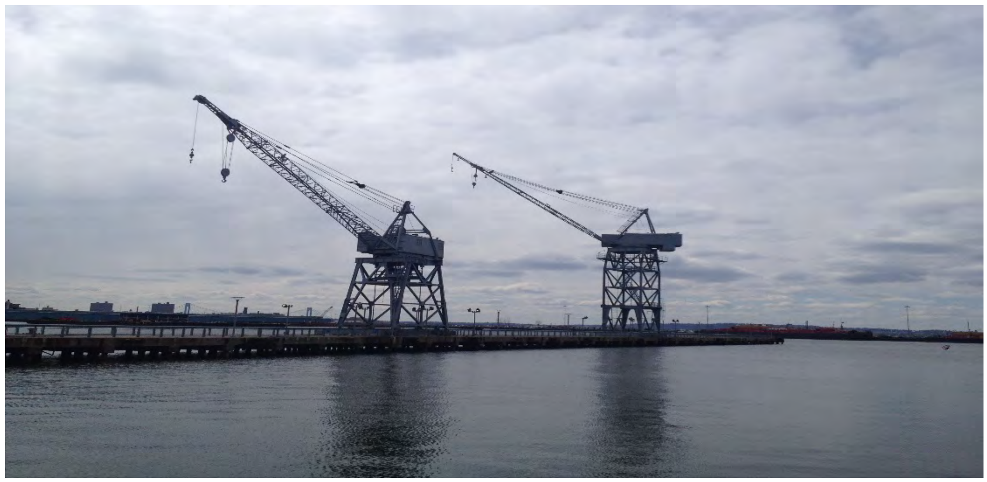
Dewberry



Red Hook Integrated Flood Protection System Feasibility Study

Feasibility Report

NYCEDC Project No. 60440001

Final – August 25, 2017

SUBMITTED BY:

Dewberry

SUBMITTED TO:

NYCEDC

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1 Executive Summary

In October 2012, Hurricane Sandy's coastal storm surge exposed the flood vulnerability within the Red Hook community. This coastal storm surge flooded over 75 percent of the Red Hook area, affected over 10,000 residents, and resulted in huge economic losses for the businesses and residential properties. To address the Red Hook community's existing and future flood vulnerabilities, the New York City Economic Development Corporation (NYCEDC) partnered with the New York City Mayor's Office of Recovery and Resiliency (ORR) to perform a feasibility study to identify ways to reduce flood risks from coastal storm surge and sea-level rise which would improve Red Hook's overall resiliency. The Advance Assistance funds from Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant Program (HMGP) funded this feasibility study. A total of $100 million is currently available through FEMA's HMGP and New York City's City Capital funds to design and construct a reliable solution identified from the feasibility study. The FEMA's HMGP funds would be available only if the feasibility study can demonstrate a viable $100 million project that meets various HMGP criteria.

The goal of the Red Hook Integrated Flood Protection System (IFPS) feasibility study (the Study) is to perform a technical evaluation to identify potential permanent and deployable features that integrate with the urban environment and work together to reduce flood risk from coastal flooding and sea level rise. NYCEDC engaged Dewberry Engineers Inc. (Dewberry Engineers Team) to conduct the Study beginning in October 2015. Figure 1-1 shows the overall feasibility study process adopted by the Team.

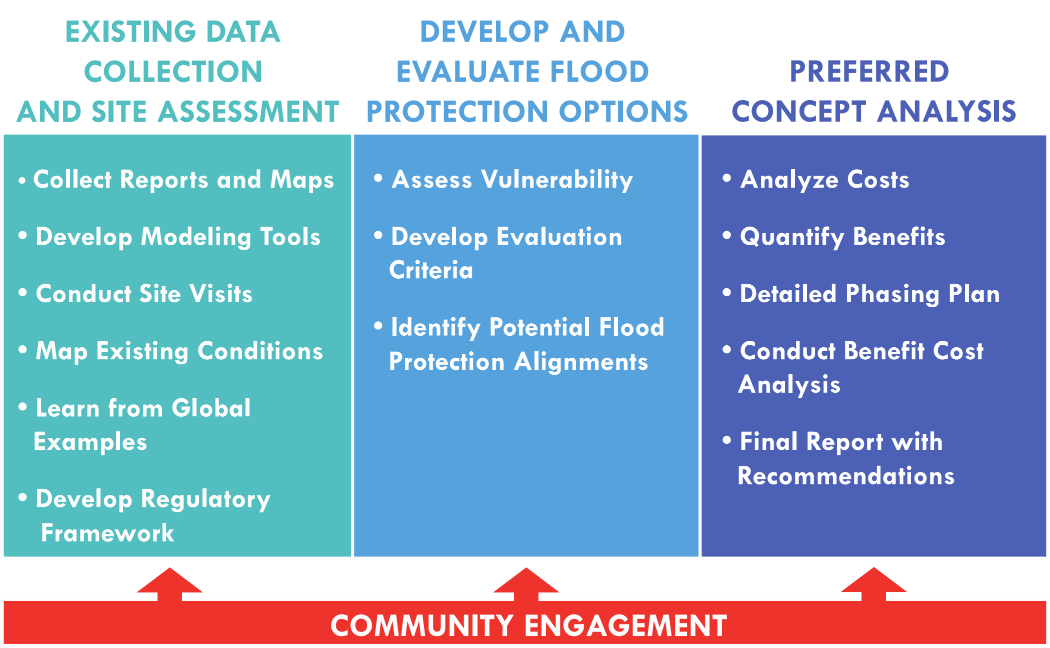


Figure 1-1. Feasibility Study Process

The Study's methodology consists of the following three broad tasks:

i. Existing data collection and site assessment
ii. Develop and evaluate flood risk reduction alternatives
iii. Identify and perform analysis on a preferred project alternative

Figure 1-2. Red Hook Study Area

During the execution of the above three tasks, the Team conducted public engagement with the community and agency stakeholders to seek and receive feedback to be incorporated as appropriate into the development of a preferred project.

The Dewberry Team collected, reviewed, and analyzed readily available datasets to understand the various constraints, opportunities, and flood vulnerabilities from coastal storm events and sea level rise within the Red Hook Study Area boundaries (*Figure 1-2*) ("the study area"). Additional data collection included geotechnical investigation consisting of subsurface soil borings, installation of groundwater monitoring wells, and laboratory testing; topographic, utility, and boundary survey along portions the study area; and environmental investigation consisting of soil borings and collection of soil and groundwater samples for laboratory testing.

Table 1-1 summarizes the various overall site constraints observed within the study area. Based on these site constraints and with feedback from the community and agency stakeholders, the Team developed three potential alignments – 1) outermost, 2) in-between, and 3) innermost – as potential locations to construct a coastal flood intervention (see *Figure 1-3*). The Team developed a toolkit of potential coastal flood intervention typologies that could be adapted within the urban fabric of Red Hook community. These intervention typologies included permanent and deployable solutions such as elevated streets, elevated bikepaths, berms, seawalls, sliding gates, and flood logs among others.

Table 1-1. Summary of Major Constraints

Data Collection Item	Findings
Flood levels (FEMA, 2013)	10- to 100-year varies from 7 feet to 16 feet North American Vertical Datum (NAVD)
Topography	Low lying topography with ground elevations generally between 4-8 feet NAVD
Transportation	Bus routes, truck routes, active bike paths, ferry stops
Buildings	Older, often attached building with multiple building openings for access
Waterfront	Active working waterfront in good to poor structural condition
Geotechnical	Historic fill with groundwater within 10 feet from ground surface
Environmental	No major hazardous environmental concerns; except at Red Hook ball fields
Property Ownership	Majority of private property ownership along waterfront

The Team performed qualitative assessment with the following set of evaluation criteria to identify optimal location and appropriate intervention typology:

i. Reliability;
ii. Constructability;
iii. Urban Design;
iv. Community Priorities;
v. Environmental Impacts;
vi. Costs; and
vii. Operations and Maintenance

Figure 1-3. Potential Coastal Flood Intervention Alignments

The qualitative, comparative assessment for each alignment as shown in *Figure 1-3* is as follows.

Outermost Alignment

- Generally follows waterfront edge and provides flood risk reduction to the largest amount of the study area compared to other alternatives
- Most expensive scenario
- Highest Design Flood Elevation (DFE)
- Significant impacts to the working waterfront
- Significant impact to views

In-between Alignment

- Provides moderate flood risk reduction benefits within the study area
- Takes advantage of the natural topographic high points reducing the overall length of a built intervention system

Innermost Alignment

- Provides flood risk reduction to the least amount of the study area
- Shortest structure length
- Potentially lowest cost scenario

Portions of the alignments could mix with each other to identify the optimal alignment for the coastal flood interventions.

A public meeting held on October 13, 2016 sought feedback from the community on the alignment alternatives and acceptable intervention heights along these alignments. Many of the community members present preferred the In-between alignment with a mixed opinion on intervention heights that varied from three feet to nine feet.

Preferred Project Alternative

Based on this community feedback and with the overall project goals in mind, the Team evaluated five alternatives with DFE ranges from 8 feet-NAVD to FEMA certification requirements. Based on this evaluation and with feedback from various agency stakeholders, the Team developed a preferred conceptual solution that would reduce the flood risk within the Red Hook community from a 10-year coastal storm surge and one (1) foot of sea-level rise or freeboard (see *Figure 1-4*). The design flood elevation (DFE) of 8 feet-NAVD that corresponds to this storm event would require coastal flood intervention along Beard Street and Atlantic Basin.

Atlantic Basin

The coastal flood intervention along Atlantic Basin consists of reconstruction of a new bulkhead along Clinton Wharf and portions of Pier 11. New high-level storm sewers (HLSS), tide gates at existing outfall and drainage improvements along the waterside of these barriers would prevent intrusion of coastal storm surge into the protected side of the barrier. Stormwater modeling results indicate that this project has no adverse drainage impact to existing drainage.

Beard Street

The coastal flood intervention along Beard Street consists of a pipe pile structure along the waterfront portion of Beard Street and T/L floodwall type configuration in the upland portions of Beard Street. The Beard Street and sidewalk is elevated to coincide with the top of this flood barrier along a major portion of Beard Street, thus resulting in minimal impact to waterfront views, circulation and potentially avoiding the need for any deployable. Additionally, the design of the structure would allow for future DFE adaptation up to 15.5 feet-NAVD.

Table 1-2 and *Table 1-3* show the total costs of this project are $100 million (excluding O&M) and the project has Benefit-Cost Ratio (BCR) of 2.03, which meets the HMGP-required BCR of greater than 1.0.

Table 1-2. Summary of Preferred Project Costs

Project Area	Total Project Costs	Soft Costs Only	Hard Costs Only
Atlantic Basin	$ 39,363,192	$ 8,368,553	$ 30,994,640
Beard Street	$ 60,636,808	$ 17,047,507	$ 43,589,301
TOTAL PROJECT COSTS WITHOUT O&M	**$ 100,000,000**	**$ 25,416,059**	**$ 74,583,941**

Table 1-3. Benefit-Cost Analysis for Preferred Project

Preferred Alternative Description	Total Project Benefits	Total BCA Project Cost with O&M	Benefit-Cost Ratio
Beard Street and Atlantic Basin alignment providing protection up to 10-year coastal storm surge + 1.0 feet freeboard	$204,106,875	$100,600,000	**2.03**

The preferred project provides the following features and benefits:

- Approximately 2,000 linear feet of flood barrier structures
- Approximately 1,200 linear feet of re-grading including raising of Beard Street
- Approximately 1,020 feet of new high level storm sewers and other drainage modifications
- No deployable structures thus maximizing the reliability and integrity of the IFPS
- Flood barrier structure along Beard Street can be adapted to higher DFE in future
- Provides opportunities to enhance community benefits at NYC Ferry stop and along Beard Street
- Negligible impacts on urban character of Red Hook
- Minimal impacts to natural environment
- Minor impacts to private property owner’s entrances along Beard Street
- No adverse impacts to existing parking and drainage patterns
- Provides flood risk reduction benefits for approximately 3,000 residents and 400 buildings in the study area

Figure 1-4. Preferred Conceptual IFPS for Red Hook

Based on discussions with NYCEDC, the Team recommends to design and construct the preferred project into two distinct phases – Phase 1A for Atlantic Basin and Phase 1B for Beard Street. These two phases can start simultaneously but can be designed and constructed separately as shown in *Table 1-4*.

Table 1-4. Preferred Project Schedule

Work Area Phase	Project Implementation Items	Approximate Timeline
1A – Atlantic Basin	Engineering Design and Permitting	January 2018 – December 2018
	Bidding and Construction	January 2019 – January 2021
1B – Beard Street	Engineering Design, ULURP, and Permitting	January 2018 – December 2018
	Bidding, Construction, and HMGP closeout	January 2019 – January 2021

2 Introduction

In October 2012, during Hurricane Sandy, coastal storm surge flooded the low-lying areas within the Red Hook community that is located in the Borough of Brooklyn, New York. The community witnessed boats marooned in roadways, inundated grocery stores, apartment complexes stripped of electricity or elevator use for weeks. The economic losses witnessed by the business community within Red Hook were huge and it took several months for these businesses to recover. To address the Red Hook community's existing and future flood vulnerabilities, the New York City Economic Development Corporation (NYCEDC) partnered with the New York City Mayor's Office of Recovery and Resiliency (ORR) to perform a feasibility study (the Study) to identify ways to reduce flood risks from coastal storm surge and sea-level rise. The Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant Program with matching funds from City of New York covers the entire project costs including feasibility study, design and construction. The purpose of the Study is to identify an optimal solution within the available $100 million funds that would reduce flood risk within Red Hook from coastal storm surge and/or sea level rise, thus improving resiliency within the community. NYCEDC engaged the Dewberry Engineers (Dewberry) Team to conduct the Study that would evaluate existing and future flood risks, develop conceptual design alternatives and ultimately a preferred alternative for an integrated flood protection system (IFPS) to reduce flood risk within the Red Hook community.

Table 2-1 shows Dewberry's multi-disciplinary Team of specialized firms to conduct the Study, which would seek community and agency stakeholder feedback to develop solutions to meet the project's goals of reducing flood risk within Red Hook.

Table 2-1. Dewberry Team Roles

Firm Name	Role
Dewberry	Project Management; Stormwater and Coastal Modeling; Civil, Structural, Geotechnical Engineering; Environmental Assessment and Investigations; Benefit-Cost Analysis and HMGP application assistance
Mott MacDonald	Structural and Geotechnical Analysis; Environmental Review
Cooper Robertson & Partners	Architecture ; Urban Design & Planning
W-Architecture & Landscape Architecture	Landscape Architecture and Community Engagement
Grain Collective	Community Engagement
Hester Street Collective	Community Outreach and Engagement
Sustainable Ports	Community Engagement
BJH Advisors	Economic Analysis
Toscano Clements Taylor	Cost Estimation
Gayron de Bruin Land Surveying and Engineering	Topographic, Utility Mapping and Property Boundary Survey
Craig Geotechnical Drilling	Geotechnical Drilling and Soil Laboratory Testing

The Red Hook study area, as shown in *Figure 2-1* covers about 1.3 square miles (845 acres) extending between Gowanus Canal to the east and Valentino Pier/Park to the west from DeGraw Street north of the Hugh Carey Tunnel to the southernmost point of Erie Basin. The population of the study area is approximately around 13,000 residents out of which approximately 6,500 to 7,000 residents live in the NYCHA Red Hook Houses and about 3,000 residents live within Red Hook (south of Hugh Carey Tunnel). The remaining 3,000 residents within the study area live north of Hugh Carey Tunnel which is mostly in the Carroll Gardens neighborhood of Brooklyn. Major sites and land use patterns within Red Hook are the privately owned working waterfront, the Brooklyn Cruise Terminal, Red Hook Container Terminal, IKEA, the New York City Housing Authority (NYCHA) development, and the limited connectivity to public transportation within the community.

Figure 2-1. Red Hook IFPS Project Study Area

3 Methodology and Analysis

The following sections describe the adopted methodology and analysis performed as part of the feasibility assessment to identify and evaluate various alternatives for coastal flood alignments and interventions.

3.1 Coastal Flood Risk Assessment

To understand both Red Hook's vulnerability to and the flow pathways of the coastal storm surge and/or sea level rise that would intrude into Red Hook, Dewberry utilized a combination of a coastal hydrodynamic model and Geographic Information System (GIS) tools. The coastal hydrodynamic model showed the flow pathways for the coastal storm surge, with and without sea level rise, entering into Red Hook. The use of GIS tools in combination with readily available Light Detection and Ranging (LiDAR) topography data provided the maximum flood inundation extents for various levels of coastal storm surge and/or sea level rise. Spatial analysis in GIS provided the numbers for vulnerable area, population, and buildings for each coastal storm.

Dewberry utilized the Danish Hydraulic Institute's (DHI) MIKE21 modeling software package to assess the flooding from coastal storm surge. A detailed 2-dimensional (2D) flexible mesh developed in MIKE 21 model represents the overland topography and bathymetry of New York Harbor. The FEMA's 2013 preliminary flood insurance study (FEMA, 2013) provided the coastal still water level boundary conditions for the 10-, 50-, 100- and 500-year coastal storm surge events. Flood vulnerability assessment included an additional 2.5 feet of sea level rise (SLR) based on the New York City Panel on Climate Change (NYPCC) projections of sea level rise (NYPCC 2015) for 2050s 90th percentile on top of the coastal still water elevations. Appendix A provides a detailed description of the coastal modeling conducted to evaluate flood risk assessment for various coastal storms. *Table 3-1* below provides a summary of the vulnerable areas, buildings and population derived by mapping the maximum flood inundation extents using GIS for various coastal storms with and without sea level rise.

Table 3-1. Summary of Coastal Flood Vulnerability and Risk within the Red Hook Study Area

Storm	Area Flooded		Affected Buildings		Affected Population	
	Acres	% of Total	# of Buildings	% of Total	Population	% of Total
Hurricane Sandy	452	76%	964	67%	10,560	85%
10%	102	17%	263	18%	1,230	10%
10% + 1' SLR	191	32%	496	34%	3,157	25%
10% + 2.5' SLR	386	65%	804	56%	9,830	79%
2%	413	69%	854	59%	10,050	81%
2% + 2.5' SLR	525	88%	1,176	81%	11,075	89%
1%	489	82%	944	65%	10,650	86%
1% + 2.5' SLR	564	94%	1,236	85%	11,080	89%

Figure 3-1 through *Figure 3-6* shows the maximum flood inundation extents for the 10-, 50- and 100-year coastal storm surge events with and without the sea level rise. The blue arrows in each figure represent the flow direction of the surge and indicate the areas where intrusion due to storm surge occurs. These figures show that coastal storm surge inundate Red Hook via the three low-lying areas; Gowanus Canal,

Smith Street, and Halleck Street; Erie Basin, Beard Street at Richards Street; and Atlantic Basin near the Brooklyn Cruise Terminal, Clinton Wharf, and Pier 11.

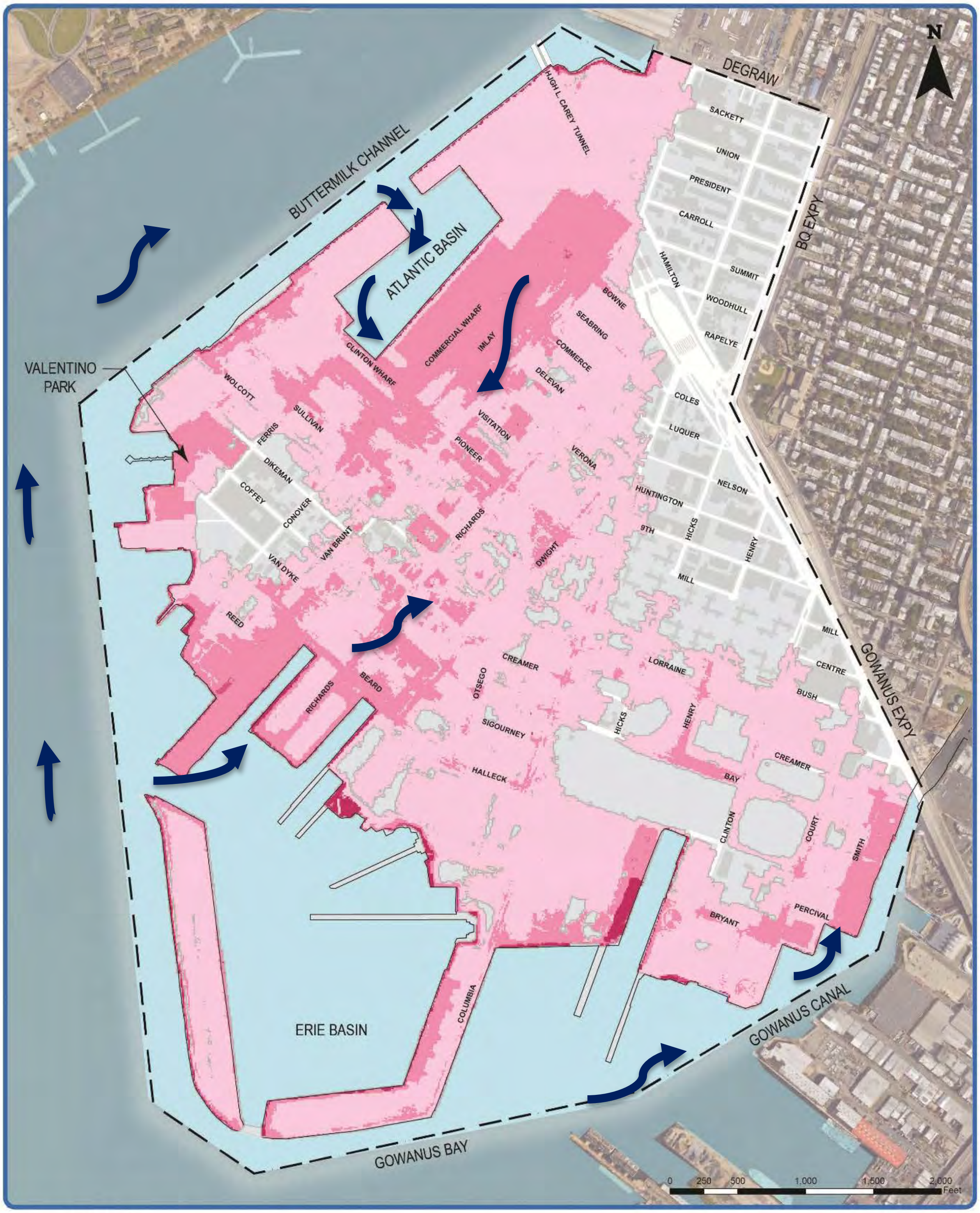
Figure 3-1. Maximum Flood Inundation for 10-Year Storm Surge

LEGEND

10 - Year (10% Annual Chance + Sea Level Rise) Flood Depths

0-3 FT | 3-6 FT | 6-9 FT | >9 FT | Red Hook Study Area

Figure 3-2. Maximum Flood Inundation for 10-Year Storm Surge with 2.5 feet of Sea Level Rise



LEGEND

50 - Year (2% Annual Chance) Flood Depths

0-3 FT | 3-6 FT | 6-9 FT | >9 FT | Red Hook Study Area

Figure 3-3. Maximum Flood Inundation for 50-Year Storm Surge

LEGEND

50 - Year (2% Annual Chance + Sea Level Rise) Flood Depths

0-3 FT 3-6 FT 6-9 FT >9 FT --- Red Hook Study Area

Figure 3-4. Maximum Flood Inundation for 50-Year Storm Surge with 2.5 feet of Sea Level Rise

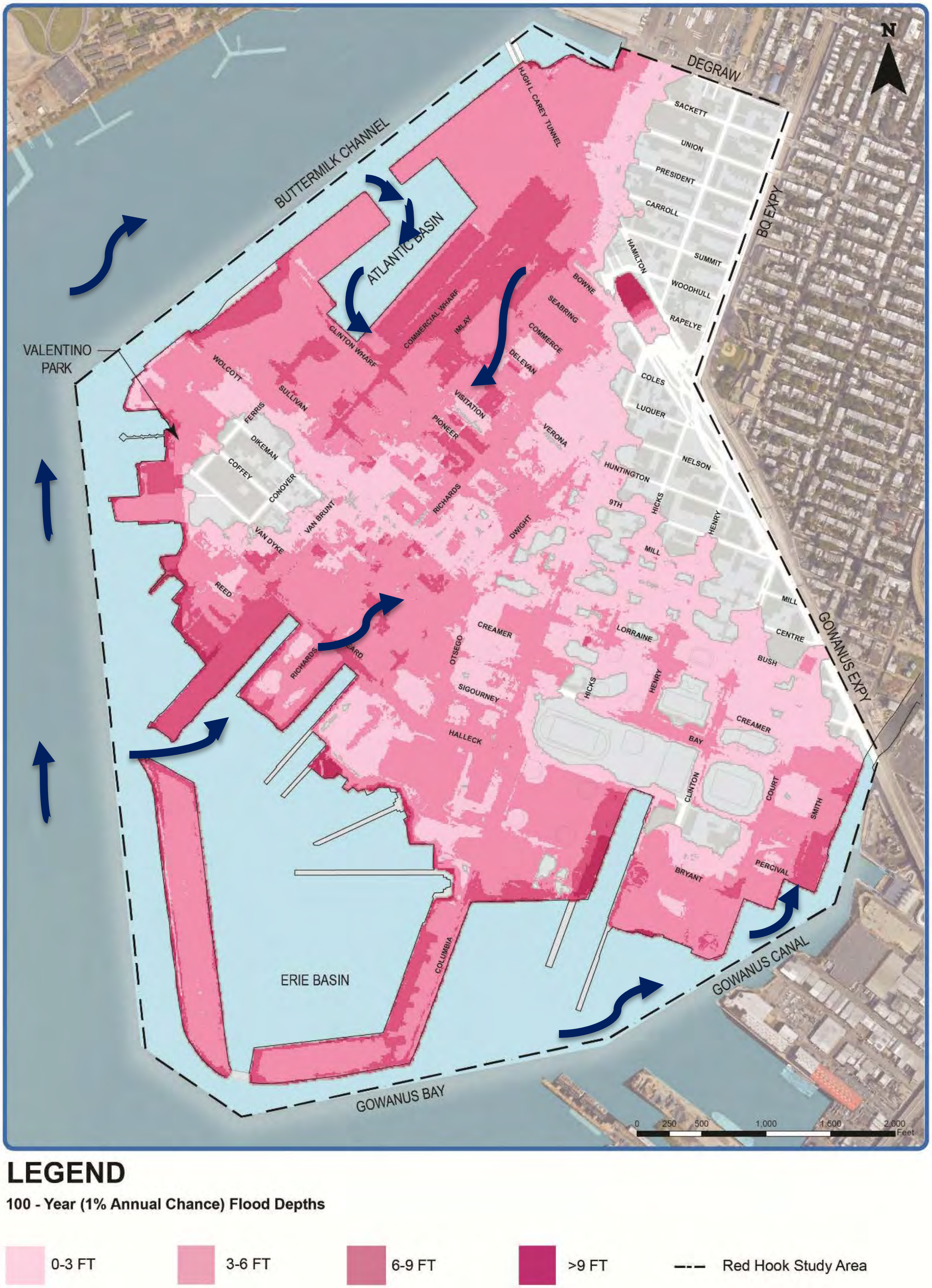


Figure 3-5. Maximum Flood Inundation for 100-Year Storm Surge

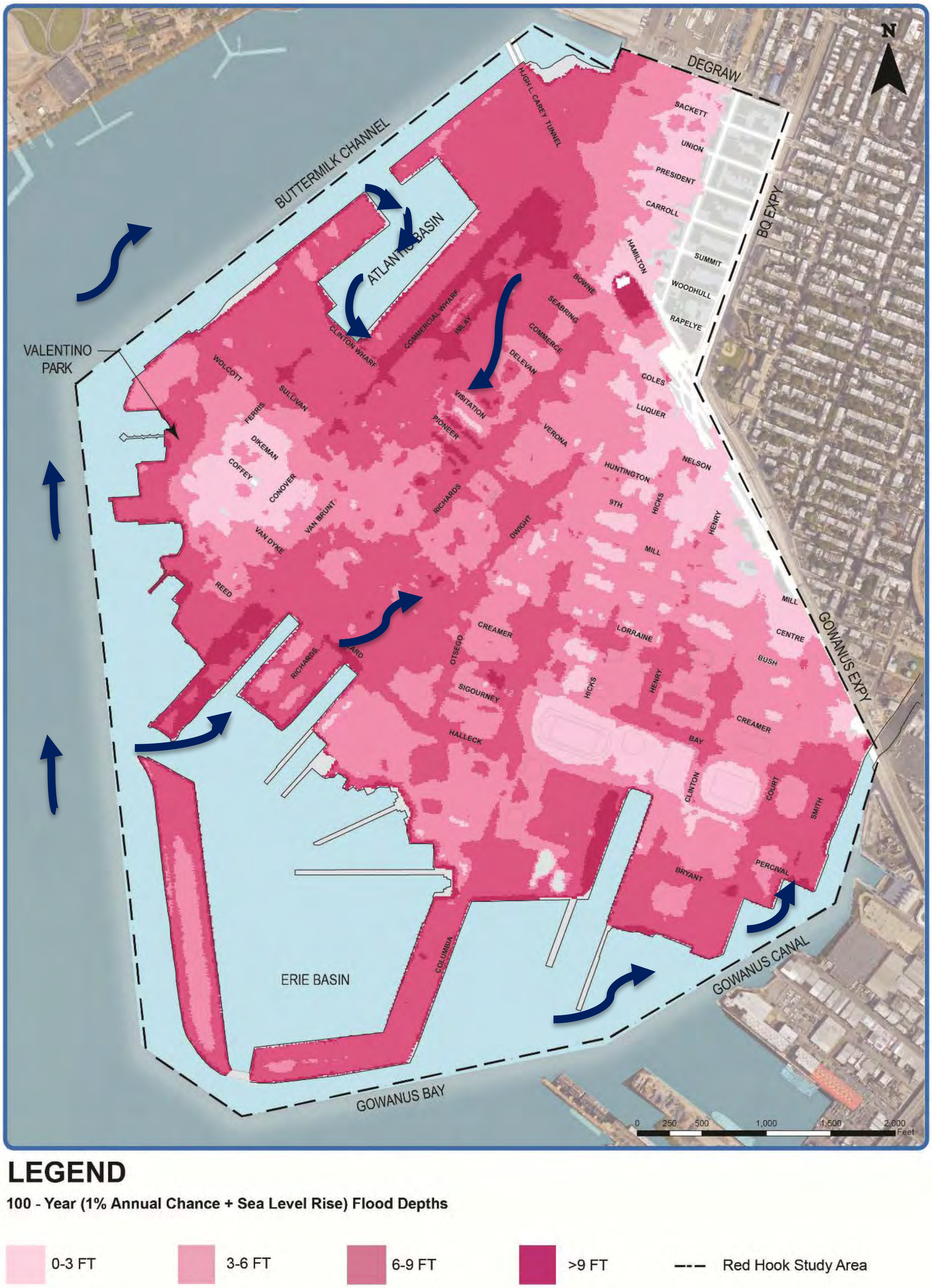


Figure 3-6. Maximum Flood Inundation for 100-Year Storm Surge with 2.5 feet of Sea Level Rise

3.2 Existing Conditions Site Constraints

The Team collected, reviewed and analyzed various types of datasets through the entire duration of the Study. The Existing Conditions Assessment Report (Dewberry, 2017) provides a detailed description of the existing conditions including the geotechnical, environmental, and topographic data collected for this Study. *Figure 3-7* through *Figure 3-10* show a few of the critical datasets such as topography, property ownership, transportation, and building openings from the existing conditions assessment report. *Table 3-2* below provides a general description of the overall characteristics, opportunities, and constraints within the various sections of Red Hook Study area.

Table 3-2. Preliminary Opportunities and Constraints Analysis

General Area	Characteristics/ Features	Opportunities	Constraints
Eastern Red Hook	▪ Close to subway ▪ Extension of Smith & Court St Corridors ▪ Predominately industrial ▪ Waterfront access occasionally utilized ▪ Regional ball fields	▪ Minimal existing views with potential to maximize ▪ High elevations in Red Hook Park for intervention on public land ▪ Historic buildings adjacent to streetscape that contribute to community character	▪ Multiple service entries and street intersections ▪ Predominantly direct drainage ▪ Portions are working waterfront ▪ Private property on Gowanus canal edge
Central/Southern Red Hook	▪ Man-made harbor with waterfront access ▪ Big-box retail and industrial uses ▪ Underdeveloped parcels	▪ Continuous open vies along the street ▪ Large amount of vacant land or parking facilities ▪ Portions of IKEA parking lot as potential area for IFPS ▪ Maximize views to Statue of Liberty	▪ Private ownership limits potential for certain interventions ▪ Public area for intervention confined along Beard Street
West & Southwestern Red Hook	▪ Large-scale, historic industrial waterfront ▪ Historic residential grain at interior ▪ Access to water, views to Statue of Liberty	▪ High elevation points to tie-ins potential interventions ▪ Valentino Pier Park is a key component of community character	▪ Lack of vacant land ▪ Larger scale historic buildings are predominately at the water's edge. ▪ Areas along waterfront are mostly privately owned
Northwestern Red Hook	▪ Working waterfront within Atlantic Basin ▪ Cruise ship terminal ▪ Unbuilt land ▪ Residential area to the north	▪ Historic buildings provide character ▪ Maritime activity and working dock opportunities ▪ Waterfront access potential ▪ New Red Hook Ferry Stop	▪ Lowest elevations in the neighborhood ▪ Intervention limited due working waterfront in Atlantic Basin

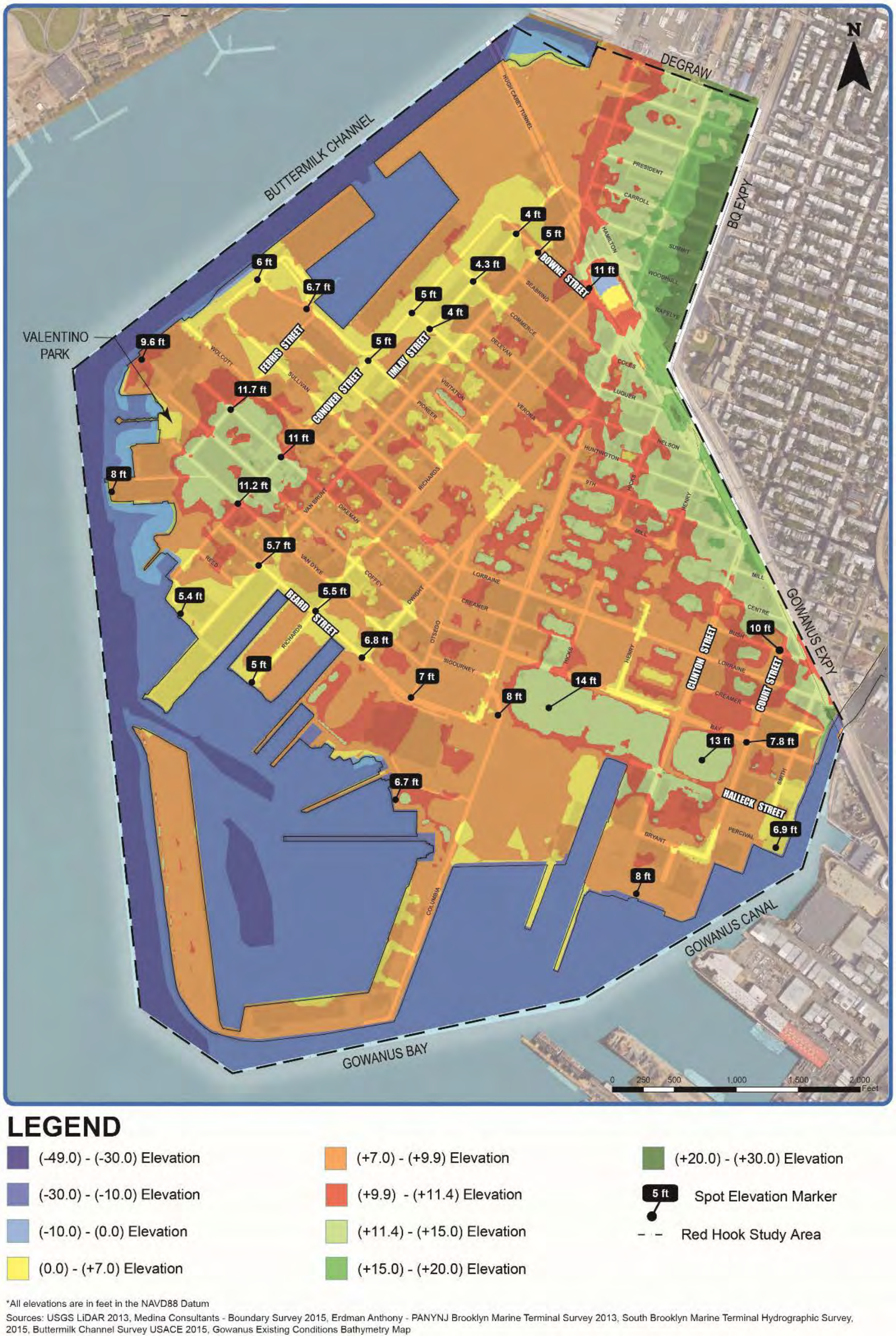


Figure 3-7. Topography within the Red Hook Study Area

Figure 3-8. Property Ownership within the Red Hook Study Area (NYC DCP Pluto 2015)

Figure 3-9. Building Openings within Select Locations of the Red Hook Study Area

Figure 3-10. Public Transportation Network within the Red Hook Study Area

Figure 3-11 shows the layout of six (6) planning blocks developed to understand the constraints, including but not limited to topography, roadway width, and structure height requirement for various storm events, within appropriate sections of Red Hook study area. Below is the list of the six (6) planning blocks with primary focus areas

i. Planning Block 1 – Court Street
ii. Planning Block 2 – Red Hook Parks
iii. Planning Block 3 – Beard Street
iv. Planning Block 4 – Ferris Street
v. Planning Block 5 – Atlantic Basin
vi. Planning Block 6 – Van Brunt/DeGraw Streets

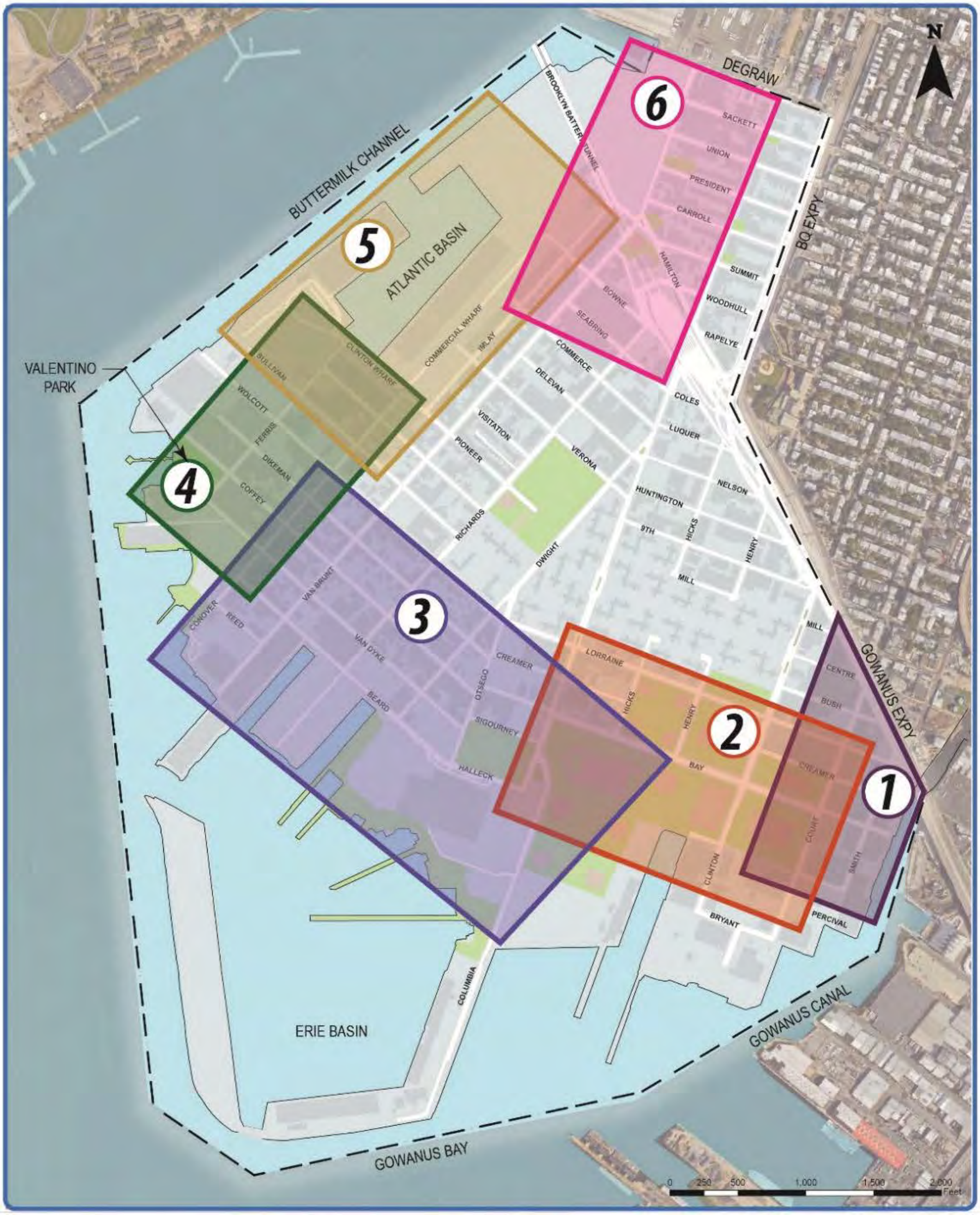


Figure 3-11. Planning Block Analysis Key Map

For each planning block as shown in *Figure 3-11*, Dewberry prepared figures to highlight the existing site constraints that present significant challenges to developing potential alignments and coastal flood interventions typologies. The most significant challenges include the following:

- Low ground elevation when compared with the various coastal storm surge elevations
- Number of intersections that would potentially require deployable gates
- Number of property access points (curb cuts and building openings) that would require deployable features to maintain access
- Street widths
- Sidewalk widths
- Property ownership
- Utilities

The following sections provide a brief description along with map, ground profile, and photos within each planning block. Appendix I includes basemaps that show the roadway site constraints such as roadway and sidewalk width for additional areas other than the ones shown in the planning blocks.

3.2.1 Planning Block 1 – Court Street

The Court Street planning block extends from west of the intersection of Court Street and Hamilton Avenue to the north, down to the intersection of Court Street and Halleck Street as shown in *Figure 3-12*. This planning block splits between the 2013 FEMA's preliminary 100-year BFE of 11-feet NAVD and 12-feet NAVD. The northern-most area along the Gowanus expressway is above the 11-feet NAVD and is therefore outside of the 100-year floodplain.

Characteristics of the land and roads within this planning block include:

- *Drainage:* Direct drainage area between Smith Street and Gowanus Canal and south of Halleck Street, and sewered drainage between Court Street and Smith Street south to Halleck Street.
- *Transportation:* Smith and Court Streets signed bike route and truck routes. Court Street between the Gowanus Expressway and Lorraine Street is part of the B57 and B61 bus route with a stop on the corner of Court Street and Lorraine Street. Both bus routes turn west onto Lorraine Street.
- *Zoning:* The land within this planning block, with the exception of the Red Hook Parks area, is zoned as a manufacturing.
- *Land Use:* The property within this planning block is mostly used for industrial/manufacturing purposes.
- *Property Ownership:* Most of the property is privately owned with the exception of the Red Hook Parks property and the Fire Department of New York (FDNY) housing Engine 279 and Ladder 131 located on the corner of Lorraine Street and Smith Street, a FEMA-designated Critical Facility.
- *Utilities:* Utility lines including water, combined sewer, electrical service, telephone service, and gas service run within the Right-of-Way beneath Court Street and Smith Street. In general, the east-west streets including Creamer Street, Bay Street, and Halleck Street have fewer main utility lines than the north-south streets within this planning block. Lorraine Street includes a large-

diameter combined sewer line that ultimately flows to the Red Hook Waste Water Treatment Plant (WWTP)

Table 3-3 provides a summary of the range of ground elevations, approximate number of building openings, curb cuts, average street width and sidewalk width between the various street segments in the Court Street planning block.

Table 3-3. Summary of Court Street Planning Block Constraints

Street Segment	Approx. Ground Elevation Range (Low to High) (feet NAVD)	Number of Building Openings	Number of Curb Cuts	Average Street Width (feet)	Average Sidewalk Width (feet)
Hamilton between Centre & Mill	~6.5 - ~11.5	-	4	-	-
Court between Centre & Bush	~10.1 - ~11.2	3	3	~39	~13-15
Court between Bush & Lorraine	~9.0 - ~10.1	5	1	~36	~14
Court between Lorraine & Creamer	~9.4 - ~9.0	5	3	~38	~12-17
Court between Lorraine & Bay	~7.6 - ~9.4	2	5	~38	~12-17
Court between Bay & Halleck	~6.8 - ~7.6	6	3	~39	~14-16
Smith between Lorraine & Creamer	~6.3 – ~13.1	7	2	~33	~10-11
Smith between Creamer & Bay	~6.3 – ~7.1	2	1	~33	~10-11
Smith between Bay & Halleck	~5.9 - ~7.1	10	1	~36	~11-12
Halleck St between Court & Smith	~5.9 – ~6.8	7	2	~28-33	~8

COURT STREET PLANNING BLOCK

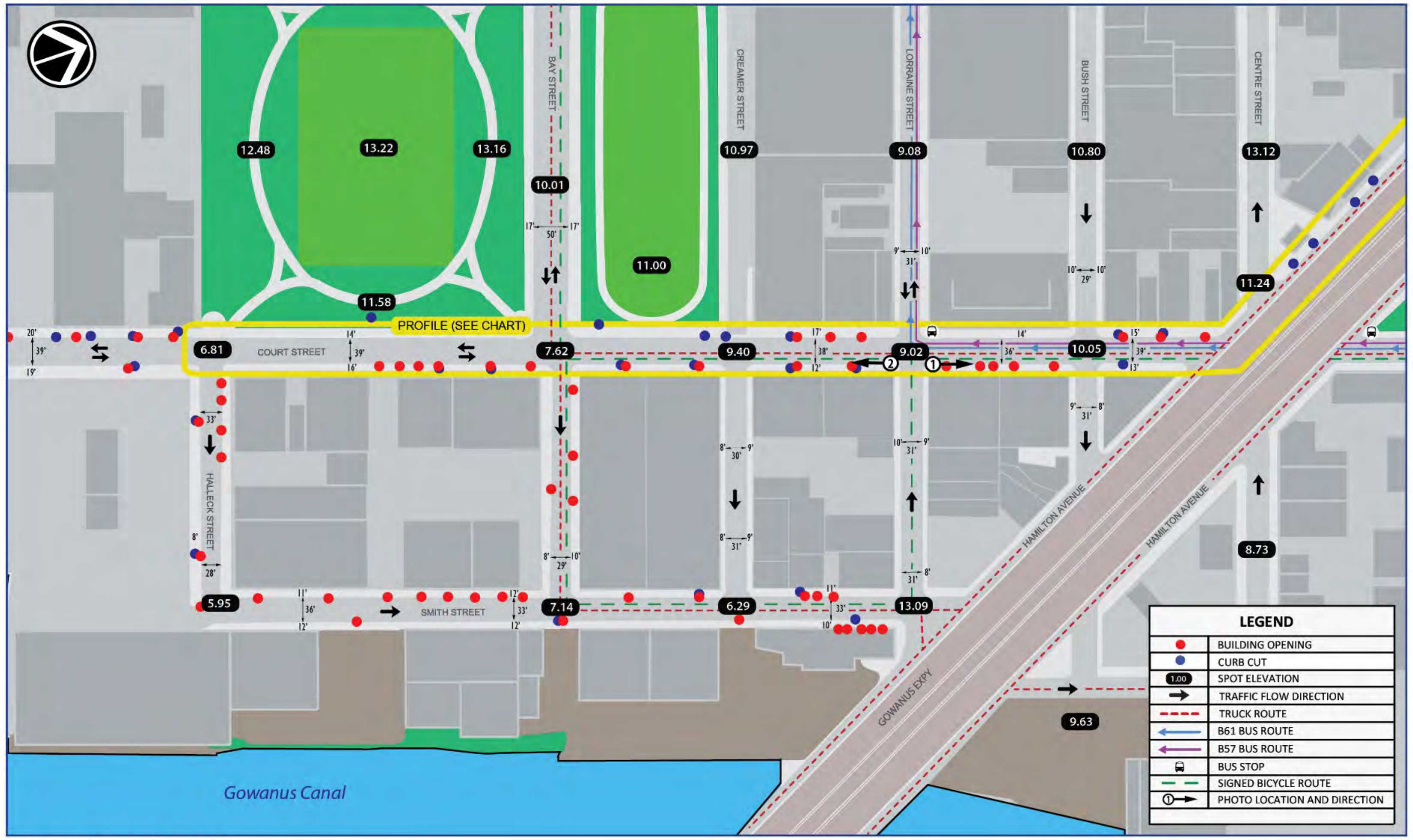
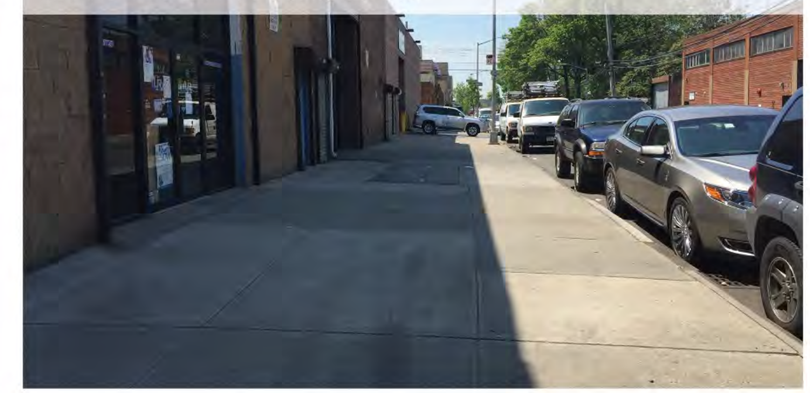
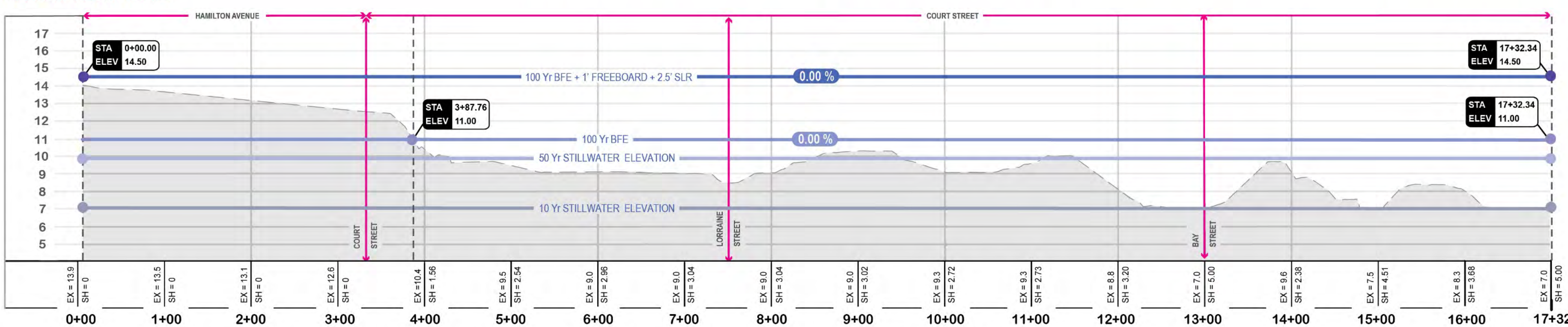


PHOTO ① : View of trucks entering/exiting IESI facility on Court Street between Bush Street and Lorraine Street facing north; May 26, 2016.

PHOTO ② : View of building openings on Court Street facing south between Lorraine and Creamer Street; May 26, 2016.



PLANNING BLOCK PROFILE



LEGEND: **BFE -** Base Flood Elevation **SLR -** Sea Level Rise **EX -** Existing Ground Elevation **SH -** Structure Height (*Shown for 100 - Year BFE + 1' Freeboard*) **GRADE BREAK** **GROUND SURFACE**

Figure 3-12. Court Street Planning Block Constraints

3.2.2 Planning Block 2 – Red Hook Parks

As shown in *Figure 3-13*, the Red Hook Parks planning block extends from Court Street (to the east) to Columbia Street (to the west) between Lorraine Street (to the north) and Halleck Street (to the south). This planning block is split between the 2013 FEMA's preliminary 100-year BFE of 11feet-NAVD inland and 13 feet-NAVD at the waterfront. The waterfront portion of this planning block, the GBX Gowanus Bay Terminal and Henry Street Basin is within the Limit of Moderate Wave Action (LiMWA) line. The Red Hook Parks property that includes the athletic track and soccer field are high ground and are not within the 100-year (1% annual chance) floodplain.

▪

Characteristics of the land and roads within this planning block include:

- *Drainage:* Most portions of Parks are completely in the direct drainage area.
- *Transportation:* The B57 and B61 buses run along Lorraine Street from Court Street to Otsego and Dwight Street. Bay Street is a signed bike route between Smith Street and Columbia Street, Clinton Street has a shared and signed bike route, and Columbia Street is a shared/signed bike route. Bay Street is a truck route from Smith Street to Columbia Street.
- *Zoning:* Most of the land within this planning block, with the exception of the Red Hook Parks area, is zoned manufacturing.
- *Land Use:* The property within this planning block, with the exception of Red Hook Parks, is mostly used for industrial/manufacturing purposes with minimal amount of commercial/office space, vacant land, and residential land use.
- *Property Ownership:* With the exception of Red Hook Parks, most of the property is privately owned with some property with unknown ownership (which is usually private).
- Two Key Community Assets are located within this planning block: the BASIS Independent Brooklyn (located near the intersection of Columbia and Sigourney) and the Red Hook Recreation Center (located on Bay Street between Henry Street and Clinton Street).
- *Utilities:* Utility lines including water, combined sewer, electrical service, telephone service, and gas service run within the Right-of-Way beneath Court Street, Clinton Street, and Columbia Street. In general, Bay Street has fewer main utility lines than the north-south streets within this planning block. Bay Street has a water service line and combined sewer line. A combined sewer running north/south from Hicks Street proceeds beneath Red Hook Parks and outfalls into the GBX Gowanus Bay Terminal. Red Hook Parks include various inlet drainage structures; the eastern portion of the parks drain via a pipe directly into the Henry Street Basin while the western portion of the park connect to the pipes draining at the GBX Gowanus Bay Terminal.

Table 3-4 provides a summary of the range of ground elevations, approximate number of building openings, curb cuts, average street width and sidewalk width between the various street segments in the Red Hook Parks planning block.

Table 3-4. Summary of Red Hook Parks Planning Block Constraints

Street Segment	Approximate Ground Elevation Range (Low to High) (feet NAVD)	Number of Building Openings	Number of Curb Cuts	Average Street Width (feet)	Average Sidewalk Width (feet)
Bay St between Court St & Clinton	~7.6 - ~7.7	-	-	~50	~17
Bay St between Clinton & Henry	~6.5 - ~7.7	-	-	~50	~17
Bay St between Henry and Hicks	~6.5 – ~10.7	-	1	~50	~17
Bay St between Hicks & Columbia	~6.9 – 10.7	-	6	~50	~13-16
Columbia St between Bay and Sigourney	~6.9 – ~7.9	1	-	~48	~8-17
Columbia St between Sigourney & Halleck	~7.0 – ~7.9	-	1	~51	~15

PARKS PLANNING BLOCK

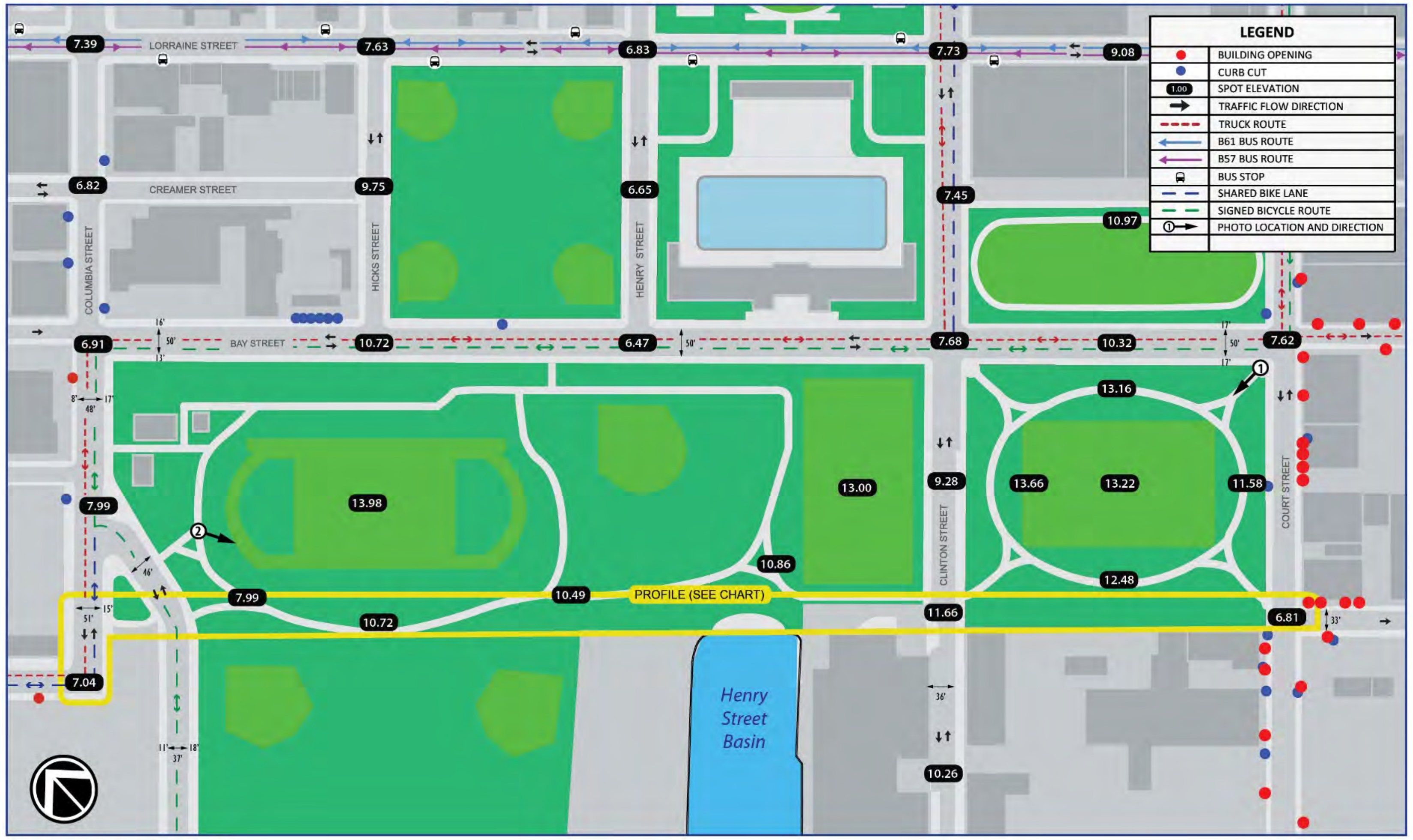
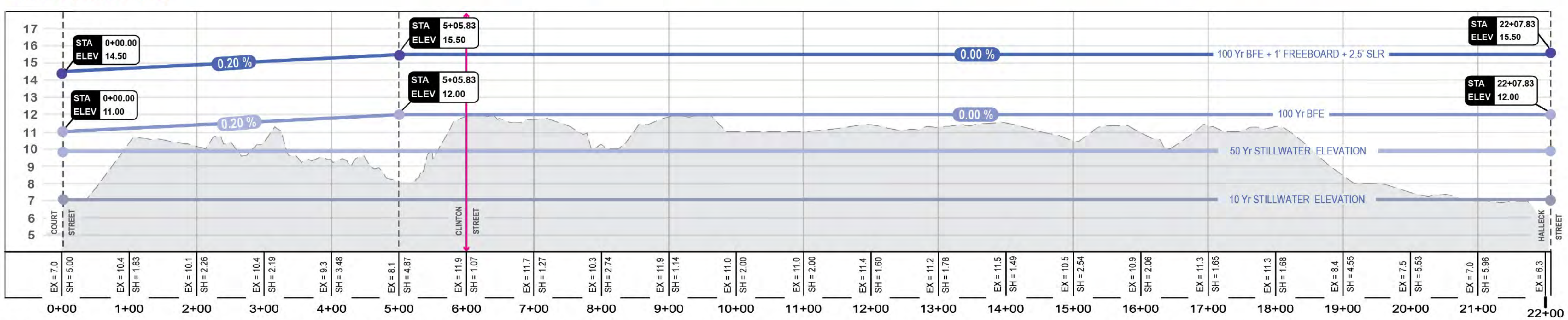



PHOTO ① : Red Hook Park entrance at intersection of Court Street and Bay Street, facing southwest; May 26, 2016.


PHOTO ② : West end of Red Hook Park athletic track (high ground area) near Columbia Street facing east/southeast; May 26, 2016.

PLANNING BLOCK PROFILE



LEGEND: BFE - Base Flood Elevation SLR - Sea Level Rise EX - Existing Ground Elevation SH - Structure Height (*Shown for 100 - Year BFE + 1' Freeboard*) GRADE BREAK ------ GROUND SURFACE

Figure 3-13. Red Hook Parks Planning Block Constraints

3.2.3 Planning Block 3 – Beard Street

As shown in *Figure 3-14*, the Beard Street Planning block extends from Columbia Street (to the east) to Conover Street (to the west) between Dikeman Street (to the north) and the Beard St/IKEA waterfront (to the south). This planning block is mostly within the 2013 FEMA's preliminary 100-year BFE of 12 feet-NAVD inland while the waterfront is within the 13-feet NAVD zone and is subject to wave action (within the LiMWA line).

Characteristics of the land and roads within this planning block include:

- *Drainage:* The land within this planning block is direct drainage south of Beard Street to the waterfront. North of Beard Street to Lorraine Street is sewered drainage.
- *Transportation:*
    - *Bus:* The B57 and B61 buses run south on Dwight Street from Lorraine Street. The B61 bus proceeds west on Van Dyke then north on Van Brunt, while the B57 proceeds east on Beard Street then north on Otsego Street.
    - *Bicycle:* Halleck Street and a portion of Beard Street north of IKEA is a signed bike route. Beard Street between Dwight and Conover Street is indicated as a Potential Future Bike Path. Van Brunt Street is a signed bike route.
    - *Truck:* Halleck Street and Beard Street to Van Brunt Street is a truck route.
- *Zoning:* Most of the land within this planning block is zoned manufacturing. The waterfront south of IKEA is zoned as park land. The property between Van Brunt and Conover street from Van Dyke south to the waterfront is zoned as mixed use district. Land north of Coffey Street is zoned as residential with some commercial overlay.
- *Land Use:* The land use within this planning block is mixed; the waterfront has commercial/office, vacant land, and industrial/manufacturing uses. Generally north of Beard Street is a combination of industrial/manufacturing, vacant land, commercial/office, mixed commercial/residential, and one/two/multi-family residential land use.
- *Property Ownership:* Most of the property is privately owned with some mixed and unknown (usually private) ownership.
- *Community Assets and Critical Facilities:* This planning block includes the Fairway Supermarket, an economic asset located at the southern end of Van Brunt Street, and the Van Brunt Pump Station, a Key Community Asset also located on the southern end of Van Brunt Street.
- *Utilities:* Utility lines including water, combined sewer, electrical service, telephone service, and gas service run within the Right-of-Way beneath Halleck Street, Beard Street, Richards Street, Van Brunt Street, and Conover Street. The corner of the IKEA/Beard Street waterfront has a 24-inch sewer outfall inside a 48-inch sleeve. The Van Brunt Street Right-of-Way includes a 24-inch combined sewer that outfalls at the waterfront south of Fairway Market.

Table 3-5 provides a summary of the range of ground elevations, approximate number of building openings, curb cuts, average street width and sidewalk width between the various street segments in the Beard Street planning block.

Table 3-5. Summary of Beard Street Planning Block Constraints

Street Segment	Approximate Ground Elevation Range (Low to High) (feet NAVD)	Number of Building Openings	Number of Curb Cuts	Average Street Width (feet)	Average Sidewalk Width (feet)
Halleck St between Columbia & Otsego	~6.6 - ~7.0	3	2	55	~16-20
Beard St between Otsego & Dwight	~6.4 - ~6.6	1	1	~54	~9-12
Beard St between Dwight & Richards	~ 5.2 – ~6.4	-	3	~30	~9-12
Beard St between Richards & Van Brunt	~5.2 - ~5.9	4	3	~32	~14
Beard St between Van Brunt & Conover	~5.9 - ~9.11	6	10	~31	~13-14
Conover St between Beard St & Van Dyke	~9.1 - ~11.3	4	4	~30	~13-14
Conover St between Van Dyke & Coffey	~11.3 - ~13.4	1	2	~31	~13-14
Conover St between Coffey & Dikeman	~13.4 - ~12.6	5	3	~31	~13-14

BEARD STREET PLANNING BLOCK

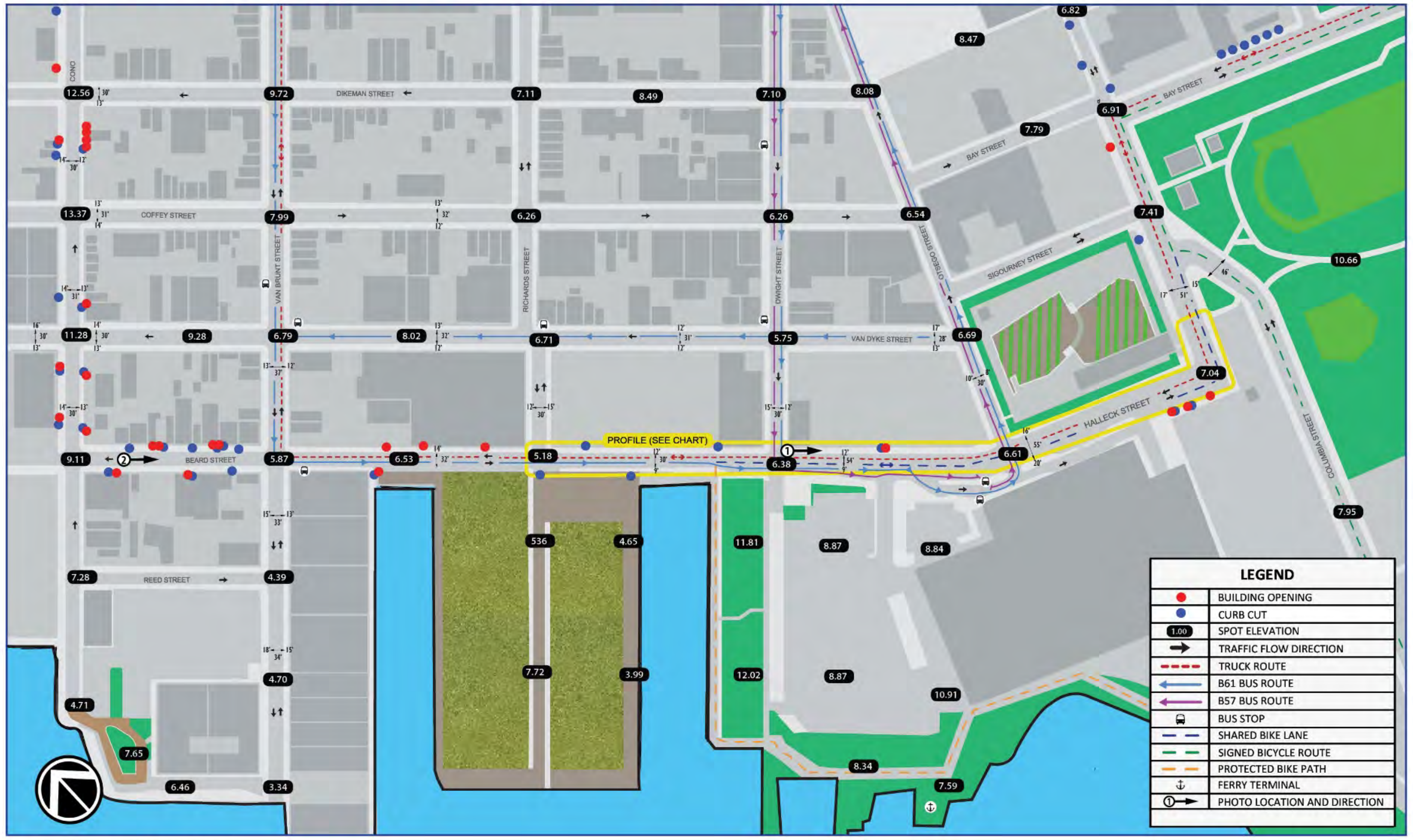
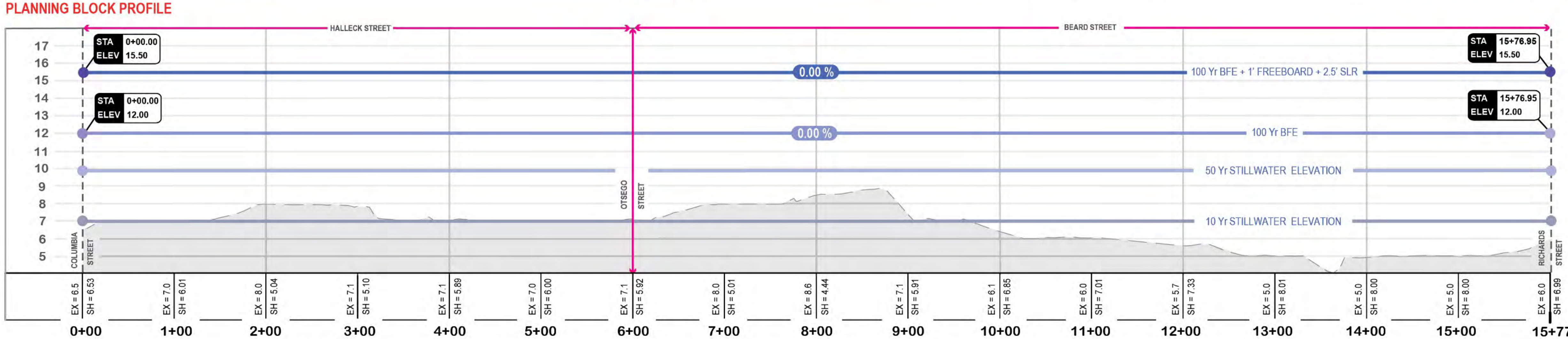


PHOTO ① : View of Beard Street facing southeast from Dwight Street; May 26, 2016.

PHOTO ② : Beard Street between Van Brunt and Conover Street facing southeast; May 26, 2016.

PLANNING BLOCK PROFILE



LEGEND: BFE - Base Flood Elevation SLR - Sea Level Rise EX - Existing Ground Elevation SH - Structure Height (*Shown for 100 - Year BFE + 1' Freeboard*) GRADE BREAK GROUND SURFACE

Figure 3-14. Beard Street Planning Block Constraints

3.2.4 Planning Block 4 – Ferris Street

As shown in *Figure 3-15*, the Ferris Street planning block extends from south of Van Dyke Street to Clinton Wharf between Conover (to the east) and west of Ferris Street near the waterfront. Most of the planning block is within the 2013 FEMA's preliminary 100-year BFE of 12 feet-NAVD inland while the areas by the waterfront are 13 feet-NAVD and subject to wave action (within the LiMWA line). Two city blocks, Van Dyke to Dikeman between Ferris and Conover, are high ground and not within the 2013 FEMA's preliminary 100-year (1% annual chance) floodplain.

Characteristics of the land and roads within this planning block include:

- *Drainage:* The land west of Conover to Van Dyke and west of Ferris St between Van Dyke and Sullivan Street is direct drainage area. East of Ferris Street between Van Dyke and Sullivan and east of Conover between Sullivan and Pioneer is sewered drainage.
- *Transportation:*
  - *Bus:* The B61 bus route turns north on Van Brunt Street. No bus service is present west of Van Brunt Street.
  - *Bicycle:* Conover Street and Van Dyke Street show Potential Future Bike Path.
  - *Truck:* No truck routes are present west of Van Brunt Street.
- *Zoning:* A significant portion of the land west of Conover Street is zoned as manufacturing district with the exception of Valentino Pier Park and the Pier 44 Waterfront Garden area.
- *Land Use:* The land use within this planning block is mixed and includes industrial/manufacturing, open space, one/two/multi-family residential, transportation/utility, parking facilities, and vacant land.
- *Property Ownership:* Property ownership is a mix of private, unknown (usually private), mixed public and private, and other public authority, state, or federal.
- *Community Assets and Critical Facilities:* This planning block includes the South Brooklyn Community High School located on Conover Street between Dikeman Street and Wolcott Street.
- *Utilities:* Utility lines including water, combined sewer, electrical service, telephone service, and gas service run within the Right-of-Way beneath Conover Street, Van Dyke Street, Coffey Street, and Dikeman Street.

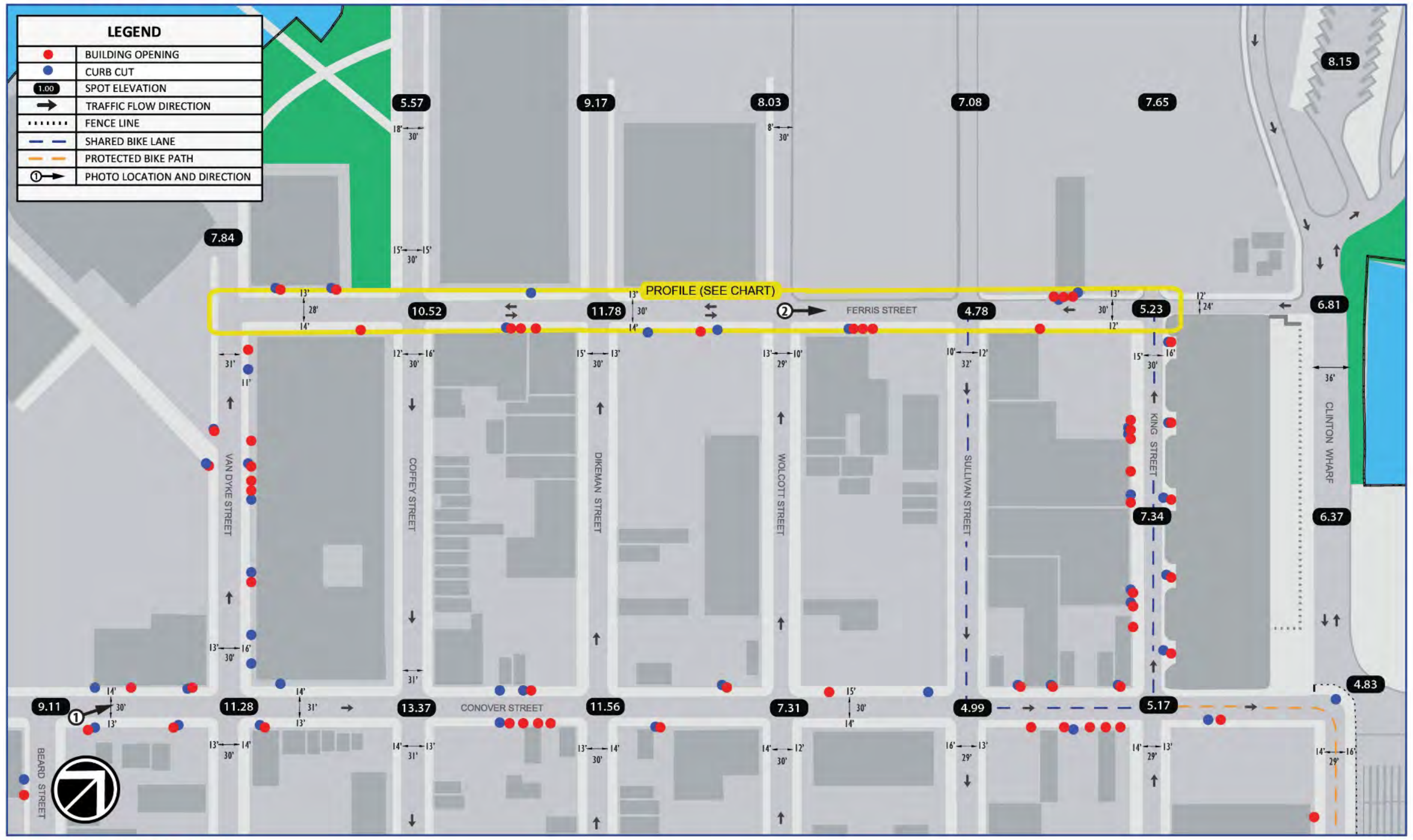
Table 3-6 provides a summary of the range of ground elevations, approximate number of building openings, curb cuts, average street width and sidewalk width between the various street segments in the Ferris Street planning block.

Table 3-6. Summary of Ferris Street Planning Block Constraints

Street Segment	Approximate Ground Elevation Range (Low to High) (feet NAVD)	Number of Building Openings	Number of Curb Cuts	Average Street Width (feet)	Average Sidewalk Width (feet)
Conover St between Beard St & Van Dyke[1]	~9.1 - ~11.3	4	4	~30	~13-14
Conover St between Van Dyke & Coffey[1]	~11.3 - ~13.4	1	2	~31	~13-14
Conover St between Coffey & Dikeman[1]	~12.6 - ~13.4	5	3	~31	~13-14
Conover St between Dikeman & Wolcott	~7.3 - ~11.6	2	2	~30	~14-15
Conover St between Wolcott & Sullivan	~5.0 - ~7.3	1	1	~30	~14-15
Conover St between Sullivan and King	~5.0 - ~5.2	8	4	~30	~14-15
Conover St between King & Pioneer	~4.8 – 5.2	1	1	~29	~14-16
Van Dyke St between Conover & Ferris	~7.8 – ~11.3	8	9	~30	~13-16
Ferris St between Van Dyke and Coffey	~7.8 – ~10.5	3	2	~28	~13-16
Ferris St between Coffey & Dikeman	~10.5 - ~11.8	3	4	~28	~13-14
Ferris St between Dikeman & Wolcott	~7.5 - ~11.8	1	2	~28	~13-14
Ferris St between Wolcott & Sullivan[2]	~4.8 - ~7.5	3	2	~30	~12-13
Ferris St between Sullivan and King[2]	~4.8 - ~5.23	3	2	~30	~12-13
Ferris St between King & Clinton Wharf[2]	~5.2 - ~6.8	-	-	~24	~12
King St between Ferris & Conover[2]	~5.2 - ~7.3	13	11	~30	~15-16

Notes:
1 Planning blocks overlap – refer to Beard Street Planning Block table.
2 Planning blocks overlap – refer to Port Authority/Atlantic Basin Planning Block table

FERRIS STREET PLANNING BLOCK



PLANNING BLOCK PROFILE

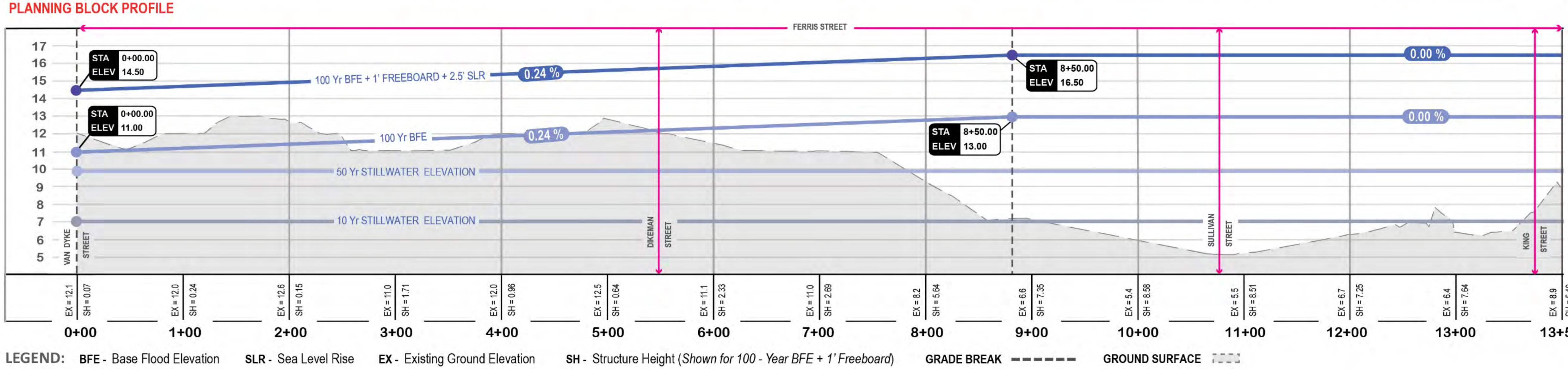


Figure 3-15. Ferris Street Planning Block Constraints

3.2.5 Planning Block 5 – Atlantic Basin

As shown in *Figure 3-16*, the Atlantic Basin planning block extends from Sullivan Street (to the south) to the intersection of Imlay Street and Summit Street (to the north) between the waterfront (to the west) and Imlay Street (to the east). The planning block includes the 2013 FEMA's preliminary 100-year (1% Annual Chance) BFEs between 12-feet NAVD more inland near Imlay Street and 14-feet NAVD on the waterfront with the waterfront subject to wave action.

Characteristics of the land and roads within this planning block include:

- *Drainage:* Land west of Conover Street/Imlay Street is direct drainage area. Land to the east of Conover/Imlay Street is sewered drainage.
- *Transportation:*
    - *Bus:* No bus routes located within this planning block.
    - *Bicycle:* Sullivan St and King St are shared bike lanes. Imlay Street has a protected bike path from Kin Street north to Hamilton St.
    - *Truck:* No Truck Rotes are located within this planning block.
- *Zoning:* The whole planning block area is zoned as a manufacturing district.
- *Land Use:* The land is mostly used as transportation/utility with some parking facilities associated with the Cruise Terminal, industrial manufacturing, and small amount of cavant land.
- *Property Ownership:* Property within this planning block includes private, unknown (usually private), city owned, mixed city/private, and other (public authority, state, or federal).
- *Community/Economic Assets and Critical Facilities:* This planning block is in large part an economic asset to the community as it includes the Brooklyn Cruise Terminal and the Red Hook Container Terminal located along Clinton Wharf and Bowne Street.
- *Utilities:* Utility lines including water, combined sewer, electrical service, telephone service, and gas service run within the Right-of-Way beneath Conover Street, Van Dyke Street, Coffey Street, Dikeman Street, Wolcott Street, Sullivan Street, and King Street. Wolcott Street includes a large-diameter combined sewer that outfalls into the Buttermilk Channel. Sullivan Street west of Ferris Street has gas lines and a sewer line.

Table 3-7 provides a summary of the range of ground elevations, approximate number of building openings, curb cuts, average street width and sidewalk width between the various street segments in the Port Authority/Atlantic Basin planning block.

Table 3-7. Summary of Atlantic Basin Planning Block Constraints

Street Segment	Approximate Ground Elevation Range (Low to High) (feet NAVD)	Number of Building Openings	Number of Curb Cuts	Average Street Width (feet)	Average Sidewalk Width (feet)
Ferris St between Wolcott & Sullivan[1]	~4.8 - ~7.5	3	2	~30	~12-13
Ferris St between Sullivan and King[1]	~4.8 - ~5.23	3	2	~30	~12-13
Ferris St between King & Clinton Wharf[1]	~5.2 - ~6.8	-	-	~24	~12
King St between Ferris & Conover[1]	~5.2 - ~7.3	13	11	~30	~15-16
Pioneer St between Conover and Imlay St	~4.8 - ~6.4	1	2	~29	~14-16
Imlay St between Pioneer and Verona	~4.1 - ~6.4	3	11	~29	~9-10
Imlay St between Verona and Commerce	~4.1 - ~4.6	7	14	~29	~9-10
Imlay St between Commerce and Bowne	~3.9 - ~4.6	3	7	~30	~8
Clinton Wharf between Ferris & Bowne	~4.8 - ~6.8	-	-	~36	-

Notes:
1 Planning blocks overlap – refer to the Ferris Street Planning Block table
2 Planning blocks overlap – refer to the Van Brunt St Planning Block table

ATLANTIC BASIN PLANNING BLOCK

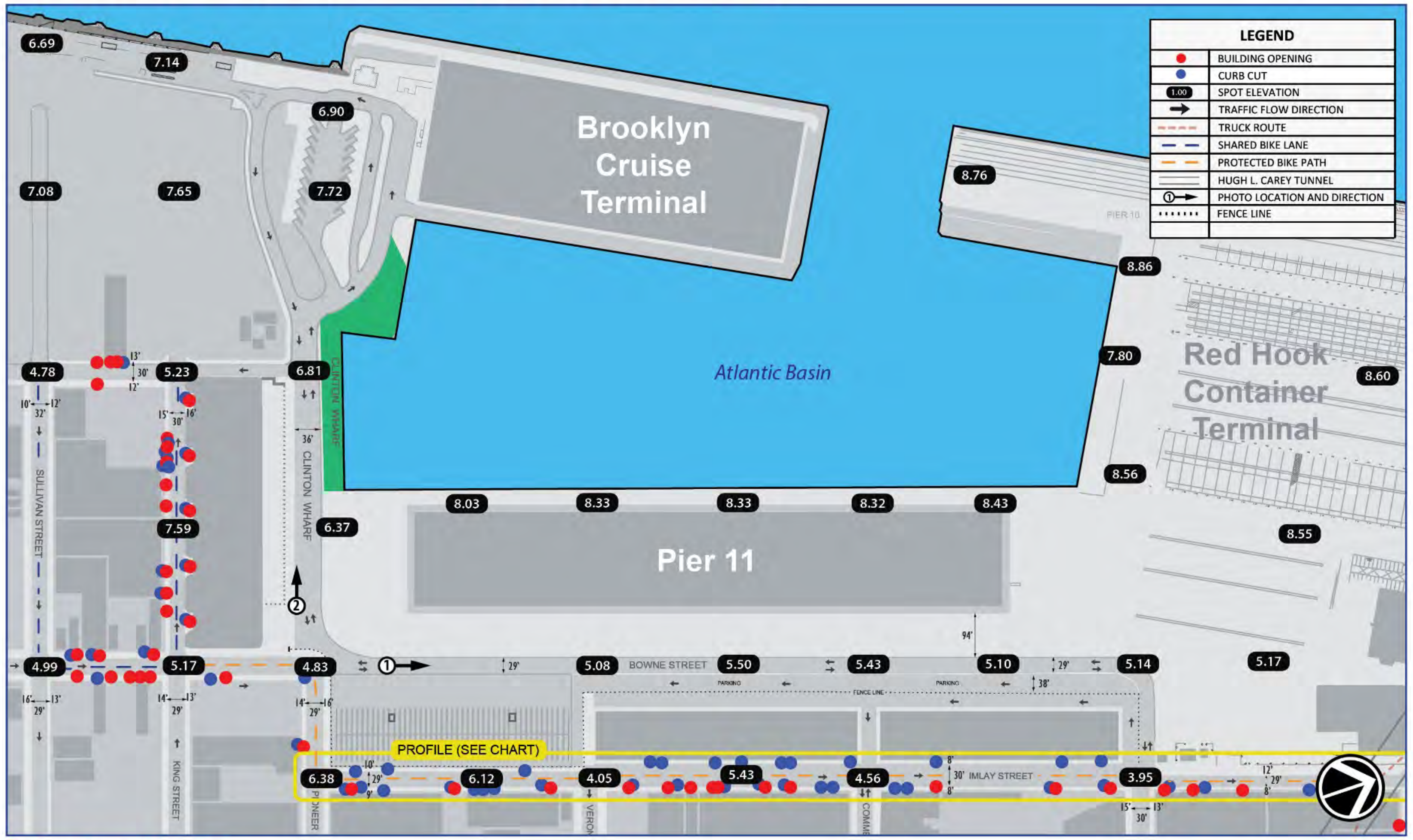
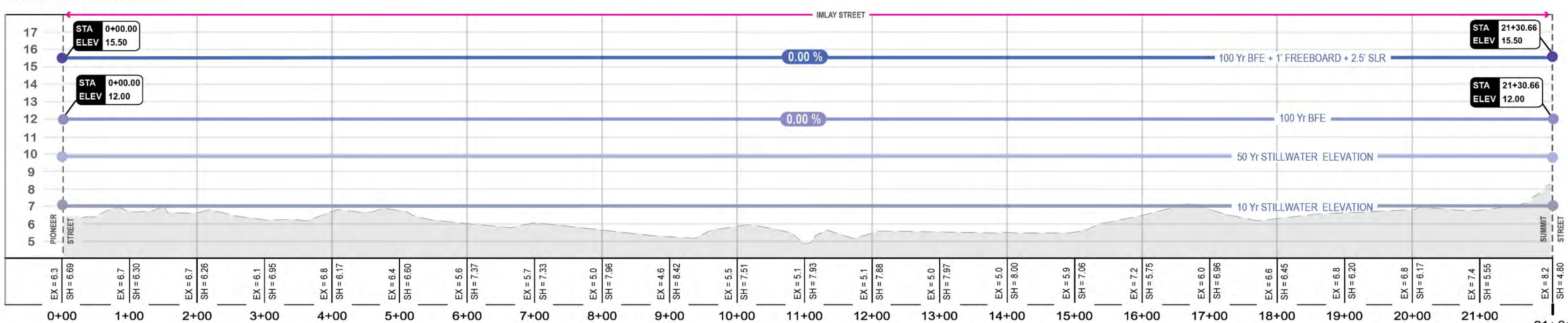


PHOTO ① : Bowne Street facing north from near Clinton Wharf/Brooklyn Waterfront Greenway; April 7, 2017.

PHOTO ② : Clinton Wharf facing north from near Pioneer Street pedestrian gate; April 7, 2016.

PLANNING BLOCK PROFILE



LEGEND: BFE - Base Flood Elevation   SLR - Sea Level Rise   EX - Existing Ground Elevation   SH - Structure Height (*Shown for 100 - Year BFE + 1' Freeboard*)   GRADE BREAK   GROUND SURFACE

Figure 3-16. Atlantic Basin Planning Block Constraints

3.2.6 Planning Block 6 – Van Brunt/DeGraw Streets

As shown in *Figure 3-17*, the Van Brunt/DeGraw planning block extends from Bowne Street (to the south) to the intersection of DeGraw Street and Columbia Street (to the north) between the Van Brunt (to the west) and Columbia Street (to the east). The planning block includes 100-year (1% Annual Chance) BFE of 11-feet NAVD.

Characteristics of the land and roads within this planning block include:

- *Drainage:* Land west of Van Brunt Street is direct drainage area. Land to the east of Van Brunt/Imlay Street is sewered drainage.
- *Transportation:*
  - *Bus:* B61 bus route runs along Columbia Street and down Hamilton Avenue to Carroll Street.
  - *Bicycle:* There are no bicycle routes on this planning block.
  - *Truck:* Truck routes run along Van Brunt Street and DeGraw Street.
- *Zoning:* West of Van Brunt Street and Union Street and Sackett Street up to Columbia Street are zoned as a manufacturing district. Columbia Street and east is zoned as residential.
- *Land Use:* The land is mostly used as residential with some mixed residential/commercial, industrial manufacturing, and small amount of vacant land.
- *Property Ownership:* Property within this planning block includes private, unknown (usually private), city owned, and other (public authority, state, or federal).
- *Community/Economic Assets and Critical Facilities:* This planning block includes the Red Hook Container Terminal located along Clinton Wharf and Bowne Street.
- *Utilities:* Utility lines including water, combined sewer, electrical service, telephone service, and gas service run within the Right-of-Way beneath most streets in this planning block. Columbia Street includes a main telephone line and large diameter combined sewer

Table 3-8 provides a summary of the range of ground elevations, approximate number of building openings, curb cuts, average street width and sidewalk width between the various street segments in the Van Brunt/DeGraw Street planning block.

Table 3-8. Summary of Van Brunt/DeGraw Street Planning Block Constraints

Street Segment	Approximate Ground Elevation Range (Low to High) (feet NAVD)	Number of Building Openings	Number of Curb Cuts	Average Street Width (feet)	Average Sidewalk Width (feet)
Imlay St between Bowne and Summit	~3.9 - ~6.9	3	7	~29	~9
Van Brunt St between Bowne & Hamilton (South Side)	~5.4 - ~7.4	4	3	~37	~10-17

Street Segment	Approximate Ground Elevation Range (Low to High) (feet NAVD)	Number of Building Openings	Number of Curb Cuts	Average Street Width (feet)	Average Sidewalk Width (feet)
Van Brunt between Hamilton (South Side) and Hamilton (North Side)	~7.4 - ~9.6	-	-	~37	~10-17
Van Brunt between Hamilton (North Side) and Carroll	~9.6 - ~10.2	N/A	N/A	~29	~11-16
Van Brunt between Carroll & President	~10.2 - ~10.4	N/A	N/A	~29	~11-16

VAN BRUNT/DEGRAW STREET PLANNING BLOCK

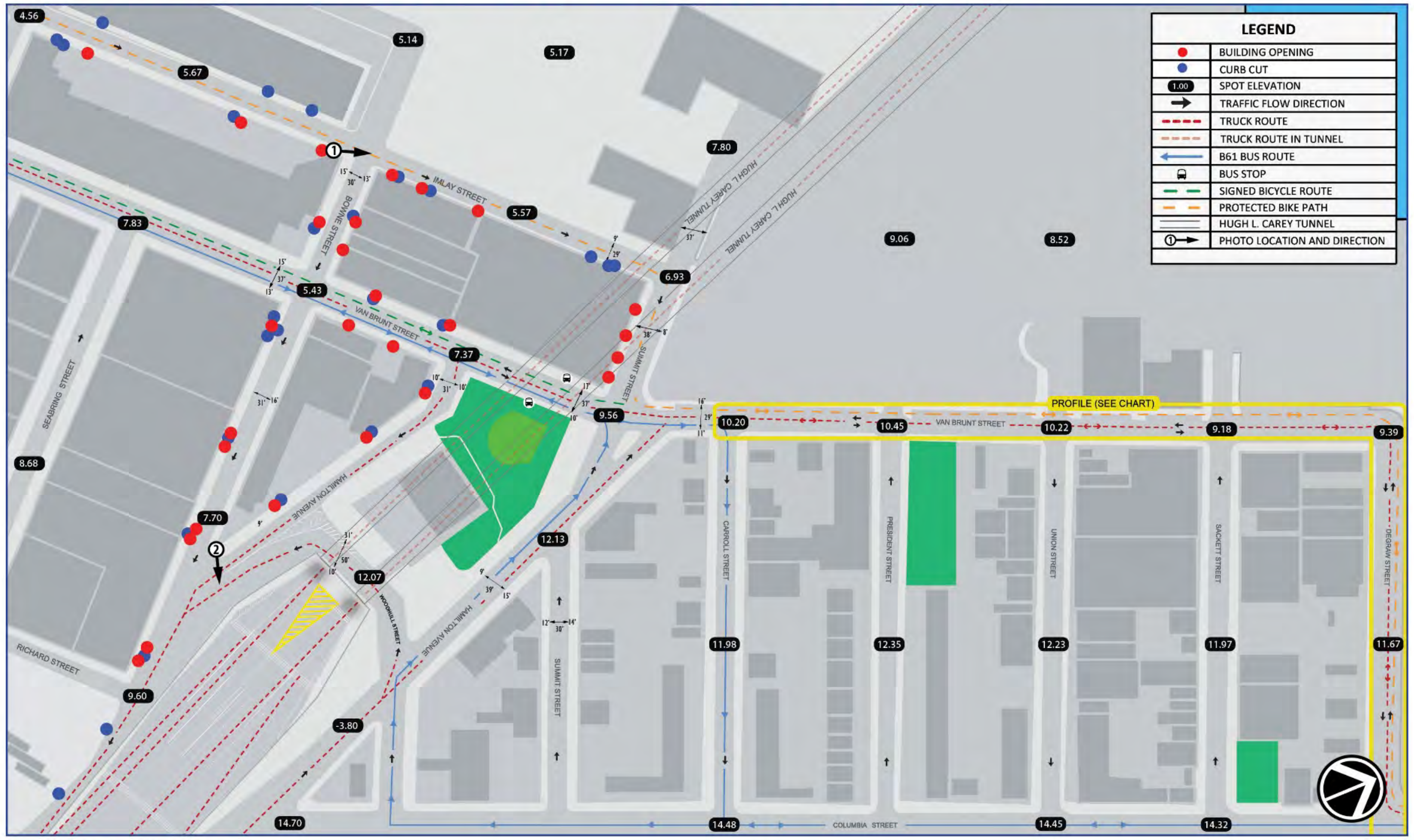
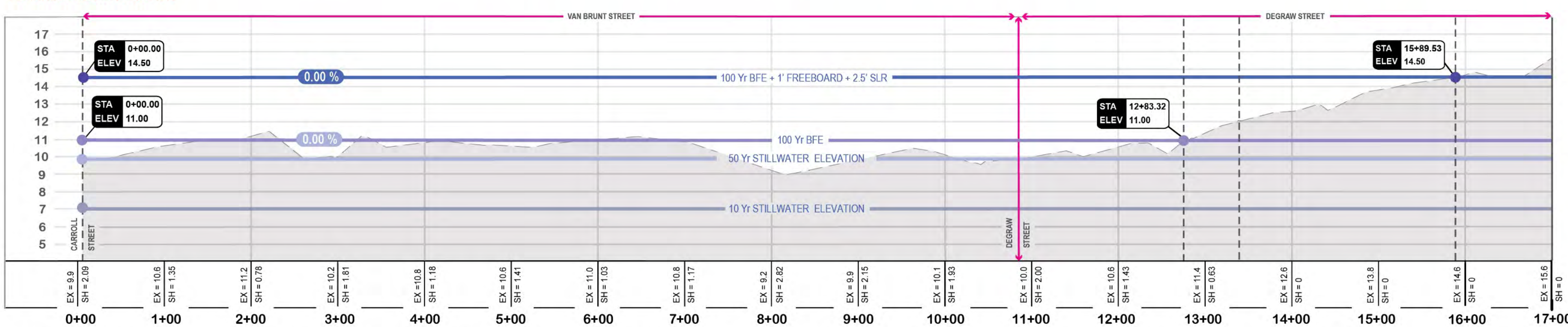


PHOTO ① : Intersection of Bowne Street and Imlay Street facing north towards the Red Hook Container Terminal; April 7, 2016.

PHOTO ② : Intersection of Bowne Street and Imlay Street facing southeastwards Hugh Carey Tunnel retaining wall; April 7, 2016.

PLANNING BLOCK PROFILE



LEGEND: BFE - Base Flood Elevation SLR - Sea Level Rise EX - Existing Ground Elevation SH - Structure Height (*Shown for 100 - Year BFE + 1' Freeboard*) GRADE BREAK GROUND SURFACE

Figure 3-17. Van Brunt /DeGraw Streets Planning Block Constraints

3.3 Coastal Flood Intervention Typologies

Using a combination of the existing site constraints and potential coastal flood intervention typologies from the NYC Department of City Planning's Urban Waterfront Adaptive Strategies Report (NYC Planning, 2013) as a guide, the Team developed a customized toolkit of intervention typologies with varying levels of potential adaption along various portions of Red Hook study area. *Table 3-9* provides a list of these coastal flood intervention typologies along with its potential location and category as either fixed (permanent) interventions or deployable interventions. A majority of the fixed interventions would include a reinforced concrete floodwall with pile-supported foundation as an integral part of the intervention thus providing the required flood structure functionality of the intervention in addition to the urban design functionality.

Table 3-9. List of Coastal Flood Intervention Typologies

No.	Intervention Typology	Preferred Location	Category Type
A1	Elevated Bike Path	Inland	Permanent
A2	Elevated Bike Path with berm	Inland	Permanent
A3	Elevated Multi-Use Path	Waterfront Edge	Permanent
B	Elevated Street	Inland	Permanent
C	Sidewalk Planter	Inland	Permanent
D	Landscaped Median Barrier	Inland	Permanent
E	Hybrid Barrier	Inland	Permanent/Deployable
F	Landscaped Berm	Inland	Permanent
G1	Flood Logs	Inland	Deployable
G2	Passive Deployable Barrier	Inland	Deployable
G3	Sliding Gate	Inland	Deployable
G4	Swing Gate	Inland	Deployable
G5	Containers	Inland	Deployable
G6	Air & Water Filled Tubes	Inland	Deployable
G7	Folding Barrier	Inland	Deployable
G8	Panel Barrier	Inland	Deployable
H	Revetment	Waterfront Edge	Permanent
I	Seawall	Waterfront Edge	Permanent
J	Breakwater	In-water	Permanent
K	Offshore Gate	In-water	Permanent
L	Wetland Edge	Waterfront Edge	Permanent

Appendix B provides a description for each of the above listed intervention typologies along with the pros and cons, photos and typical illustrative sections. The feedback provided during the inter-agency stakeholder meetings helped to narrow down appropriate permanent and deployable intervention typologies based on relative qualitative assessment of criteria such as reliability, constructability, operations and maintenance, costs and other factors (see *Figure 3-18*). Additionally, *Table 3-10* and *Table 3-11* show a qualitative and/or relative quantitative assessment on the various types of permanent and deployable solution to assess its reliability, space requirements, impacts to urban environment, operation and maintenance, and opportunities for community benefits.

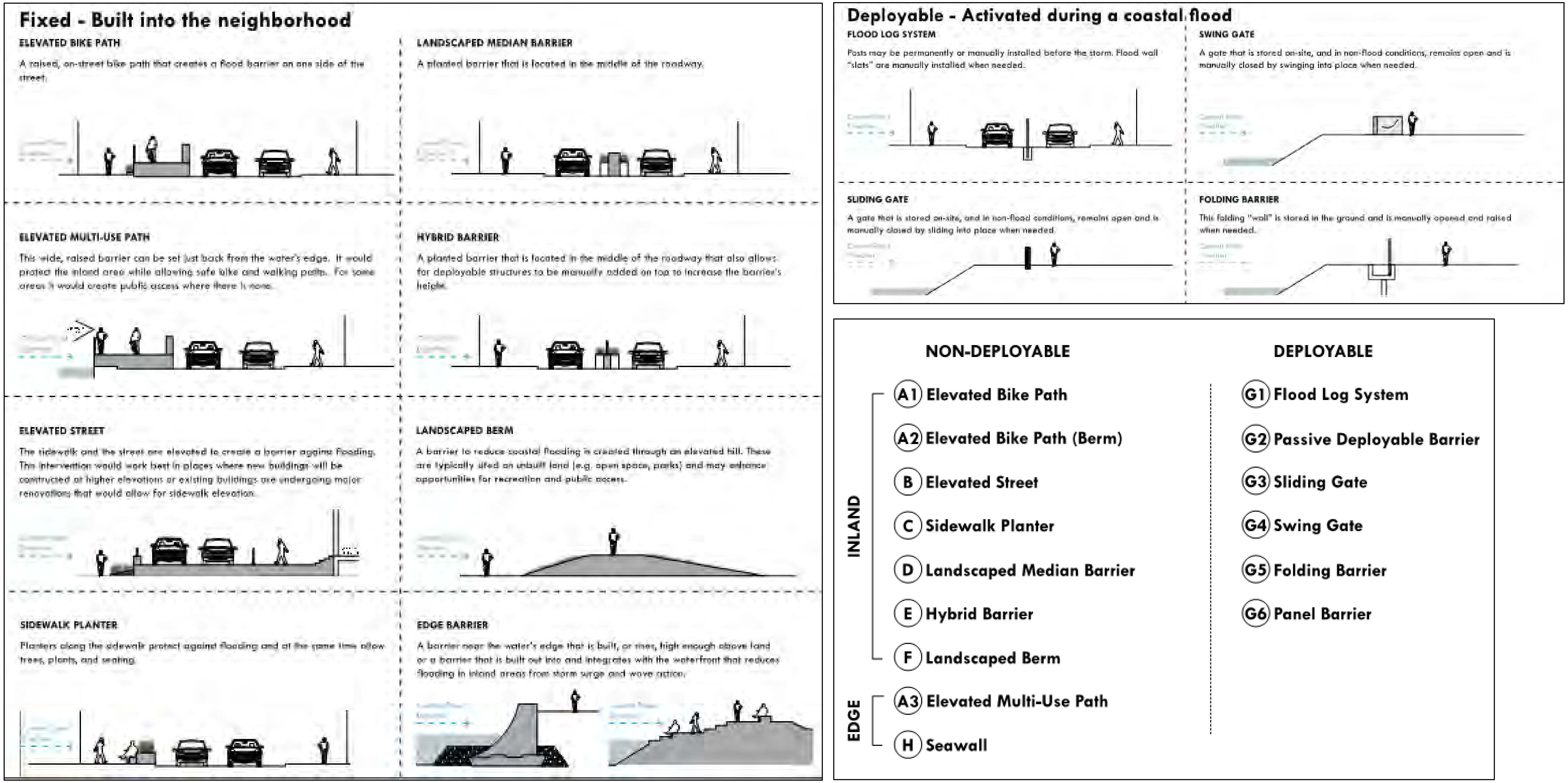


Figure 3-18. Potential Applicable Coastal Flood Intervention Typologies within Red Hook

Table 3-10. Assessment of Permanent Intervention Typologies

Permanent Interventions	Intervention Min. Req. Width	Allowable Height w/o Major Viewshed Impacts	Max. Suitable Height w/ Major Viewshed Impacts	Reliability	Opportunity for Urban Benefits
1. Floodwall	2 feet	3.5 feet (42 inches)	Unlimited	Good	Bad
2. Elevated Bike Path w/ Floodwall	12 feet	3.5 feet (42 inches)	3’ (Bike path) + 3’ (Flood Wall) = 6’ Intervention	Good	Fair
3. Elevated Street	11 feet per road lane	3.5 feet (42 inches)	2’-3’ (Dependent on accessibility requirements)	Good	Good
4. Sidewalk Planter	4 feet	3.5 feet (42 inches)	Dependent on req. height at specific location	Good	Fair
5. Landscaped Barrier	5 feet	3.5 feet (42 inches)	Dependent on req. height at specific location	Good	Fair
6. Hybrid Barrier	5 feet	3.5 feet (42 inches)	Dependent on req. height at specific location	Good	Fair
7. Landscaped Berm	15 – 50 feet	3.5 feet (42 inches)	Dependent on req. height at specific location	Good	Good

Notes: w/o –Without; Min. – Minimum; Max. – Maximum; Req. – Required

Table 3-11. Assessment of Deployable Intervention Typologies

Deployable Interventions Rating	Is Intervention Stored On-Site? Good-Yes; Bad-No	Reliability to Withstand Wave Load/Debris Impact	Time Required to Operate/Deploy: Good - <24hrs; Fair – 24-48hrs; Poor - >48hrs	Operations & Maintenance (See Notes)	Space Req.: Good - <3’; Fair – 3’-5’; Bad - >5’
1. Rolling/Sliding Gate	Good	Good	Good	Good	Fair
2. Swing Gate	Good	Good	Good	Good	Fair
3. Flood Log System	Bad	Fair	Poor	Fair	Good
4. Folding Barrier	Good	Poor	Fair	Poor	Good

Notes:
Good – Less Mechanical Parts Required and Easily Procurable
Fair – More Mechanical Parts Required and Procurable
Poor – Dependent on Manufacturer

3.4 Design Flood Elevation

The Design Flood Elevation (DFE) corresponds to the top elevation of the coastal flood intervention typologies above North American Vertical Datum of 1988 (NAVD). The value of DFE varies based on the level of the coastal storm recurrence interval. In general, the DFE calculation involves use of one or many of the following factors:

- Coastal Stillwater Elevation (feet-NAVD)
- Wave Height (feet)
- Sea Level Rise (feet)
- Required Freeboard (feet)
- Additional Height for Settlement/Subsidence (feet)

Table 3-12 and *Table 3-13* show the coastal stillwater elevation obtained the 2013 FEMA preliminary study and the sea-level rise scenarios for years 2050 and 2080 from the 2015 New York Panel of Climate Change study. The values from these two studies provided the range of DFE values for various locations within the Red Hook study area.

Table 3-12. Return Period Stillwater Elevations (feet-NAVD88, Preliminary 2013 FEMA Study)

10-year (10% annual chance)	50-year (2% annual chance)	100-year (1% annual chance)	500-year (0.2% annual chance)
7.0	9.9	11.4	14.9

Table 3-13. NYPCC Sea Level Rise Scenarios (in feet)

Time Period	Low Estimate (10th percentile)	Middle Range (25th to 75th percentile)		High Estimate (90th percentile)
2050s	0.7	0.9	1.8	2.5
2080s	1.1	1.5	3.3	4.8

The 2013 FEMA preliminary study estimated the wave heights for a 1% annual chance coastal storm event (100-year) only. The 2013 FEMA preliminary maps shows the 1% annual chance event (100-year) Base Flood Elevation (BFE) that includes the combined effects of the 1% annual chance still water and wave heights as it travels from water edge into upland portions of the study area. The BFE terminology is applicable to 1% annual chance storm event only and does not apply for other coastal storm events such as the 10-year (10% annual chance) or 50-year (2% annual chance) events. *Figure 3-19* graphically demonstrates the concept of BFE and DFE for the 1% annual chance storm event. *Figure 3-20* shows the 2013 FEMA preliminary BFE floodplain extents along with its elevation values. As shown in *Figure 3-20*, the BFE varies from elevation of 16 feet-NAVD along the waterfront edge to an elevation of 11-feet NAVD further inland within the Red Hook study area.

Freeboard measured in terms of height in feet above either BFE or coastal still water elevations (10-year/ 50-year) provides additional factor of safety for the potential coastal flood intervention typology.

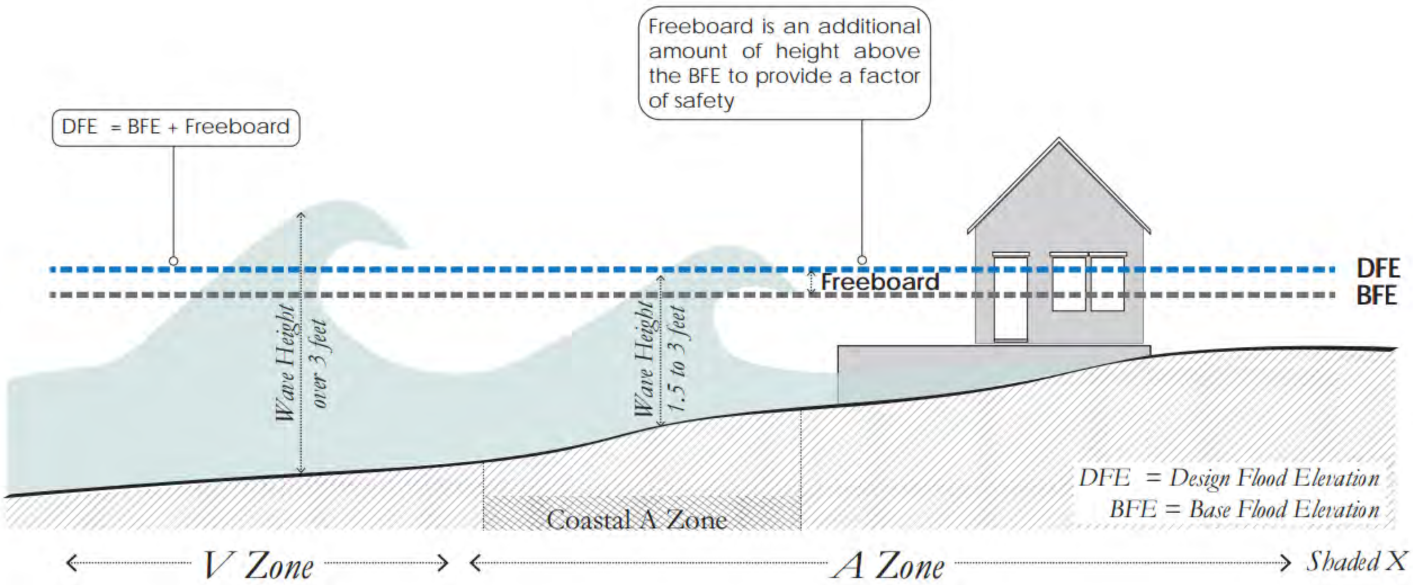


Figure 3-19. Graphical Representation of BFE and DFE for the 1% Annual Chance Event (100-year) Only

Table 3-14 shows the eight (8) DFE scenarios that provide DFE values from the 10-year storm surge to the 500-year storm surge with and without sea level rise that the Team initially considered for the Study. Using GIS techniques, Dewberry estimated approximate structure heights required for these various scenarios by subtracting the LiDAR topography elevation values from the DFE value at various locations within the study area.

Figure 3-21 provides an example of the required structure heights at various locations within Red Hook for the following three DFE values and scenarios:

i. **Scenario 1** - DFE of 10 feet-NAVD that corresponds to either a 10% annual chance (10-year) coastal still water elevation plus 2.5 feet of SLR plus 0.5 feet (6 inches) of freeboard or approximately a 2% annual chance (50-year) coastal still water elevation
ii. **Scenario 2**- DFE of 13 feet-NAVD that corresponds to a 2% annual chance (50-year) coastal still water elevation plus 2.5 feet of SLR plus 0.5 feet (6 inches) of freeboard
iii. **Scenario 3** - DFE of 16 feet-NAVD that corresponds to a 1% annual chance (100-year) BFE plus 2.5 feet of SLR plus 1 feet of freeboard

Figure 3-22 shows that the required structure height for Scenario 1 ranges from 0.7 feet to 5.4 feet whereas it ranges from 5.2 feet to 10.9 feet for Scenario 3 along various locations within the Red Hook study area. The required height of the structure depends on the DFE scenario. As DFE increases, the structure height increases as well which can result in major impacts to the urban fabric of the Red Hook community.

Figure 3-20. 2013 FEMA Preliminary 100-Year (1% Annual Chance) Storm Base Flood Elevation

Table 3-14. Design Flood Elevation Scenarios

Coastal Storm Surge Scenario	Design Flood Elevation (feet-NAVD 88)
10-Year Coastal Storm Surge[1]	7’ NAVD
10-Year + 1’ Freeboard[2] (or Sea Level Rise [SLR[3]])	8’ NAVD
10-Year[1] + 2.5’ SLR[3] + 6” Freeboard	10’ NAVD
50-Year Coastal Storm Surge[1]	9.9’ NAVD
50-Year[1] + 2.5’ SLR[3] + 6” Freeboard	12.9’ NAVD
100-Year Base Flood Elevation (BFE)[4] (includes wave effects)	11.4’ NAVD (Inland) 15.3’ NAVD (Waterfront)
100-Year BFE + 2.5’ SLR[3] + 1’ Freeboard	~15’ NAVD (Inland) ~18’NAVD (Waterfront)[5]
500-Year Coastal Storm Surge[6]	14.9’ NAVD

Notes:
1 Does not include effects from waves
2 Assumption to account for SLR
3 New York City Panel on Climate Change (NYPCC) projections of Sea Level Rise (NYPCC 2015) for 2050s
4 BFE obtained from the 2013 preliminary FEMA for 100-year Coastal Storm Surge Event only
5 DFE does not include additional effects from wave runup and overtopping
6 Coastal Stillwater elevation only and does not include effects from waves

Figure 3-21. Example Structure Height Locations

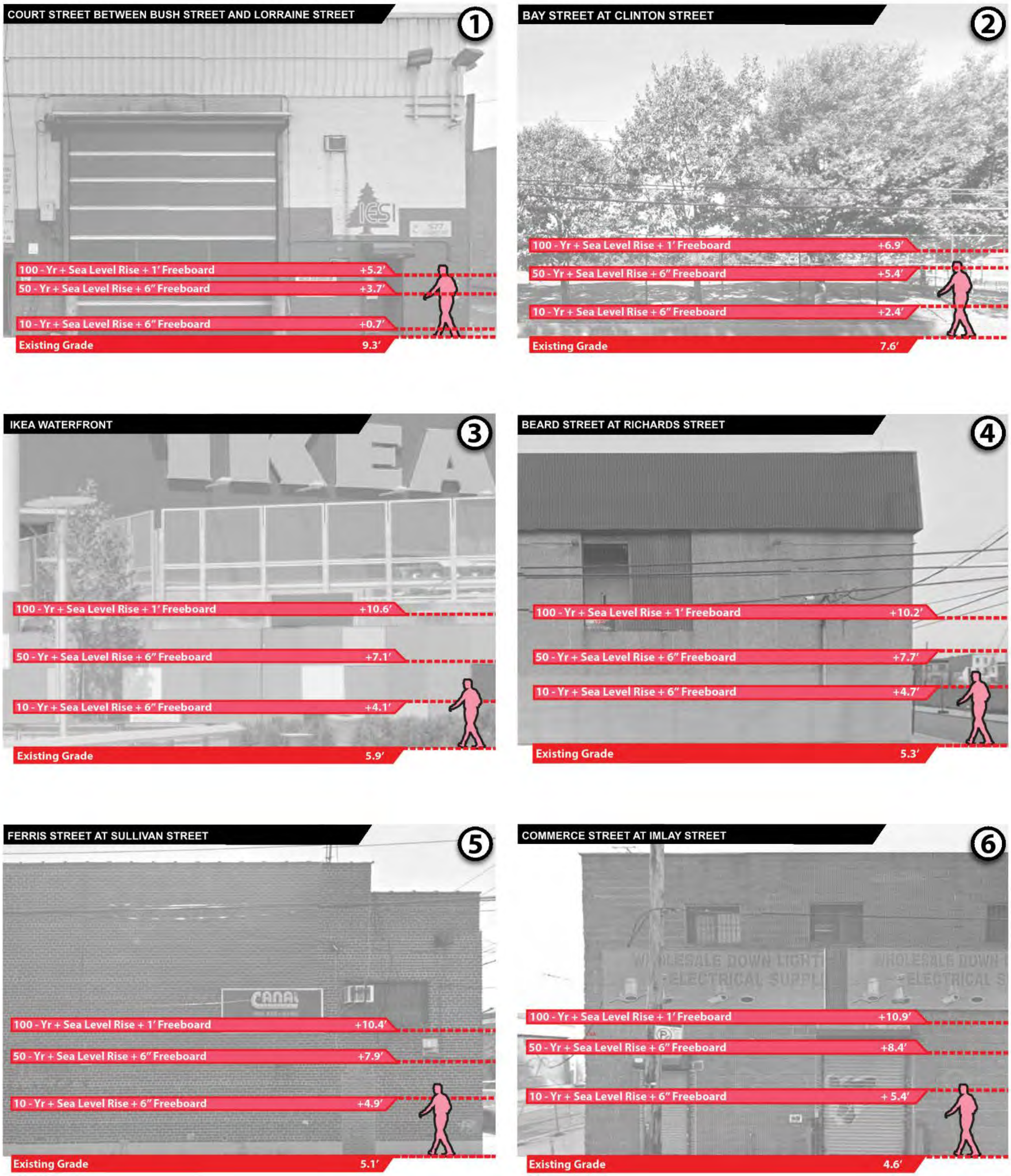


Figure 3-22. DFE Scenarios and Example Structure Heights

3.5 Coastal Flood Risk Reduction Alignments

The methodology and analysis described in Sections 3.1 to 3.4 provided the basis to develop comprehensive coastal flood risk reduction alignments that would provide varying levels of flood risk reduction benefits for the Red Hook community. The Team took into account several key critical attributes such as area (people, buildings, critical facilities, etc.) receiving flood risk reduction benefits, impacts to public/private property, impacts to drainage, existing high ground for tie-ins, and range of structure heights for various DFE scenarios among others. Additionally, due to the presence of the Metropolitan Transportation System (MTA)'s Hugh Carey Tunnel and challenges associated with the constructability of a coastal flood intervention over the tunnel, the Team decided to develop alignments with tie-in location at the southern portion of the tunnel by Hamilton Avenue. The Team performed qualitative assessment on numerous segments that could be combined together to develop a comprehensive coastal flood alignment. A qualitative assessment of applicable coastal flood intervention typologies along these segments for range of DFE scenarios provided potential impacts and constructability issues. After analyzing these numerous segments, the Team developed three (3) comprehensive potential alignment alternatives – 1) Outermost, 2) In-between, and 3) Innermost alignment – as shown in *Figure 3-23*. *Table 3-15* provides a summary of these three alignment alternatives.

Table 3-15. Comparison of the Three Alignment Alternatives

Alignment Alternatives	Approximate Length (feet)	Approximate No. of Deployables	Average Structure Height (feet)	Impacts to Private Property
Outermost	19,122	31	15	Significant
In-Between	11,840	43	9	Negligible
Innermost	10,009	38	8	Negligible

*Average height assumes a DFE scenario equal to the BFE + 1' Freeboard + 2.5' SLR

The alignment concepts, shown in *Figure 3-23* extents shows the length and spatial extents to provide flood risk reduction up to the 100-Year (1% annual chance) storm event plus 2.5 feet of SLR plus 1 feet of freeboard. The alignment concept extents and lengths reduce with a reduction in the DFE scenario. *Table 3-16* provides a qualitative assessment of the various pros and cons of each alignment option.

Table 3-16. Qualitative Assessment of the Three Alignment Alternatives

Alignment Option	Qualitative Assessment
Outermost	▪ Generally follows waterfront edge and includes greatest amount of area within IFPS ▪ Potentially most expensive scenario ▪ Requires highest structure height ▪ Impacts to the working waterfront ▪ Impacts to views
In-Between	▪ Provides moderate flood risk reduction benefits within the study area ▪ Takes advantage of the natural topographic high points reducing the overall length of a built intervention system
Innermost	▪ Least area of protection ▪ Least amount of length ▪ Potentially lowest cost scenario

LEGEND

Three Alignment Scenarios

Innermost Alignment — In-Between Alignment — Outermost Alignment — Red Hook Study Area

Figure 3-23. Three Concept Coastal Flood Risk Reduction Alignments

3.5.1 Outermost Alignment

The Outermost Alignment as shown in *Figure 3-24* generally follows the waterfront. Beginning at high ground on Hamilton Avenue between Mill Street and Centre Street, the alignment proceeds southeast to the waterfront east of Smith Street. The alignment proceeds west to Halleck Street, south on Court Street to Bryant Street, then north on Clinton Street to encounter the high ground at Red Hook Parks. The alignment crosses Red Hook Parks and proceeds south around the Ball Fields, then south on Columbia to the waterfront. The alignment proceeds west along the waterfront, south of IKEA, then north along the IKEA walkway to connect with Beard Street, south along the bulkhead to the walkway near Red Hook Star Revue facility, then proceeding west.

The alignment continues along the waterfront to the northwest, through Valentino Pier, to the Red Hook Cruise Terminal. The alignment proceeds inland along the southwestern side of the Cruise Terminal building, along Clinton Wharf, and north along Pier 11. The alignment proceeds further inland at the northeastern corner of Atlantic Basin towards Bowne Street. The alignment connects to high ground at the Hugh Carey Tunnel retaining wall at the intersection of Bowne Street and Hamilton Avenue. This alignment has the longest length at almost 19,000 feet and highest BFEs, ranging from 11 feet-NAVD to 16 feet-NAVD.

Figure 3-24. Outermost Conceptual Coastal Flood Risk Reduction Alignment

3.5.2 In-Between Alignment

Similar to the Outermost Alignment, the In-Between alignment begins on Hamilton Avenue between Mill Street and Centre Street as shown in *Figure 3-25*. The alignment would turn and proceed south along Court Street to Red Hook Parks then turn west, crossing Clinton Street and connecting to Columbia Street. Following Halleck Street to Beard Street, the alignment would proceed further west along Beard Street to Conover Street, north to Van Dyke Street, west on Van Dyke Street, then north along Ferris Street. The alignment would pass through Port Authority property along Clinton Wharf before heading back onto the public right-of-way for two blocks on Imlay Street. This alignment would then return to Port Authority property along Commercial Wharf before turning east on Bowne Street and continuing until tying into the retaining wall for the Hugh L. Carey tunnel at the intersection of Bowne Street and Hamilton Avenue.

As mentioned in Section 3.5, this alignment would be about 12,000 LF and have a range of BFEs from 11 feet NAVD to 13 feet NAVD. *Figure 3-25* below shows this alignment isolated from the other scenarios; the alignment shown does not consider any specific DFE but rather just shows graphically the route that the alignment would follow along Red Hook.

LEGEND

In-Between Alignment — Red Hook Study Area

Figure 3-25. In-Between Conceptual Coastal Flood Risk Reduction Alignment

3.5.3 Innermost Alignment

The innermost alignment has the shortest length of the three alignment scenarios but also reduces flood risk for the least amount of area when compared to the previous two alignment scenarios. As shown in *Figure 3-26*, this alignment begins on Clinton Street and Mill Street and heads south down Clinton Street to the Red Hook parks and turns west until connecting to Columbia Street. From Columbia Street, the alignment follows the same route through Beard Street as the In-Between alignment before turning north and continuing up Conover Street. The alignment then turns east at Pioneer Street and continues north along Imlay Street until Bowne Street.

LEGEND

Innermost Alignment — Red Hook Study Area

Figure 3-26. Innermost Conceptual Coastal Flood Risk Reduction Alignment

4 Alignment Analysis and Development of a Preferred Alignment

Dewberry used the information learned from the methodology and analysis described above to present the alignment and DFE concepts to the Red Hook community either in a public meeting and/or in a community stakeholder engagement meeting. Using the input provided by the community along with discussions with various agencies, the Team selected the In-Between alignment as the preferred alignment to move forward with additional analysis. However, the Team kept the option of incorporating segments of the other two comprehensive alignments with the in-between alignment. The sections below highlight the process utilized by the Team to determine the preferred alignment.

4.1 Community Meetings

The Team conducted a public meeting on June 15, 2017 to present the alternative analysis and the proposed HMGP project. Prior to this meeting, on October 13, 2016, the Team presented the three alignment alternatives along with supporting data to show potential structure heights required within various portions of Red Hook in a public meeting. Priorities and themes drawn from community feedback during the public meeting included the following:

- Desire to build for maximum protection, while ensuring future adaptability;
- Uncertainty around the potential impacts to the community of various intervention types along each of the alignments;
- General preference for the In-between alignment due to the relatively lower DFE and use of public right-of-way;
- Desire to ensure that the waterfront and public transportation remain accessible to the neighborhood

Prior to October 2016 public meeting, the Team had previously conducted two (2) public meetings to inform the public about the project and seek input from them, which fed into the development of these three alignment alternatives. Appendix C provides detailed description for each of these four public meetings.

4.1.1 Additional Community Engagement

In addition to the four public meetings, the Team also conducted a number of small community engagement events throughout the summer of 2016. The Team met with various community groups and advocates including Resilient Red Hook (formerly Community Reconstruction Program), Red Hook Initiative (RHI) Digital Stewards, and RHI Local Leaders among others. These smaller group events allowed the Team to gain insight from specific groups and engage with residents who may not have had a chance to attend the public meetings.

4.2 Alignment Evaluation and Selection

Figure 4-1 shows the list of qualitative assessment criteria used by the Team to compare the three alignments for a range of DFE scenarios. Additionally, the Team incorporated feedback from various agencies on these alignments during the evaluation process. Additional evaluation criteria includes flood risk reduction benefits, property impacts, potential to achieve a benefit–cost ratio of greater than 1.0, and potential for a reliable and feasible project within $100 million. *Table 4-1* shows the qualitative comparison assessment for the three alignments. As seen from this table, although the outermost alignment provides the maximum flood risk reduction benefits, it would pose significant impacts to private property and would not produce a potential project with a lower DFE, a BCR greater than 1.0, and construction costs of $100 million. Both the in-between alignment and innermost alignment, however, yield significantly fewer conflicts with private properties and each have the potential to produce a project(s) with an optimal DFE generating a BCR greater than 1.0. Of these two alternatives, the in-between alignment would provide the greater level of flood risk reduction benefits.

Figure 4-1. General Feasibility Evaluation Criteria for Alignment Alternatives Comparison

Table 4-1. Comparison of Qualitative Assessment Criteria on the Three Alignments

Criteria	APPLICABLE ALIGNMENTS		
	Outer Alignment	**In-Between Alignment (Court Street – MTA)**	**Innermost Alignment (Clinton Street – MTA)**
	Length -19,125'	**Length – 11,840'**	**Length – 10,009'**
Population Receiving Benefits assuming same DFE scenario (Flood Risk Reduction Benefits)	Highest	Medium	Lowest
Reliability of System (based on potential no. of deployable)	31 deployable	43 deployable	38 deployable
Viewshed and Access to Waterfront Impacts	Major Impacts	Minor Impacts	Minor Impacts
Impacts to Private Property	Major Impacts	Minor Impacts	Minor Impacts
Environmental Impacts	Major Impacts	Minor Impacts	Minor Impacts
Constructability	Major Challenges	Relatively Minor Challenges	Relatively Minor Challenges
Potential for a project within $100 million dollars	None	Possible with a lower DFE scenario	Possible with lower DFE scenario
Potential for BCR > 1.0	No	Possible with a lower DFE scenario	Possible with a lower DFE scenario
Community Priority/Preference for Alignment	No	Yes	No
Notes Green Color rating is Good, Orange Color rating is Fair and Red Color rating is Poor			

As can be seen in the table above, the In-Between alignment and Innermost Alignment both had a BCR greater than 1.0; however, since Innermost Alignment had a poor rating for community preference and overall flood risk reduction benefits, the Team decided to select the In-Between alignment as the preferred alignment. The In-between alignment has a balanced evaluation rating that has a potential for a $100 million project with a lower DFE and potentially fewer number of deployables. The Team conducted additional analysis to identify optimal DFE along this preferred alignment option with minimal impact to the urban fabric of the Red Hook community.

5 Alternatives Development and Assessment of Selected Preferred Alternative

With the preferred alignment, the Team developed three alternatives designed for a specific Design Flood Elevation (DFE). The Team identified a segment along the Atlantic Basin, original to the outermost alignment, for a lower DFE scenario in conjunction with the preferred alignment that lead to the development of a fourth alternative. Additionally, based on feedback from EDC and ORR, the Team considered a hybrid alignment with potential for FEMA levee certification as the fifth alternative. In total, the Team analyzed and compared five (5) alternatives with the feasibility assessment criteria that led to the selection of the preferred HMGP alternative.

5.1 Design Flood Elevation Analysis on Selected Alternatives

With input from NYCEDC and ORR, the Team developed alternatives with each alternative corresponding to a specific DFE scenario:

i. Alternative 1 - 10-Year Storm Surge + 1 feet. Sea Level Rise = DFE 8 feet-NAVD
ii. Alternative 2 - 10-Year Storm Surge + 2.5 feet Sea Level Rise + 6 in. Freeboard = DFE 10 feet-NAVD
iii. Alternative 3 - 50-Year Storm Surge + 2.5 feet Sea Level Rise + 6 in. Freeboard = DFE 13 feet-NAVD
iv. Alternative 4 - 100-Year Storm Surge + 2.5 feet Sea Level Rise + 1 feet Freeboard = Elevation starting at 15 feet-NAVD
v. Alternative 5 – FEMA levee certification DFE scenario along a hybrid alignment

Figure 5-1 and *Figure 5-2* show the spatial extents for Alternative 1 – 4 and Alternative 5, respectively.

5.1.1 Design Flood Elevation Intervention Length and Structure Heights for Alternatives

The spatial extent covered by each alternative along with the height required for an appropriate coastal flood intervention typology are critical to understand the potential impacts The choice of appropriate coastal flood intervention typology is dependent of the height of structure and available space for the intervention. Additionally, the construction cost for a project is also dependent on the spatial extent and height of the structure. Since the topography along the alignment changes and rises above most of the DFEs at certain points, the spatial extent of each alternative breaks at various locations where it meets the required high ground elevation.

Figure 5-1 illustrates the concept that each DFE requires a different length for potential coastal flood intervention. One location that requires some form of intervention in every DFE is at the intersection of Van Brunt Street and Beard Street; *Table 5-1* below compares the required structure heights for each DFE at this location. Appendix D provides a table for the required structure height at additional reference points throughout the Red Hook study area. *Figure 5-3* to *Figure 5-6* shows the spatial extents and structure heights at various locations for Alternative 1 -4, respectively

Table 5-2. Structure Height Required at Van Brunt Street and Beard Street

Alternative	Coastal Design Storm Event	Approx. Ground Elevation (feet-NAVD)	DFE (feet-NAVD)	Structure Height (feet)
1	10 Yr + 1' SLR	5.5	8	2.5
2	10 Yr + 2.5 ' SLR	5.5	10	4.5
3	50 Yr + SLR	5.5	13	7.5
4 and 5	100 Yr + SLR	5.5	15.5	10

*Figure 5-1. Comparison of Spatial Extents for Alternatives 1 to 4 **

* Spatial locations of alignments are shifted for demonstration purposes and do not reflect actual alignment locations

Figure 5-2. Alternative 5: Potential Alignment for FEMA Levee Certification

Figure 5-3. Alternative 1: 10-Year + 1' SLR Protection Extent and Structure Heights

Figure 5-4. Alternative 2: 10-Year + 2.5' SLR Protection Extent and Structure Heights

Figure 5-5. Alternative 3: 50-Year + 2.5' SLR Protection Extent and Structure Heights

Figure 5-6. Alternative 4: 100-Year + 2.5' SLR Protection Extent and Structure Heights

5.2 Comparison of Assessment Criteria on the Four Alternatives

Figure 5-3 through *Figure 5-6* illustrate the length of intervention required for each alternative with unique DFE along with example structure heights. As seen from *Table 5-1* and the figures mentioned above, the structure heights required for the Alternative 3 and 4 with two highest DFEs (50-Year + SLR and 100-Year + SLR) often exceeds 6 feet. A structure that requires greater than 6 feet height would cause extensive impacts throughout the Red Hook community and significantly affect the quality of life for many residents and businesses on both sides of the alignment. The Team did not perform any assessment for Alternative 5 because the Team anticipated that the costs for a project meeting FEMA levee certification requirements would exceed $100 million budget without satisfying the HMGP BCR criteria of greater of 1.0. *Table* 5-3 compares Alternative 1 to Alternative 4 with applicable quantitative and qualitative assessment on each criterion for each alternative.

Table 5-3. Comparison of Alternatives

Assessment Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	10-Year + 1' SLR (8' NAVD)	10-Year + 2.5' SLR + 6" FB (10' NAVD)	50-Year + 2.5' SLR + 6" FB (13' NAVD)	100-Year + 2.5' SLR + 1' FB (15'+ NAVD)
Overall Structure Length (Linear Feet)	~2,000 of Structure ~1,450 re-grading	~7,400	~9,000	~12,275
Maximum Structure Height (feet above grade)	~3	~6	~9	12 +/-
Number of Approximate Deployable	0 (zero)	26	40	43
Urban Design	Negligible Impacts	- Viewshed impacts generally in lower/ lowest elevation areas - Circulation Impacts (truck and bus routes)	- Significant viewshed impacts - Circulation impacts to truck, bus, and pedestrian routes	- Significant viewshed impacts - Circulation impacts to truck, bus, and pedestrian routes
Project Costs within $100 Million	Yes	Yes, but with significant tradeoffs on reliability	No	No
Potential Coastal Flood Intervention Typologies	Elevated Street with embedded floodwall, sidewalk planters, floodwall along water's edge	Various types of I, L and T- floodwalls with limitations on pile lengths, sizes and spacing	Not evaluated because potential project costs exceeds $100 Million	Not evaluated because potential project costs exceeds $100 Million
Potential BCR > 1.0	Yes	Yes	Not evaluated	Not evaluated

Assessment Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	10-Year + 1’ SLR (8’ NAVD)	10-Year + 2.5’ SLR + 6” FB (10’ NAVD)	50-Year + 2.5’ SLR + 6” FB (13’ NAVD)	100-Year + 2.5’ SLR + 1’ FB (15’+ NAVD)
Potential for Future DFE Adaptability	Yes	No	Not evaluated	Not evaluated
Potential for Community Benefits	Yes	No	Not evaluated	Not evaluated

A review of the impacts, benefits and other assessment criteria for each alternative from *Table 5-3* indicates that Alternative 1 provides the balanced and optimal solution to reduce flood risk from coastal storm surge within Red Hook. After discussions and input from the NYCEDC, ORR and other NYC agencies, the Team selected Alternative 1 as the preferred alternative that meets the project’s goals, provides reliable flood risk reduction benefits, has negligible impacts on the urban fabric of the community, does not require deployables, and has a BCR greater than 1.0. As seen from *Figure 5-3*, the required intervention associated with Alternative 1 is primarily restricted to a small portion of Beard Street and a corner of Atlantic Basin. Additionally, the maximum height along the alignment would be approximately 3 feet. and would not require use of any deployable features, thus reducing the costs and efforts associated with Operations and Maintenance (O&M).

5.3 Conceptual Design and Analysis for the Preferred Chosen Alternative

The preferred chosen alternative for the Red Hook Integrated Flood Protection System (IFPS) is a completely passive system designed to reduce flood risks within Red Hook from a 10% annual chance (10-year) coastal storm surge event plus 1 foot of Sea-Level Rise (SLR) or 1 foot of freeboard with a Design Flood Elevation (DFE) of 8 feet-NAVD. As shown in *Figure 5-3*, the preferred alternative has two distinct areas – Beard Street and Atlantic Basin. The Team assessed the feasibility of various coastal flood intervention typologies within the existing site constraints in these two areas. With the goals to maximize use of publicly available Right of Way (ROW) footprints and minimize the use of deployable features, the Team developed a conceptual design for these two areas as shown in *Figure 5-7*. A multi-disciplinary Team performed analysis that covers drainage, structural engineering, geotechnical engineering, urban design, landscape treatments, project costs, and benefit-cost to develop a reliable project that is both HMGP eligible and adaptable to a future DFE, as shown in *Figure 5-7*. Appendix E shows the conceptual design drawings for the Atlantic Basin and Beard Street areas. The following section provides a detailed description of the analysis performed on the various components of this conceptual design.

Figure 5-7. Conceptual Design Features of the Preferred Alternative

5.3.1 Preferred Project Features and Benefits

Figure 5-8 illustrates the areas within Red Hook that would see flood risk reduction with the preferred alternative IFPS in place while *Figure 5-9* shows the entire floodplain of the 8 ft. NAVD DFE in existing conditions. *Table 5-4* summarizes the flood risk reduction in terms of area, buildings, and population as a percentage affected by 10-year coastal storm surge and 1 feet of SLR (8 feet DFE) as shown in *Figure 5-9*. *Table 5-5* summarizes the flood risk reduction in terms of area, buildings, and population as a percentage for the entire Red Hook study area.

Table 5-4. Summary of Flood Risk Reduction for Preferred Alternative (8 Feet Flood Inundated Area)

Area Protected		Buildings Protected		Population Protected	
Acres	% of Affected	# of Buildings	% of Affected	Population	% of Affected
96	50%	413	88%	3,039	96%

Table 5-5. Summary of Flood Risk Reduction for Preferred Alternative (Entire Study Area)

Area Protected		Buildings Protected		Population Protected	
Acres	% of Total	# of Buildings	% of Total	Population	% of Total
96	16%	413	29%	3,039	25%

Atlantic Basin

In the Atlantic Basin area, the conceptual design consists of replacing a portion of the Clinton Wharf bulkhead with new bulkhead to DFE of 8 feet- NAVD, reinforcing the bulkhead along Pier 11 to reduce any seepage, removing a portion of Clinton Wharf, and constructing a new landscaped walkway that would integrate with the Red Hook ferry stop. Portions of the Brooklyn Cruise Terminal parking lot immediately adjacent to the west/southwest of Atlantic Basin require re-grading that would raise the lot to 8 feet-NAVD.

Beard Street

The conceptual design of Beard Street area is located along Beard Street just west of Dwight Street to a few hundred feet west of Van Brunt Street. The Beard Street IFPS segment consists of an elevated roadway and sidewalks with an embedded floodwall located along the waterside of Beard Street. Additionally, the floodwall structure along this segment has the ability to adapt to a future DFE. The streetscape of the raised street and sidewalk would allow for new landscape and urban design features. Along these two areas, drainage modifications would be required in the form of installing new high level storm sewers (HLSS), watertight manholes, new outfalls and tide gates as needed to prevent the intrusion of coastal storm surge through the existing storm-sewer system into the protected side of Red Hook.

Table 5-6 provides the approximate quantities of the project features in the Atlantic Basin and Beard Street areas.

Table 5-6. Summary of Components for the Preferred Alternative in Each Area

Area	Length of Floodwall (feet)	Length of Raised Roadway/Walkway (feet)	Length of High Level Storm Sewers (feet)	Other Drainage features
Atlantic Basin	~700	~250 (Re-grade)	~220	Watertight manholes, new outfall, tide gates
Beard Street	~1,300	~1,200	~800	Watertight manholes, new outfalls, tide gates

Figure 5-8. Area Receiving Flood Risk Reduction from 8 feet-NAVD DFE with Preferred Alternative

Figure 5-9. Flood Inundation Extents from 10-Year Coastal Storm Surge and 1 Foot SLR (8 Feet-NAVD)

5.3.2 Conceptual Design Features of Atlantic Basin

Figure 5-10 shows the conceptual design of Atlantic Basin components. The conceptual design involves removal and reconstruction of approximately 700 linear feet of the Clinton Wharf bulkhead (floodwall) up to an elevation of 8 feet-NAVD; reinforcement of Pier 11 bulkhead; and demolish and removal of around 3,900 cubic yards of the existing Clinton Wharf bulkhead. Additionally, the concept design requires re-grading of roughly 2,200 square feet within the Brooklyn Cruise Terminal parking lot to elevation 8' NAVD and drainage modifications along Wolcott Street and Sullivan Street. The design of new bulkhead at Atlantic Basin would require accommodating a new ferry platform with opportunities to enhance the ferry stop terminal with landscaping and community benefits options. *Figure 5-11* and *Figure 5-12* below show illustrative renders for two potential landscape and community benefit design options that involves creation of a new landscape, ADA accessible walkway along the new bulkhead at Atlantic Basin that integrates with the new NYC ferry stop.

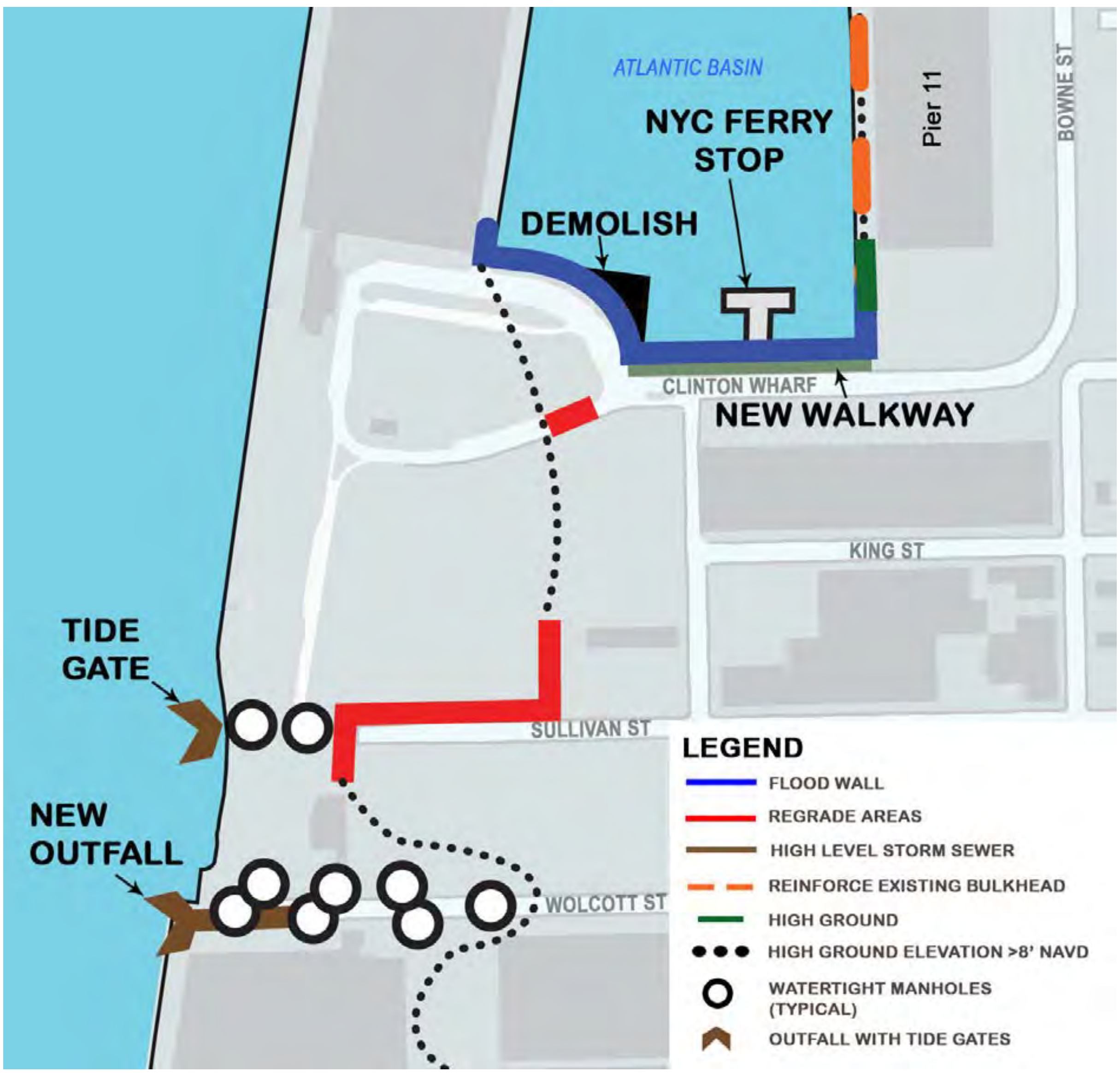


Figure 5-10. Proposed Conceptual Design of Atlantic Basin

Figure 5-11. Conceptual Rendering of Landscape Design and Community Benefits Option 1 at Atlantic Basin

Figure 5-12. Conceptual Rendering of Landscape Design and Community Benefits Option 2 at Atlantic Basin

The recent 2017 waterfront inspection report along Pier 11 indicates severe damage along a portion of the Pier 11 bulkhead that is coincident with proposed floodwall alignment (Langan, 2017). It is our understanding that this severe damage is limited to the fender system only. The report states the existing steel sheet pile has at least 10-years of useful life to accommodate anticipated loads. The conceptual design currently considers rebuilding this portion of the Pier 11; however, Dewberry recommends evaluating the potential to extend and/or reinforce the existing sheetpile bulkhead to increase the design life to 50-years during the preliminary and final design phase. Additionally, the proposed sheetpile bulkhead alignment could be relocated further inland with a pile-supported platform with rock for scour protection for the walkway; which may provide additional environmental benefits.

5.3.3 Conceptual Design Features of Beard Street

Figure 5-13 shows the overall conceptual schematic design of the Beard Street area of the preferred alternative. *Figure 5-14* shows the conceptual schematic of the Beard Street intervention. This intervention includes approximately 450 linear feet of T or L shaped pile-supported floodwall structure and approximately 850 linear feet of pipe piles built at an elevation of 8 feet-NAVD. The floodwall structure follows the sidewalk on the south side of Beard Street which is exposed to the waterfront. Additionally, the conceptual design includes raising the roadway and sidewalk along roughly 1,200 linear feet of Beard Street to an elevation of 8 feet-NAVD which allows the concealment of the proposed flood wall and pipe piles. This allows the creation of a system that does not require any deployables. However, this conceptual system requires the provision of ramps for driveways in the adjacent private properties. The raised roadway begins to ramp down to meet existing grade at the intersection of Van Brunt Street and Beard Street. A small portion of the floodwall located west of the intersection with Van Brunt Street is exposed (extends above existing grade) and would have landscape planters along the street side of the floodwall, thus minimizing the effect of the floodwall structure.

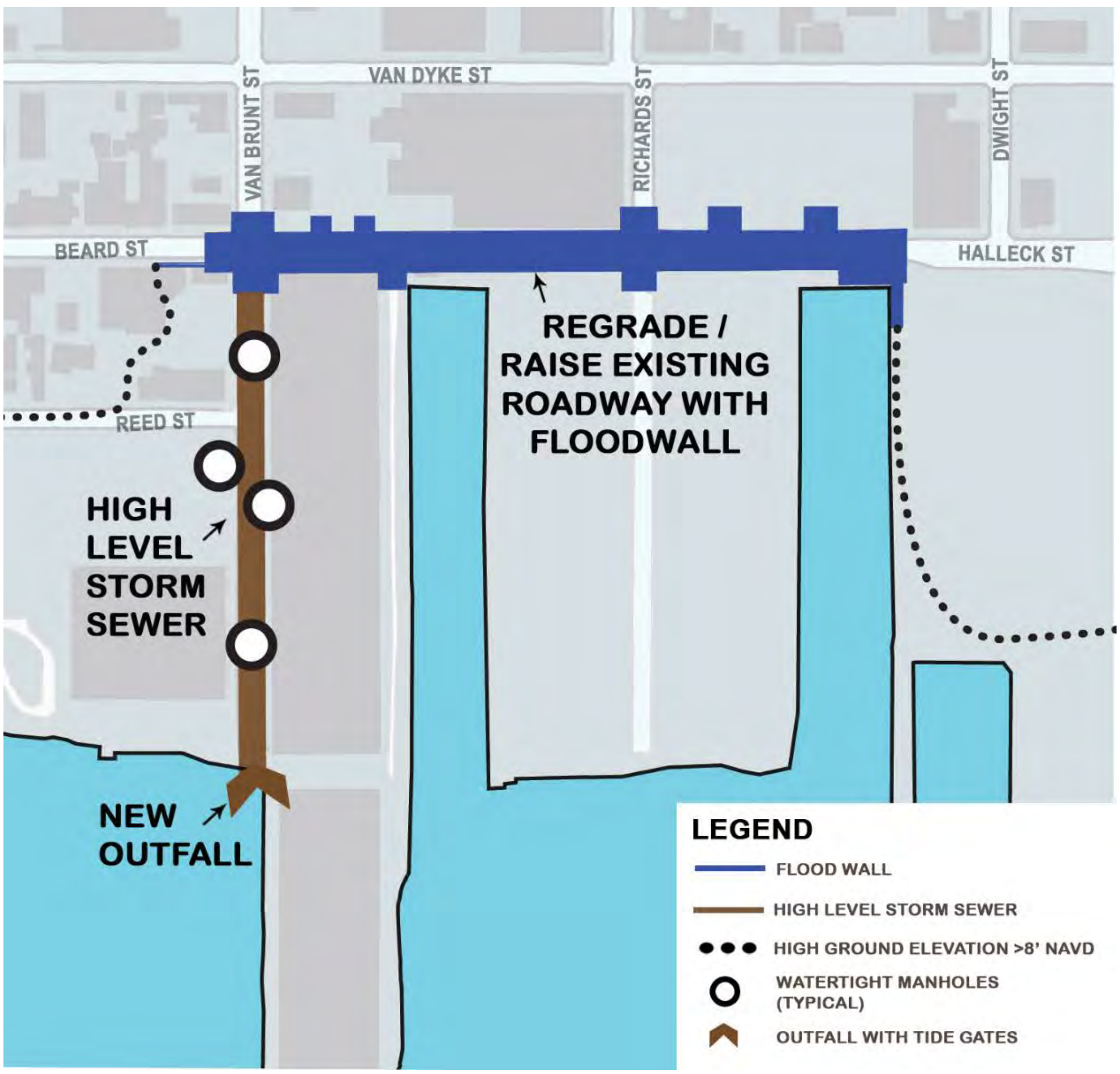
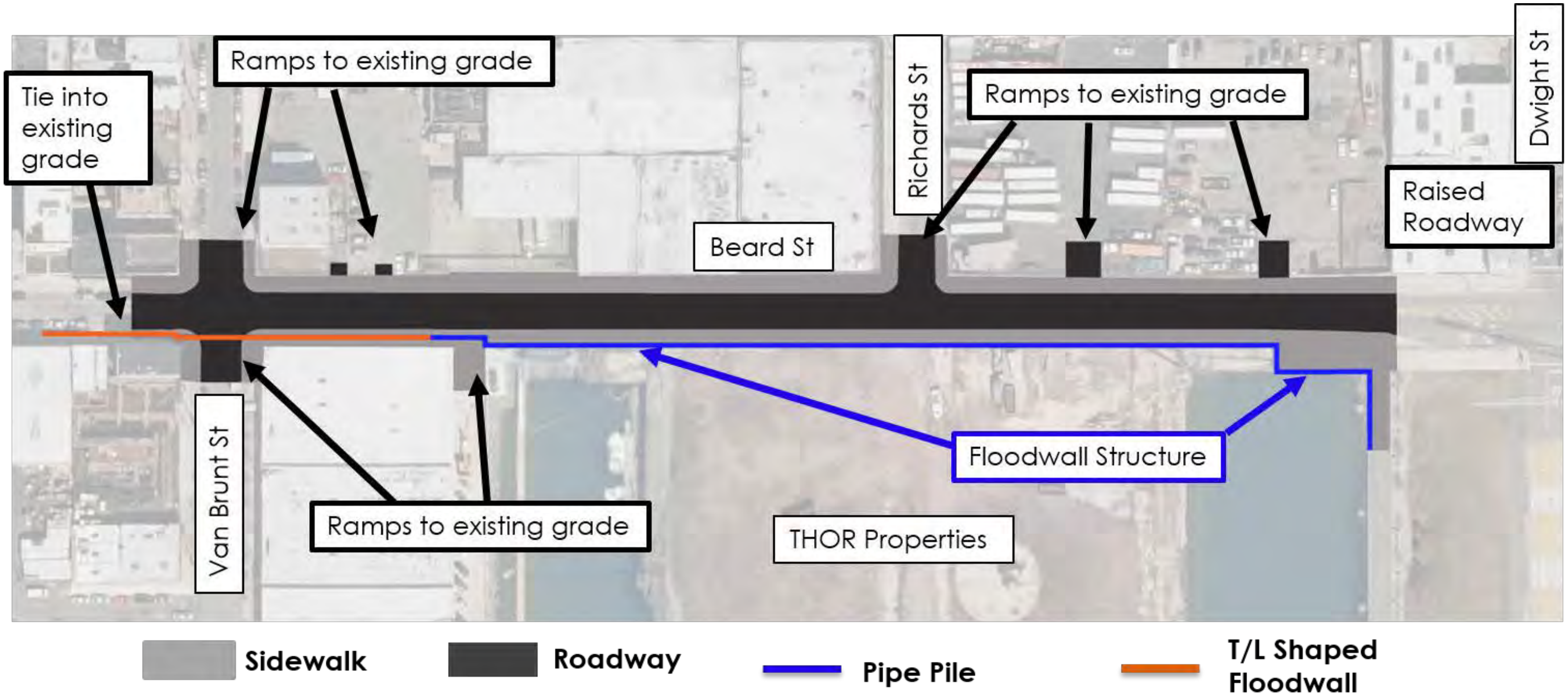


Figure 5-13. Proposed Overall Conceptual Design Schematic of Beard Street Area



Average Existing Grade Elevation: 5 feet – 8 feet NAVD
Proposed Floodwall: +8 feet-NAVD (at waterfront)
Maximum Road Raise: ~3.3 feet (at Richards Street)

Figure 5-14. Proposed Conceptual Design of Beard Street Only

Figure 5-15 and *Figure 5-16* below show illustrative renders for two potential landscape design options to improve urban design and incorporate community benefits along the new pipe pile floodwall along Beard Street. *Figure 5-15* shows the pipe pile floodwall located along the edge of the waterfront whereas *Figure 5-16* shows the pipe pile floodwall located further inland at an elevation of 8 feet-NAVD, which allows for stepped waterfront access. This option would also allow the waterfront access walkway to be built on a pile-supported platform with rock for scour protection, which may provide additional environmental benefits. *Figure 5-17* shows an illustrative render of the proposed raised Beard Street and Van Brunt Street intersection with the exposed floodwall covered by landscaped planters along the portion of Beard Street.

Figure 5-15. Conceptual Rendering of Landscape Design and Community Benefits at Beard Street (Baseline)

Figure 5-16. Conceptual Rendering of Landscape Design and Community Benefits at Beard Street (Option 1)

Figure 5-17. Beard Street – Intersection at Van Brunt Street Rendering

5.3.4 Drainage Analysis

Dewberry conducted drainage analysis using an integrated coastal and stormwater model to determine areas subject to flooding in existing conditions and evaluate any potential impacts of the proposed preferred alternative on the existing drainage patterns within the Red Hook study area. Additionally, Dewberry performed a qualitative analysis using New York City Department of Environmental Protection (NYCDEP)'s storm-sewer infrastructure GIS datasets to determine potential areas for coastal storm surge intrusion into the areas receiving flood risk reduction benefits from the preferred alternative.

Dewberry updated NYCDEP's existing Long Term Control Plan (LTCP) InfoWorks model for Red Hook Water Pollution Control Plant (WPCP) with additional details such as pipes, drainage areas near the preferred project's alignment. Dewberry performed sensitivity analysis and simulated various rainfall events using this InfoWorks model to estimate areas subject to the flood risks from rainfall during existing conditions within the Red Hook study area. Appropriate hydrologic, hydraulic and boundary conditions data from InfoWorks model were imported into Danish Hydraulic Institute (DHI)'s MIKE URBAN model and was integrated with the MIKE 21 coastal hydrodynamic model using the MIKE FLOOD program. This integrated stormwater and coastal surge MIKE FLOOD model allowed the Team to evaluate any potential impacts of the proposed IFPS barrier on existing drainage. NYCDEP provided recommendations to utilize a 5-year rainfall event only to evaluate potential impacts on existing drainage patterns of the preferred project. Additionally, Dewberry relied on tide-rainfall analysis on historical observed datasets at the Battery tidal gage and Central Park rainfall gage from the Rebuild by Design-Hudson River (RBDH) project (Dewberry and NJDEP, 2017). The tide-rainfall analysis from the RBDH project indicates that historically for a majority of event with less than a 10-year coastal storm surge event, the study area received 5-year or lesser rainfall event simultaneously. Hence, Dewberry performed MIKE FLOOD model simulations with a 24- hour 5-year rainfall event with rainfall depth obtained from NOAA Atlas 14 with normal tide and 10-year coastal storm surge.

Figure 5-18 shows results from MIKE FLOOD model simulation during a 5-year rainfall event and with peak of normal tide coincident with the peak of the 5-year rainfall event. Model simulations show that the preferred project's IFPS barrier has no adverse impacts to drainage when compared with the existing conditions under the similar rainfall and tidal conditions. Hence, Dewberry concluded that the preferred project does not have an adverse impact on the existing drainage patterns and would not require any stormwater mitigation. Appendix F provides a detailed memo describing the stormwater modeling methodology and additional results.

Dewberry determined that drainage modifications would be necessary along segments of the preferred IFPS alignment through a qualitative analysis of the DEP sewer system using DEP's GIS data. This analysis showed that there were areas where the coastal storm surge could enter into the DEP sewer system and potentially reduce the benefits provided by the preferred IFPS. In particular, coastal storm surge could travel through catch basins and inlets on the "wet" side of the preferred alignment that could result in flooding on the protected side of the preferred alignment. *Figure 5-19* shows two areas – one within the Beard Street area and second within the Atlantic Basin area – that have catch basins, inlets and manholes that are located on the "wet" side of the preferred project alignment with hydraulic connections to the protected side of the preferred alignment. For example, on Van Brunt Street, there are catch basins and inlets with top rim elevations below 8 feet-NAVD connected to a pump station that conveys the stormwater towards the Red Hook Waste Water Treatment Plant (WWTP). During a coastal storm surge event with water levels below 8 feet-NAVD, the coastal storm surge would inundate these catch basins and inlets, which would then overwhelm the pump capacity and result into flooding in areas lowers than 8 feet-NAVD on the protected side of the preferred project alignment. Similarly, in the Atlantic Basin area, catch basins, inlets, and an outfall without tide gate located along Wolcott Street and Sullivan Street would allow intrusion of coastal storm surge into the protected side of the preferred project. Additionally, we recommend to conduct additional investigations on the existing drainage features such as inlets and pipes in the Atlantic Basin that may be connected to NYCDEP's CSO outfalls and evaluate the need to disconnect these drainage features from draining directly through CSO outfalls.

Disconnecting the catch basins and inlets below 8 feet-NAVD from the existing sewer network and constructing new "High Level" storm sewers (HLSS) and with new outfall along with tide gate would be the preferred way to mitigation intrusion of coastal storm surge into drainage network. In addition to the HLSS, the mitigation would requires replacement of all the manholes that have rim elevations below 8 feet-NAVD on the unprotected side of the alignment with watertight manhole covers which would minimize the intrusion points. *Figure 5-19* below shows the need for proposed drainage mitigation requirements along Van Brunt, Sullivan, and Wolcott Streets.

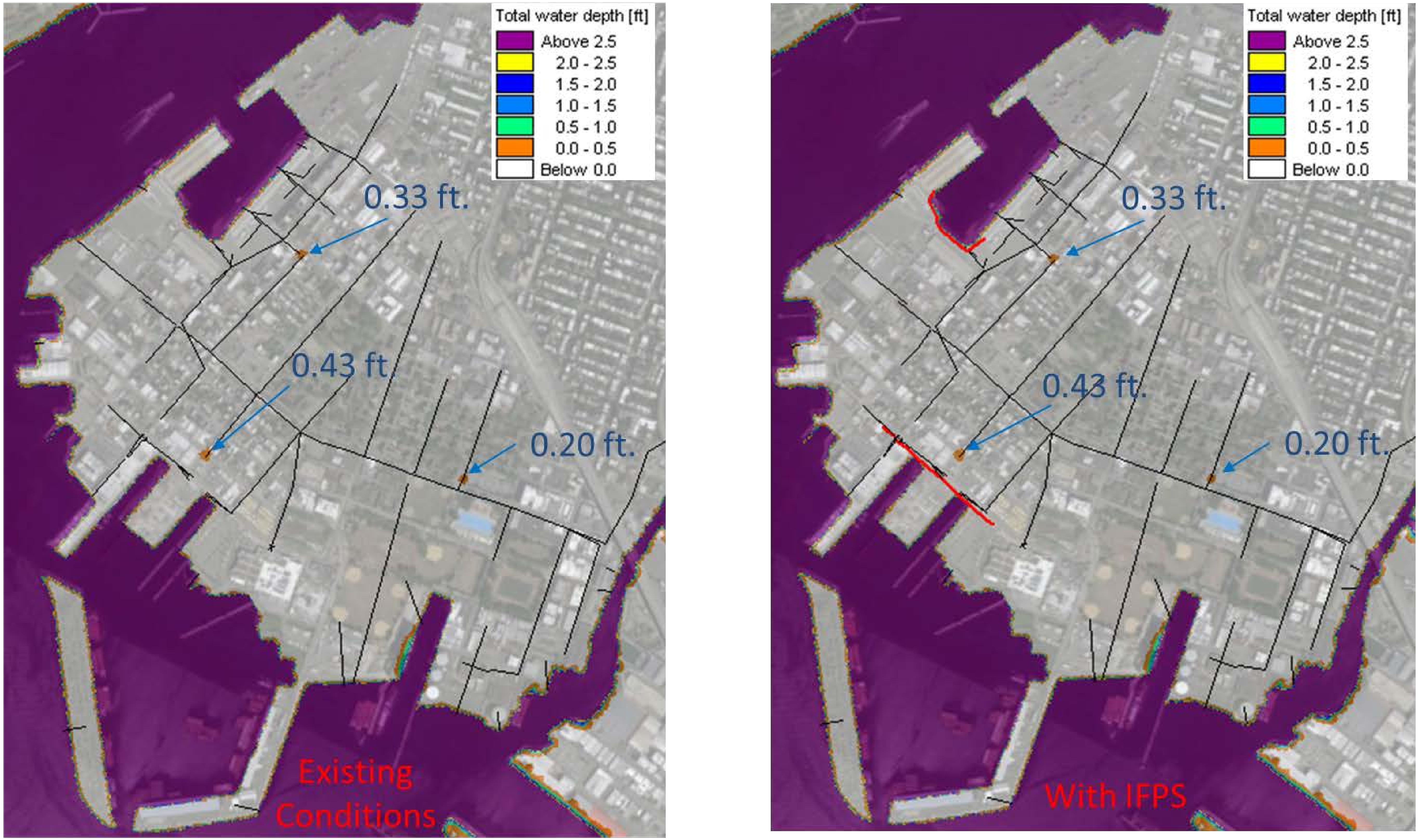


Figure 5-18. Integrated Coastal and Stormwater Modeling Results with Proposed Preferred IFPS Project During Normal Tide and with 5-Year Rainfall Event

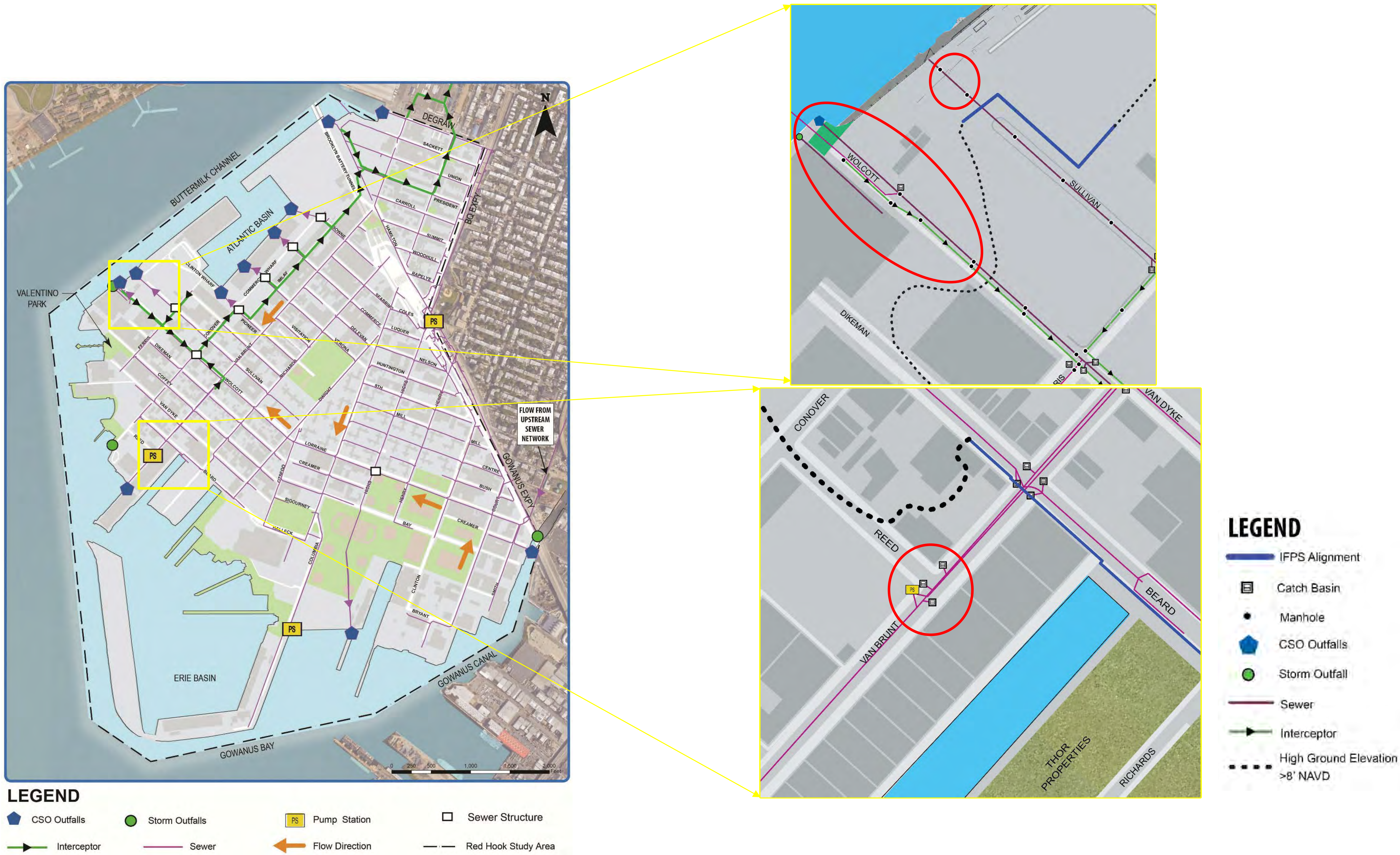


Figure 5-19. Combined Sewer Network and Risk of Coastal Storm Surge Intrusion

5.3.5 Conceptual Level Structural and Geotechnical Design

The Dewberry Team utilized the geotechnical boring data along the preferred project's alignment to develop and analyze the proposed project's substructure and superstructure structural and foundation requirements. The structural and geotechnical analysis resulted in a conceptual structural and geotechnical design of the preferred project's floodwall including a foundation system that the Team utilized to develop cost estimates. The Team developed a conceptual level basis of design that identifies use of appropriate design guidelines, engineering manuals, various types of forces and use of appropriate software needed to perform the analysis. The Team utilized the following design codes and software package to perform geotechnical and structural analysis.

Document and Codes

- NYC BC 2014
- FEMA Coastal Construction Manual
- FEMA fact sheet, "Importance of the Limit of Moderate Wave Action"
- Design Guide for Improving Critical Facility Safety from Flooding and High Winds, FEMA 543/ January 2007
- Flood Proofing Non-Residential Structures, FEMA 102/ May1986.
- Flood Resistant Design Construction, ASCE 24.
- Minimum Design Loads for Buildings and Other Structures, ASCE 7-10
- Specifications for Structural Steel Buildings, AISC 360
- Hurricane and Storm Damage Risk Reduction System, Design Guidelines, USACE June 2012
- Design of Sheet Pile Walls, USACE EM 1110-2-2504
- Retaining and Flood Walls, USACE EM 1110-2-2502.
- Design of Sheet Pile Cellular Structures Cofferdams and Retaining Structures, USACE EM 1110-2-2503
- Seepage Analysis and Control for Dams, USACE EM 1110-2-1901
- Bearing Capacity of Soils, EM 1110-1-1905
- Steel Sheet Piling Design Manual, USS 1984
- AASHTO LRFD 2012 Specifications, 2012
- Critical Elements for Design, Skyline sheet piles recommendations.
- Structures Design Guidelines, FDOT 2009

Software Packages

- Microsoft Excel
- Microsoft Word
- SMath Studio Desktop
- ArcelorMittal ProSheet
- SEEP/W

The New York City Building Code 2015 refers to ASCE 7 and ASCE 24 codes for the design of new structures subjected to flood loads. Both ASCE 7 and ASCE 24 in addition to FEMA guidance publications recommend adopting the following loads in the design of new structures subjected to coastal flood hazards:

- Water level and hydrostatic pressure
- Wind driven, depth limited wave action
- Debris impacts
- Vehicular impacts
- Durability and Corrosion Assessment
- Heave/piping assessment
- Water tightness
- Scour and Erosion Protection

Water Level and Hydrostatic Pressure

Hydrostatic loads caused by a depth of water to the Still Water Level (SWL) shall be applied over the wall surfaces on the flood side, both above and below ground level.

Wind Driven, Depth Limited Wave Action

During a storm event, the fetch in the bay adjacent to Red Hook would lead to locally generated waves. Ocean (swell) waves can also propagate north across New York's Upper Bay reaching as far as the Red Hook waterfront. The preferred project's DFE of 8 feet-NAVD does not explicitly include wave action in addition to the 10-year coastal stillwater elevation. Hence, the Team did not develop a wave model to determine a design wave at the location of the floodwall for the 10-year storm event. Therefore, the Team has identified the most conservative combination of water depth versus freeboard for a wave to act on the wall for only the 10-year storm event and the corresponding Top of Wall. Where applicable, the Team utilized ASCE 7-10 method for determining the breaking wave loads on a vertical wall. It is recommended that further assessment of the wave impact loads is carried out at detailed design stage by using one of the available analytical procedures for non-standing wave actions such as Goda's formulation.

Debris Impact

During a coastal storm surge event, large quantities of debris, especially uprooted trees, dislodged tanks, remnants of manmade structures such as docks and buildings pose significant threat to the integrity of the floodwall. The floodwalls located in close proximity to the waterfront in Red Hook are also at risk of extreme impact loads resulting from less common sources, including - shipping containers, boats and barges. The magnitude of these loads is very difficult to predict, however the Team assumed reasonable allowance of these impacts during the conceptual design analysis. Appendix G shows the use of assumed debris impact loads for applicable floodwalls in the design calculations. Dewberry recommends carrying out further assessment of the debris impact loads during the detailed design stage. Additionally, structural barriers to restrict vessels and barges from impacting the flood walls can also be investigated.

Vehicular Impact

Due to the proximity of the proposed floodwall alignment to public roads where the risk of vehicular collision to the floodwall is high, Dewberry recommends considering vehicular impact on floodwalls. As recommended by AASHTO, the structures located within a distance of 30-ft to the edge of roadway shall be investigated for collision. Providing structural resistance or by deflection or absorption of collision loads are few techniques to incorporate vehicular impact loads into the design of the floodwall during the detailed design phase.

Durability and Corrosion Assessment

The steel sheet piles driven in fill soils such as those encountered in Red Hook are subject to corrosion during the service life of the structure. This is especially significant above grade levels and at shallow depths below grade in which the sheet piles are exposed to sea air or moisture, or are located above the water table. Therefore, the sheet piles will require corrosion protection within the fill subsoil strata and above grade levels, since the rate of corrosion increases rapidly with the presence of oxygen and salt. The Team recommends adding a sacrificial thickness of steel sheet pile sections to accommodate the future loss of material due to corrosion. This sacrificial layer approach is typical in these applications. Salts and organic acids contribute to the corrosiveness of the soil, and generally, the higher the soil conductivity and acidity, the higher corrosion rates. The Team recommends carrying out further testing for soil, ground water pH, chloride concentration, sulphate concentration, and resistivity at detailed design stage of the project to enable the corrosion rates assessment and design for durability.

The Team recommends considering marine type steel sheet piles (i.e. ASTM A690) should the chemical soil test results show an extremely aggressive environment. It may be necessary to consider additional corrosion protection measures such as passive cathodic protection should excessive corrosion occurs during the serviceable life of the wall. Also, it is recommended to consider other corrosion protection measures such as protective coating solutions or reinforced concrete encasement for corrosion protection for the sheet piles at detailed design stage of the project.

Heave/Piping Assessment

The stability of the sheet pile floodwall can be adversely affected by the action of water pressure on the soils at grade and shallow depths below grade level to the extent that collapse under flood event may occur. In granular soils such as the sand and fill layers encountered in Red Hook, excess water pressure causes "piping". Also, in cohesive or very tightly packed soils such as the encountered organic layers, heave may result due to the buildup of water pressure in flood event. Piping occurs when the pressure on the soil grains due to upward flow of water is so large that the effective stress in the soil approaches zero. In this situation, the soil has no shear strength and assumes a condition that can be considered as a quick condition, which will not support any vertical loads. Obviously, this unstable soil condition will lead to significant reduction in passive resistance afforded to the floodwall by the soil on the protected side. In extreme cases, this can lead to a complete loss of stability of the wall and structural failure under flood event.

Insufficient penetration of sheet piles into the ground may cause piping or heave conditions. Failure to consider the effect on soil pressures of piping and heave, would result in inadequate stability conditions. The Team recommends that a Geotechnical Engineer investigate this condition during the detailed design stage of the project. The safety against piping/heave can be achieved by installing the sheet piles at greater depth below the critical depth where overburden soil weight balances the upward hydrostatic pressure, thereby increasing the flow path length and reducing the hydraulic gradient. To allow sufficient pile penetration to prevent heave, the Team utilized a required Factor of Safety (FOS) of 1.40 for a total weight analysis during the analysis.

Water Tightness

The sheet piles proposed for various wall types not only provide overall stability and strength to resist the lateral flood loadings, but also provide an above ground impervious barrier and a cutoff seepage barrier below grade. The continuous nature of the interlocks between the sheet piles and the soil trapped in these interlocks will form low permeability barrier below grade. Therefore, the required below grade water tightness of the sheet pile cutoffs is obtained through natural deposition of soil in the sheet piles interlocks. The above ground water tightness is provided through the impervious nature of reinforced concrete part of the floodwalls. However, the above ground concrete capping could be omitted altogether with use of welding to achieve water tightness. The sheet piles proposed for the floodwall types could be supplied to site in wider sections by welding of the common interlocks of sheet piles supplied to site in pairs or triples that could be done in the workshop rather than onsite above excavation level. Welding could also accommodate construction tolerances and various gap sizes between the interlocks as follows:

- When the gap between adjacent interlocks is small enough, it is possible to create a seal by applying a simple fillet weld across the joint.
- Where the gap is too large to be bridged by a single pass, introduction of a small diameter bar can be effective with a weld run applied to either side of the joint to create the seal.
- For wider gaps, an acceptable weld can be made by welding a plate of sufficient width to suit specific conditions across the joint is possible to create a vertical watertight joint.

Scour and Erosion Protection

Future flood events could cause a gradual lowering of the ground surface on the flood side of the wall due to the scouring effect of wave action. Localized scour could also occur due to marginal turbulence at the ground level around the sheet piles. The fill material at shallow levels near the ground surface could be eroded under flood events or surface water runoff during heavy rainfall events. Also, waves overtopping of the wall could increase the risk of soil erosion on the protected side of the wall. Scour and erosion protection may be deemed necessary on both sides of the proposed wall. To counteract this effect, the Team suggests that all wall types shall be provided with minimum 3- foot wide corridor of road pavements and/or concrete sidewalks to provide solid, impermeable, and continuous strip for erosion and scour protection. The pavements and sidewalks will also serve as surface drainage to guide surface water runoff away from the wall in heavy rainfall events. The erosion protection strip will be required to be keyed into the existing grade with 6-inch minimum thickness into existing ground, to provide scour and erosion protection.

The Team utilized the above basis of design parameter to develop conceptual design and perform analysis on various types of floodwalls for the preferred project. Along Beard Street, the Team developed a conceptual design of the floodwall, which would be built up to an elevation of 8 feet-NAVD but provides the capacity for future adaptability to an elevation of 15.5 feet-NAVD with potential increases in roadway grades as well. *Figure 5-20* shows the location of three typical floodwall types along Beard Street. Section 1 floodwall is a 30-inch pipe pile floodwall that generally follows the sidewalk Right-of-Way boundary along Beard Street. Section 2 floodwall is a 48-inch pipe pile floodwall that follows the remaining waterfront portion of Beard Street. Section 3 floodwall is a T/L wall type floodwall with a pile supported foundation and sheet pile cutoff barrier to reduce seepage. Appendix G shows the conceptual structural analysis carried out by the Team to determine the structural integrity of these three sections.

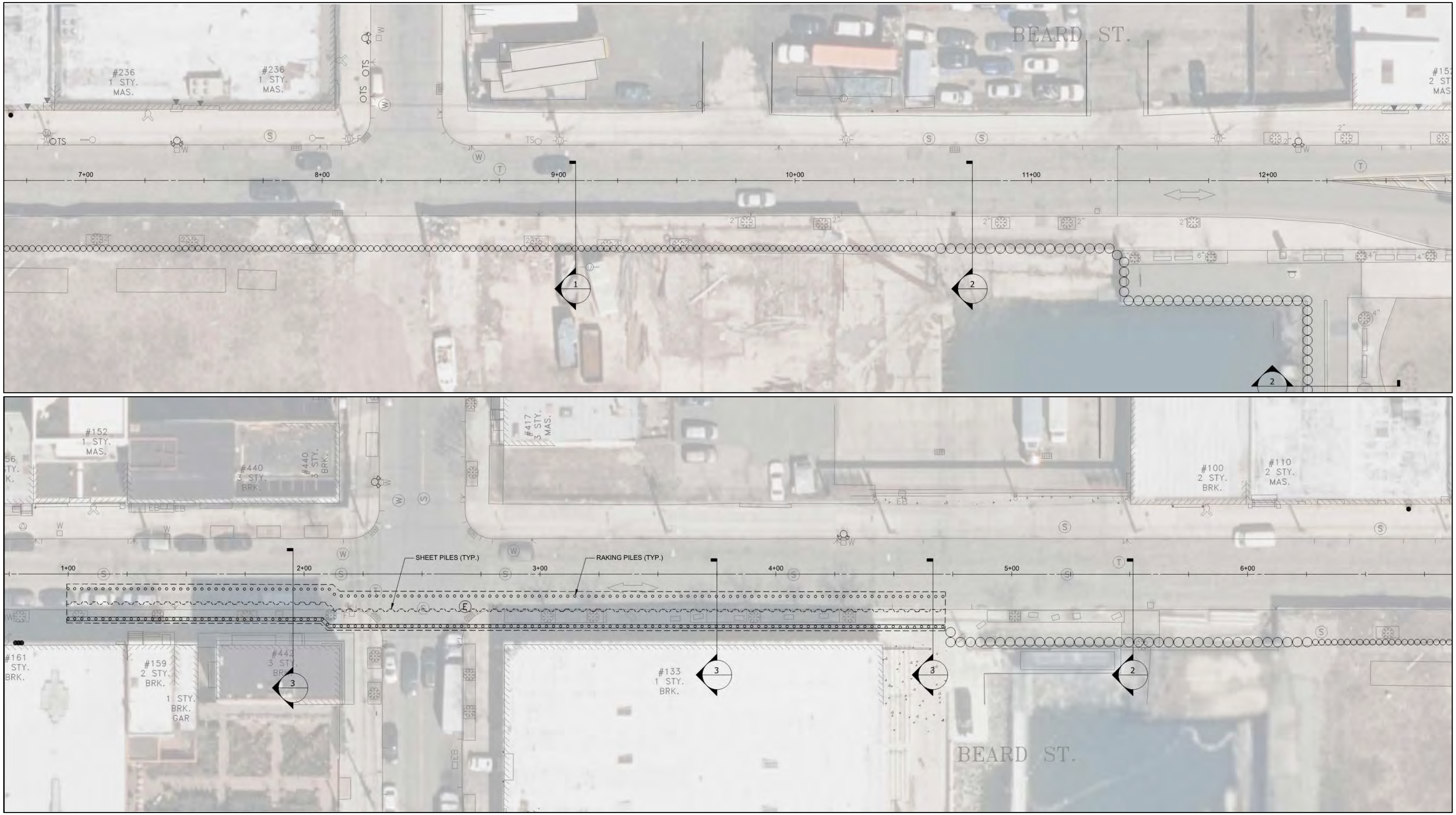


Figure 5-20. Beard Street Structural Plan

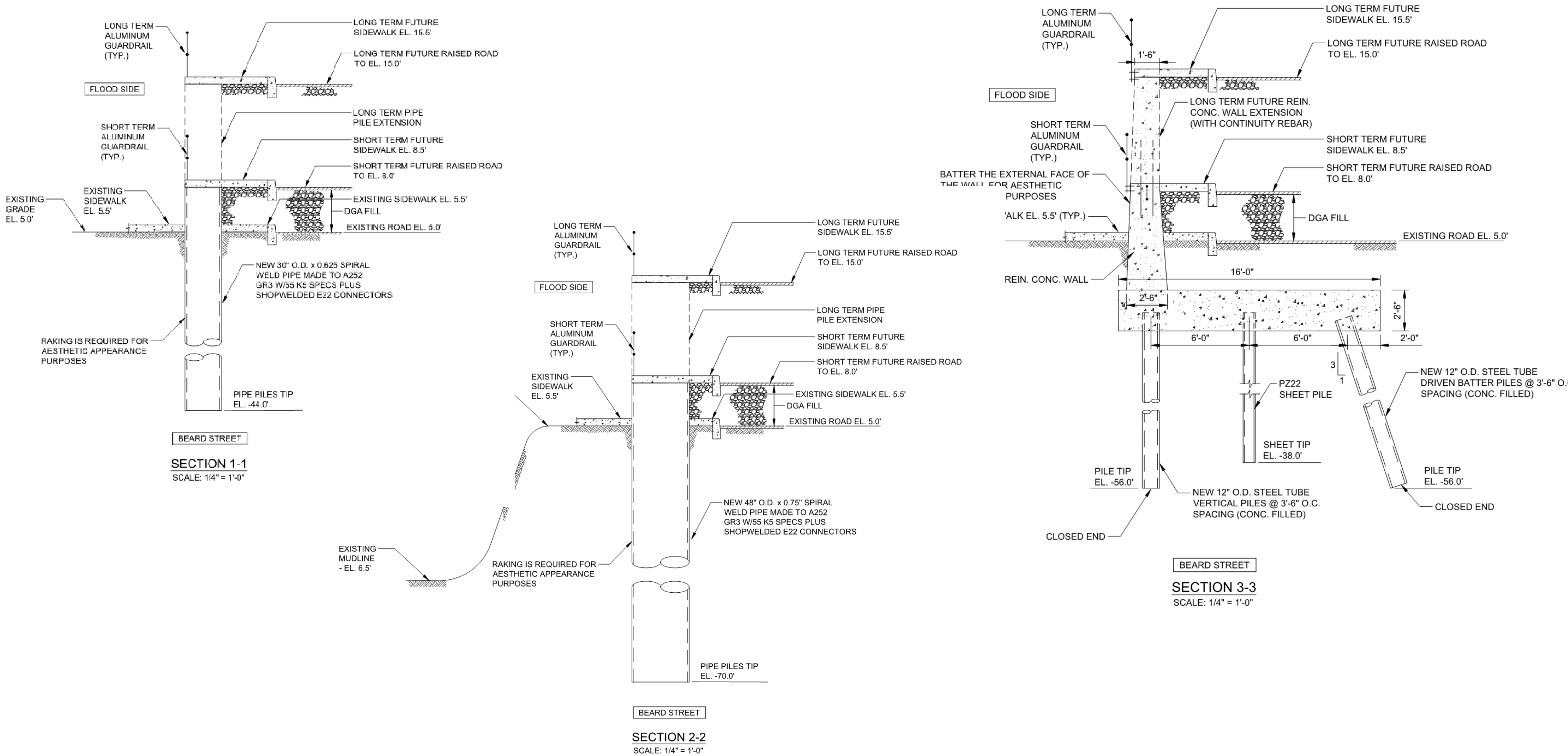


Figure 5-21. Typical Conceptual Sections (1-1, 2-2, 3-3) of Beard Street's Future Adaptable Floodwall

In the Atlantic Basin area, the Team developed a conceptual design of the proposed floodwall as a bulkhead, which would act as a vertical retaining wall along the unused portion of Clinton Wharf. The new bulkhead floodwall would serve the following purposes:

- Hold or prevent the Clinton Wharf fill on the landside of the wall from sliding seaward; and
- Reduce erosion and prevent coastal flooding from the 10-year coastal storm surge event (DFE of 8 feet-NAVD)

The conceptual design of the bulkhead floodwall at Clinton Wharf does not allow future adaptability to higher than 8 feet DFE. Topographic survey and existing reports indicates that lowest existing grade at Clinton Wharf is around 6 feet-NAVD and the mudline in the Atlantic Basin is around -24 feet-NAVD. However, the original dredge line is unknown at this stage and therefore the Team assumed that the design dredge line at -33 feet-NAVD. The Team recommends confirming the design dredge and design mudline elevations during the detailed design phase.

Due to the significant retained height of the bulkhead, a cantilever type of bulkhead is not viable due to anticipate significant stresses and deflections that would result from such embedded retaining wall arrangement. Therefore, the Team recommends anchored bulkhead for Clinton Wharf with sheet piles tie back arrangement connected together with tie rods. With this arrangement, the bulkhead will gain additional support from sheet pile anchors embedded on the landward side to limit bulkhead deflections and avoid section overstressing. The anchor sheet piles will be located on the landside of the bulkhead far enough so that the full passive earth pressure can be utilized to resist the anchor pull. The Team recommended that the anchor is located at 110 feet at the back from the bulkhead that is far enough so that it will not add loading to the wall. The Team assumed that this new bulkhead floodwall would not be subjected to marine type loadings such as mooring pull and berthing loads. The Team also neglected the use of vessel impact loads during the conceptual design analysis; however, during the final design phase the Team recommends to coordinate with applicable NYC agencies to incorporate appropriate vessel impact loads during the detailed design phase. The Team considered the following three load combinations (LC):

- LC1 – To support earth fill with finished grade elevation to 8 feet-NAVD plus surcharge load of 250 pounds per square foot (psf) on the landside of the wall
- LC2 – Flood event scenario with top of wall elevation of 8 feet-NAVD and still water level of 4.36 feet-NAVD for maximum effect of reflected breaking waves plus small boat impact load
- LC3 - Flood event scenario with top of wall elevation of 8 feet-NAVD and still water level of 7 feet-NAVD with overtopping to elevation of 13 feet – NAVD plus small boat impact load

The Team anticipates use of temporary works and excavation support system to support the earth fill on the landside before removing the existing Clinton Wharf walls and installing the new bulkhead arrangement with the tie back sheet piles and tie rods. Appendix G provides the structural and geotechnical calculations for the Clinton Wharf bulkhead. Based on this analysis, the Team recommends a PZ40 steel sheet pile with a tip elevation approximately at -75 feet-NAVD.

Seepage Analysis

The Team performed seepage analysis below the proposed floodwalls at Beard Street and Atlantic Basin utilizing the finite element program Geostudio SEEP/W with the updated geotechnical design parameters under steady-state conditions. Given that the geotechnical borings show that the underlying marine silt layer may not be continuous across both project areas, the Team modified the seepage model to provide high and low estimates of seepage flow volumes based on the presence or absence of the marine silt layer. The underlying organic layer was observed in 10 of the 12 borings utilized to model Atlantic Basin and Beard Street and is therefore assumed to be present in the seepage model. The low-end estimate represents the estimated seepage through a general idealized subsurface profile for each site. The high-end estimate represents the seepage through the idealized subsurface profile modified to exclude the marine silt layer. The Team selected appropriate lateral extents of the finite element models such that the difference in the calculated seepage is negligible for further increase in the selected dimensions. The geotechnical boring data shows that no presence of underlying bedrock or other impermeable layer. Therefore, the Team used a depth of 100 feet for both sections of the finite element models. This is a conservative assumption considering that the Team assumed 24 hours as the maximum design flood duration. Appendix G provides the design soil profiles for seepage calculations for Beard Street and Atlantic Basin.

Seepage Model Results – Atlantic Basin/Clinton Wharf

The estimated high and low seepage rates are nearly the same for both wall options. The total seepage volumes were calculated for an area within a 100-foot offset from each proposed floodwall alignment. For the short-term flood duration of 6 hours, both wall options have high and low estimated total seepage volumes of 1.6 to 10.9 cubic feet (12 to 82 gallons), respectively.

Seepage Model Results – Beard Street

For the short-term flood duration of 6 hours, the summation across the three wall sections indicated the high and low estimated total seepage volumes were 1.3 and 19.8 cubic feet (10 to 148 gallons), respectively. For the long-term flood duration of 24 hours, the summation across the three wall sections indicated the high and low estimated total seepage volumes were 15.6 and 263.6 cubic feet (117 to 1972 gallons), respectively. The exit hydraulic gradient for Section 1-1 is 0.350 and 0.100 for Section 2-2 and Section 3-3. The exit hydraulic gradients of 0.350 and 0.100 correspond to FOS values of about 5 and 17.5, respectively and are higher than the generally proposed range of 2.5-3.0.

Seepage Model Results – Outside of Proposed Floodwall Locations

The Team performed seepage analysis at three locations – Wolcott Street, Smith Street and Court Street – to assess seepage potential of the underlying soils in these areas. The results of the analysis indicated that that the bulk of the seepage flow occurred in the upper granular fill soils that are present immediately below ground surface. When the seepage was applied across the selected area, the estimated total seepage volume for the 6-hour duration flood event (8 feet- NAVD) was approximately 31,400 cubic feet (234,900 gallons) and the 24-hour flood (+15 NAVD) was approximately 150,000 cubic feet (1.12 million gallons). However, these seepage estimates should only be interpreted as a means to highlight the permeability and conductivity of the upper granular soils. These volumes of water assume the presence of an impermeable above-grade barrier that would restrain a flood event. However, given that no such barrier currently exists in these areas, a flood event would simply cause surface flooding in these areas and the mechanism of seepage would be irrelevant. Additionally, the seepage analysis ignores the presence of waterfront structures, which would have led to additional reduction in seepage volumes.

5.3.6 Environmental Assessment

During construction of the IFPS, the subsurface will be disturbed. Soil impacted with PAHs, metals and other contaminants above a regulatory concern will require appropriate treatment and handling. Driving of sheet piles will minimize the quantity of excess material generated resulting in decreased volumes of soil requiring management. The Team assumes that the majority of the soil can be reused under the new roadway, which will effectively be "capped." However, consideration should be given to available laydown/stockpile areas within the defined construction area for soil intended for re-use during project design and planning. Additional area may be required if soil is to be segregated based on presence/absence of fill materials such as bricks, ash, etc. and/or to manage soil with indications of contamination, if any, which are not indicative or urban fill or which have evidence of petroleum or other contamination through field screening. Any soil generated during construction that is not reused under the roadway will need to be transported off-site and disposed of in accordance with Federal, State, and local regulations. Appropriate characterization of excess soil will be required in advance of disposal and will provide information to determine an appropriate recycling or disposal facility. The NYC Clean Soil Bank (CSB), a no-cost soil exchange operated by the NYC Office of Environmental Remediation, may present a cost effective opportunity to handle excess soil and to obtain any soil needed for the project. As a note, this program focuses on deeper native soil, so it is unlikely to provide an option for historic fill materials.

The groundwater data collected during this project indicates groundwater at approximately five (5) feet Below Ground Surface (BGS) at or near the location of the proposed IFPS. Based on the results of groundwater sampling, groundwater is impacted with VOCs and PAHs. Any dewatering of groundwater will require appropriate management and handling and may potentially be discharged to the NYC storm drains.

5.3.7 Benefit Cost Analysis

Dewberry utilized the flood depth grids for various coastal flood events and combined it with United States Army Corp of Engineers (USACE) depth damage functions to model flood damages for various building types within the Red Hook study area. These depth damage functions allows to estimate the monetary damages avoided to structures, structure contents, residential displacement, and losses of commercial and public services. Dewberry provided these avoided damage losses monetary values as input into the latest FEMA BCA software (Version 5.3.0) along with social benefits associated with flood protection to determine the annualized benefits.

Project Benefits

Appendix H provides a detailed description and calculation of the calculated project benefits including social benefits for the population that would be receiving flood risk reduction benefits. *Table* 5-7 provides a summary of the project benefits associated with the preferred project.

Table 5-7. Monetary Benefits for the Preferred Project Alternative

Project BCA Description	Flood Event RI	Damages Before Mitigation	Damages After Mitigation	Annualized Benefits	Base Benefit	Final Benefit with social benefits
10-Year DFE Project – 8 feet-NAVD (10-yr + 1 feet freeboard)	10-year	$103,018,646	$0	$14,563,804	$200,991,364	$204,106,875
	50-year	$321,702,045	$321,702,045	$0		

Project Costs

The Dewberry Team utilized the conceptual design drawings shown in Appendix E to develop rough estimates of the quantities, materials and construction techniques required to construct the preferred alternative. The Team utilized the best available current market pricing rates for various common materials such as concrete, steel, backfill, asphalt and others to develop cost estimates for each cost line item. The Team arranged various cost line items based on the following general categories - subsurface, superstructure, site/civil/roadway, drainage, utilities, environmental remediation, landscaping and others. The labor element associated with the costs is priced using New York City crew configuration and union hourly rates. The pricing of material components is based on vendor quotations for specialized items such as interlocked pipe pile system. Equipment pricing is based on current rental rates and union labor for operating crews. The costs also includes items such as materials; labor; escalation; general conditions such as mobilization, maintenance and protection of traffic; overhead; profit and others. The Team recommends coordinating with private property owners on Beard Street to determine easement needs required for this project. The project costs includes $3.0 million real estate easement acquisition or agreement cost that may be required for the preferred project along Beard Street.

The Team utilized a percentage of total hard construction costs to obtain soft costs for design and permitting; and resident engineering and construction management. In addition, in order to ensure that FEMA only funds cost-effective investments, the BCA must include additional operation and maintenance (O&M) costs necessary to maintain the effectiveness of the project throughout its useful life. The Team assumed 0.6% of the total project costs as the annual O&M costs. Due to a fully passive preferred alternative solution, the Team anticipates O&M would be limited to inspection and cleaning of proposed drainage features such as tide gates, outfalls and high-level storm sewer system once or twice a year.

Table 5-7 shows the soft and hard cost breakdown for Atlantic Basin area, Beard Street area and the total preferred alternative project for the whole project. As seen from this table, the Teamestimated the total costs for the preferred alternative at $100 million.

Table 5-8. Project Costs for Atlantic Basin Area of the Preferred Project Alternative

DIV No.	Intervention Description	Unit	Quantity	Costs	
Atlantic Basin					
Hard Cost Estimate					
01	New Bulkhead, Removal of Existing Clinton Wharf Section and Rehabilitation of Pier 11	Linear Feet (LF)	699	$	30,373,466
02	Raise/Resurface Cruise Terminal Parking Lot Grade	Square Feet (SF)	7,103	$	164,092
03	High Level Storm Sewer, Outfall, Tide Gate and Other Drainage	Linear Feet	220	$	457,081
Soft Cost Estimate					
04	Design and Permitting	Lump Sum (LS)	12%	$	3,719,357
05	Resident Engineering & Construction Management	Lump Sum (LS)	15%	$	4,649,196
Project Estimate for Atlantic Basin Area				**$**	**39,363,192**
Beard Street					
Hard Cost Estimate					
01	Floodwall with Elevated Street	LF	1,258	$	37,476,589
02	Landscape Planter	LF	115	$	26,280
03	Beard Street Drainage	LF	1,035	$	1,085,815
04	High Level Storm Sewer	LF	810	$	1,381,380
05	Environmental Remediation	LS	1	$	619,238
06	Right of Way Easements	LS	1	$	3,000,000
Soft Cost Estimate					
07	Design, Environmental and ULURP	LS	22%	$	8,929,646
08	Resident Engineer & Construction Management	LS	20%	$	8,117,860
Project Estimate for Beard Street Area				**$**	**60,636,808**
TOTAL PREFERRED ALTERNATIVE PROJECT ESTIMATE				**$**	**100,000,000**

Benefit-Cost Ratio

Table 5-9 shows the monetary project benefits and the total project costs along with the estimated Benefit-Cost Ratio (BCR) of 2.03, which exceeds the HMGP requirement of BCR > 1.0. Appendix H provides additional details on the BCR calculations along with the output from the FEMA BCA software.

Table 5-9. Benefit-Cost Ratio (BCR) for the preferred alternative

Preferred Alternative Description	Total Project Benefits	Total BCA Project Cost with O&M	Benefit-Cost Ratio
Beard Street and Atlantic Basin alignment providing protection up to 10-year coastal storm surge + 1.0 feet freeboard	$204,106,875	$100,600,000	**2.03**

5.4 Permitting Requirements and Next Steps for the Preferred Project Alternative

The preferred project would require changes to the New York City's official City Map to alter the street grade along Beard Street, which may trigger the need to complete the Uniform Land Use Review Procedure (ULURP) process. The required level of environmental review has yet to be determined and will be decided in a subsequent phase of this project. As a result of receiving federal funding, the project is required to comply with National Environmental Policy Act (NEPA) requirements. The lead agency for the subsequent phase of the project will dictate whether an Environmental Assessment (EA) or Environmental Impact Statement (EIS) will be performed. Additionally, FEMA may require Environmental and Historic Preservation Review (EHP). *Table 5-10* shows the list of anticipated permits and compliance requirements for the preferred project alternative.

Table 5-10. Anticipated Permit Requirements

	Permitting Agency	Permit
Federal	United States Army Corps of Engineers (USACE)	Nationwide Permit #7: Outfall Structures[1]
		Nationwide Permit #13: Bank Stabilization[2]
		Nationwide Permit #19: Minor Dredging
		Nationwide Permit #18: Minor Discharge (Minor Fill)[3]
		Nationwide Permit #33: Temporary Construction, Access, and Dewatering
State	New York State Department of Conservation (NYSDEC)	Coastal Erosion Management
		Tidal Wetlands
		401 Water Quality Certification
		Waterfront Revitalization Plan
	New York State Department of State (NYS DOS)	Coastal Zone Consistency Determination

	Permitting Agency	Permit
	New York Station Office of General Services	Lands Under Water[3]
	Essential Habitat Review	N/A[4]
Local	New York City Department of Small Business Services	Waterfront Permit
Local	New York City Department of Environmental Protection	Storm Sewer Permit[1]
National Marine Fisheries Services (NMFS), US Fish and Wildlife Service (US FWS), and NYSDEC		Threatened and Endangered Species (T&S) Review[4]

Notes:

[1] Applicable for construction of new High Level Storm Sewer Outfall as proposed on Wolcott Street and Van Brunt Street.

[2] Permit restricted to 500 Linear Feet (LF) of Bulkhead; Waiver can be obtained for lengths >500LF. Not anticipated to present major obstacle since this is essentially a bulkhead replacement, not new construction; potentially time consuming.

[3] Specific to the Beard Street portion of IFPS construction.

[4] Not a permit requirement. This involves a letter requesting information for the work area and an informal consultation with the appropriate agency.

The Dewberry Team recommends the consideration of following items during the final design of this preferred project:

- Conducting additional topographic survey and geotechnical analysis within the project boundaries
- Coordination with property owners on Beard Street to assess impacts and real estate easement needs
- Coordination with NYCDOT to develop detailed design for Beard Street
- Coordination with NYCDEP to develop detailed design for high level storm sewers and placement of tide gates at outfalls
- Coordination with NYCEDC and PANYNJ to develop detailed design for Atlantic Basin area
- Coordination with NYCDOB to obtain as-built drawings of buildings along Beard Street
- Coordination with NYCEDC, NYC DDC, NYCDOT, and others on other on-going projects
- Coordination with relevant local, state, and federal agencies to obtain necessary permits
- Coordination with NYC DCP and the Brooklyn Borough President's office to determine the ULURP process requirements for increasing the street grade along Beard Street
- Conducting Environmental and Historic Preservation (EHP) compliance study
- Conducting Cultural Assessment Phase 1 study to evaluate any impacts to cultural and historical properties

Based on discussions with NYCEDC and ORR, the Team recommends designing and constructing the preferred project into two distinct phases: Phase 1A for Atlantic Basin and Phase 1B for Beard Street. These two phases can start simultaneously but can be designed and constructed separately. *Figure 5-22* shows the proposed timeline for the two phases of the preferred project. The Team anticipates January 2018 as the start dates for both phases with design and permitting completed by December 2018. The

Team anticipates the overall project completion date of January 2021, which includes the construction and closeout of the HMGP application for this project.

Phase 1A: Atlantic Basin Area Flood Risk Reduction System

	Year 2018	Year 2019	Year 2020
Preliminary and Final Design	Jan. 2018 - Dec. 2018		
Environmental Assessment & Permitting	Jan. 2018 - Dec. 2018		
FEMA HMGP Update & Bidding		01/19 - 04/19	
Construction & Project Closeout			May 2019 - Jan. 2021

Phase 1B: Beard Street Area Flood Risk Reduction System

	Year 2018	Year 2019	Year 2020
Preliminary and Final Design	Jan. 2018 - Dec. 2018		
Environmental Assessment/ULURP/Permitting	Jan. 2018 - Dec. 2018		
FEMA HMGP Update & Bidding		01/19 - 04/19	
Construction & HMGP Application Closeout			May 2019 - Jan. 2021

Figure 5-22. Proposed Schedule Time for Design and Construction of Atlantic Basin and Beard Street Portions of the Preferred Project Alternative

6 References

1. Dewberry, 2017, Red Hook Integrated Flood Protection System Feasibility Study - Existing Conditions Assessment Report

2. Federal Emergency Management Agency, 2013, Preliminary 2013 Flood Insurance Study

3. Langan, 2017, Pier 11 Waterfront Inspection Report

4. Dewberry Engineers, 2016, Rebuild by Design – Hudson River Hydrology and Flood Risk Assessment Report