccde.maps.arcgis.com/apps/webappviewer/index.html.

Most natural assets at Fort Dupont are located along the southern portion of the coast.

Existing forest is located inland from the coast to the south of the point. Forested area north of the point has been removed through the development of the military base as well as open space. Forested area is crucial to the site's hydrology because it acts as a riparian buffer, filtering runoff that drains to the Delaware River. Of the many ecosystem services that forests provide, their ability to uptake and transpire water significantly impacts stormwater management and mitigates flooding.

Wetlands are one of the most productive ecosystems because they host a diverse range of species and have a significant capacity to uptake atmospheric carbon. Most wetlands on site are tidally inundated, though some are located further inland. With the migration of river inland, wetlands have been lost, primarily on the northern shore.

Marsh - a form of wetland dominated by herbaceous plants - has been protected along the southern shore and degraded along the northern shore. The dominant species of marshland on site is smooth cordgrass, *Spartina alterniflora*.

With plans for new development at Fort Dupont, the coastal design solution will increase biomass where it is most needed in order to establish a riparian buffer and enhance productive, diverse habitat space.

CONNECTIVITY

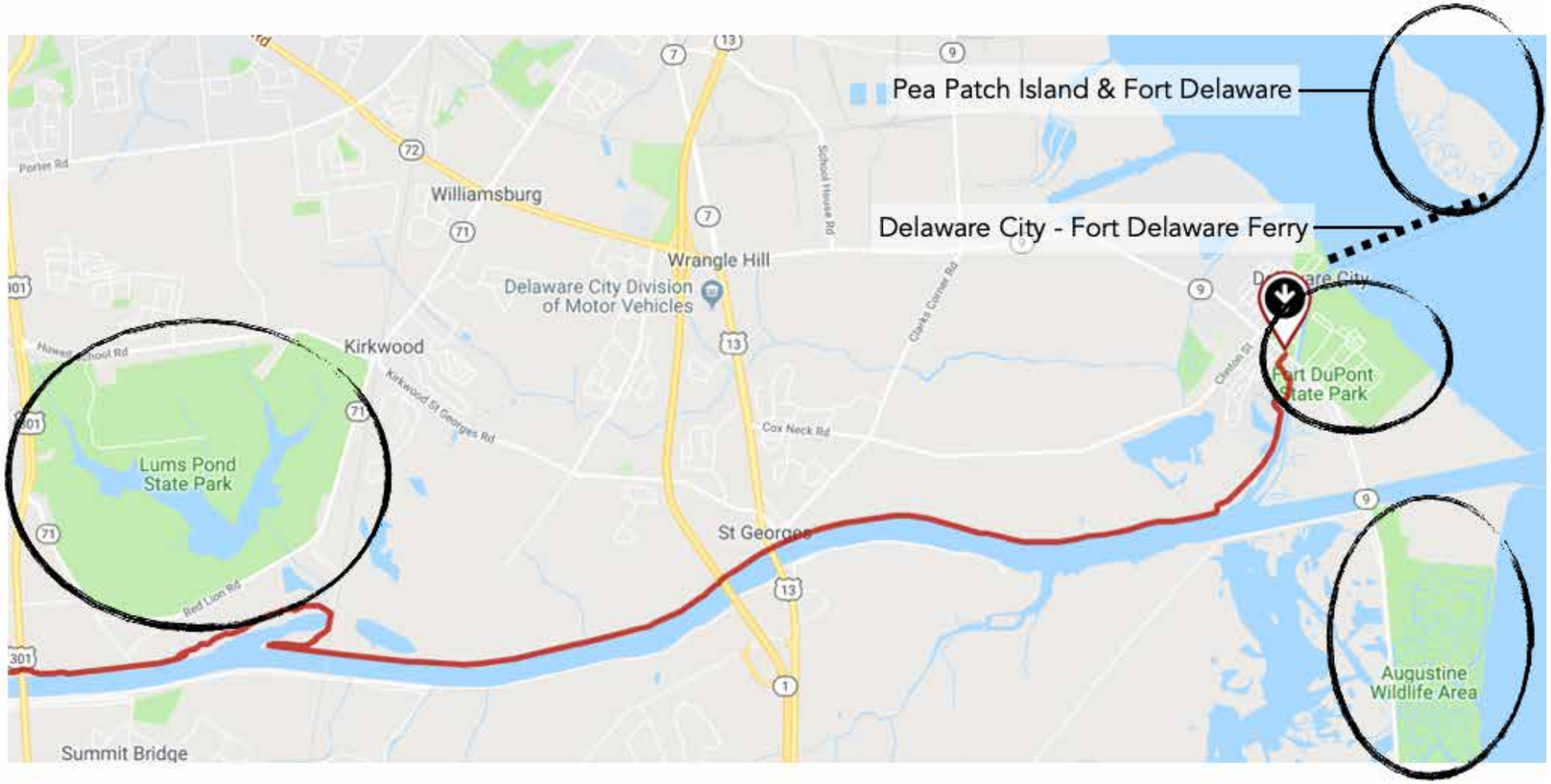


Figure 28. The Michael Castle Trail connects Delaware City to Lum's Pond State Park and the Fort Delaware Ferry line connects Delaware City to Pea Patch Island.
Google Maps. (2019). Michael Castle Trail. Retrieved from https://www.traillink.com/city/delaware-city-de-trails/.

Fort DuPont is in a prime location relative to other natural and cultural amenities in the vicinity, such as the Augustine Wildlife Area, Lum's Pond State Park, Fort Delaware and historic Delaware City. The Michael Castle Trail currently connects Delaware City to Lum's Pond State Park and the Fort Delaware Ferry line connects Delaware City to Pea Patch Island. Existing pathways on site suggest a need for updated access to these amenities. The opportunity to connect natural and cultural nodes with a multi-use pathway promotes nature- and history-based tourism. The proposed pathway improves regional access from Fort DuPont to outlying amenities.

PLANT COMMUNITY & INVASIVE PRESSURE

Emergent Wetland Plants

Spartina alterniflora, salt marsh cordgrass

Plant Community: emergent brackish tidal marsh
Dominant plant species: *Spartina alterniflora*, salt marsh cordgrass

Most healthy marsh on site is comprised of salt marsh cordgrass, a native deciduous grass with golden fall color. Other grasses and rushes are present, though not as numerous, including *Schoenoplectus tabernaemontani*, an indicator species that does not tolerate high salinty. The presence of this species indicates that the brackish water may be more freshwater influenced and low in salinity.

There are introduced and weedy species throughout the wooded and upland areas. Of greatest concern, *Phragmites australis* is an invasive species on site that has the potential to displace native shoreline planting if it is not strategically removed and monitored.

Introduced Plants

Rosa multiflora, multiflora rose

Hibiscus moschutos, rose-mallow

Panicum virgatum, switchgrass

Schoenoplectus tabernaemontani, softstem bullbrush

Artemisia vulgaris, mugwort
noxious weed

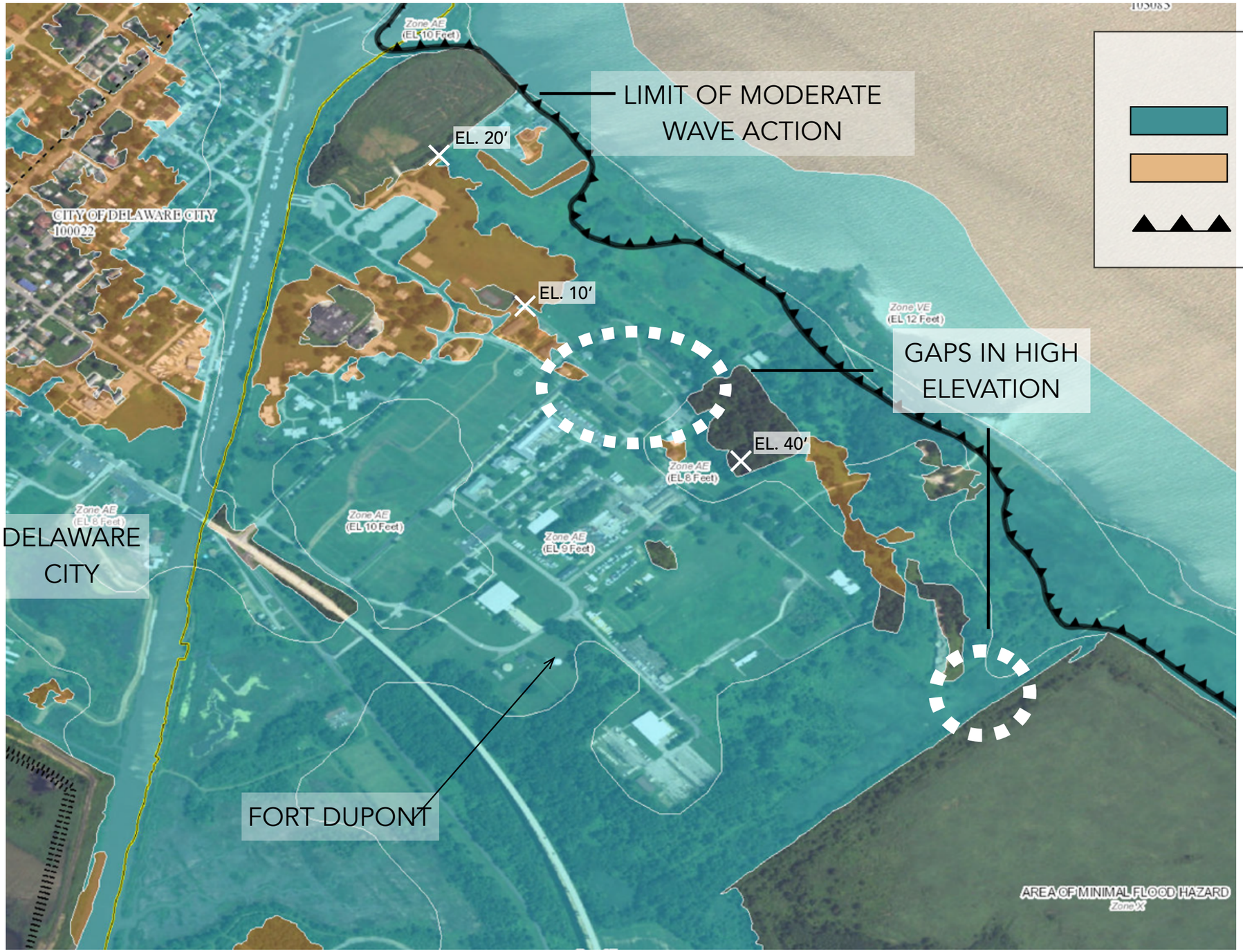
Samolus parviflorus, water pimpernel

Lilaeopsis chinensis, eastern lilaeopsis

Juncus canadensis, tailed rush

Phragmites australis, invasive phragmites

TOPOGRAPHY



The property lies at a relatively low elevation, below 10', yet several areas and points of high elevation connect along the length of the property, parallel to the coast. Two gaps exist between areas of high elevation, circled in white. By **bridging the gaps in high elevation** with a flood berm, the site's topography acts as a natural and cost-effective levee to protect the historic structures at Fort DuPont.

Land indicated in orange has an elevation of 10' or greater, while land not indicated by color has an elevation of at least 20'. The highest spot elevation is atop the mortar bunker at 40'.

Figure 29. FEMA flood map showing areas of low and high elevation, as well as gaps between high elevations.
FEMA. (2017). National Flood Hazard Layer (NFHL) Viewer [Online Map Viewer]. Using: Esri ArcGIS [GIS software].Retrieved from https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html.

INSTAGRAM ANALYSIS

By accessing the Instagram page for the Fort DuPont State Park location, I was able to use social media to see how people currently utilize the space and what feelings the space might evoke for a visitor. By systematically reviewing 240 photographs, I documented each instance of a subject that was captured as an image. By reviewing each of the captions with each photograph, I recorded the number of times a descriptive word was used, or a word that explained how the user was engaging with the site. It is from this public data and my own experiences on site that I was able to understand the allure of discovery and adventure, which led to design decisions that showcase the historic military infrastructure in a way that is beatiful and engaging.

Top Posts

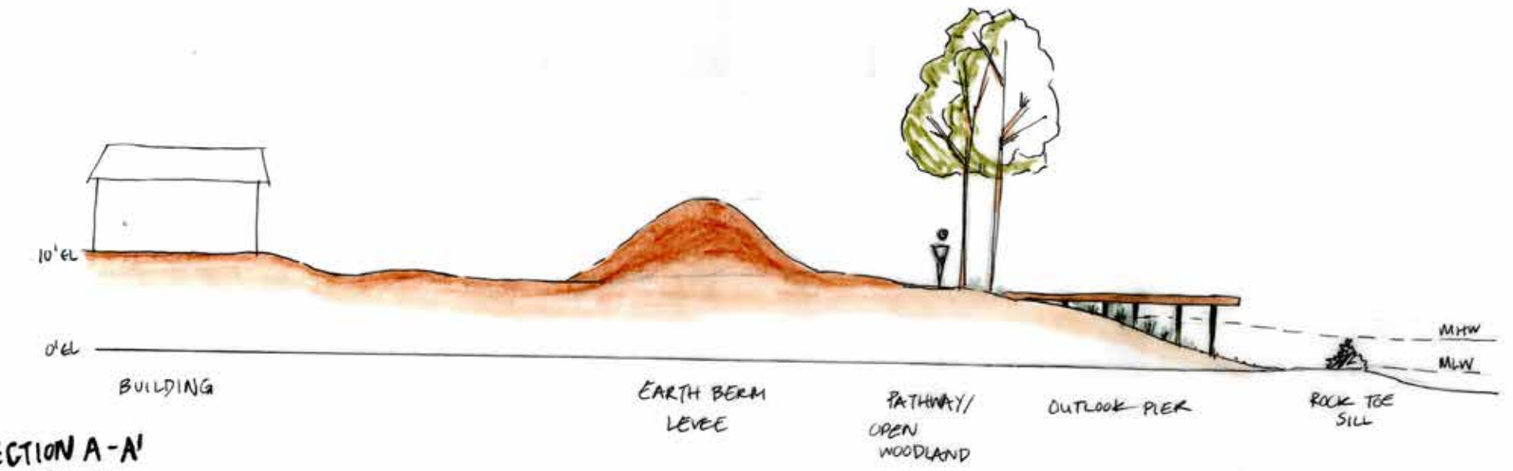
173 Infrastructure
(buildings, concrete, bridges, etc.)
112 Delaware River
70 Marsh / Other Planting
54 Self
53 Point / Wharf Remains
49 Water's Edge
(rip rap, rocks, ceramics, driftwood)
42 Biking / Hiking / Trails
37 Sky (sunrise, sunset)
34 Open Space Use
(yoga, baseball, sitting, eating)
25 Watercraft
23 Wildlife (birding, fishing)
20 Festival
12 Pets
11 View to Pea Patch Island
9 Forest

Top Descriptors / Comments

30 Explore / Adventure / Discover / Find
26 History / Military
26 Abandoned / Ruins / Rustic / Old
18 Beauty / Views
17 Friends / Family
17 Interesting / Cool
17 Hike / Run
14 Nature

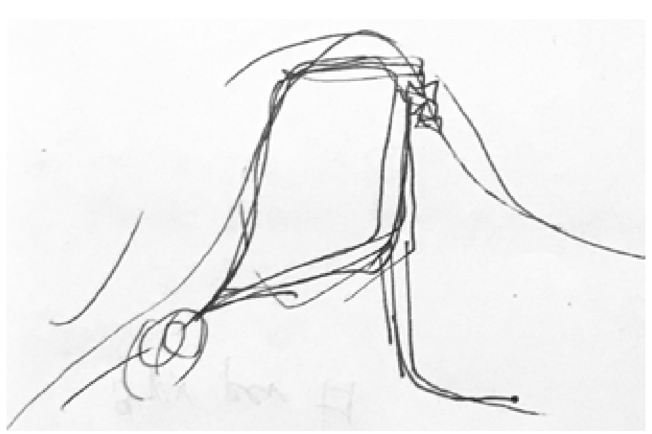
PROCESS

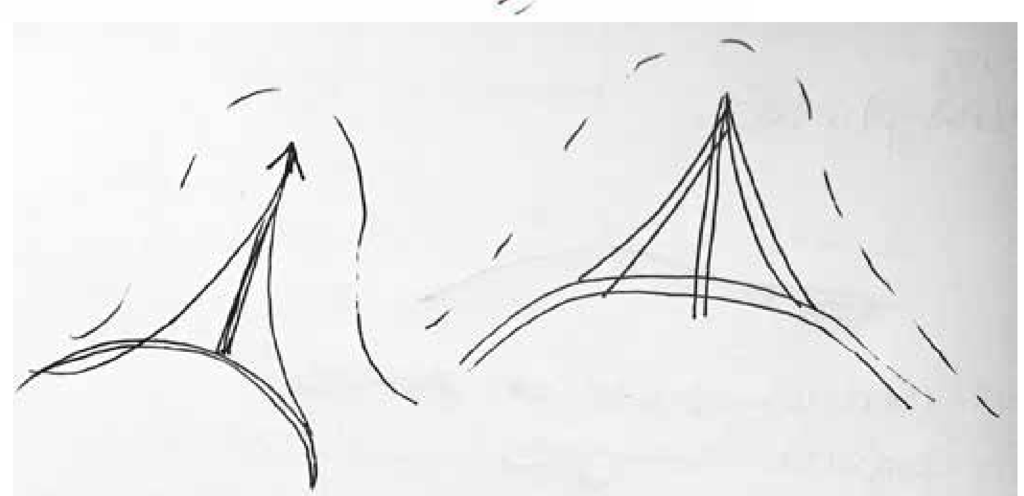
SECTION B-B'
VERTICAL SCALE: 1" = 10'-0"

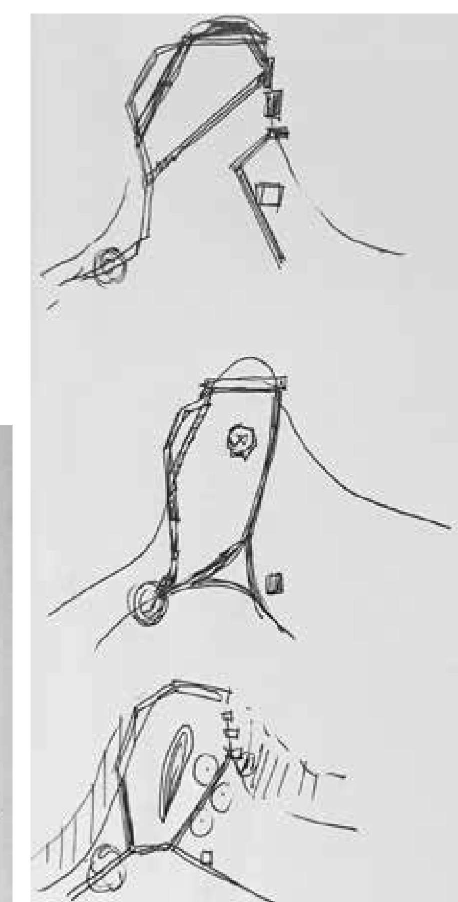


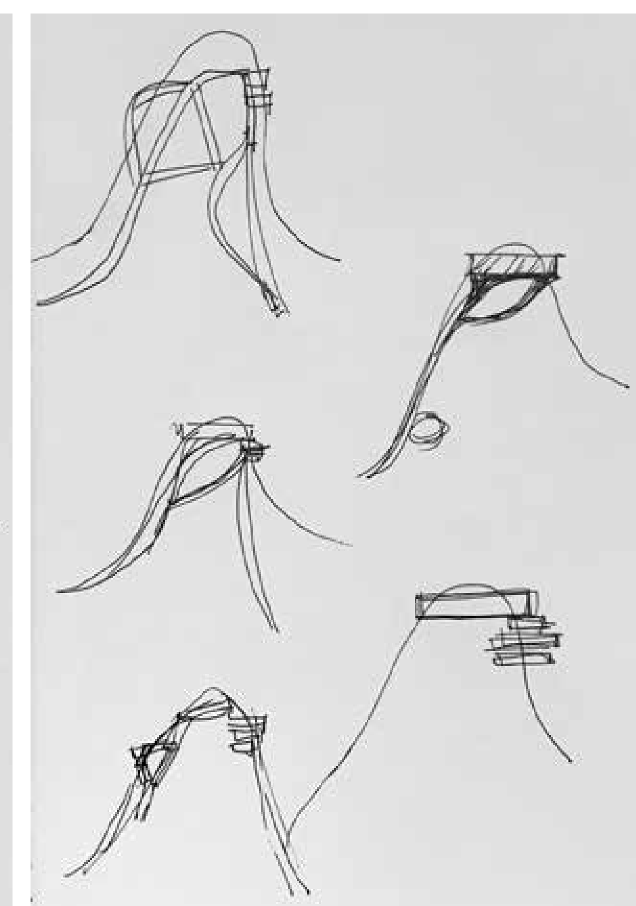
SECTION A-A'
Vertical Scale: 1" = 10'-0"

pier
wetland rip rap
tidal pool 'freshwater' mussel habitat
remove debris - plant shoreline
low gabion groins
enhance beach here
kayak launch
historical parking interpretation
parking
lighting
earth berm 8' tall
* BOAT LAUNCH ACCESS









MASTER PLAN

To address how landscape architects might implement green infrastructure to protect shoreline ecosystems, mitigate the effects of climate change, provide habitat for wildlife, and encourage environmental stewardship as well as a human-coastline connection, the following design proposes:

1) improved access points and connectivity to the Delaware River and to the amenities of Fort DuPont to increase a sense of environmental stewardship among Delaware City residents and an understanding of the potential risks associated with sea level rise. This relates to my first objective - to promote human connectivity to the Delaware River and to the amenities of Fort DuPont's natural and cultural history.

2) living shoreline elements including shallow breakwaters and rock toe sills to re-establish healthy marsh that protects the shore against storm surge and flooding and provides habitat. This relates to my objectives to provide design solutions for coastal change associated with the degradation of marshland and future sea level rise and to enhance habitat for emergent tidal wetland plants and animals.

3) a connection of wooded and riverfront trails with elements of environmental and historic interpretation that link to natural and cultural amenities and regional destinations in order to promote nature- and history-based tourism. This relates to my objective to interpret and protect the cultural history of Fort DuPont and its coastal historic structures.

4) an earthen berm levee with corresponding stormwater bioswale to connect high points of elevation that protect Fort DuPont's history and improve the quality of stormwater runoff from developmental projects at Fort DuPont.

LARC450 - SENIOR DESIGN
PROFESSOR JULES BRUCK

EMMA RUGGIERO
UNIVERSITY OF DELAWARE

FORT DUPONT SHORELINE
DELAWARE CITY, DE

DATE: 04 JANUARY 2019

SCALE: 1" = 150'-0"

0 75' 150' 300'
0" 1/2" 1" 2"

N

5.9′

2.0′

MARSH TO

BREAKWATERS

A

MARSH TOE SILL

REMOVE BULKHEAD

BOARDWALK

LOW
MEADOW

HIGH MEADOW

MARINA

A′

PARKING

FLOOD BERM

STORMWATER
SWALE

DIVERSE
MARSH
PLANTING

BERM
LEVEE

BREAKWATER

UPLAND BUFFER

LOW MEADOW

MULTI-USE
PATH

SWALE

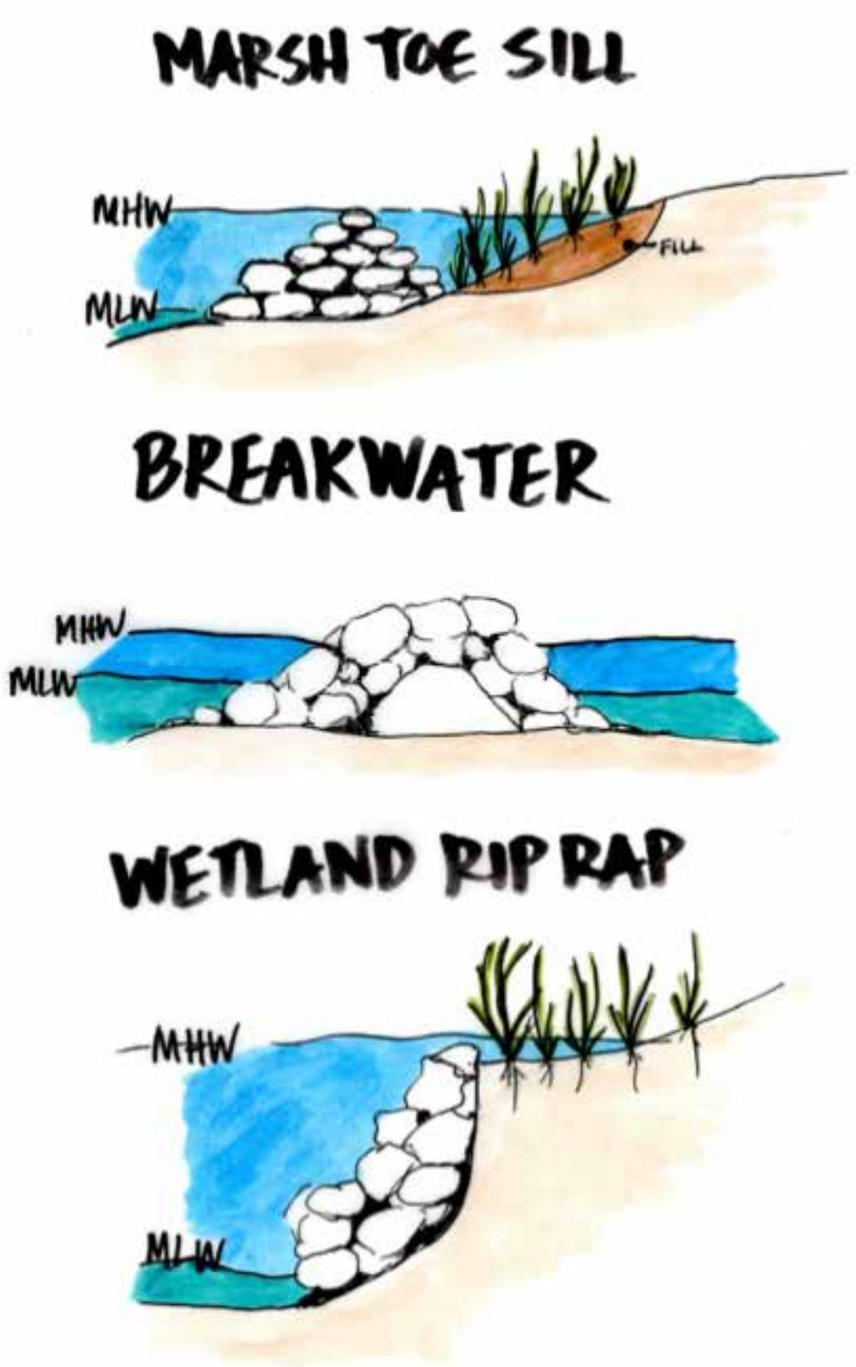
Figure 30 (above). Final site design showing an installation of new trails, a berm connecting high points of elevation, a stormwater swale, two meadow areas, living shoreline treatments, an overlook, and a pocket beach.
Figure 31 (left). Section A - A' Breakwater and living shoreline connection to upland buffer, low meadow planting, and berm.

The riverfront trails east of the point follow the form of the limit of moderate wave action, and provide an opportunity for interpretation of the changing coastline. Woodland trails weave through property west of the point and pass historic structures determined significant to visitors by the Instagram analysis. Visitors may learn about Fort DuPont's historic land use as a military base through interpretive signage at various structures and points of interest. The points of interest include a pump house, Battery Elder, Batteries Read and Gibson, the Mortar Battery, and the remnants of bulkhead and wharf off of the point.

SHORELINE PROTECTION

Combination Techniques

Strict Hard Armor



Site analysis results indicate receding marsh edge, increasing sea level rise, and recurring tidal flooding on the Fort DuPont property. Therefore, the design solution combines a living shoreline coastal structure and protective earthwork to protect upshore areas and preserve historical features.

Combination living shoreline techniques are more natural and allow for wave attenuation that does not cause scouring, unlike other hard-armorned techniques. Designed breakwaters will allow for the accretion of sediment and the creation of further marsh habitat over time, while marsh toe sill will dissipate wave energy near shore.

Figure 32 (left). Five engineered shoreline protection measures were considered for the design, with the final selection combining marsh toe sill and living breakwaters.

BREAKWATERS

The site experiences high wave energy and action caused by passing ships, storms and wind. Techniques that combine the use of engineered “hard” structures such as breakwaters, along with “softer” living shoreline treatments are best suited to the needs for attenuating wave action and preventing significant erosion. The design solution combines offshore living breakwaters with nearshore marsh toe sill. Living components are incorporated into the design of each, with tidal marsh planting incorporated behind the rock sill and atop the breakwater. This design provides habitat for wildlife both above water in diverse marsh plant life and below water in the crevices between submerged rocks and concrete.

Careful calculation of breakwater dimensions, including height and crest width were utilized to ensure the attenuation of waves caused by ship wake would offer significant coastal protection.

Calculations for Breakwater Width and Height

Assume currents to be **1.39887 knots = 2.361 ft/sec**, measured at a NOAA sensor in Philadelphia (closest station: stronger currents upstream for conservative calculation).

Tide Measurements @ Delaware City (NOAA):

MHW @ 2.62 NAVD88
MLW @ -2.82 NAVD88

Crest width = 3 ft
Structure height = 7 ft

@ MWH, kt = 0.3669
@ MLW, kt = 0.8128

Kt values describe the attenuation at MHW and MLW and indicate living shoreline protection methods are feasible.

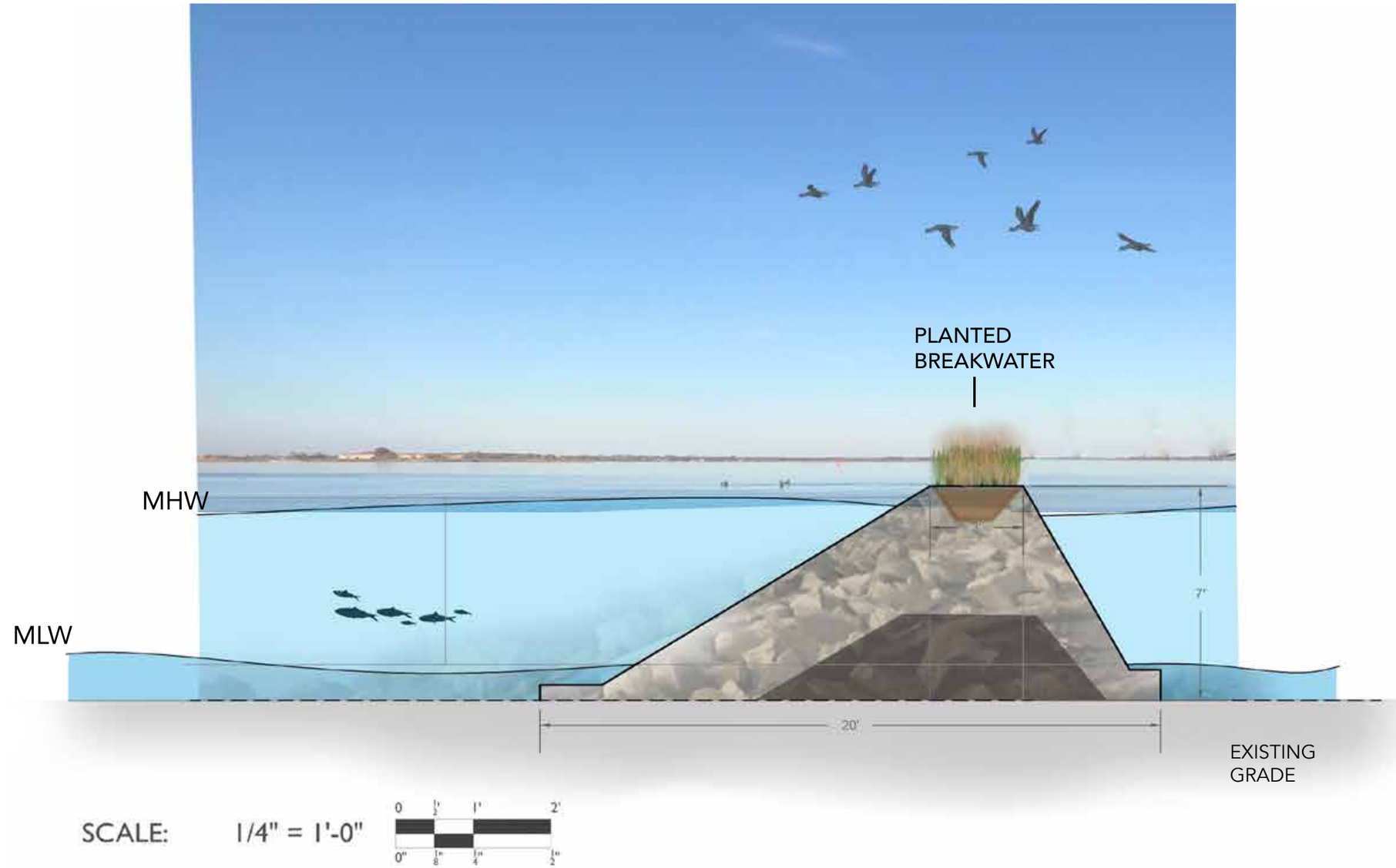
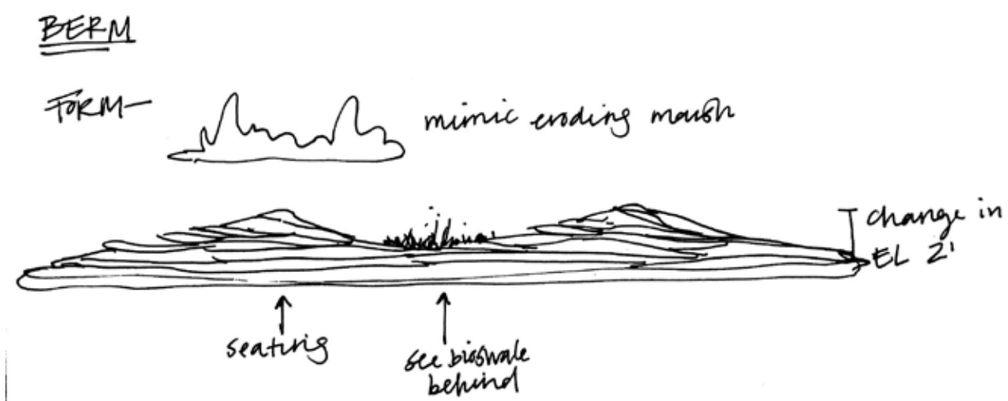


Figure 33. A planted breakwater will promote biodiversity both above and below water and offer an aesthetic green alternative to traditional concrete structures.

GRADING PLAN

The grading plan for the site will establish an irregularly shaped berm for flood protection. The shape mimics the natural forms of eroding marsh along the coastline. Most of the berm will reach a top height of 10 feet, though some smaller areas of the berm will be raised to 12 feet. This variation will provide interest and frame views.

FLOOD BERM



Design inspiration for the berm originated from coastal elements found along the shore, including the irregular form of extending marsh, elongated lines and strips in the driftwood, and the natural even grade found in an evaporating tidal pool.

The berm will function not only as a **natural levee**, but also as **seating space** overlooking a low meadow to the Delaware River and as a stormwater check before runoff from developed space enters the marsh. A **bioswale** will follow the inland side of the berm to infiltrate some runoff.

The berm will rise and fall between 10' and 12'. At 10' height, the bioswale planting will show from the other side (see diagram left).

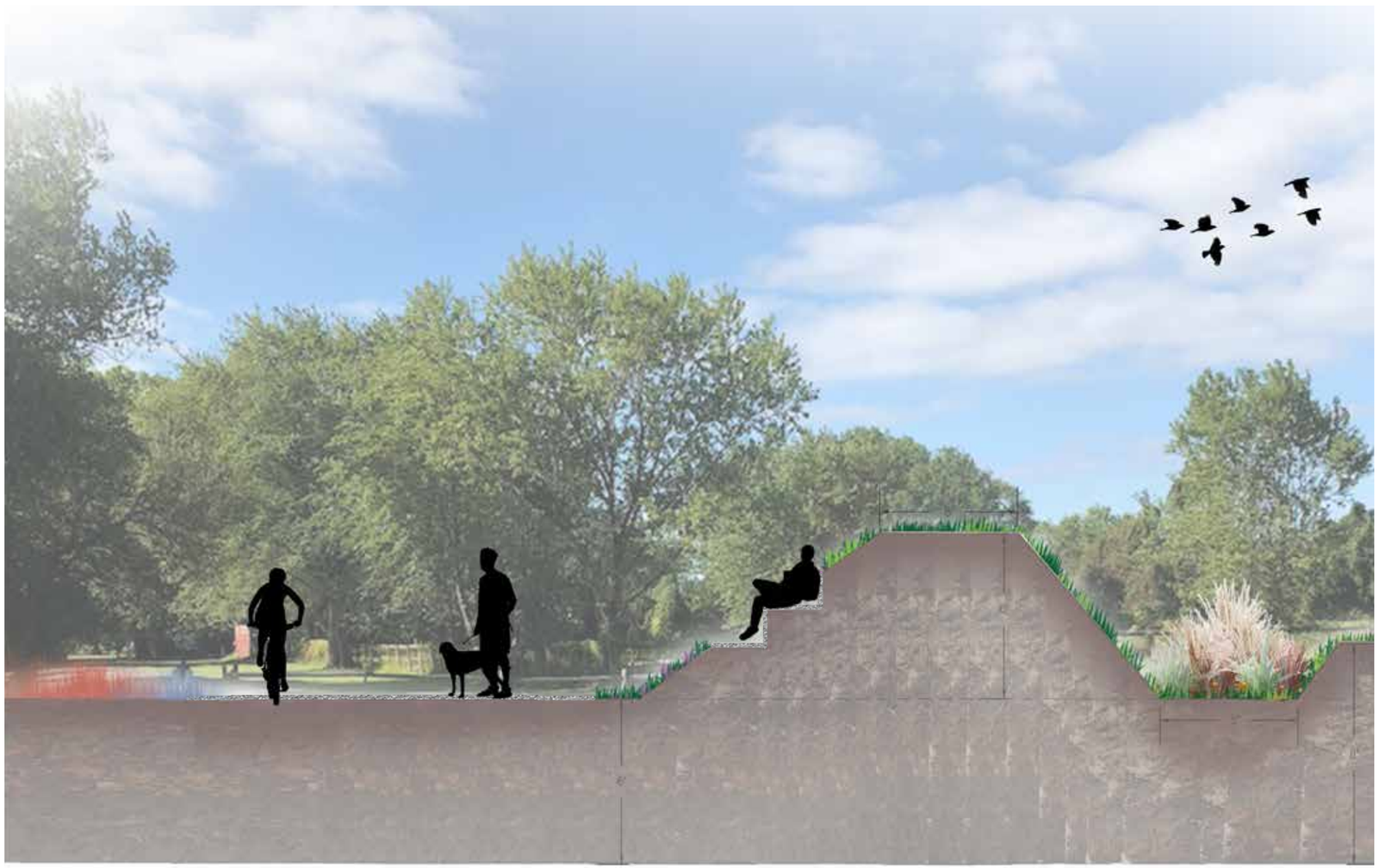
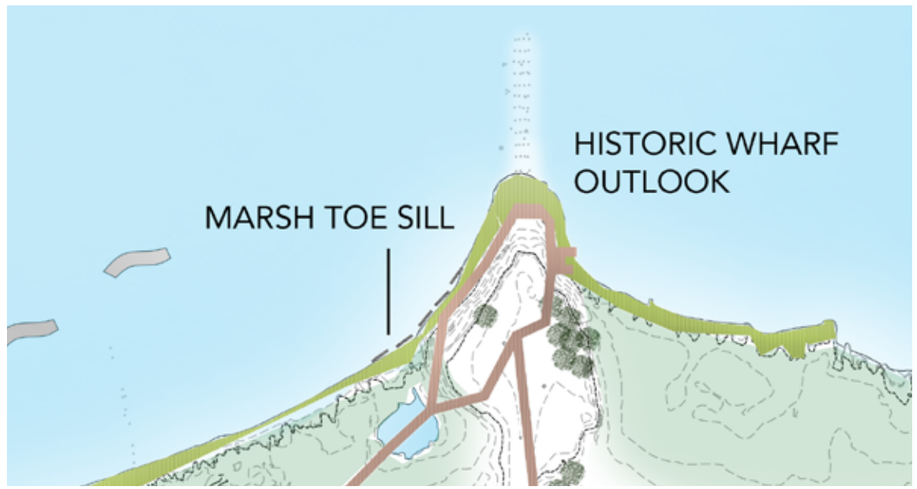


Figure 35. Berm section, site photos expressing berm design, and (top right) precedent image of a multi-use path adjacent to a planted berm.

EXPERIENCE THE HISTORIC WHARF OUTLOOK

Figure 36. Walking down the boardwalk, visitors will pass by marsh toe sill and view breakwaters in the distance.

Figure 37. From the overlook, visitors will watch historic pilings emerge at low tide and fade beneath the water as the tide rises.



Visitors will experience the living shoreline on the Fort DuPont Nature Trail, walking among marsh planting on the boardwalk and out to the overlook which provides an opportunity to engage with the rise and fall of the tides that display the hidden historic remains of the military pier.

The northwest-facing outlook is an ideal location for recreational fishing or birding, watching the sunset or observing passing ships.

PLANT PALETTE & WILDLIFE HABITAT

Restore Brackish Marsh

Hibiscus moschutos, rose-mallow

Sagittaria latifolia var. latifolia, broadleaf arrowhead

Panicum virgatum, switchgrass

Schoenoplectus pungens, three-square bulrush

Juncus canadensis, tailed rush

Spartina cynosuroides, big salt marsh cordgrass

Spartina alterniflora, salt marsh cordgrass

Sparganium eurycarpum, large bur-reed

Establish Upland Buffer

Lobelia puberula var. puberula, downy lobelia

Eragrostis spectabilis, purple lovegrass

Eutrochium dubium, three-nerved Joe-pye-weed

Penstemon digitalis, tall white beardtongue

Schizachyrium scoparium var. scoparium, little bluestem

Asclepias tuberosa var. tuberosa, butterfly milkweed

Solidago juncea, early goldenrod

Vernonia noveboracensis, NY ironweed

Create Wildlife Habitat

Migratory birds, such as the Great Blue Heron

Migratory and rare fish species, such as the Atlantic Sturgeon

Bivalves, such as freshwater mussels

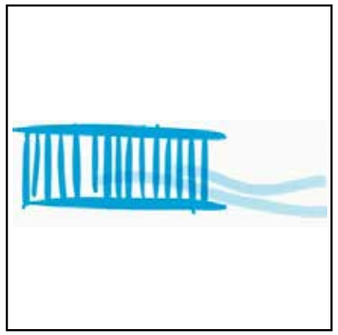
Reptiles, such as snapping turtles

APPENDIX

VISUAL GLOSSARY

Attenuation

the disappation of energy or the reduction of its force

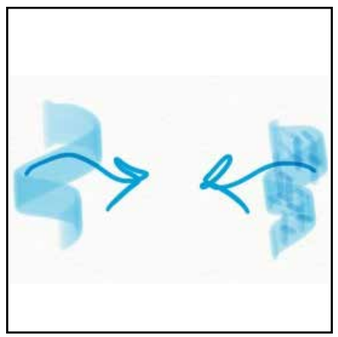


Bulkhead

hard armor coastline protection in the form of a retaining wall

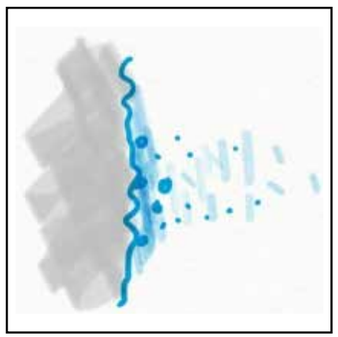
Rock Toe Sill

a piling of rocks at the base of the marsh planting used to attenuate wave action



Brackish Tidal Marsh

marsh living in a mixture of salt and freshwater, in this case, where freshwater marsh and streams meet tidal flows from the river

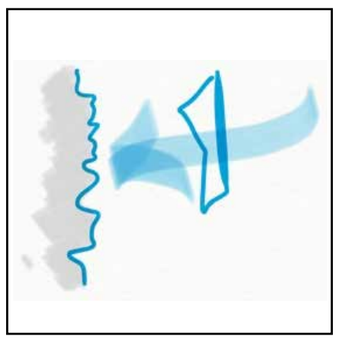


Erosion

depletion of sediment along the coast, sometimes undercutting vegetation; influenced by wave action, storm surge, tides, ice, and wind

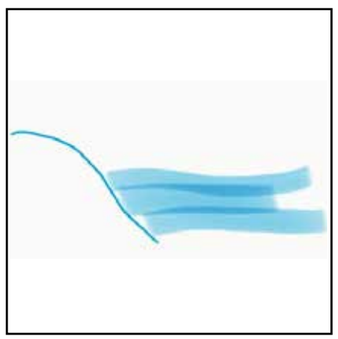
SIRB

site investigation and restoration branch; organizes restoration of contaminated sites in DE



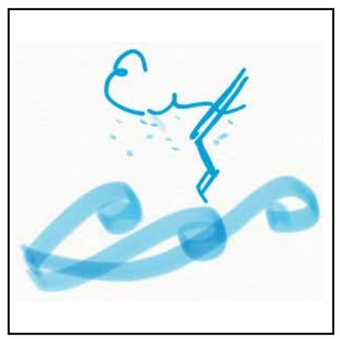
Breakwater

an offshore structure used to dissapate wave energy and protect the coastline from the full force of wave action



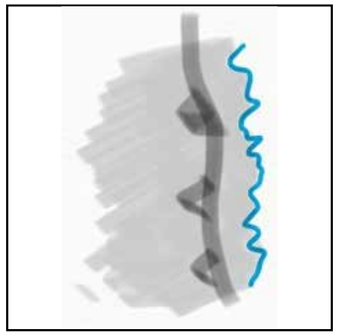
Flood Berm

an earthen barrier acting as a levee to protect an area from flooding



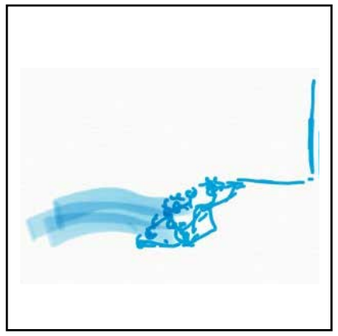
Storm Surge

significant rise in sea level that occurs during a storm



Limit of Moderate Wave Action

the inland limit where tidal waves reach during the one year storm event



Rip-rap Revettment

a gradual sloping of stones (rip rap) against a back wall (bulkhead) used as hard-armor coastal protection

Wave Attenuation Device (WAD)

a protective shoreline element that decreases wave action while still allowing some water to flow through toward the shore

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